# USING QUICK RESPONSE (QR) CODES AS AN INDOOR WAYFINDING TOOL

A Ph.D. Dissertation

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Ankara
December 2022

To my family

# USING QUICK RESPONSE (QR) CODES AS AN INDOOR WAYFINDING TOOL

The Graduate School of Economics and Social Sciences
of
İhsan Doğramacı Bilkent University

by

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İHSAN DOĞRAMACI BİLKENT UNIVERSITY
ANKARA

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By Çetin Tünger

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy in Interior Architecture and Environmental Design.

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ABSTRACT

USING QUICK RESPONSE (QR) CODES AS AN INDOOR WAYFINDING TOOL

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With the advent of the Covid-19 pandemic, the use of quick response (QR) codes has increased rapidly in many areas. However, the adoption of QR code-based indoor wayfinding models is still limited. The reliance on location-aware technologies, the development of smartphone applications, and the need for programming language knowledge could be counted among the reasons for the limited use of these models. In the present study, we proposed a lightweight QR code-based indoor wayfinding model that is low-cost, easy-to-adapt, free of sensors, and solely functions with smartphones. Accordingly, we conducted two experimental studies to test the model under two conditions: first, in a complex university campus building with 38 participants; then in the virtual model of that building with 72 participants. In both environments, we compared the use of You-Are-Here maps displayed on smartphones by scanning the QR codes on the walls (the QR condition) to the use of the same maps located on the walls (the No-QR condition). We measured task performances, perceived ease of task, comfort level, and evaluations of the proposed model. To reveal the relationships between the variables and differences between conditions, we conducted the Pearson correlation coefficient test and repeated measure ANOVA. Our findings revealed that even though the participants completed the wayfinding tasks in the QR condition in a longer time than in the No-QR condition, the positive responses of the participants revealed that they would be willing to use QR codes in complex indoor environments. Findings and evaluations suggested that the proposed model,

in its current form, may function as expected and be a useful, lightweight, and low-cost alternative to You-Are-Here maps.

**Keywords**: quick response (QR) codes; wayfinding; maps; indoor environments; complex buildings

ÖZET

KAREKODLARIN İÇ MEKANDA YÖN BULMA ARACI OLARAK KULLANIMI

Tünger, Çetin
Doktora, İç Mimarlık ve Çevre Tasarımı
Tez Danışmanı: Dr. Öğr. Üyesi Çağrı İmamoğlu

Aralık 2022

Covid-19 pandemisinin ortaya çıkmasıyla birlikte birçok alanda karekod (QR) kullanımı hızla artmıştır. Bununla birlikte, iç mekanlarda yön bulma amaçlı geliştirilen karekod tabanlı modellerin kullanımı hala sınırlıdır. Konuma duyarlı teknolojilerin kullanımı, akıllı telefonlar için uygulama geliştirilmesi ve programlama dili bilgisi ihtiyacı bu modellerin sınırlı kullanımının sebepleri arasında sayılabilir. Bu çalışma, akıllı telefonlarla çalışan, sensörlere ihtiyaç duymayan, düşük maliyetli ve uyarlaması kolay, karekod tabanlı bir iç mekan yön bulma modeli önermektedir. Önerilen modelin etkinliğini test etmek için, bir üniversite kampüsünde yer alan karmaşık bir binada birisi fiziksel ortamda 38 katılımcı ile, diğeri sanal ortamda 72 katılımcı ile olmak üzere iki farklı deneysel yön bulma çalışması yürütülmüştür. Her iki çalışmada da, duvarlara yerleştirilmiş karekodların taranmasıyla akıllı telefonlarda görüntülenen 'Şu an buradasınız' haritalarının kullanımını (karekodlu koşul), aynı haritaların duvarlara yerleştirilmiş kullanımıyla karşılaştırdık. (karekodsuz koşul). Katılımcıların yön bulma performansını, algılanan görev zorluğunu, rahatlık düzeylerini ölçtük ve çalışmayla ilgili değerlendirmelerini inceledik. Değişkenler arasındaki ilişkileri ve koşullar arasındaki farklılıkları ortaya çıkarmak için Pearson korelasyon katsayısı testi ve tekrarlanan ANOVA ölçümü kullandık. Bulgularımız, katılımcıların yön bulma görevlerini karekodlu koşulda karekodsuz koşula göre daha uzun sürede tamamlamalarına rağmen, katılımcıların olumlu yanıtları, karekodları karmaşık iç ortamlarda kullanmaya istekli olduklarını ortaya koydu. Sonuçlar ve değerlendirmeler gösteriyor ki, önerilen model şu anki

haliyle kullanılması durumunda beklendiği gibi çalışabilir ve ‘Şu an buradasınız’ haritalarına kullanışlı, hafif ve düşük maliyetli bir alternatif olabilir.

**Anahtar Kelimeler:** karekodlar, yön bulma, haritalar, kapalı mekanlar, karmaşık binalar

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# CHAPTER I

## INTRODUCTION

Wayfinding is closely related to spatial cognition, a concept used to comprehend the compatibility of people and their surroundings (Kaplan, 1983). Wayfinding is a spatial problem-solving activity that answers questions about one's location, destination, and the route that connects them. While navigating in an environment, consciously or unconsciously, we make an effort to understand our location, destination, and the route that connects them (McAndrew, 1993) using the cues in the environment, such as visual accessibility, the configuration of the environment, architectural differentiation, and use of signage.

However, gathering spatial knowledge and wayfinding in a space with insufficient environmental information or legibility could be difficult, particularly in interiors. Indoors consist of more complicated layouts, similar zones (McAndrew, 1993), and vision-blocking elements such as walls and ceilings compared to outdoors (Wang et al., 2019). Thus, visitors of buildings with complex layouts, such as shopping malls, campus buildings, and hospitals, may face difficulties finding their way, understanding, and remembering their interior configurations (R. Li & Klippel, 2016; O'Neill, 1992). Individuals who do not understand the overall layout of the setting struggle with wayfinding, causing anxiety and stress (Arthur & Passini, 1992;

Carpman & Grant, 2002). Typical solutions to this problem involve the use of wayfinding aids such as signage (O'Neill, 1991) and You-Are-Here (YAH) maps (C. H. Chen et al., 2009; Klippel et al., 2006; Levine, 1982) or help desks to provide directions. However, technological advancements that led to the adoption of smartphones may reduce the need for such conventional tools and offer new wayfinding solutions based on mobile and smart devices (Bauer & Ludwig, 2019; Ishikawa et al., 2008).

Among the technology-based navigation offerings, the Global Positioning System (GPS) is the most common way to provide satisfactory positioning and navigation outdoors (Zheng & Ni, 2005). However, GPS technology is rather limited in enclosed spaces. Typical GPS signals require a line of sight, which is blocked by roofs, walls, and nearby buildings (Turgut et al., 2016). Although one may pick up satellite signals indoors, they have low strength and reliability in most cases (Mulloni et al., 2009). Due to that reason, this system may not be functionally sufficient for interiors that require a more precise positioning system.

Today, several indoor navigation systems enable visitors to view building maps on their phones. These systems rely on different technologies, such as Wireless Fidelity (Wi-Fi), Bluetooth, or Radio Frequency Identification (RFID), which require costly devices or cabling (Ciavarella and Paternò, 2004; Montanes et al., 2013). Unlike those, quick response (QR) codes provide a fast and cost-effective way to transmit information that a QR code scanner can reveal. With the development of specific software and hardware, smartphones have enabled their users to take advantage of this tagging technology (Ashford, 2010; Sinkinson and Stoeckel, 2011). Moreover, there is more access to QR codes through the growth of smartphone adoption.

QR code is a widely used technology helping us easily access information. As smartphones have become ubiquitous, their ability to scan QR codes, coupled with the emergence of Covid 19 led to a significant leap in QR code usage; they offer an easy, fast, and end-to-end contactless experience, which is in line with the needs of

the post-pandemic world. Statistics show that the number of searches worldwide for the QR code increased by 187% approximately after the first Covid cases (Google Trends, n.d.). QR codes are commonly used for mobile payment, ATM withdrawal, e-tickets in travel, and menus digitally displayed in restaurants. Alternative ways to use them in other fields are constantly being sought, one of which is wayfinding.

However, the majority of the studies focusing on QR code-based indoor wayfinding (Ambareesh et al., 2017; Mulloni et al., 2009; Nicholson et al., 2009; Pearson et al., 2017; Serra et al., 2010; Sushma & Ambareesh, 2017; Torrado et al., 2016) rely on location-aware technologies, which necessitate electronic infrastructure, wiring, specific sensor devices, and smartphone application coding. Implementing such a wayfinding model in complex environments may require a significant investment in both money and time. Furthermore, visitors might be unwilling to install an application for a building they may not visit again, which limits the use of such local wayfinding models.

### 1.1. Aim of the Study

The simple use of QR codes can be a solution to the limitations imposed by indoor navigation tools, requiring high budget, additional devices, and scripting. As QR codes are low-cost and easy-to-implement, their practical application in their most basic form could spread rapidly. Due to that reason, we proposed a QR code-based indoor navigation tool that does not require such tools as smartphone sensors, emitters in the environment, or the use of a particular application and operates solely with the users' smartphones, which makes it low-cost and easy to install. To test the effectiveness of our model, we created an environment with QR codes and compared it with currently widely used wayfinding situations without QR codes. In the first phase, we conducted a physical study. In the second phase, based on the results and evaluations of the first study, we improved the methodology in-depth and conducted a second study in a virtual environment. The results and our

suggestions for the use of the model are expected to help institutions for providing a satisfactory indoor wayfinding experience.

### 1.2. Structure of the Thesis

This thesis consists of nine chapters. Following the introduction in Chapter 1, the second chapter elaborates on the concepts of wayfinding and cognition. After explaining the main definitions, three types of spatial knowledge acquisition are defined: landmark, route, and survey knowledge. This chapter also described the factors affecting wayfinding under two headings: environmental and individual factors. Environmental factors are described in four categories: visual access, layout complexity, spatial differentiation, and signage systems. Because the current study's wayfinding model relies on digital YAH maps, recommendations for the use of YAH maps, as well as the benefits and drawbacks of digital maps, are highlighted under signage systems. In addition, since the second study is conducted in a virtual environment, in the last part of this chapter, the use of virtual environments in wayfinding is introduced, followed by the subheadings: types of virtual environments based on immersion, their advantages and disadvantages, active and passive explorations, and their use in wayfinding studies.

The third chapter presents the localization techniques for indoors under two categories. The first category introduces localization systems based on applications and sensors, which is followed by the second category, barcodes. Because the present study proposed a wayfinding model based on QR codes, a variant of barcodes, the second category is expanded under four items: a comparison of one-dimensional (1D) and two-dimensional (2D) barcodes, an in-depth explanation of QR codes, their usage areas, and their use in wayfinding studies.

In the fourth chapter, the research design and methodology of the physical study are explained, addressing the research questions and the hypotheses. The setting where the task is conducted and the participants' demographics are also defined in this chapter. After that, the materials used in the physical study, which are maps,

QR codes, and other equipment, are described, followed by detailed definitions of the pre-task and post-task questionnaires. This chapter concludes with the presentation of task procedures and measurements of task performances. The fifth chapter presents the results of the physical study, grouping the data under four headings: wayfinding performance, perceived ease of task and comfort level, evaluations of the proposed model, and correlations between the variables.

Chapter six presents the research design and methodology of the virtual study, addressing the research questions and the hypotheses. After that, the research setting and the participants' demographics are explained, followed by the materials used in the virtual study: maps, QR codes, and other equipment. The detailed definitions of the pre-task and post-task questionnaires are also emphasized in this chapter. Last, task procedures and measurements of task performances are introduced. The seventh chapter expresses the results of the virtual study grouped under four headings: wayfinding performance, perceived ease of task and comfort level, evaluations of the proposed model, and correlations between the variables.

In chapter eight, in the discussion, the interpretation of results of the physical and virtual studies are given together in detail to avoid repetition. This chapter is described under four categories similar to the results chapter: wayfinding performance, perceived ease of task and comfort level, and the evaluations of the proposed model. For those who are enthusiastic about adopting the model, the last category introduces the preliminary design guidelines for the proposed model.

# CHAPTER II

# WAYFINDING

This chapter provides a review of the relevant literature considering the subject of the current study. Our research aims to propose a QR code-based indoor wayfinding tool based on You-Are-Here (YAH) maps and test the model in both a physical and virtual environment. Therefore, this chapter introduces (1) the concepts in wayfinding and the process of spatial cognition, which is a crucial component of wayfinding, (2) the methods to acquire spatial knowledge from the environment while navigating, (3) the factors affecting the wayfinding performance in which YAH maps, one of the signage types, are described in detail because the current study utilized these aids in the development of the proposed model, and (4) the knowledge about the virtual environments as well as their use in wayfinding studies.

## 2.1. Wayfinding and Spatial Cognition

Wayfinding is a spatial problem-solving activity that requires cognitive and behavioral effort (J. L. Chen & Stanney, 1999; Passini, 1984; Rovine & Weisman, 1989) (Figure 1) and aims to answer questions about one's location, destination, and route that connects them (McAndrew, 1993). Responding to these questions necessitates the use of spatial cognition, which is central to the study of person-environment compatibility (Kaplan, 1983) and investigates how individuals acquire and use knowledge about their surroundings to determine where they are, how to

obtain resources, and how to get to their destination (Waller & Nadel Lynn, 2013). These capabilities allow individuals to manage various levels of cognitive tasks in everyday life, such as wayfinding.

The terms wayfinding and navigation are frequently interchanged in the literature such that navigation is used as a synonym for wayfinding in particular studies. Despite the semantic overlap between these terms, these terms have a substantial difference. Indeed, navigation contains two components which are wayfinding and locomotion (Montello, 2005). Wayfinding refers to cognitive actions and includes information processing and decision-making, while locomotion refers to the act of moving one's body from one location to another and includes decision execution.

To navigate through an environment, we need to acquire spatial knowledge, which is the spatial relationships of objects in an environment, as well as an understanding of how to move in that environment (Sorrentino et al., 2019). While navigating, we consistently utilize and organize sensory cues that we are exposed to in the environment to obtain information about the space (Lynch, 1960). In other words, reaching a destination is a wayfinding task and its completion relies on a number of hints derived from the spatial setting. To gather spatial knowledge, these cues could be obtained from direct experience (Baskaya et al., 2004), maps (Abu-Obeid, 1998), photos (Herzog & Leverich, 2003), and videos and virtual navigation (Hunt, 1984).

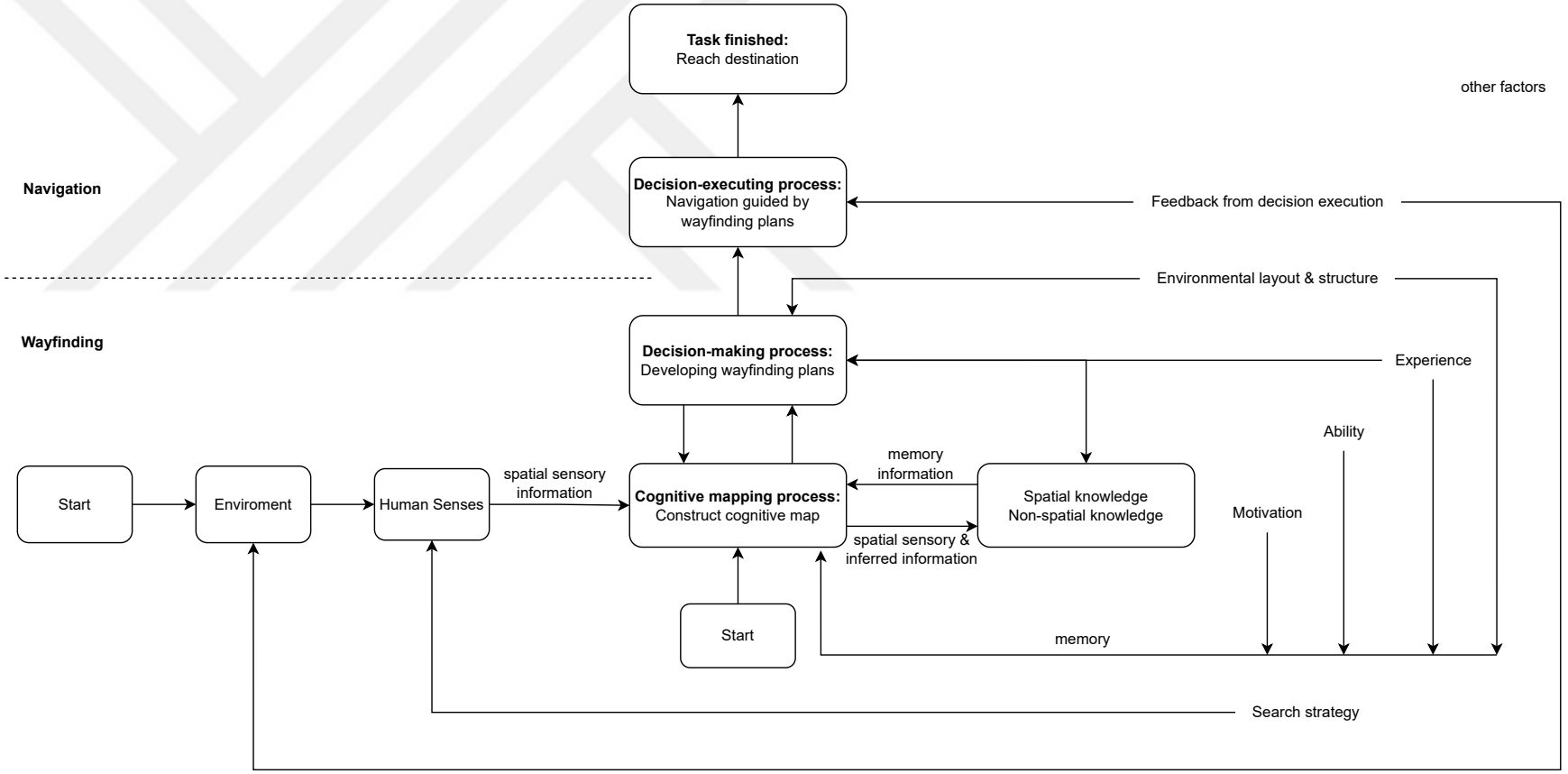


Figure 1. The theoretical model of wayfinding

Adapted from (Chen & Stanney, 1999, p. 681)

Based on the theory of Arthur and Passini (1992), there are three interrelated processes in wayfinding, which are the decision-making (planning a set of actions), decision execution (converting the actions into physical movements), and information processing (gathering spatial information using the senses while moving in the environment). Information processing is grounded on perception and cognition. Perception is the collection of information through the senses, whereas cognition is the comprehension and manipulation of information (Arthur & Passini, 1992).

Navigation requires the constant work of perceptual and cognitive processes. The information describing the environment is not passively retained; instead, it is interpreted, organized, or incorporated into existing knowledge. It is critical to emphasize that the environment dealt with, subjugated, and, most importantly, experienced during this process rather than simply being “seen”. While reaching a destination, people not only pick up cues from the environment but also recall information from memory about that or similar environments that can help them in wayfinding (Passini, 1984).

All the actions we performed while perceiving an environment, such as obtaining, coding, storing, retrieving, and decoding information about the relative location and attributes of the physical environment refer to as ‘cognitive mapping’ (Tolman, 1932). Cognitive maps contain impressions about a place's structure or appearance (Lynch, 1960), relative location, use, and values (Lang, 1987); they are guided by schemata (Neisser, 1977) and, thus, are closely related to the individuals’ experiences as well as the spatial environment (İmamoğlu, 2009). As a result, they vary from person to person and may include partial, schematized, topological, or distorted representations of the physical environment (Lang, 1987). Cognitive maps are dynamic mental images of an environment, which develop with the acquisition of spatial information.

## 2.2. Spatial Knowledge Acquisition

In terms of spatial cognition, Siegel and White (1975) identify three types of spatial knowledge: landmark, route, and survey knowledge. Landmark knowledge refers to being able to identify distinct items without knowing the spatial relationships between them. Landmarks are points of reference external to the observer due to their visual, semantic, or structural attractiveness (Lynch, 1960). Route knowledge refers to following directions to get from one location to another without knowing our position in relation to the destination point (Rossano et al., 1999). This type of knowledge includes the location of landmarks and the routes that connect them. Survey knowledge refers to a holistic understanding of an environment's layout and the interrelationships of the spatial components available in the environment (Golledge, 1991). This type of knowledge could be obtained through maps or repeated exposure to the environment.

### 2.2.1. Landmark Knowledge

Landmark knowledge is the ability to identify distinct items without knowing their spatial relationships. Landmarks are external points of reference that are visually, semantically, or structurally appealing to the observer (Lynch, 1960). Appleyard (1969) states that landmarks differentiate from their surroundings and have a "figure" quality. Due to that reason, when we are exposed to a new environment, we tend to detect landmarks as they deviate from the norm, making them visually striking. As they refer to a certain item or area in an environment, landmark knowledge is defined as "point-level information" (Siegel & White, 1975) (Figure 2).

Landmark knowledge takes the first place in the hierarchy of spatial knowledge acquisition before route and survey knowledge. This type of knowledge is essential to route and survey knowledge as they are built on landmark knowledge. Steck and Mallot (2000) divided landmarks into two, local and global. While global landmarks are visible from a distance and do not disappear as the observer moves, local landmarks are visible reference elements at a very close range.

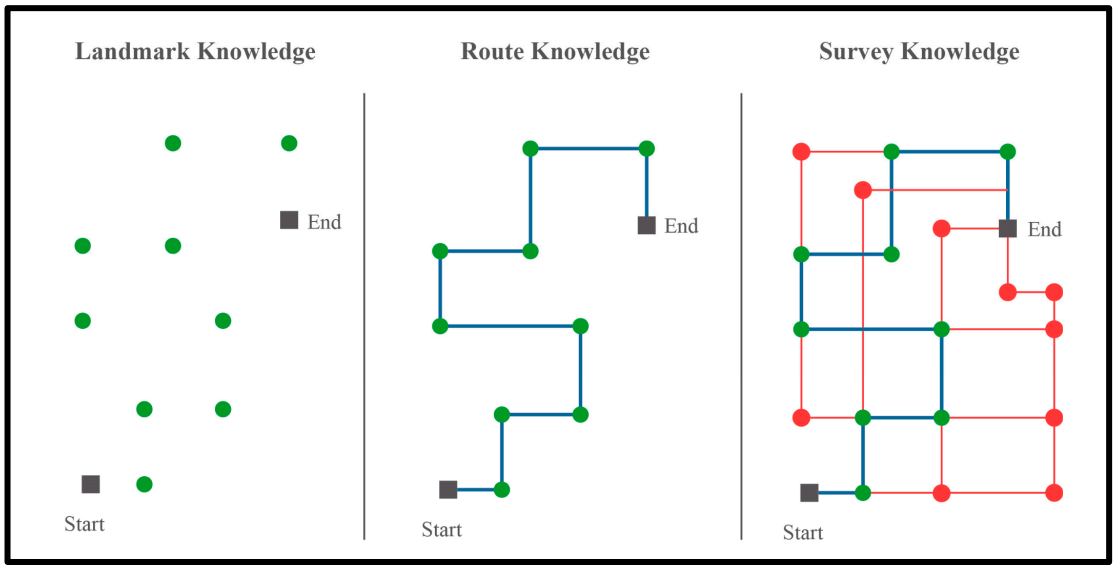


Figure 2. Landmark (left), route (middle), and survey (right) knowledge theory, according to Siegel & White (1975)
(Quesnot & Roche, 2015)

### 2.2.2. Route Knowledge

Route knowledge (or procedural knowledge) refers to following directions to get from one location to another without knowing our position in relation to the destination point (Rossano et al., 1999). According to MacEachren (1992), this type of knowledge is a set of features or movements required to follow the path between the two points. Landmark information becomes more useful when a spatial relationship is established between other landmarks in the environment. For this, we establish a distance and location relationship between the landmarks, and thus the routes connecting the landmarks emerge. Therefore, route knowledge includes the location of landmarks and the routes that connect them.

As navigation is frequently intentional and aims to get a destination, route knowledge is more useful compared to landmark knowledge. Route knowledge is saturated when the path is accomplished in practice a few times. Additionally, it provides an egocentric point of view and involves an object-to-object representational system (Figure 3). Due to that reason, the spatial knowledge

gathered from a route is perspective and ground plane (eye level) dependent and defined as “one-dimensional information” (Rossano et al., 1999).

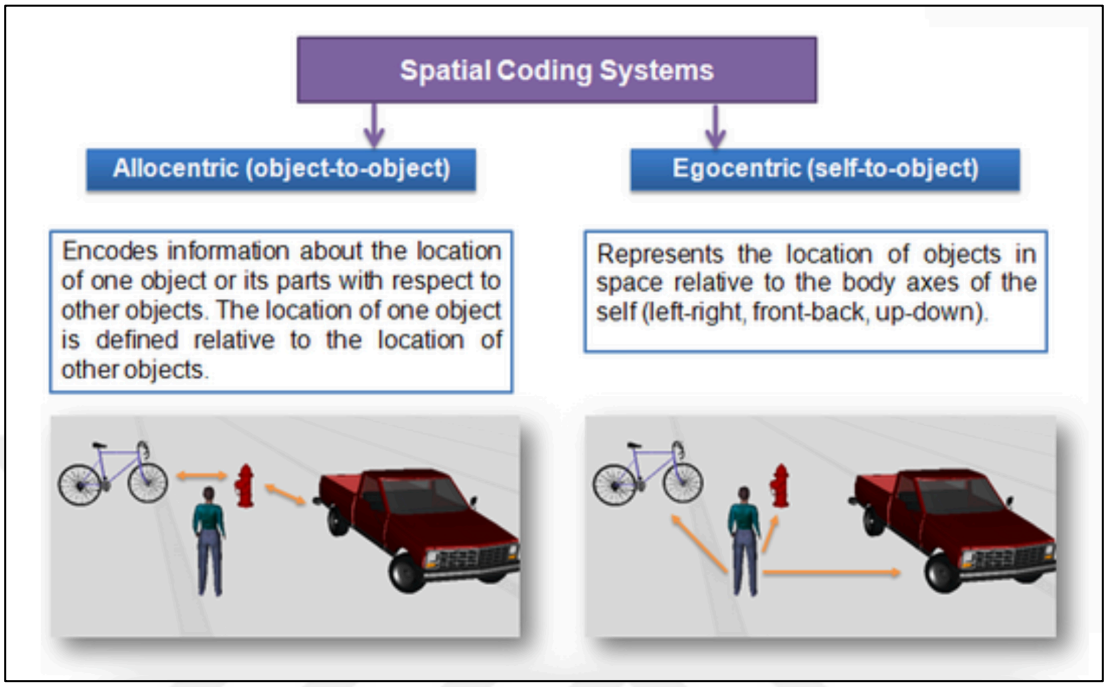


Figure 3. Spatial reference frames
(Imagery Lab, n.d.)

### 2.2.3. Survey Knowledge

Survey knowledge refers to a holistic understanding of an environment’s layout and the interrelationships of the spatial components available in the environment (Golledge, 1991). It is more valuable than route knowledge because a survey representation of the environment contains a bird’s-eye view of the environment and provides the highest level of spatial knowledge since it includes both landmarks and routes as well as the relationships between them.

Benefiting from survey knowledge, the relationship between the objects could be given using cardinal directions (south, west, etc.), angular degrees (Golledge, 1991), or some other objective measurement that is not possible in the landmark and route knowledge. It provides an allocentric point of view and involves a self-to-object representational system (see Figure 3); therefore, it eliminates the reliance

on egocentric perspectives from the ground level that we have in route knowledge (Darken & Sibert, 1996).

For example, while following a route, we see the environment from a single point of view, but if we follow different paths to reach the target and combine different perspectives of that environment, we can understand the layout of the environment. That is, we associate and integrate independent spatial inputs with each other to have a "two-dimensional" survey knowledge (Rossano et al., 1999). This type of knowledge could be obtained through maps or repeated exposure to the environment. Instead of looking at maps, gaining direct experience may aid in forming a more detailed cognitive map because we can see additional information such as building material, texture, color, and so on.

### 2.3. Factors Affecting Wayfinding

As mentioned before, we gather environmental information from the setting to navigate our surroundings. The organization of the setting and its features, such as the degree of visual access, spatial differentiation, and the signage systems, affect the quality of the information we receive, which are defined as environmental factors. While processing the information absorbed from the environment, we perceive and code the environmental knowledge differently because of our experiences, age, gender, culture, and social background, which could be defined as individual factors. Additionally, the actions of others in the environment might influence our wayfinding behaviors. We can make inferences from their movements or from the traces they leave in the environment as a result of social interaction while navigating. Therefore, information processing is the stage where the personal, social, and environmental attributes are merged to help us find our way.

#### 2.3.1. Individual Factors

During the wayfinding process, people perceive, decode, store, and retrieve spatial information differently for various reasons. In addition to environmental factors, there are certain individual factors that affect spatial navigation performance in a

crucial way, such as gender, age, and other aspects, including familiarity, visuospatial skills, disabilities, experience, the field of profession, and background differences.

Previous research (Lawton, 1994) indicates that using a route or survey knowledge might be gender-related. While women tend to develop route wayfinding strategies, men prefer to develop survey wayfinding strategies. A similar trend is also observed in the way people give directions. Women are more likely to use landmarks compared to men, whereas men are more likely to use cardinal directions (North, South, East, West) compared to women. Correspondingly, a study (Coluccia et al., 2007) conducting a map drawing test argued that males approach maps from a global perspective (allocentric/survey wayfinding strategy), while females give attention to local features like landmarks (egocentric/route wayfinding strategy). In addition, men's visual attention to landmarks and legend factors on the map is less than that of women when they try to remember the route (Wang et al., 2019). Other researchers (Babin et al., 2015) argue that women show more hedonistic tendencies than men, and hedonistic people are more prone to be distracted easily by the stores around them, move more slowly, and stop more frequently (Wang et al., 2019). This finding may explain why women pay more attention to landmarks or local objects compared to men.

In the literature, there was also an effort to reveal the effect of gender on wayfinding performance. While there are studies (Lawton et al., 1996; Lawton & Kallai, 2002) showing that men and women have similar navigational performance, many studies (Chen et al., 2009; Lawton, 1994, 1996) indicate that men perform better in wayfinding than women. In addition to these, others (Coluccia & Louse, 2004) concluded that gender differences appear when the task is more complex and disappear when it is easy. Wang et al. (2019) focused on eliminating the gender difference in navigational performances and discovered that the type of navigational support might be helpful. They compared directional signs and YAH maps as an orientation sign, and results showed that directional sign support

significantly increases the performance of females, which eliminates the gender difference, but the same is not valid with YAH map support.

Level of anxiety is another failure in wayfinding such as being lost in a setting or being disorientated from a route has negative consequences such as missed appointments (Zimring, 1981) or unnecessary long travel routes (Bronzaft et al., 1976) and leads to negative feelings such as annoyance, confusion, and frustration that are associated with anxiety (Arthur & Passini, 1992). Regardless of gender, spatial anxiety negatively correlates with the capability of survey wayfinding strategy. Individuals having difficulty maintaining their position in relation to the overall environment described more confusion and anxiety. Alternatively, anxiety about becoming lost may diminish individuals' concentration on wayfinding cues. This type of concern can reach higher levels for individuals who do not have a good wayfinding experience before because prior performance awareness of spatial ability impacts spatial anxiety (Lawton, 1994).

Women reported higher levels of anxiety about environmental navigation (Lawton, 1994), environmental confusion (Lagrone, 1969), less confidence while drawing a map of a floor plan (O'Laughlin & Brubaker, 1998), greater feelings of uncertainty about wayfinding in indoor environments (Lawton et al., 1996; Lawton & Kallai, 2002). One factor contributing to gender differences in wayfinding strategy and anxiety may rely on early wayfinding experiences. A number of findings revealed that there is a perception that the outside environment is less safe for girls, and thus they are given less freedom to go outside in their childhood and early adolescence. Lawton and Kallai (2002) indicate that men's greater childhood experience in the outside environment may lead them to feel more comfortable while performing wayfinding tasks compared to women. Moreover, it may clarify the gender difference in wayfinding strategy preference in such a way that since boys have a wayfinding experience further from home, they are more likely to develop a survey wayfinding strategy (Lawton & Kallai, 2002).

Researchers also discovered age-related differences in wayfinding (Head & Isom, 2010; Taillade et al., 2013, 2016). Numerous studies have examined how age differences affect wayfinding behavior and mental processes that occur while finding our way (Cornell et al., 1999; Lawton, 1994; Passini et al., 1998, 2000). According to Lawton (1996), older and younger subjects used different orientation strategies. Elderly people are more prone to memory loss and disorientation, which limits their wayfinding ability. According to studies, aging-related factors like memory disorder and lack of concentration, which are common in Alzheimer's disease, have an impact on wayfinding behavior and accuracy (Passini et al., 1998, 2000). Elderly people have trouble locating landmarks and themselves in strange environments. Similarly, age effects were observed in environmental scene recognition and landmark recall in wayfinding. However, the age differences in wayfinding accuracy decrease by gaining more experience (Evans, 1980). According to a study (Rodgers et al., 2012), younger adults preferred both egocentric and allocentric strategies equally, whereas older adults overwhelmingly preferred an egocentric approach.

Vision could be considered the most important information source for people to perceive their surroundings and find their ways (Kandalan & Namuduri, 2020; Patla et al., 2011). Due to that reason, wayfinding independently in unfamiliar environments might be one of the most complicated tasks for those who are blind or visually impaired (Brady et al., 2013). They need to accurately follow a path while avoiding obstacles and mostly rely on the use of a cane or a guide dog. However, with the enhancements in technology, they began to benefit from assistive technologies, such as a laser cane based on optical triangulation (Benjamin, Ali, & Schepis 1973), a wearable device to avoid obstacles (Shoval, Borenstein, & Koren 1994) and a smart walking stick (Dada et al., 2017) both based on ultrasonic sensors.

Similarly, people with cognitive disabilities may have difficulties in finding their way and need aiding tools as navigation includes physical (locomotion) and cognitive

(wayfinding) actions (Postma & van der Ham, 2016). People with cognitive disabilities seem to be unable to connect landmarks and paths using a top view of their daily surroundings (Antonakos, 2004). Therefore, they mostly perform their activities in familiar spaces and even avoid going outside for fear of becoming disoriented (Sohlberg et al., 2005). To overcome these limitations, researchers have focused on smartphone-based solutions such as the use of GPS for outdoor navigation (Bulat et al., 2016; Liu et al., 2017) or indoor localization techniques (see Chapter 3) (Torrado et al., 2016) to track the user and assist them in navigating within the environment while providing autonomy using simple interfaces.

Spatial familiarity is another individual factor influencing wayfinding and refers to "how well a place is known" (Chalmers & Knight, 1985). Thorndyke and Hayes-Roth (1982) defined the term as being familiar with an environment in which one has improved knowledge about objects or locations in the environment in comparison to unfamiliar surroundings. Performance on wayfinding and spatial orientation tasks improves as one becomes more accustomed to a place. Moreover, as familiarity increases, the visitor forms a cognitive map (Golledge, 1991), and the environment's level of complexity becomes less significant (Bryant, 1982; O'Neill, 1992). According to Doğu and Erkip (2000), familiarity is a crucial component having an impact on wayfinding behavior indoors and is relevant to education, occupation, and experiences.

Background, experience, field of expertise, and visuospatial ability also impact wayfinding behavior. Saku (1992) indicated that geography students outperformed psychology students in tests of reading contour maps and planning routes. Similarly, Tkacz (1998) suggested that to enhance navigational skills, individuals may learn map-reading as well as navigational methods. Another individual factor that shapes our spatial thinking and wayfinding behavior is visuospatial cognitive abilities. They refer to skills required to develop, preserve and transform abstract visual images (Lohman, 1988) and consist of a set of capabilities (Hegarty & Waller, 2005), such as those required for transformations like mental rotation. In orienteering – a sport

that involves navigating – experts performed better than the control group (people that do not practice sport) on the majority of visuospatial tasks, reported more positive wayfinding attitudes such as sense of direction, familiarity with the cardinal points, regular map use), and demonstrated improved map learning. The visuospatial ability has been intensely linked to large-scale abilities like environment learning (Hegarty et al., 2006). In addition, students in mathematics score better on visuospatial tasks than students in the humanities.

Wayfinding behavior is also dependent on individuals' sense of direction. Individuals with a good sense of direction outperformed those with a poor sense of direction in route learning and employed more flexible and diverse wayfinding strategies (Kato & Takeuchi, 2003). Hund and Nazarczuk (2009) discovered that participants with a strong sense of direction make fewer mistakes and reach their destination faster than those with a weak sense of direction, especially when given directions with cardinal descriptors. Besides, training experience improves the wayfinding performance of those having a weak sense of direction.

### 2.3.2. Social Factors

Indoor environments do not only include stationary entities such as landmarks, architectural elements, and signages but also people. Therefore, while navigating in a building, we encounter people moving around and standing as well as the traces they leave. Just like the environmental information we obtain, people in the environment also have the potential to affect others' wayfinding behavior. Silva et al. (2015) mention that the movement of people may affect how someone interacts with their surroundings and the choices they make when trying to find their way. Wayfinder's plans and expectations may be impacted by the presence of and interactions with other people (Zacharias, 2001). According to Dalton et al. (2019), "others" may have contributed to the wayfinding process as an environmental cue. Others' presence or activities, in the present or the past, may affect the wayfinding behavior and cognition, which is referred to as 'social wayfinding' or 'the influence of the social in wayfinding'.

Individuals pay attention to moving objects for a variety of reasons. According to, things that move attract attention (James, 1890) since the movement seems to draw attention unintentionally (Abrams & Christ, 2003). When viewing videos, participants' eye movements tend to congregate around motions than the still features (Mital et al., 2011). To plan actions and prevent collisions, it is also necessary to elaborately monitor the movements in the environment (Plumert & Kearney, 2014). According to Spiers and Maguire (2008), drivers must actively monitor moving objects to turn around them while searching for a turn-in point. Similarly, pedestrians need to be cautious to avoid colliding with other pedestrians or stepping in front of passing vehicles (Jovancevic et al., 2006).

However, Yang et al. (2018) emphasize that moving entities could be temporary. In other words, moving entities is not always present when the environment is experienced. A crowd or a flow of people in the environment might exist due to a temporary event. This may cause a discrepancy between the moment the environment is learned for the first time (learning) and when the environment is revisited (retrieved). For instance, on the day of a concert held once a year, the environment may include a crowd in groups socializing before the event or a mass of people moving to the concert area. If a person processes the crowd for the concert (moving entity) as a stationary entity in the environment occurring every day, the environment learned might look quite different when the moving entities are eliminated due to the specificity encoded (Godden & Baddeley, 1975), and vice versa. Because the removal of landmarks in the retrieval phase, which are available in the learning phase, typically decreases the wayfinding performance (Biegler & Morris, 1993; Forloines et al., 2015), the same effect may apply to the availability of the moving entities and might influence how we perceive our environment (Yang et al., 2018).

Dalton et al. (2019) propose one of the most comprehensive approaches to social wayfinding, divided into two: strong and weak. While strong social wayfinding

refers to collaborative wayfinding, weak social wayfinding refers to the use of people as cues. Strong social wayfinding contains people intentionally communicating about wayfinding with one or more people to share information about a place or how to get there. Strong social wayfinding typically entails face-to-face direct interaction between the person giving directions (senders) and the person receiving them (recipients), and it most frequently occurs between people who are nearby to one another. On the other hand, weak social wayfinding includes people unintentionally communicating about wayfinding. The person sending wayfinding cues as part of Weak social wayfinding is generally unaware of providing this information, of course, but even the recipient may not always be aware they are picking up and following cues from others. Most senders are unaware of sending cues; indeed, even the recipient might not be aware that they obtain information from others and follow them. Weak social wayfinding can mostly occur distantly but within the limits of sensory access.

Social wayfinding is also categorized into two different time modes: synchronous and asynchronous social wayfinding (Dalton et al., 2019). Synchronous mode corresponds to the sending and receiving cues at the same time and place. People in the act are perceptually reachable to one another. In the asynchronous mode, however, the sender and receiver are not co-present during the transfer of cues. In the end, Dalton et al. (2019), propose four types of social wayfinding situations, namely, (1) strong synchronous social wayfinding, (2) strong asynchronous social wayfinding, (3) weak synchronous social wayfinding, and (4) weak asynchronous social wayfinding. Strong synchronous social wayfinding contains interaction with others during navigation, such as asking others to give directions and requesting them to draw a map. Strong asynchronous social wayfinding refers to providing wayfinding information prior to navigation, such as using a city map or a navigation system with predefined instructions and algorithms. Weak synchronous social wayfinding entails paying attention to others' dialogues and trails, such as hearing a spatial cue about the route to a destination that we need to plan from a specific distance (Hall, 1966) following a crowd of people with new-year costumes moving

to the place of the new-year event that we are unsure how to get to, changing our route due to an uncanny group of people appearing on our route at midnight, and trying to avoid the slow crowd to walk faster. Last but not least, weak asynchronous social wayfinding refers to using physical traces of previously performed human activity, such as following the human footprints on the snow in an environment where we are lost and need help and avoiding a pavement with bloodstain as it indicates danger.

Group interactions are another component of social wayfinding (Galton, 1907; He et al., 2015; Hill, 1982). As each group member has a unique personality, the decision-making process in wayfinding can be complicated as a result of the individual factors conveyed by group members. The degree of involvement in wayfinding may vary from full to no involvement for each actor in the group (Dalton et al., 2019). Full involvement may imply navigating alone or being the only person in the group who gives directions, such as a tourist guide. Group members involved partially may contribute to the wayfinding process by expressing their opinion to a certain degree. No involvement would be the same as silently accepting whatever others decide, such as college students following a guide in a university they visited.

Galton (1907) states that reaching a consensus within the group is more accurate compared to all the opinions of group members and highlights the wisdom in crowds. Another study (Hill, 1982) suggests that group decisions may not be superior to individual decisions in terms of wayfinding performance. He et al. (2015) examined pairs of people taking different routes in an unfamiliar environment and compared the pairs both having a good sense of direction, both having a poor sense of direction, and having a different sense of direction. Their research showed that the task appears more challenging and time-consuming to the pairs with a different sense of direction.

### 2.3.3. Environmental Factors

Environmental information is the architectural and graphic representation of information required to solve wayfinding problems (Passini et al., 1998). Wayfinding design aims to provide the environmental information necessary for decision-making and decision execution while respecting the user's ability to deal with basic perceptual and cognitive tasks. The structure of the built environment affects its legibility (Güneş, 2018), the accuracy of the cognitive map, and thus our spatial behavior and wayfinding performance. When there is insufficient architectural information or legibility, we may have difficulty acquiring spatial knowledge and wayfinding (Doğu & Erkip, 2000), especially indoors. Compared to the outdoors, indoor environments might have more complex layouts, zones similar to one another (McAndrew, 1993), and a narrower field of vision due to architectural elements such as walls and ceilings (Wang et al., 2019). Nonetheless, it remains a problem that is only discovered when concerns from post-use reviews occur. Visitors who cannot estimate the overall configuration of settings encounter difficulties in wayfinding that may increase their stress levels and cause anxiety (Arthur & Passini, 1992; Carpman & Grant, 2002).

Contrary to what is believed, poor wayfinding performance is a result of architectural deficiencies rather than the use of signage. As a result, while wayfinding signage may improve navigation performance, there may be instances where they do not overcome all the architectural failures causing wayfinding issues (Arthur & Passini, 1992). Architects and designers should consider wayfinding design in the early phases of the design process. Nevertheless, it is still a problem that is only identified when concerns from post-use evaluations arise.

#### 2.3.3.1. Visual Access

As buildings grow in size, the complexity of spatial organizations causes various architectural difficulties, such as intersection points, dead ends, and obstructions that hinder visual accessibility. Visitors with sufficient visual access can obtain spatial information about both horizontal and vertical circulation systems and the

spaces attached to these paths. To comprehend the organization of the space, the essential elements in the building need to be legible, which requires visual accessibility.

When the buildings have adequate visual access, which is provided by clear open areas, the visitors can absorb the clear depiction of the layout of the buildings. Open areas offer visitors to view numerous floors together with the circulation path and the spaces, allowing them to sense the spatial order of a substantial portion of the building's interiors (Lawton, 1996). Having visual access to every part of a building aids in orientation (Gärling et al., 1983; Moeser, 1988; O'Neill, 1991). Due to that reason, indoor legibility is enhanced by introducing open spaces via visual access. As demonstrated by Doğu and Erkip (2000), people found a mall containing shops and stores arranged around a central atrium to be an easy setting in terms of wayfinding.

If the buildings consist of separate blocks with no visual access between them, individuals have difficulty comprehending the entire configuration, resulting in a faulty cognitive map. If possible, designers and architects may apply different design solutions instead of using opaque walls, such as using glass separators or plants. This approach not only fits the need for a separator element but also enables visual access.

#### 2.3.3.2. Layout Complexity

The term 'configuration' corresponds to the relationship between spaces and the overall pattern that they form. In addition to the visual access providing local spatial knowledge, a complex building is expected to reveal information about the overall layout (Peponis et al., 1990). The circulation paths are essential elements in a setting. They are the spaces we navigate and try to find our ways. Due to that reason, we employed all the cognitive and perceptual processes regarding wayfinding in these spaces.

Several studies (Haq & Zimring, 2003; O'Neill, 1991) suggest that the complexity of floor plan configurations has the biggest impact on wayfinding and perceived legibility. According to Best (1970), there is a direct correlation between the number of decision points (such as the intersection points of two or more corridors) and the difficulty of navigation. Understanding the building configuration aids visitors in forming a mental image more easily and accurately, resulting in improved wayfinding performance (Gross & Zimring, 1992; Weisman, 1981). The buildings with simple layouts contribute positively to the generation of mental representation (McKean, 1972; Passini, 1984; Weisman, 1981). Therefore, visitors navigating buildings with complex spatial configuration experience difficulty forming a mental image, which causes a drop in the wayfinding performance (O'Neill, 1991).

Thus, one's cognitive map could be improved by enhancing the legibility of the environment. Lynch (1960) defines five elements that people use to shape their cognitive maps and aid them in understanding complex environments. These are paths, edges, districts, nodes, and landmarks. Although these elements resemble the structural elements of a city, they are primarily based on the Gestalt laws of the visual organization (Lang, 1987). Because we perceive our surroundings in a similar way regardless of the type of built environment, these elements are also used to increase the legibility of buildings to aid people in wayfinding.

Symmetry, regularity, and continuity are the characteristics of good form, supporting wayfinding (Canter, 1974). Furthermore, positive orientation is also associated with simple corridors and central atrium systems that permit perceptual access between spaces (Lawton et al., 1970). Furthermore, the form of a building needs to support its circulation system to be instructive so that people approaching the building from the outside can estimate the interior configuration and consider that knowledge while making and executing their decisions while finding their ways.

#### 2.3.3.3. Spatial Differentiation

A simple floor plan alone is insufficient to aid visitors in forming precise environmental images; additionally, pictorial differentiation must be present (Abu-Obeid, 1998). Monotony creates repetitive and routine environments, even in buildings with simple configurations, resulting in more difficult wayfinding experiences. Corridors, which are similar to each other and without landmarks, cause a poorer wayfinding performance (Wright et al., 1993). According to Passini (1984, p. 85), “A main reason for the difficulty in understanding labyrinths is their absence of spatial identity. When a person walks through a uniform labyrinth, each zone looks just the same as the one visited before. The absence of spatial identity leaves the user without building blocks to construct a cognitive map or to form an overall image of the layout”. Therefore, there needs to be a certain degree of environmental complexity.

Features embedded in the environment can be distinguished from their surroundings when they include distinct surfaces and clear contours, making them more image-giving (Appleyard, 1969; Murakoshi & Kawai, 2000). For instance, the use of color improves the differentiation of elements within an environment (Lang, 1987). Nevertheless, when differentiation is used excessively, it loses its advantage since the setting becomes chaotic.

#### 2.3.3.4. Signage Systems

Passini (1980) discovered that whereas some people relied more significantly on signage while navigating a large complex building, some relied largely on the building's configuration and clarity. Navigation difficulties influenced by buildings with insufficient architectural information can be compensated to some extent by using signages, which are graphic information aids. The use of signs considerably diminishes the time to reach the destination and the negative feelings such as perceived crowding, discomfort, anger, and confusion (Wener & Kaminoff, 1983). The most crucial factors in helping people comprehend and utilize the signs are their applications and design standards. Legibility and recognizing the information

are both influenced by the features of a sign, such as its graphic design, the font type and size, foreground and background components providing contrast, position, size, and illumination (Passini, 1984). These tools have been developed in the form of directional signs, identification signs, and orientation signs (Arthur & Passini, 1992).

Directional signs guide people to a destination along with a designated or pre-selected route (Arthur & Passini, 1992) and provide cues for visitors to navigate a setting. These signs consist of arrows and plain-language descriptions involving the use of building features or landmarks. While the design of directional signs should be in harmony with the environment they are located, they need to be clearly identifiable. Directional signs, for example, may be located at the entrance of a large hospital complex to guide a visitor to a laboratory, a specialty care center situated in another building, or a specific patient room inside a unit. Although they are fast to process, a new one is required at every decision point.

Identification signs give information identifying the destination, such as an object, a place, or a person in space, upon arrival. These signs consist of names or pictographs at the entrance to destinations. Typically, the destination is reached once they are perceived. Because of this, they include the information needed to conclude both the decision-making and decision-executing processes.

Orientation signs are designed to ease one's understanding of the overall configuration of a setting by providing its simplified top view (Levine, 1982). They include information about the layout of the building, the position of the visitor looking at the map, and where the destination lies (Passini, 1984). The most widespread orientation signs are YAH maps and since the model we proposed operates together with YAH maps, the remaining part of this section describes (1) the essential components of these tools we consider and (2) the advantage of digital maps that we used in one of the conditions with QR codes.

#### 2.3.3.4.1. You-Are-Here Maps

You-Are-Here (YAH) maps are standard aids for newcomers to complex settings (Levine, 1982). Today, many public buildings include a variety of functions and are constructed on large scales. Therefore, users navigating these complex settings have difficulty perceiving the whole setting. Designers of these spaces are well aware of this problem and add a space map to fix the problem. It is generally vertically fixed, either against a wall like a picture or in an open area around the entrances and vertical axes such as stairs, escalators, and elevators. It might be colored from four to six colors.

YAH maps ease understanding of the overall configuration of the setting by offering an image of the environment from the top. However, knowing where and how a YAH map is placed in a setting is essential. Below, a set of recommendations is listed for a well-served YAH map.

1. *Adding labels*: One of the problems for a YAH map user is to relate the map to the setting. To do that, the map should include labels, which are also available in the environment. The minimum information required to relate them is provided by the "Two-Point Theorem" in transformational geometry (Maxwell, 1975). According to this theorem, if two pairs of corresponding points can be matched with a one-to-one relationship, then two entire figures will match at every point (Figure 4). Therefore, at least two labels/information items should be given on the YAH map. Another option could be using a YAH icon together with a label or a visible landmark identifiable on the map and the setting.

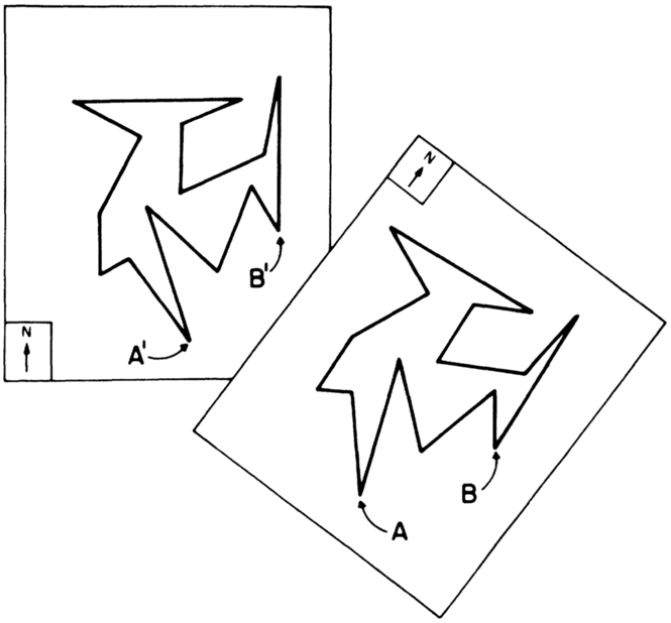


Figure 4. An example of the two-point theorem: “two congruent forms which are mismatched by some unknown degree of rotation and translation”.
(Levine, 1982, p. 225)

2. *Using asymmetrical structure:* placing the map asymmetrically in the setting helps users to match the map with the setting easier and faster.

3. *Improving the YAH symbol:* The mission of the YAH symbol is to provide users with a general index of location. However, symbols in the form of an arrow may also indicate the user's direction. It may refer to where the user stands and which direction they look at. Another solution could be using a short line symbolizing the map and its orientation and an arrow simultaneously representing the user and its orientation. This way of solution is called the “bi-part YAH symbol”.

4. *The Forward-Up Equivalence:* According to Levine (1982), there is a psychological equivalence between forward and up, which is the “Orientation Principle”. If the direction in front of you is indicated as up on the map, it means that the map and the setting are aligned. However, if the

direction in front of you is indicated as down, it means that the map and the setting are contra-aligned. This may lead to difficulty in using the map. The reason behind the idea is simple. If the map holds a forward-up relationship, your left and right will be the same as on the map. However, if the map holds a forward-down relationship, your left and right will reverse on the map. In other words, for example, your right in the setting will be your left on the map.

5. *Employing redundancy:* this statement contributes to the idea that for a well-served YAH map, designers of the maps should apply all the set of recommendations above.

A lack of one of these recommendations can make the map more challenging to use. “Indeed, certain placements are counterproductive, causing the viewer to become lost, that is, to walk in a direction leading away from his target” (Levine, 1982, p. 222).

#### 2.3.3.4.2. Advantages and Disadvantages of Digital Maps

Today, we live in the era of Google Maps and smartphones, and thus many people benefit from digital maps. However, paper maps and digital maps have both their advantages and disadvantages.

Digital maps have a clear advantage in terms of functionality and details of the visuals. The following are some of the benefits of digital maps:

- By zooming in on the map, users can see more detail, whereas zooming out on the map allows them to see the overall setting they are looking at.
- Some navigation systems may dynamically change the amount of information provided to the user while zooming in and out.
- If the navigation system includes a route planner, users can search for locations and find the quickest route to their desired location. Furthermore,

some systems offer customized route planners such as the greenest path, the most proper path for wheelchair users, and so on.

- Some navigation systems enable users to customize the map by selecting different layers of information. For example, one may prefer to display ATMs and shopping malls in a specific area or on their route.
- Digital maps can be updated easily.

The following are some of the drawbacks of digital maps:

- Because digital maps are used with an electronic device such as a smartphone, there may be some battery issues, particularly when GPS-based applications are used, which drains the battery significantly.
- If a navigation system requires an internet connection, and your signal drops out, it would be problematic. The problem may be solved by downloading an offline map, which, on the other hand, requires a significant amount of storage.
- As smartphones may contain bugs and crash occasionally, software-related issues must be considered.
- Since mobile phone screens are not as large as paper maps, users may not be able to see and understand the overall configuration of a setting.
- The use of digital maps, as a part of technology, might be age-related. Although older people are willing to adopt new technologies, they may have a certain degree of concern about the complexity of technological devices (Heinz et al., 2013). In comparison to younger participants, they perceived less comfort, efficacy, and control over technology (Czaja & Sharit, 1998). Cognitive problems and low self-efficacy, which are associated with older age, diminish participants' ability to adopt and use technology (Alvseike & Brønnick, 2012).

### 2.4. Wayfinding in Virtual Environments

As previously mentioned, there are various ways and mediums for learning an environment by gathering spatial knowledge, one of which is virtual environments

(VE) (Thorndyke & Hayes-Roth, 1982). The term virtual reality refers to a computer-generated, three-dimensional environment. In these simulations, the user can navigate and interact with the three-dimensional virtual environment in real time. During this interaction, they often experience a sense of being in the VE, which refers to the presence or immersion in which they mentally remove themselves from the real world to the virtual world. In other words, presence can be regarded as how powerfully the user focuses on the task.

Virtual Reality (VR) is a compilation of technologies creating human-computer interfaces by which individuals experience three-dimensional computer-based environments while using their natural senses and motor skills. To understand the physical and psychological experience gained in VE, we may examine the concepts of presence, involvement, immersion, and interaction (Rebelo et al., 2011). During their engagement, they experience a sense of being in the VE at a certain level, called 'presence' (Rebelo et al., 2011).To be fully spatially present in the VE, the individuals are expected to be isolated from the physical environment and consider the VE only (Riecke, 2003). To do so, the VE should immerse and involve the user. Involvement and immersion are presented as required conditions for experiencing presence. Involvement is "the psychological state experienced as a result of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events" (Witmer & Singer, 1998, p. 227). Since involvement directly correlates with the degree of concentration on the VE, every factor causing user distraction can have an impact on involvement. Immersion, however, refers to "the psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli" (Witmer & Singer, 1998, p. 227). As a result, the level of immersion influences both the degree of isolation from the physical environment and the quality of interaction with VE. Even though involvement and immersion are distinct components, they are interdependent. In other words, people may become more immersed in a VE as their level of involvement increases, and vice versa (Witmer & Singer, 1998). Interaction, however, refers to the communication between the user

and the system running the VE. The system recognizes user motions and activities while updating the VE and creates outputs based on user inputs, followed by new user inputs based on the system outputs. Thus, it is an iterative cycle of interaction between the user and the VE.

To be fully spatially present in the VE, the individual has to forget about the physical environment and accept the VE as the only reference frame (Alsina-Jurnet & Gutiérrez-Maldonado, 2010; Riecke, 2003). If the users lose their awareness of being in a real environment while performing in a VE, a high degree of presence could be achieved (McCreery et al., 2013; Riecke, 2003). To do that, the VE should be immersive and easy to use so that the user does not concentrate on using the equipment and can experience a sense of being there. According to the classification of another study (Gutiérrez et al., 2008), there are three types of immersion based on the physical configuration of VEs, which are full-immersive (using head-mounted display), semi-immersive (using large projection screens), or non-immersive (using a desktop).

### 2.4.1. Types of Virtual Environments Based on Immersion

Fully-immersive VR systems give the users the highest degree of presence among all the VE types and so the most realistic experience possible but require pricey equipment like VR headsets, VR glasses, and other accessories to increase the interaction, like gloves helping simulate other senses like touch (Süzer & Olguntürk, 2018). The popularity of VR systems that provide full-fledged experiences is increasing, so new modes have emerged to organize events and socialize, such as ‘metaverse’, which offers a three-dimensional virtual world network.

A typical headset, a so-called Head-Mounted Display (HMD), has two small display screens and an optical system that channels the images from the screens to the eyes. The user’s position and orientation are continuously measured by a motion tracker, allowing the image-generating computer to adjust the scene representation to the current view. As they exclude the user from the real environment, this method provides the user with a field of view of 360 degrees, meaning a stereo

view of the virtual environment. As a result, the viewer can look around and walk through the surrounding virtual environment. The sense of immersion depends on several parameters, including the field of view provided by the HMD, the resolution, the update rate, and the contrast and illumination of the display (Vilar & Rebelo, 2010). Until recently, the necessary hardware and software were limited to high-end technologies; however, recent improvements have lowered their costs and have made it an efficient tool. The headsets available recently have been designed to be compatible with the smartphones we use daily, so no additional hardware and software are required.

Semi-immersive systems provide a lower sense of presence compared to fully-immersive systems and necessitate ultra-wide monitors, large projector systems, or multiple screens located side by side to surround the user (Vilar & Rebelo, 2010). The system provides immersion using large screens, requiring costly graphic computing systems to achieve high screen resolution. As this type of VE is used for training, a physical environment may be necessary to supplement the virtual reality. In flight simulations, for example, pilots follow the virtual content on the screens. However, the virtual environment is controlled by the physical key and buttons in the real environment that is designed as a replica of a cockpit's interior. Due to that reason, some semi-immersive reality experiences are considered mixed reality, where digital objects interact with physical objects (Vilar & Rebelo, 2010).

Non-immersive VE systems, as the name suggests, are the least immersive implementation of VR techniques and provide the slightest sense of presence among all the immersive VE systems (Vilar & Rebelo, 2010). However, as the experience is achieved with the standard desktop systems or laptops using the tools such as a keyboard and mice, they appear as the lowest cost and most accessible VR solution. In addition, if built well, less immersive systems using desktop computers or laptops are easy to access and provide sufficient visual realism in spatial knowledge tasks (Sayers, 2004).

### 2.4.2. Advantages and Disadvantages of Virtual Environments

VEs offer many benefits to their users. One of the remarkable advantages of VEs is to permit experimental control. Using VE allows researchers to manipulate the environment's layout systematically, and different kinds of interactions can be designed to create suitable experimental conditions (Dombeck & Reiser, 2012; Sauzéon et al., 2011; Vilar & Rebelo, 2010), increasing the validity of the studies (Schultheis et al., 2002). For this reason, with the intentional differences in these environments, a researcher can create control and treatment environments. This feature increases the reliability of the study since it eliminates other potential variables that may affect dependent variables (Jansen-Osmann & Wiedenbauer, 2004).

While conducting a study in physical environments, observers should follow the subjects and take notes simultaneously in the field. This situation requires a high cognitive effort and may cause missing information to record (Krathwohl, 1998). However, VEs allow researchers to record subjects' behaviors for further evaluation (Dombeck & Reiser, 2012; Morganti et al., 2007; Rey & Alcañiz, 2010). Researchers may use a video camera and a built-in screen recorder to record the setting and screen. After the experiment, they can watch the record and analyze the variables, such as the experiment's duration, the number of errors, and the direction they were looking.

Being in a VE isolates participants from the risks we have in real life (Vilar & Rebelo, 2010). Experiments in the physical world might expose the chances of tripping and falling, scratching or cutting the skin, or being hit by a car. Since participants do not have these risks in VEs, they feel safe.

In addition to the benefits, VEs include several limitations as well. VEs enable researchers to have greater control over visual features and the complexity of the environment. Researchers may provide a more complex and well-designed virtual 3D environment to represent better real environments (Jansen-Osmann & Wiedenbauer, 2004). However, generating a detailed VE is time-consuming and

requires great effort. Moreover, since not all researchers are good at using computers to create a VE, the end product would remain poor in terms of details and complexity (Rey & Alcañiz, 2010). This may lead to unrealistic environments in VEs that might negatively affect the feeling of presence (Witmer & Singer, 1998).

In addition, the feel of presence may also decrease if any lagging occurs on the screen. Lagging appears if the hardware of the computer is not strong enough. Therefore, if lagging appears on the screen while navigating in the VE, it probably distracts one's concentration. The problem could disappear with the use of powerful hardware, but it will increase the cost.

Furthermore, VEs have another constraint: Field of View (FOV). The standard FOV for a human is about 200 degrees, whereas a 21" monitor, for example, has a FOV of 40 degrees (Vilar & Rebelo, 2010). This means subjects have a narrower FOV in VEs. Besides, since people navigating in the VEs do not move physically (self-motion) in the real world, they do not have accurate kinesthesia (movements of the muscles) (Jansen-Osmann & Wiedenbauer, 2004; Vilar & Rebelo, 2010). To prevent the lack of self-motion, the experiments may use a large curve screen or VE glasses so that subjects may move their body while standing. However, at this point, studies reveal that using a 360-degree immersive VE with VE glasses might cause some people to feel the symptoms of motion sickness, disturbance of balance, and drowsiness (Jansen-Osmann & Wiedenbauer, 2004).

### 2.4.3. Active and Passive Exploration in Virtual Environments

Spatial knowledge in VEs can be acquired by active and passive exploration. Passive navigation typically entails taking a guided tour by following a pre-recorded route in the VE, whereas active navigation refers to a situation in which the participant has the motor and/or volitional control over their movement within an environment by moving in the VE with a joystick or keyboard (ref: Active and passive contributions to spatial learning).

According to Downs and Stea (1973), active navigation results in a more precise understanding of space. Nevertheless, the advantages of active exploration are typically restricted to particular spatial knowledge metrics (Péruch & Wilson, 2004). On the other hand, it was found that passive exploration is preferable to active exploration for the acquisition of environmental information and suggested for indoors utilizing predefined routes (Cao et al., 2019). A number of studies revealed no significant difference between active and passive exploration modes in terms of error scores (Wilson, 1999), pointing tasks (Carassa et al., 2002), and level of performance (Sandamas, 2003). According to Wilson and Péruch (2002), the cause of the conflicting results between active and passive exploration is attention. This data demonstrates that if attention is enough, the differences between the learning strategies are minor (Farrell et al., 2004).

### 2.4.4. Use of Virtual Environments in Wayfinding Studies

Virtual reality technology is used in various fields, such as military, aviation, medicine, psychology, and architecture, as they offer numerous advantages for training and research purposes. Computer-based three-dimensional simulations allow researchers to control or change specific factors in a real environment (Rossano & Reardon, 1999; Wilson et al., 1997). Besides, when it is hard to gather the participants in the real environment, they may access and experience the environment by interacting with its computer-generated model (Ishikawa et al., 1998).

With the increase in computer usage, VEs have replaced conventional simulation methods and become the new navigation media. They enable simulated explorations in computer-generated three-dimensional (3D) environments. Since this exploration has great potential to acquire spatial knowledge, many researchers benefit from these environments in their studies. VEs enable researchers to have greater control over the environment's visual features and examine how people navigate and what navigation strategies they use in unfamiliar environments (Vilar & Rebelo, 2010; Walkowiak et al., 2015).

Studies investigated that spatial knowledge gained through VEs can be used effectively to navigate in real environments (Walkowiak et al., 2015). Likewise, spatial knowledge tests revealed that people who navigated in a real-world building revealed similar accuracy with those who navigated in a virtual replica of that building (Ruddle et al., 1997). In other words, these results demonstrated that people could transfer spatial information between the environments. For example, in a study (Wilson et al., 1996), students navigated in a computer-generated model of a real building, including only the major architectural cues such as corridors and doors. After the experience gained in the VE, students could estimate directions to the objects in the real building. Similarly, (Bliss et al., 1997) found that firefighters who discovered a simulated building could find their direction in the real building. Another study indicated that the wayfinding performance between the real and virtual environments is largely the same (Dong et al., 2022).

Many researchers have benefited from virtual environments for wayfinding studies. Memikoğlu and Demirkan (2020) examined the stairs as local architectural cues in a multi-level building. Natapov et al. (2022) investigated the relationship between the human factors of emergency wayfinding and architectural design, including the transparency of the walls, starting point of the evacuation, and landmarks. Süzer and Olguntürk (2018) concentrated on the impact of cool, warm, and cool color settings on the visuospatial navigation performances of elderly people in a virtual polyclinic environment. Lin et al. (2012) evaluated the gender differences in wayfinding performance in environments with both local and global landmarks. Lingwood et al. (2018) studied if children aged 8, 10, and 12 could learn a route after only experiencing it once.

# CHAPTER III

# LOCALIZATION TECHNIQUES FOR INDOORS

Indoor positioning systems (IPS) are a network of devices that are used to locate people or objects in environments where GPS and other satellite technologies are imprecise or completely ineffective, such as underground locations (parking garages, metro stations, etc.) and areas of complex buildings away from facades. This section introduces the localization techniques used for indoor wayfinding. The methods requiring the use of applications or sensors are presented together, whereas barcodes, including QR codes, are described in-depth separately, as the current study adopts these tags.

## 3.1. Localization Techniques Based on Applications or Sensors

The first method, pattern recognition localization, requires collecting the setting's raw data in the first step. Localization is accomplished by collecting and matching the perceived data gathered while navigating with the raw data previously collected. However, generating a database is the drawback of this method, as it takes time. Pattern recognition techniques can be divided into two: 'Computer Vision' and 'Signal Distribution or Fingerprinting'.

Computer vision localization uses image capturing. Before the system is opened to the public, images from closed spaces or circulation routes are captured. In other

words, a database of images is generated. While the users are navigating in the environment, a device's camera, like a smartphone, captures images of the environment. After that, by matching the images taken by the users with the images stored in the database, the system estimates the location and orientation of the users. As mentioned before, this system requires the use of a device that can take photos, like a smartphone. However, since matching the images while navigating requires significant computing, it could be challenging to implement this system using handheld devices. Moreover, taking photos sequentially and computing to match the images drains the device's battery quickly. Also, a high storage capacity is needed to store all the photos taken indoors.

Signal distribution or fingerprinting localization works similarly to computer vision. The indoor is installed with sensors that emit signals. However, this system uses the Wireless Local Area Network (WLAN) instead of the previously mentioned methods. As this system has almost become a standard to connect to the internet, many institutions already use this signal distribution. Therefore, they use the existing base station, and no extra investment in infrastructure is needed throughout the building (Hightower & Borriello, 2001). Before its public use, a map of signal strength from different locations inside the building is recorded as a training phase. While a user is navigating, the received signal strength is measured and compared with the pre-recorded map to find the best match and, as a result, locate the user in the environment.

The second method, dead reckoning localization, requires a previously estimated or known position to calculate the user's location (Fallah et al., 2013; Khalili et al., 2022). This system can determine a person's position with an accuracy of 0.6 meters (Sharp & Yu, 2014) and benefits from a combination of sensors such as accelerometers, magnetometers, gyroscopes, and barometers. In general, the first position is determined via GPS or direct sensing technologies like Radio Frequency Identification (RFID) or Beacons. After that, calculations are made using the sensors of devices such as smartphones to estimate the user's location, and each sensor

contributes to this process differently. The accelerometer and gyroscope work together. While an accelerometer measures the linear acceleration of movement, a gyroscope measures the rotational angular velocity (Hsu et al., 2015). In other words, both sensors measure the rate of change, but for different things. A user's number of steps can be calculated with these sensors (Serra et al., 2010). Compass functionality in smartphones utilizes a magnetometer to measure the strength and the direction of magnetic fields. Therefore, it allows a phone to determine its orientation by analyzing Earth's magnetic fields (Serra et al., 2010). The barometer is used to get data about altitude, and this feature refers to obtaining data about floor numbers in closed spaces.

The location estimation in dead-reckoning systems is an iterative process. If any inaccuracy in location estimation occurs, the number of errors accumulates over time (Fallah et al., 2013). However, the user's position could be updated using environmental knowledge, map-matching, or other sensor-based technologies. Because only a few sensors are required, it could be considered a low-cost localization system.

The third method, triangulation, is known that direct sensing technologies mainly use one identifier to locate the user. However, these systems benefit from multiple identifiers, making calculations to locate the user. This system operates at least three identifiers installed in a known position to identify the user's location (Zheng & Ni, 2005). The distance between the user and at least three known points refers to 'lateration', whereas the angular measurements from at least three known positions refer to 'angulation'. In other words, lateration and angulation reveal users' position and direction, respectively (Zheng & Ni, 2005). The most known outdoor localization technique, GPS, processes this technology and estimates users' location according to the calculations of at least three known satellites (Official U.S. Government Global Positioning System (GPS) Webpage, 2017).

The fourth method, direct sensing localization, uses bilateral relations. This system depends on receivers/readers and tags installed in the environment. Specific data is uploaded into tags and retrieved with the help of receivers/readers of these tags (Fallah et al., 2013). Tagging technologies can be divided into five: 'Radio Frequency Identifier (RFID) Tags', 'Infrared Localization', 'Ultrasound Identification (USID)', 'Bluetooth Beacons', and 'Barcodes'.

The first technique, Radio Frequency Identifier (RFID) tags could be passive or active. Active RFID tags contain a battery that transmits signals automatically. The tags have a more extensive range, which reduces the number of required tags that need to be installed. Their impact area is larger, which diminishes the number of tags that must be installed, which may decrease the installation cost. Active RFID tags can store data up to 128 kilobytes (Techspirited, n.d.). However, since active RFID tags hold a battery, they require maintenance, like replacing batteries.

Passive RFID tags are powered and emit signals only when a reader approaches the tag. Because these tags include no battery, they require no maintenance. However, since their impact area is narrower compared to active RFID tags, more tags should be installed in the environment, which may increase the installation cost. They can store data of less than 128 bytes (Techspirited, n.d.). In general, although RFID sensors are relatively inexpensive, their installation in large buildings might be costly due to the large number of tags required.

The second technique, Infrared Localization (IR), is similar to RFID technology and uses infrared transmitters located in a specific position (Baus et al., 2002). They broadcast a unique ID in a cone-shaped region, and an IR receiver picks up signals that users carry. Natural and artificial lighting are the drawbacks of IR technology as they can interfere with IR (Moreira et al., 1996). Additionally, they have a narrow transmission angle (Liu et al., 2007); thus, IR tags should be positioned carefully to provide a clear line of sight. Similar to RFID, since its application in large buildings requires the use of a significant number of tags, their installation could be costly.

The third technique, Ultrasound Identification (USID), uses emitters that broadcast ultrasound waves with a short wavelength (Baus et al., 2002). USID, like other tagging technologies, uses an emitter installed in a closed space and a receiver carried by the user to pick up the signals. The time difference between the signals and the receiver picks up from the closest two emitters is used to calculate the user's position. This is also called flight time difference. However, as a drawback, walls may reflect or block the signals (Baus et al., 2002), which may cause inaccurate localization. The line of sight between the receiver and the emitter is another drawback for the localization based on ultrasound.

The fourth technique, localization based on Bluetooth beacons, is another method for localization in closed spaces. When a device like a smartphone is in close proximity to a beacon, an action is performed between the emitter and the receiver. However, the user with a receiver needs to walk slower due to the device delay (Chawathe, 2009). Beacons need a power source, so they need maintenance. Similar to RFID localization, because the receivers or emitters must be assembled on the ceiling, the change in infrastructure is one of the disadvantages of this method.

The fifth technique, localization based on barcodes, is also used for localization. When a barcode is scanned with a barcode scanner, users navigating a path can see their location on the path. Tags may provide information about the users' location, surroundings, and direction (Nicholson et al., 2009). The disadvantage of this method is that the user must locate and scan each barcode, which can be time-consuming and slow navigation. Nevertheless, as barcodes are made of paper and do not include any electronic mechanism, they are low-cost and easy to install. The current study utilized a variant of barcodes, QR codes, for the indoor localization technique. Thus, the following part focuses on barcodes in detail.

### 3.2. Barcodes

A barcode (also bar code) is an optical, machine-readable representation of data. Barcodes provide a convenient way to label a tag on a product so that people can easily identify the content of the product itself. One needs to have a barcode reader to reveal the content assigned to a barcode. When the barcode reader decodes the barcode, the information embedded into the barcode could be retrieved either from a local database (D'Atri et al., 2007) or from a central database through a wireless connection (Torrado et al., 2016).

The local database approach is more reliable than the central database since this way of decoding removes the need for an internet connection. However, as the data is stored in local systems, the information embedded into barcodes can only be revealed using specific barcode readers, such as those used at cash points in supermarkets. In addition, any update in the data should be done for all the barcode readers. Storing the information could also be problematic for barcode readers with limited storage capacity.

On the other hand, systems using the central database do not require a specific barcode reader. As the data is retrieved from the central server, even a smartphone using a barcode reader application can decode a barcode. Because no information is stored in barcode readers, central systems have no data storage issues. Furthermore, when the data in the central server is updated, users will have access to the most recent representation of the data. Additionally, since the availability of a wireless connection with a high bandwidth has been increasing, connecting to a central server is getting easier. Barcodes are divided into two categories: one-dimensional (1D) and two-dimensional barcode (2D) (Figure 5).

#### 3.2.1. One-Dimensional (1D) vs. Two-Dimensional (2D) Barcodes

In general, they differ in representing the data they hold. 1D barcodes, also known as singular barcodes, use lines with different widths and spaces to represent the data embedded into them (Figure 5). Code 39, Code 128, EAN-13, EAN-128, and

ISBN are examples of 1D barcodes. On the other hand, 2D barcodes, also known as matrix barcodes, look like squares or rectangles that contain numerous tiny dots to represent the data. QR code, PDF417, Data Matrix, and Maxi Code are examples of 2D barcodes.

Figure 5. 1D barcodes vs. 2D barcodes
(Chuang et al., 2010)

1D and 2D barcodes have different data storage capacities. 1D barcodes have less storage capacity than 2D barcodes, so only a few pieces of data might be embedded, like “product identification. However, in terms of data storage, 2D barcodes outperform 1D barcodes by providing more information, such as "product description. While product identification refers to the product’s name or other identifying information, product description refers to additional information about the product, such as its ingredients, items, details, and web links (Chuang et al., 2010).

Readability is another issue for the barcode (Chuang et al., 2010). 1D barcodes are generated in a single direction and can only be scanned in that direction. Therefore, if the scanning angle does not match the direction of the barcode, the data will not be read. However, because 2D barcodes have a wide range of scanning angles, they can be scanned with less effort.

### 3.2.2. Quick Response (QR) Codes

QR codes are a variant of 2D barcodes (Ashford, 2010). They are named “Quick Response”, because they allow contents to be decoded at high speeds. A QR code involves small squares in black and white. At three corners, there are large squares called “Position Detection Patterns” (Figure 6). Although most QR codes appear in black and white, they could be generated in a colored way. QR codes were first developed in 1994 by a Japanese company, Denso-Wave Incorporated (a Toyota subsidiary), and it is used to track automotive parts in manufacturing. QR codes are currently in their third generation, and with each new generation, they increase their storage capacity and gain new features, such as displaying a logo inside the code (Demir et al., 2015).

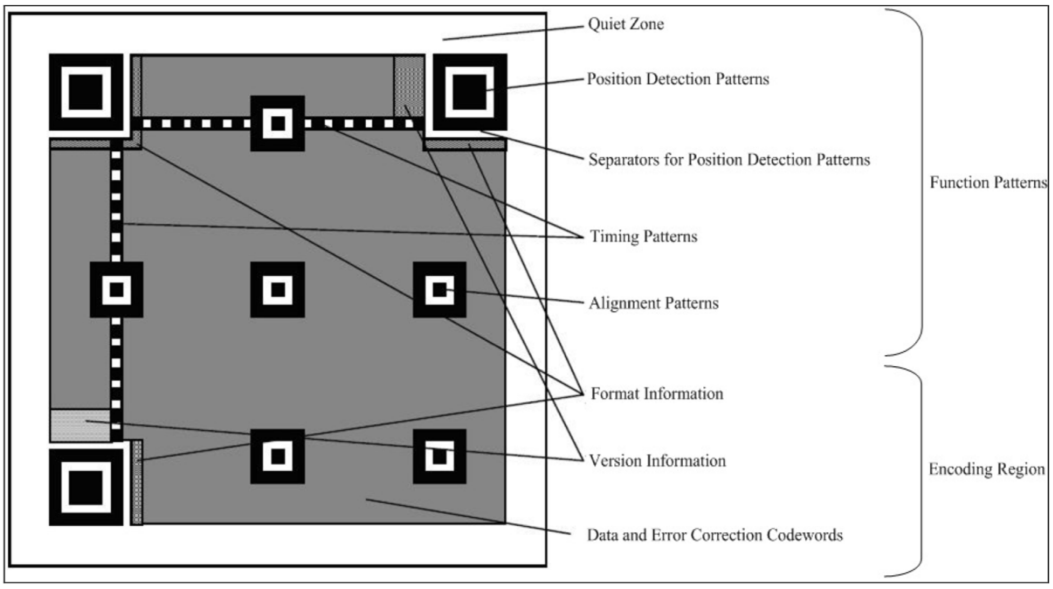


Figure 6. The basic structure of a QR code.
(Chuang et al., 2010)

QR codes offer several advantages in their use as follows:

- High data capacity: The storage capacity of a QR code depends on the embedded data characteristics. A QR code can store 7,089 numeric characters (numbers only), 4,296 alphanumeric characters (numbers and characters), and 1,817 kanji characters (Chinese language).

- High-speed scanning: The response time of a barcode reader to decode a barcode is easy and fast.
- Low cost: QR codes can be printed on paper, making their generation almost at no cost. As they do not have any electronic mechanism, no maintenance is required.
- Error correction: QR codes can still work without any problem, even if 50% of the barcode is damaged.
- Freedom direction scanning: Since QR codes are 2D barcodes, they can be scanned from any angle.
- Reusability: The content of a QR code can be changed by using a dynamic QR code generator, eliminating the need to replace the QR code after the change.

There are numerous free QR code generators available on the internet, including Kaywa, i-nigma, Deliver, Microsoft Tag, Bee Tagg, BeQurious, and Bit.ly. At first, these websites primarily require defining a content type embedded into the QR code, such as a web page, audio, video, text, phone number, etc. When the user enters the content information and clicks the "generate" or "create QR code" button, a QR code appears on the screen. Users can download the QR code in various formats such as jpeg, pdf, png, etc. If desired, the QR code can be printed out as well.

QR codes can be generated as “static” or “dynamic”. In the generation process, if the QR code type is selected as static, content cannot be modified later. Instead, dynamic QR codes allow their generator to revise the content even after the QR code is generated or printed. Dynamic QR codes could be useful in places like museums, where the content can change depending on the exhibition while the QR code tag remains constant (Pérez-Sanagustín et al., 2016).

QR codes have a simple working principle and usage. Today, with the advancements in technology, using QR code reader applications, smartphones on the market can

read QR codes having data stored in a central database, which is open to the public. In addition to this, QR readability could be embedded into smartphones' built-in camera applications. In 2017, with the release of the iPhone Operating System (iOS) 11, Apple Incorporation introduced this feature to its users. Currently, most smartphones running the Android operating system include this feature as standard. To do that, the smartphone's camera needs to be good enough. If the quality of the camera, in terms of resolution, is too low, then QR code scanning could be problematic. Also, the illumination level in the environment should be adequate so that the QR code can be seen. Even if the environment is sufficiently illuminated, cameras with narrow lenses may not pick up enough light, and QR code scanning could be difficult.

When the camera decodes the QR code, the smartphone application displays a pop-up window that must be clicked to access the content or automatically prompts the device to perform an action, such as opening a web browser, starting another application, dialing a number, and so on. If the content embedded in the QR code is a website link, the system requires an internet connection via a Wireless Local Area Network (WLAN) or cellular connection via the Global System for Mobile (GSM) operators. If the content stored in a QR code contains private information, users scanning the QR code may be directed to a login page to see the content.

### 3.2.3. Usage Areas of QR Codes

As previously stated, the most common way to scan a QR code is to use a smartphone. Since the use of mobile devices is expanding, institutions and organizations have begun to take advantage of using QR codes (Ashford, 2010). They can be seen on product packaging, coupons, magazine advertisements, newspaper and magazine news, outdoor advertisements, televisions, and other documents. They have been used mainly for obtaining "more information" on a specific topic or directing someone to a link without having to type the website link into the web browser. In other words, their use has been limited to providing basic

information in many areas, so their popularity in the public domain has declined rapidly. They have been primarily utilized by businesses to track logistics.

However, during Covid-19, social distancing has gained importance, resulting in less physical contact. As QR codes provide an easy, fast, and end-to-end contactless experience, they align with the needs of the post-pandemic world. Due to that reason, their use after the pandemic has increased substantially. Based on QrTiger's database (2022b), dynamic QR code scans depicted a 433% increase compared to 2021. According to a Statista survey (2022) conducted in the United States in June 2021, 59% of respondents believe QR codes will become a permanent part of their smartphone usage in the future. In a June 2021 survey, Insider Intelligence (2021) discovered that 75% of their respondents are willing to use more QR codes in the future. To find practical solutions to the difficulties caused by contactless life during Covid-19, QR codes have been used in various ways.

Digital menu: Restaurants have become one of the first businesses to adopt QR codes. Hospitality Tech's report (2022) on restaurant technology shows that 66% of restaurants provide QR codes at the table to access menus, with 19% planning to add them in 2022.

Withdraw money from ATMs: Banks have begun to use QR codes to send or withdraw money using ATMs. For instance, users type/select the amount of money they want to withdraw using the bank's application installed on their phone. As they click on "Continue", the application initiates the camera application. When the user scans the QR code displayed on ATM's screen, ATM recognizes the client's account information and gives the money.

Cashless payments: Contactless payments could be divided into two. In the first method, after the cashier scans the products with a local scanner and the total price is revealed, the payment option with the QR code is selected on the Point of Sale (POS) device. Following that, users scan the QR code on the POS device using the

mobile application of the bank they are a member of. The second method is the inverse of the first. Using the company's mobile application, such as Starbucks, users generate a QR code the cashier scans.

Product evaluations: Another example is that some institutions, such as Decathlon, currently place QR codes in price tags so that customers can access more information about the products and read users' comments.

Direct Wi-Fi access and network sharing: QR codes could be used for network sharing. By scanning the QR code, people can access the internet provided by the institutions without entering a password.

Information about the items: Libraries and museums have also started experimenting with this technology. Libraries use QR codes to provide maps showing books' location, the schedule of a study room, and live chat windows to receive reference help. Museums and archaeological sites utilize these tags to provide more written, audio, and video information about the artwork.

In addition to these, QR codes are used on television commercials to purchase a product, on business cards to share individual information, on products to see a brief video about how they are used, on buildings in real estate to see information about a specific house, on tickets to pass contactless, on boards to share a satisfaction survey with the customers, on headstones to receive information about the deceased, and on posters or brochures to create a route to a location (QrTiger, 2022).

### 3.2.4. Use of QR Codes in Wayfinding Studies

In the literature, there have been efforts to benefit from QR codes as a wayfinding tool for indoors. It is seen that studies mainly develop a QR code-based wayfinding system that functions with location-aware technologies and mobile applications requiring the knowledge of programming language. While some of them tested the

effectiveness of their wayfinding model compared to a control group, the others tested their model only to assess if it functions. Although there are studies focusing on improving the wayfinding experience of visually impaired or cognitively impaired people using QR codes, several studies concentrate on benefiting from barcode-rich environments rather than implementing a new barcode system in the existing environment.

A study (Serra et al., 2010) developed a pedestrian navigation system based on the dead-reckoning system for indoor environments. In the prototype of the navigation system, the initial location of the users is identified by scanning a QR code. Then movements of the users are calculated solely by the sensors embedded into the smartphone (compass and step counter). The user opens the application and reads a QR code placed aside the map of the floor using the integrated camera. The study focuses on if their proposed model works as expected instead of comparing it with a control group. They found that fixed-value step length could cause cumulative errors.

Torrado, Montoro & Gomez (2016) emphasize an indoor wayfinding model for cognitively impaired people. This study aims to help these people to walk independently in public spaces. To do so, a smartphone application is generated called AssisT-In. At first, they defined specific points named “nodes, " which are placed with QR codes. When a QR code is scanned, it guides the user to the location of the next QR code on the route. In other words, people are expected to find their ways by following a trail of clues in the setting. For example, QR code 1 directs the person to QR code 2. In the condition of a mistake, the application warns the user with descriptions such as “You skipped a hint” or “This hint isn’t valid. It belongs to another route”. Their model reached a usability score of 63 out of 100, slightly below the average, which is 68. The users’ answers revealed that they enjoyed the use of the smartphone in wayfinding.

Another study (Nicholson et al., 2009) introduces a wearable system for visually impaired shoppers called “Shoptalk”. This study integrates both verbal route directions and barcode scans. Rather than installing new barcodes, it utilizes existing barcodes located on the shelves below the relevant products. This application requires the researcher to enter data for each barcode. To save the location of a barcode, three types of information are needed: the location of the shelf in the store, the shelf section the barcode is located on, and the row number the barcode is located in this shelf section. They reveal that verbal route directions and search instructions based on barcode scans may be sufficient for independent supermarket shopping for the blind.

Another study (Pearson et al., 2017) also utilizes the existing barcodes, which they called “piggybacking”, for wayfinding in libraries. Researchers use the barcodes on the books to propose a wayfinding solution. As the users scan the barcodes, a map appears on the screen of users’ smartphones that shows the book's location in the setting via a smartphone application. After scanning a QR code, the application generates a route to the location of the book the user searched for. This solution may offer different levels of precision, such as high and low granularity. For instance, the location of a book might be indicated as “look at the art room”, or “look at shelf 1 in the art room”. However, as in the previous example, entering data could be time-consuming. The proposed model is compared with a control group, in which the participants use paper maps. According to the results, the use of the proposed model diminishes the task completion time and increases the ease of wayfinding in comparison to the use of paper maps.

In a study (Mulloni et al., 2009), researchers benefit from the QR codes located on banners and posters in a congress building. QR codes offer users three types of mapping: no localization (such as maps), discrete localization (such as YAH maps); and continuous localization (such as GPS-based navigation systems). According to the users’ evaluations, continuous localization appeared as the easiest method that was followed by discrete and no localization methods, respectively. They indicated

that even if it is discrete, seeing the current location increases location awareness. Similarly, they discovered that discrete (marker-based) localization increased user confidence significantly more than no localization. In that research, users can select the optimum map they need or want.

Another study (Sushma & Ambareesh, 2017) examined the use of QR codes for wayfinding using Google Maps for indoors. To do that, researchers upload the floor plans to Google Maps and locate QR codes at certain points in the building. In their study, after scanning a QR code and searching and selecting their destination, Google Maps displays the location of the user on the floor plan and generates a route between these locations. When a new QR code is scanned, the user's location and route to the destination are updated.

Zhang et al. (2021) examined the impact of immersive augmented reality (IAR)–based systems on human wayfinding performance from the cognitive perspective. For this, they compared three groups: a control group with no IAR assistance, a second group benefiting from an IAR-based navigation system that contains only superimposed guideposts, and a third group utilizing an IAR-based navigation system that involves both guideposts and a 3D layout model. The participants scanned the QR codes near the decision points, using the HoloLens to update and calibrate the navigation information. Their findings indicate that the third group completed the task in the shortest amount of time, followed by the second and third groups. Despite the fact that there was no difference in the difficulty of completing the wayfinding task, the third group reported the least anxiety. They conclude that IAR technology can aid people in improving their cognitive maps more effectively and can significantly improve their wayfinding performance with a much lower workload. Their research also shows that incorporating a 3D layout model can improve the performance of an IAR-based navigation system in terms of cognitive map development.

Following a similar approach, (Tadepalli et al., 2021) combine the use of QR codes with AR technology. Using the application based on Google AR Core, users scan one of the QR codes distributed in the building, which is considered the starting point, and select a destination from the list of predefined locations. The A * algorithm finds the shortest path to the chosen destination, and Augmented Reality displays directions to the destination on the user's camera screen.

# CHAPTER IV

# METHODOLOGY OF THE PHYSICAL STUDY

In the first part of the study, we employed an experimental wayfinding task in a physical environment to test the proposed model. This chapter presents research questions, hypotheses, and the method that was followed to seek answers to the questions and assess our assumptions.

## 4.1. Research Questions and Hypotheses

In the present study, we proposed a QR code-based indoor navigation tool that does not require such tools as smartphone sensors, emitters in the environment, or a specific application. Therefore, the proposed model can function solely with the users' smartphones, making it low-cost and simple to implement. In accordance with Levine's (1982) recommendations, we created YAH maps and embedded them in dynamic QR codes, allowing smartphone users to access the maps. To examine the performance of the proposed model, we conducted a study by comparing two conditions in which the participants performed similar wayfinding tasks in a no-QR condition (N_QRC) and a QR condition (QRC). In N_QRC, we aimed to simulate an everyday wayfinding situation in which maps are located at the entrances of buildings, whereas in QRC, we provided QR codes near the decision points. The

research questions, hypotheses, and all the variables (Table 1) we examined were as follows:

Research questions:

Q1. Are there any differences between the task performances in wayfinding in N_QRC and QRC?
   a. task completion time
   b. travel distance
   c. travel speed
   d. number of maps used
   e. number of times to look at maps[1]
   f. time spent looking at maps[1]

Q2. Are there any differences between the perceived ease of task and comfort level in wayfinding in N_QRC and QRC?
   a. perceived ease of the task
   b. comfort level

Q3. How will the proposed QR Model be evaluated?
   a. usability
   b. willingness for future use

Q4. Are there any gender differences in the task performances, ease and comfort of the wayfinding experience, and evaluation of the proposed model?

Hypotheses:

H1. Because (1) the number of studies comparing QR code-based indoor wayfinding models with conventional methods is insufficient to draw a conclusion, (2) they use route generation or directional signage in their model,

[1] Measured only in the virtual study.

which requires less learning effort than YAH maps used in the current study, and (3) the participants would be less familiar with QRC, we did not generate specific hypotheses involving the condition.

H2. Because of the near-constant availability of the maps, we expected an easier and more comfortable wayfinding experience in the proposed condition compared to the conventional condition.

H3. In view of the flexibility provided in QRC, we expected that the proposed model would be evaluated positively in terms of its usability and in terms of participants' willingness to use it in the future.

H4. As the influence of gender, considering the literature favoring men over women (Chen et al., 2009; Lawton, 1994, 1996), compared to women, we expect men to complete tasks faster, travel shorter distances, travel slower, use fewer maps, look at fewer number of maps, spend less time looking at maps, and perceive the task easier and more comfortable.

Table 1. Dependent and independent variables of the research

| Dependent variables | Independent variables |
|---|---|
| 1. Wayfinding performance | 1. Condition |
| a. Task completion time | a. No-QR condition (N_QRC) |
| b. Travel distance | b. QR condition (QRC) |
| c. Travel speed | 2. Gender |
| d. Number of maps used | a. Men |
| e. Number of times to look at maps* | b. Women |
| f. Time spent looking at maps* | |
| 2. Evaluations | |
| a. Perceived ease of task | |
| b. Comfort level | |
| c. Usability** | |
| d. Willingness for future use** | |

Note. *measured in the virtual study only; **measured in QRC only.

### 4.2. Setting

To attain similar layouts and signage systems in both wayfinding tasks, the experiment was conducted in the Faculty of Art, Design, and Architecture (FADA) Building at İhsan Doğramacı Bilkent University (APPENDIX E). The building was a large multi-story building consisting of three blocks housing departments of design (Figure 7). There were slight differences between the number of floors in the building. While all the blocks consisted of three main floor levels, blocks A and B included an additional ground level connected to the first level with a few steps. The building contained design studios, classrooms, exhibition areas, and offices. Wayfinding in the building was challenging for visitors for several reasons: The floor levels in each block were different, so the blocks were connected with stairs. In addition to the main floors, the building consisted of mezzanine floors designated for offices. Also, the plan configuration and the atmosphere of the interiors were almost identical in each block. There was no wayfinding signage within the building except for the hierarchical room numbering on the doors. The complexity of the

building interiors was considered to increase the participants' cognitive load during wayfinding, which made it suitable to test the proposed model.

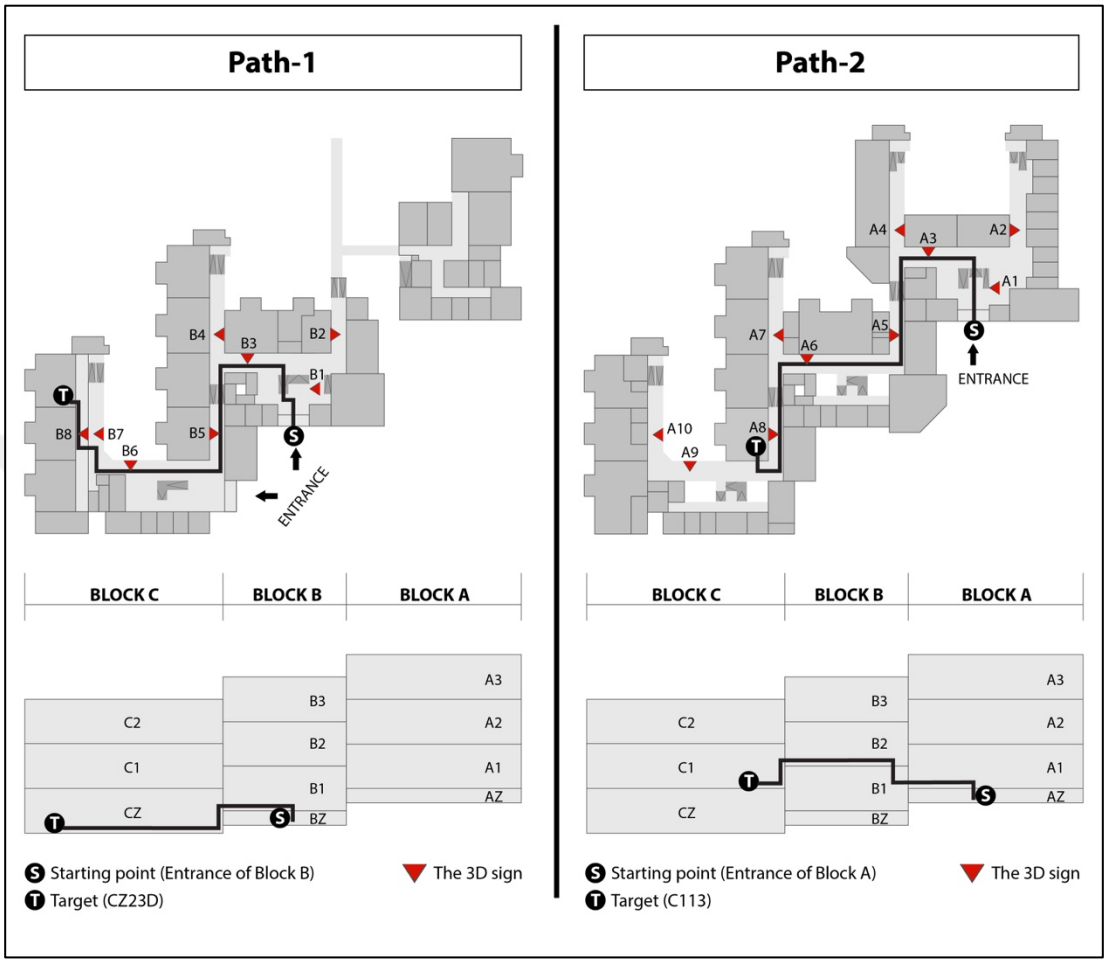


Figure 7. Path-1 and path-2 used in the physical study indicated on the plans and sections of the building and QR code locations shown on the plans only.

To avoid a learning effect, we did not use the same path in N_QRC and QRC; we chose two non intersecting paths at different levels in the building. We determined the paths with the intention of having similar path lengths, number of turns, and level changes (Table 2). The participants started from the entrance of block A to find room "C113" in path-1 and from the entrance of block B to find room "CZ23D" in path-2 (as can be seen in Figure 7). The study was limited to two floors.

Table 2. Optimal path length, level changes, turns, and block changes for the optimal paths in the physical study.

| Path Number | Paths | Optimal Path Length (m) | Level Changes | Turns | Block Changes |
|---|---|---|---|---|---|
| Path-1 | A → C113 | 102 | 3 | 5 | 2 |
| Path-2 | B → CZ23D | 96 | 6 | 8 | 1 |

### 4.3. Participants

Thirty-eight undergraduate students (19 women and 19 men, after two extreme outliers were dropped) with a mean age of 23 years (range: 20-28 years) agreed to participate in the study. They were selected using quota sampling from the Department of Interior Architecture and the Department of Architecture at Çankaya University. Thus, all participants were unfamiliar with the building, and none had a prior wayfinding experience with QR codes.

### 4.4. Materials

#### 4.4.1. Maps

To generate the map of the experiment area, AutoCAD drawings of the building (the complex including FA, FB, and FC Blocks) were requested from the Construction and Maintenance Department at Bilkent University. Two floor plans were chosen where the experiment was performed. However, since AutoCAD drawings contained too many details to be easily understood by the participants, they needed to be simplified. As the first step of the simplification process, floor plans in AutoCAD format were converted to pdf format. Then, floor plans in pdf format were opened in Adobe Illustrator. Tracing the pdf file, the contour of the spaces and the doors (entrances to the spaces) were drawn, disregarding the details such as built-in furniture, columns on the corridor, shafts, etc. Indeed, floor plans could be simplified with any other graphic design software. In this study, we preferred Adobe Illustrator because the resolution of work generated with a vector-based graphic design software application is not affected by scaling or zooming, preventing loss of detail.

Color coding was the second step in generating the map. Coloring was used to group similar spaces and ease the maps' reading. This study preferred a monochromatic color coding for aesthetic purposes and used four different tones of brown for four distinct spaces, which were offices, studios/classes, service areas/technical areas, and seminar areas/exhibition areas. Numbering the spaces was the third step in generating the map. However, since the building had a certain numbering system, we processed the same numbering to the maps without any revision.

Moreover, below the map, we provided a list of alphabetically ordered space names in the building. On the list, each space was linked to a room number and a group based on its function. Therefore, for example, if visitors search for room "C108" in the building, at first, they need to look at the list ordered alphabetically under the "Office" column where C108 belongs to this specific area. This might operate vice versa. If visitors search for the function of C108, they may find that space on the map, look at its category under the map, and get information about its function.

We generated two maps with identical designs for use in the two conditions (Figure 8). The physical maps were printed on A3-size papers and were only available on the glass panes of the entrance doors. Therefore, by looking at the physical map, the participants could see the building's general layout and their location at one of the building entrances. The digital maps, on the other hand, were accessible after scanning a QR code in the building and indicated a YAH icon (Figure 8, right), which was not available in the physical maps.

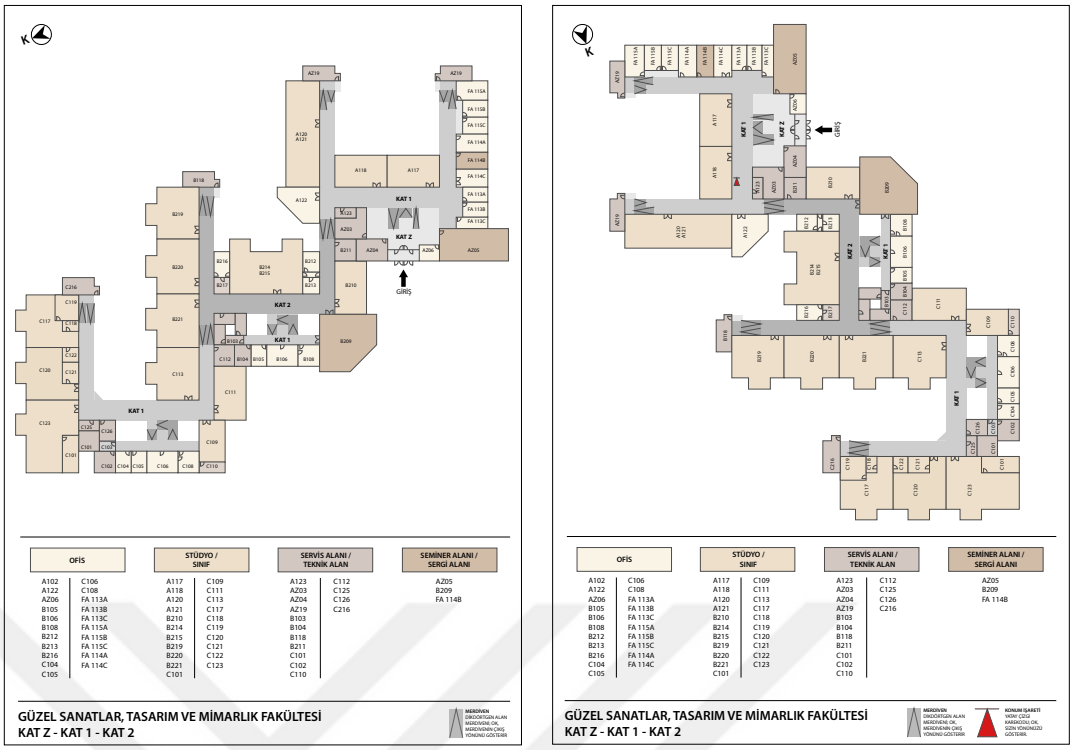


Figure 8. Samples from the physical study: a physical map used in N_QRC (left) and a digital map used in QRC (right), where the map is rotated according to the scanning direction of a QR code.

For the digital maps, considering Levine's (1982) recommendations, we designed a YAH symbol that denoted two distinct terrain features: the QR code and the viewer. The short straight line indicated the location and the orientation of the QR code within the setting. The red arrow indicated both the viewer's location within the setting and on which side of the 3D sign (left or right) the viewer was standing. In other words, while the physical maps gave no clue as to the participant's position within the setting, the digital maps indicated the location of the participants and the direction they were facing in the building. We also adopted the "align the map with the terrain" recommendation by Levine (1982). To do so, the digital maps were rotated at specific angles to ensure that while scanning the QR codes, the participants' directions (indicated by a red arrow) consistently showed the front/forward on the digital maps. Thus, they did not need to make an effort to match the digital map with the layout of the setting.

### 4.4.2. QR Codes

To display the digital maps in QRC, we utilized dynamic QR codes. Therefore, if there were any changes in the layout of the map's setting or design, we had the opportunity to update the map while using the same QR code tag in the setting. To do so, we used Google Drive to generate QR codes. Google Drive allows the generation of (1) dynamic QR codes with no cost and (2) multiple QR codes at once, saving much time. At first, a Google Drive account is created. Maps generated in PDF format were uploaded to an empty folder in that account. By default, every file uploaded to Google Drive could be assigned to a link for the purpose of file sharing. The "Manage Versions" feature could change while keeping the link the same. In other words, Google Drive provided the opportunity to assign a link for each uploaded file, and allowed making changes in the content while keeping the link the same, which imitated dynamic QR codes. Therefore, if there had been any changes in the building layout, we would have had the opportunity to update the map while using the same QR code tag in the building that was already installed.

In the next step, each link was assigned a QR code. To do that, we created a blank Google sheets file, pasted the list of links into Column A, gave a specific name for each map/QR code in Column B, and created QR codes in png format in Column C using a formula, and saved each QR code in jpeg format in Google Drive by taking their screenshots one by one (Figure 9).

| | A | B | C |
|---|---|---|---|
| 1 | **URL OF THE MAPS IN PDF FORMAT** | **QR CODE NAMES** | **QR CODES IN PNG FORMAT** |
| 2 | https://drive.google.com/open?id=12cQpmAoOBIfwJVbyXxcBMGjr4J7fp_iz | A1 L | |
| 3 | https://drive.google.com/open?id=1epLAXLy25GoXGLvGT4VVY8I1qQS9sjIX | A1 R | |
| 4 | https://drive.google.com/open?id=1-KQ-3RLgKclUHW-Hcl7XCd_R8IGP2FsJ | A2 L | |
| 5 | https://drive.google.com/open?id=16LCX8z3tky3dQdVwVJP99m1XNyMMai7u | A2 R | |
| 6 | https://drive.google.com/open?id=1-i696h_XuSmEW8KuPpEpKBnicJoV2pWE | A3 L | |
| 7 | https://drive.google.com/open?id=1TJ0T3sZyQWrfWRjtwdkKtGl5LoKsDPuI | A3 R | |
| 8 | https://drive.google.com/open?id=15oYSMG2he6Vfp4mFkY6L5kGVy0N48-Tn | A4 L | |
| 9 | https://drive.google.com/open?id=1IpjsG76XhMgwFnMrKDgbVLg3iFq5XWFX | A4 R | |

Figure 9. A screenshot of the Google Sheets file that was used to generate QR codes for the physical study.

Visibility was one of the main concerns in determining the location of the QR code tags on the walls. Individuals walking parallel to the walls could have difficulty perceiving tags parallel to the wall, while those walking toward a wall could have difficulty perceiving tags perpendicular to the wall. To overcome this issue, we designed a 3D sign in the form of a triangle by folding an A4-sized paper, pasted QR code tags on its two faces, and attached it to the wall on its third face (Figure 10). This form provided angles (approximately 15 degrees on each side) that made the QR codes visible from all sides. We used bright green for visibility and differentiation from other signage (Arthur & Passini, 1992).

At the last step, before printing, each QR code was required to be named systematically. To do so, we developed a naming system consisting of three criteria, for example, “A1-X”. “A” refers to the name of the block where the QR code is located in the FADA building complex. “1” refers to the location of the QR code on the related floor plan. Numbering begins with the right-bottom corner of the floor plan and continues in a clockwise direction (Arthur & Passini, 1992). “X” refers to

the side where the QR code is pasted on the 3D sign. Therefore, there were only two options for this character: L (left) or R (right). For example, a QR code that was named “A3-L” means that the QR code belongs to Block A (first character: A); is the third QR code based on a systematic order defined above (second character: 3); and appears on the left side of the 3D sign (third character: L). Names were located at the right-bottom corner of the QR codes. When these arrangements were completed, QR codes were printed, cut, and glued to the paper (Figure 10).

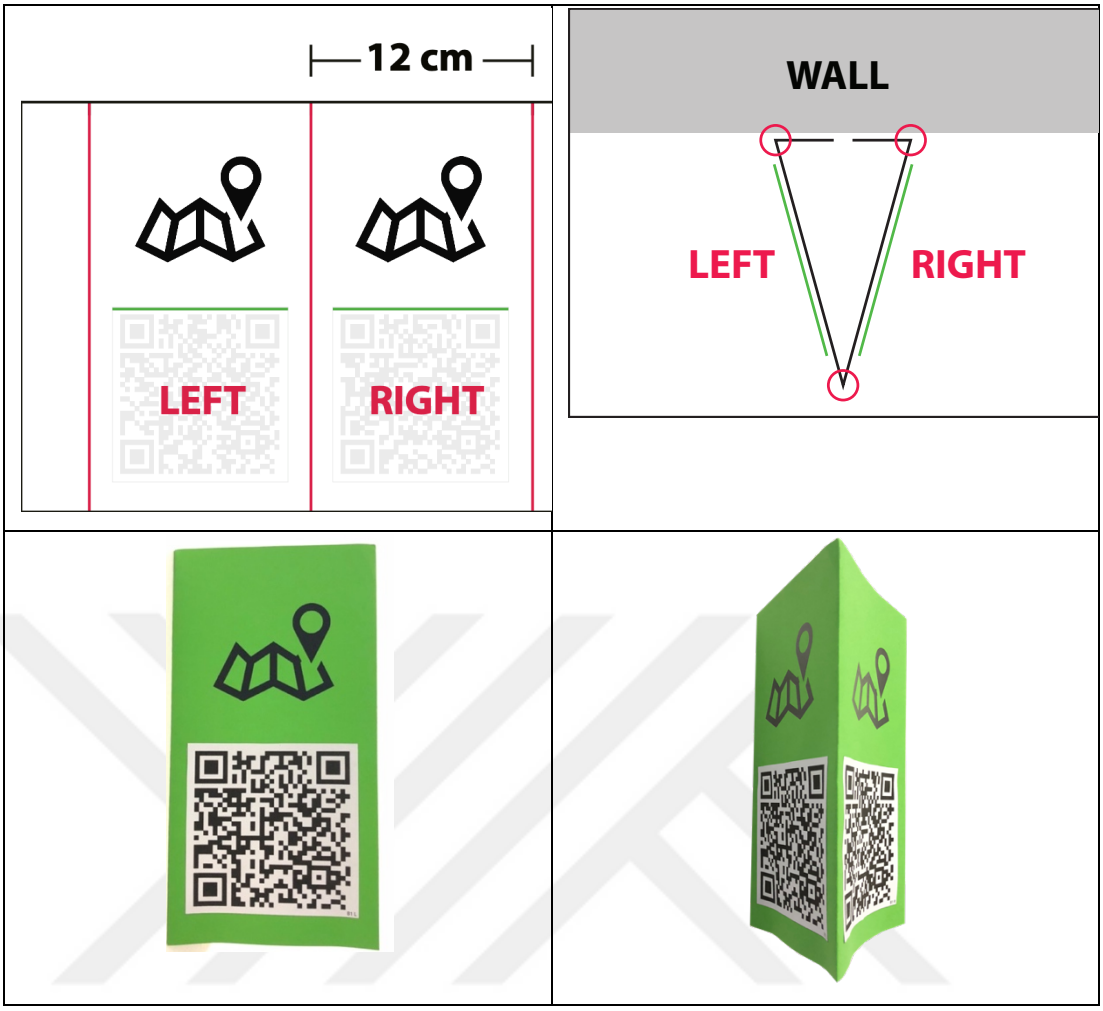


Figure 10. The 3D sign used in the physical study: the digital template of the 3D sign (left-upper); the top view of the 3D sign (right-upper); the 3D sign viewed either from the right or left (left-bottom); the 3D sign viewed from the front (right-lower) (in the physical study).

Additionally, we devised an order to place the QR codes within the setting. As mentioned before, in N_QRC, the physical maps were located on the entrance doors. However, in QRC, we took advantage of the compact size of the QR codes (provided links to the digital YAH maps) and located them at the decision points where two or more corridors intersected, those locations where people most need help (Arthur & Passini, 1992; Tadepalli et al., 2021). We located them near the end of corridors so the participants could view the digital maps before arriving at decision points. Thus, a total of 18 pairs of signs were used in the QR condition (20 and 16 QR codes on path-1 and path-2, respectively; see Figure 7). As QR codes in

the physical setting referred to YAH symbols on the digital map, a total of 36 digital maps were generated.

### 4.4.3. Equipment

In the present study, we used an iPhone 6 in the experiment based on its screen size and the native camera application with the QR code reading feature. The participants launched the default camera application to search for a QR code in the environment. When the smartphone recognized a QR code, a notification dropped down from the top of the screen with a preview of the link associated with the QR code (Figure 11, left). Tapping the notification triggered iOS's native web browser (Safari), which displayed the digital maps with the YAH symbol (Figure 11, middle and right).

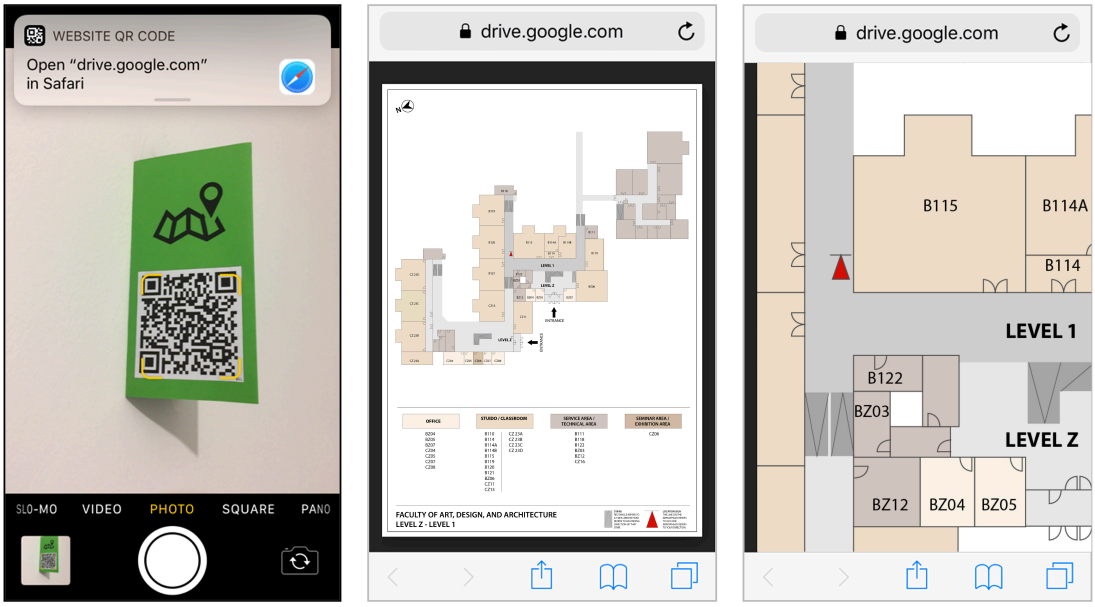


Figure 11. Screenshots from the physical study: the QR code scan (left), the digital map (middle), and the zoomed digital map with the YAH symbol (right).

Revealing the information embedded into a QR code required an internet connection; this could be a Wireless Fidelity (Wi-Fi) network or cellular data. Although there was a Wi-Fi network in the experiment area, tests before the study

indicated that the signal's strength dropped significantly in some areas of the building. Therefore, we used the cellular data, Vodafone 4.5G, as it had a more stable and robust signal strength in the building.

### 4.5. Questionnaires

The study included two questionnaires given before and after the task. Here, we mentioned the essential sections and questions from both questionnaires. As a result, the section and question numbers listed below may not match their equivalents in the questionnaire. Pre-task and post-task questionnaires, including all the questions, can be seen in APPENDIX G and APPENDIX H, respectively.

#### 4.5.1. Pre-task Questionnaire

The pre-task questionnaire consisted of three sections. In Section 1, they rated their interest in QR codes. In Section 2, the participants were asked to rate their navigational abilities using the Santa Barbara Sense of Direction Scale (SBSOD), which was introduced in 2002 (Hegarty et al., 2002) and is a self-report measure of environmental spatial ability. It measures people's judgments about their own environmental spatial abilities. The SBSOD questionnaire consists of 15 items on a 1 (*strongly agree*) to 7 (*strongly disagree*) Likert scale and contains eight positive (e.g., "I am very good at giving directions", "I am very good at reading maps") and seven negative statements (e.g., "I very easily get lost in a new city", "I have trouble understanding directions") about spatial and navigational abilities, navigational aptitudes, and experience.

Before computing one's score, as a lower rating refers to a better sense of direction, the scores given to positively stated items were reversed. After summing all the scores, the total value is divided into 15 to reveal the average score of a person. However, to continue the consistency among all the questions in the questionnaire using a 7-point Likert scale, we reversed the values (1 = *strongly disagree*, 7 = *strongly agree*). Therefore, instead of positive items, we reversed the scores of negative statements. Thus, higher scores referred to a better sense of direction.

According to Hegarty et al. (2002), individuals with a good sense of direction are good at updating their position and orientation in an environment.

### 4.5.2. Post-Task Questionnaire

The questionnaire consisted of five sections. In Section 1, the participants responded to two items for each condition to rate their perceived ease of task ("I easily found my way") and comfort levels ("I felt comfortable during wayfinding") using 7-point scales (1 = *strongly disagree*, 7 = *strongly agree*).

In Section 2, the participants rated the equipment used in the QRC to understand the feasibility of the proposed model in its current form. They evaluated the QR codes' size, number, ground clearance, 3D form, and perceptibility, answering multiple-choice questions, and assessed the performance of the smartphone ("Screen size of the phone was enough", "The performance of the phone was enough"), maps ("I was satisfied with the readability of the map", "I am satisfied with the design of the map"), and internet connection ("I was satisfied with the internet speed", "I did not experience any internet outages") on a 7-point scale.

In Section 3, the participants assessed the usability of the proposed model on the USE test (Lund, 2001; 7-point scale), which consisted of 30 items divided into four categories: (a) Usefulness, which consisted of 8 items; e.g., "It is useful", "It meets my needs"; (b) Ease of Use, which consisted of 11 items; e.g., "It is easy to use", "Using it is effortless"; (c) Ease of Learning, which consisted of 4 items; e.g., "I learned to use it quickly", "I quickly became skillful with it", and (d) Satisfaction, which consisted of 7 items; e.g., "I am satisfied with it", "I feel I need to have it".

In Section 4, we asked the participants to rate their willingness to use QR codes for indoor wayfinding in the future again and the change in their interest levels using a 7-point scale (1 = strongly disagree, 7 = strongly agree) in two parts. In the first part, the participants rated the change in their interest levels in QR codes ("I raised interest in QR codes") and their intentions to use the proposed model in the future

("If available, I would prefer to use QR code-based wayfinding tools inside buildings"). In the second part, they assessed nine wayfinding situations with complex buildings in which QR codes could be helpful. (e.g., "In closed/multi-story car parks [finding vehicles]", "In shopping centers [finding shops]"). Thus, this section overall explored the degree to which participating in the present study motivated people to use QR codes for indoor wayfinding. Finally, in Section 5, the participants were asked to make a suggestion for the development of the QR Code application they had experienced in this study or any method that might be useful in wayfinding.

### 4.6. Procedure

The study proceeded based on appointments, and the participants were not allowed to enter the building before their appointment. Before starting the wayfinding tasks, an online pre-task questionnaire was given to the participants via Google Forms using a touch-screen tablet computer, an iPad. Since the ground floors of the building were within the area where the task was conducted, the pre-task questionnaire was issued outside the building to avoid familiarity.

After completing the pre-task questionnaire, the researcher guided them to the starting point of each route outside the building according to their task type. The participants were then informed about the number of maps, their distribution in the building, and how the maps worked. Additionally, before the QRC task, the researcher instructed the participants to scan the QR codes in the building using the provided smartphone. They were told that they could not talk to anyone while performing. The participants started to perform the tasks after they indicated that they understood the rules and how to use the QR codes.

After that, we conducted a wayfinding study performed in the form of an experiment based on a 2 (gender) x 2 (condition: N_QRC, QRC) design with repeated measures on the last variable (Table 3). The participants were divided into four groups considering their gender. We aimed to have an equal number of male

and female participants in both conditions. In the first stage, while the participants in the first and the second group performed path-1 in N_QRC and QRC, respectively, the participants in the third and the fourth groups performed path-2 in N_QRC and QRC, respectively. In the second stage, we switched both the path and the condition for all the participants to control for order effects. After the wayfinding tasks, a post-task questionnaire was administered to the participants.

Table 3. Research design of the physical study.

| | Number of Participants | | | Phase I | | Phase II | |
|---|---|---|---|---|---|---|---|
| **Task Type** | **Total** | **Men** | **Women** | **Condition** | **Path** | **Condition** | **Path** |
| A | 9 | 5 | 4 | N_QRC | 1 | QRC | 2 |
| B | 9 | 4 | 5 | N_QRC | 2 | QRC | 1 |
| C | 10 | 5 | 5 | QRC | 1 | N_QRC | 2 |
| D | 10 | 5 | 5 | QRC | 2 | N_QRC | 1 |
| | N=38 | N=19 | N=19 | | | | |

While performing in N_QRC, the participants were allowed to use the physical maps only, located on the glass panes of the entrance doors of blocks A and B. They could go back to the building entrance if they needed to look at the physical maps while performing in N_QRC. On the other hand, in QRC, the participants did not have access to the physical maps at the entrances. Instead, they were expected to scan the QR codes within the setting at least once to access the digital maps on the smartphone. During the task, the researcher followed the participants from a distance and did not interfere unless they tried to go beyond the designated floors. After completing the two tasks, we asked the participants to indicate their responses to an online post-study questionnaire using the touch-screen tablet computer.

### 4.7. Measuring the Task Performances

To record the participants' data while performing the study., we generated an observation sheet (APPENDIX D) consisting of two A4 sheets. The first sheet asked for demographic information, task type, target, and task completion time. The other

sheet included the two maps used in the current study, each on one side, and all the QR codes were marked on the maps. The task completion times were recorded using a timer, and there was no time limit for any of the tasks. We started measuring as they began to read the physical map on the glass pane in N_QRC and as they entered the building in QRC. We stopped measuring as they reached the target. We traced their routes and marked the QR codes they used on the maps on the observation sheet. Their travel speed (m/s) was obtained by dividing the travel distance by the time spent. We also measured the number of times the maps were accessed. If the participants went back to the building entrance to look at the physical maps in N_QRC or followed a series of actions in QRC, such as opening the camera application, scanning a QR code, and waiting for the map to load, it was referred to as map access.

# CHAPTER V

# RESULTS OF THE PHYSICAL STUDY

Data were analyzed using separate 2 (gender) X 2 (condition: N_QRC, QRC) analysis of variance (ANOVAs) for factorial designs with repeated measures on the last variable. Below, we present the results involving the dependent variables of sense of direction, wayfinding performance, perceived ease of task, comfort level, usability of the proposed model, and willingness to use the proposed model in the future. In addition, QR code usage based on their locations and correlations between the variables were examined.

## 5.1. Sense of Direction

The participants' mean score of sense of direction was 4.3 points out of seven (*SD* = 0.94). The results of the independent samples t-test revealed that there was a significant difference between the sense of direction scores of men (*M* = 4.8, *SD* = 0.9) and women (*M* = 3.8, *SD* = 0.6), $t(36) = 4.30$, $p < .001$.

## 5.2. Wayfinding Performance

According to ANOVA results involving task completion time, the condition main effect indicated that the participants completed the wayfinding tasks in N_QRC (*M* = 188.2, *SD* = 94.1) in less time compared to QRC (*M* = 267, *SD* = 125.6), $F(1, 36) = 9.58$, $p = .004$, $\eta 2 = .21$ (Table 4). Gender main effect showed that men (*M* = 200, *SD* = 64.6) spent less time completing the given task compared to women (*M* = 255.3,

*SD* = 84), $F(1, 36) = 5.19$, $p = .03$, $\eta 2 = .13$. Follow-up Bonferroni post hoc test revealed that women spent significantly more time in QRC (*M* = 302.6, *SD* = 143.1) compared to N_QRC (*M* = 207.9, *SD* = 95), $p = .03$.

Table 4. ANOVA results involving condition main effects and post hoc comparisons of the participants' wayfinding performance in the physical study.

| Variable | *N* | N_QRC Mean (*SD*) | QRC Mean (*SD*) | *F* statistics | Significance | Effect Size |
|---|---|---|---|---|---|---|
| Task completion time (in sec.) | 38 | 188.2 (94.1) | 267.0 (125.6) | $F(1, 36) = 9.58$ | $p = .004$** | $\eta 2 = .21$ |
| Men | 19 | 168.4 (91.4) | 231.5 (96.2) | | $p = .06$ | |
| Women | 19 | 207.9 (95.0) | 302.6 (143.2) | | $p = .03$* | |
| Travel distance (in meters) | 38 | 156.3 (78.3) | 148.7 (68.8) | $F(1, 36) = 0.24$ | $p = .63$ | $\eta 2 = .01$ |
| Men | 19 | 139.8 (56.0) | 138.7 (46.8) | | $p = .94$ | |
| Women | 19 | 172.9 (94.2) | 158.6 (80.6) | | $p = .62$ | |
| Travel speed (m/s) | 38 | 0.9 (0.2) | 0.6 (0.2) | $F(1, 36) = 39.72$ | $p < .001$** | $\eta 2 = .78$ |
| Men | 19 | 0.9 (0.2) | 0.6 (0.2) | | $p = .002$** | |
| Women | 19 | 0.8 (0.2) | 0.6 (0.1) | | $p < .001$** | |
| Number of map use | 38 | 1.1 (0.3) | 2.6 (1.3) | $F(1, 36) = 38.04$ | $p < .001$** | $\eta 2 = .51$ |
| Men | 19 | 1.0 (0.2) | 2.2 (1.3) | | $p = .001$** | |
| Women | 19 | 1.2 (0.4) | 2.9 (1.2) | | $p < .001$** | |

Note. *N* = sample size; N_QRC = no-QR condition; QRC = QR condition; *SD* = standard deviation; **$p < .01$; *$p < .05$.

According to the ANOVA results pertaining to walking distance, the condition main effect revealed no significant difference between the participants' walking distances in both conditions. The participants' walking speed, however, indicated a significance between N_QRC (*M* = 0.9, *SD* = 0.2) and QRC (*M* = 0.6, *SD* = 0.2), $F(1, 36) = 39.72$, $p < .001$, $\eta 2 = .78$. According to the follow-up Bonferroni post hoc test, the data showed that both men (N_QRC: *M* = 0.9, *SD* = 0.2; QRC: *M* = 0.6, *SD* = 0.2; $p = .002$) and women (N_QRC: *M* = 0.8, *SD* = 0.2; QRC: *M* = 0.6, *SD* = 0.1; $p < .001$) walked slower during QRC compared to N_QRC.

We also examined the time spent by the participants to access the physical maps in N_QRC and the digital maps in QRC. During the wayfinding tasks, the participants used the physical maps 1.1 times (*SD* = 0.3) in N_QRC and the digital maps 2.6 times

(*SD* = 1.3) in QRC. In N_QRC, since the participants started the tasks at the entrances of the blocks where the maps were located, the first look at the physical maps did not require an extra effort to reach the map. For this reason, in calculating the time spent accessing the physical maps, we considered only the second attempt of the participants, if any. The results showed that only five participants (one man and four women) went back to the building entrance to look at the maps for a second time and spent 88 seconds (*SD* = 36.8). In QRC, the participants accessed the camera application, scanned the QR code, and waited for the map to load to achieve a digital map, all taking an average of 21 seconds (*SD* = 11.2). Furthermore, the participants spent 52.3 seconds (SD = 46.2) in total to access the digital maps while performing the task in QRC.

### 5.3. Perceived Ease of Task and Comfort Level

Differences did not reach significance in terms of ease of task and comfort level except for a trend suggesting participants may feel more comfortable in QRC compared to N_QRC (Table 5). ANOVA results involving the reported comfort levels of the participants showed that there was a significant interaction between gender and condition, $F$ (1, 36) = 5.08, $p$ = .03, $\eta 2$ = .13. Post-hoc paired comparisons revealed a significance for men, who had a higher comfort level in QRC ($M$ = 6.1, $SD$ = 1.2) compared to N_QRC ($M$ = 4.7, $SD$ = 1.9), $p$ = .003.

Table 5. ANOVA results involving condition main effects and post hoc comparison of the perceived ease of task and comfort level in the physical study.

| Variable | *N* | N_QRC Mean (*SD*) | QRC Mean (*SD*) | *F* statistics | Significance | Effect Size |
|---|---|---|---|---|---|---|
| Perceived ease of task | 38 | 5.6 (1.4) | 5.6 (1.6) | $F(1, 36) = 0.40$ | $p = .85$ | $\eta 2 = .001$ |
| Men | 19 | 5.8 (1.4) | 6.0 (1.5) | | $p = .76$ | |
| Women | 19 | 5.4 (1.4) | 5.2 (1.6) | | $p = .65$ | |
| Comfort level | 38 | 5.1 (1.8) | 5.7 (1.5) | $F(1, 36) = 3.73$ | $p = .06^{\#}$ | $\eta 2 = .09$ |
| Men | 19 | 4.7 (1.9) | 6.1 (1.2) | | $p = .003$** | |
| Women | 19 | 5.4 (1.7) | 5.3 (1.6) | | $p = .84$ | |

Note. *N* = sample size; N_QRC = no-QR condition; QRC = QR condition; *SD* = standard deviation; N.S. = not significant; **$p$ < .01; *$p$ < .05; $^{\#}$p = .06.

### 5.4. Evaluations of the Proposed Model

Participants rated the USE test with a mean of 6.3 (*SD* = 1.2) points out of seven. In other words, our proposed model reached a usability score of 89.9%, which stands for "excellent usability" in similar tests (Bangor et al., 2009; Brooke, 1996). The proposed tool was rated positively in terms of usefulness (*M* = 5.9, *SD* = 1.4), ease of use (*M* = 6.3, *SD* = 1.2), ease of learning (*M* = 6.8 *SD* = 0.5), and satisfaction (*M* = 6.5, *SD* = 1.1). In the last section of the questionnaire, the participants rated their willingness to use QR codes for indoor wayfinding in the future with a score of 6.4 points (*SD* = 1.2). The participants' ratings for the possible wayfinding situations with complex buildings reached a score of 6.52 points (*SD* = 0.64).

Participants' responses indicated that the performance of the research equipment and setting used in QRC was relatively high on average, with a score of 6.11 (SD=1.49) out of seven. This section included six statements that could be divided into three pairs: the performance of the smartphone, the internet, and the map. The smartphone performance (M=6.39, SD=0.83) received the highest score from the participants, which was followed by map performance with a score of 6.05 (SD=1.31), and the lowest score was given to the internet performance (M=5.89, SD=1.76). The participants rated the question asking whether the interest level in QR codes increased with a score of 6.45 (SD = 0.98) out of seven.

### 5.5. Correlations

This section presents the results involving the Pearson correlation coefficients (r values) between the variables in QRC (Table 6). The data revealed that the participants who spent longer time tended to perceive the task easier. The ones who traveled longer distances tended to spend more time, access more maps, perceive the task easier, and feel more comfortable. As they had more attempts to access the maps, they were disposed to walk longer distances and spend more time. The participants who perceived the task easier and felt more comfortable tended to describe the proposed model as more usable. In addition, those who had higher comfort were likely to use the model in the future. The ones who had a

better sense of direction tended to spend less time, travel shorter distances, access fewer maps, and perceive the task easier.

Table 6. Correlations between the measures in N_QRC and QRC in the physical study.

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| N_QRC | | | | | | | | | |
| 1. | Sense of direction | | | | | | | | |
| 2. | Task completion time | –.42** | | | | | | | |
| 3. | Travel distance | –.37* | .87** | | | | | | |
| 4. | Travel speed | .18 | –.29 | .17 | | | | | |
| 5. | Number of maps used | –.27 | .78** | .71** | –.14 | | | | |
| 6. | Perceived ease of task | .45** | –.59** | –.50** | .15 | –.52* | | | |
| 7. | Comfort level | .17 | –.25 | –.21 | .10 | –.05 | .42* | | |
| QRC | | | | | | | | | |
| 1. | Sense of direction | | | | | | | | |
| 2. | Task completion time | –.36* | | | | | | | |
| 3. | Travel distance | –.37* | .81** | | | | | | |
| 4. | Travel speed | .10 | .48** | .05 | | | | | |
| 5. | Number of maps used | –.37* | .78** | .54** | –.54** | | | | |
| 6. | Perceived ease of task | .42** | –.42** | –.49** | .13 | –.45** | | | |
| 7. | Comfort level | .28 | –.18 | –.36* | –.16 | –.31 | .66* | | |
| 8. | Usability (USE) score | .14 | –.06 | –.30 | –.41* | –.04 | .36* | .58** | |
| 9. | Willingness for future use | .15 | .11 | –.10 | –.36* | –.01 | .15 | .55** | .74** |

Note. N_QRC = no-QR condition; QRC = QR condition; **$p < .01$; *$p < .05$.

# CHAPTER VI

# METHODOLOGY OF THE VIRTUAL STUDY

In the second part of the study, we employed an experimental wayfinding task in a virtual environment to test the proposed model. This chapter presents research questions, hypotheses, and the method that was followed to seek answers to the questions and assess our assumptions.

## 6.1. Research Questions and Hypotheses

In the second part of this study, we aimed to improve the proposed model and setting based on task performance results and participant evaluations that we revealed in the physical study. Thus, using the input from the physical study, we conducted the current study in a virtual space. In the virtual study, we aimed to minimize the limitations of the prior study conducted in a physical environment. APPENDIX B contains all the differences between the methods of the two studies. Below, we listed the major improvements made in the virtual study.

- increasing the sample size,
- including all floors in the building in the study,
- improving the map content and design,
- improving the distribution of the physical maps to achieve more balanced two conditions,
- detailing the questionnaires,

- being able to record the participants' behaviors for the analysis of map use.

Similar to the physical study, we aimed to compare the proposed model with a currently widely used indoor wayfinding situation. Thus, we conducted a study in which the participants performed similar wayfinding tasks in a no-QR condition (N_QRC) and a QR condition (QRC). N_QRC referred to the setting with an everyday wayfinding model that included maps near the stairs, which was more realistic and slightly different than what we did in the physical study, where the physical maps were only found at the building entrances. QRC, however, referred to a setting with the proposed model that included QR codes near the decision points in each corridor, which was the same configuration we used in the physical study.

In the current study, we examined the same variables as in the physical study. Therefore, the research questions and the hypotheses remain the same, as can be seen in section "4.1. Research Questions and Hypotheses" However, as we had the chance to record the participants' interaction with the maps in the virtual study, we investigated two more variables that were not available in the physical study:

- number of times to look at maps
- time spent looking at maps

### 6.2. Setting

The experiment utilized a three-dimensional computer-generated model of the building (APPENDIX F) that we used in the physical study. As mentioned before, the building had a complex configuration, different floor levels, and similar spaces. Therefore, the building's interior was complex enough to increase the participants' cognitive load during wayfinding, making it suitable to test the proposed model. Unlike the pilot study, on the maps, we indicated the distinct areas in the building, such as (1) a private café area, (2) study areas with white tables and red chairs, (3) a specific area with vending machines, (4) spaces housing sculptures, (5) wall surfaces covered by large graffiti, ceramic artwork, and a glass showcase. These objects or elements differed from the environment due to their distinctive function, color, form, size, and texture. Thus, we considered those elements landmarks that might

aid participants' wayfinding performance as the reference points (Balaban et al., 2017).

Because the current study was conducted online throughout the lockdown, we were completely reliant on the participants' equipment. As a result, we used a non-immersive VE system based on a simple equipment configuration, such as a laptop or desktop computer with mice and a keyboard.

The computer-generated model was built using a three-dimensional modeling tool, ArchiCAD, and the model was transferred to the BIMx desktop viewer to navigate the model. Therefore, before the study, the researcher requested the participants to download the BIMx desktop viewer until the appointment time. Before the study, the BIMx model of the building was uploaded to Google Drive to share the document with the participants via a link on the chat window in Zoom.

We retained all the default settings the BIMx offered, including the camera height at 160 cm, which is the average eye level (Figure 12). The only parameter we changed was the walking speed, which we increased to 25 since the default value (20) was slightly slow. To eliminate the skill differences in keyboard use gained through different activities like gaming, we did not allow them to jump by pressing the space key and move faster by holding the shift key while walking, which might affect their wayfinding performance.

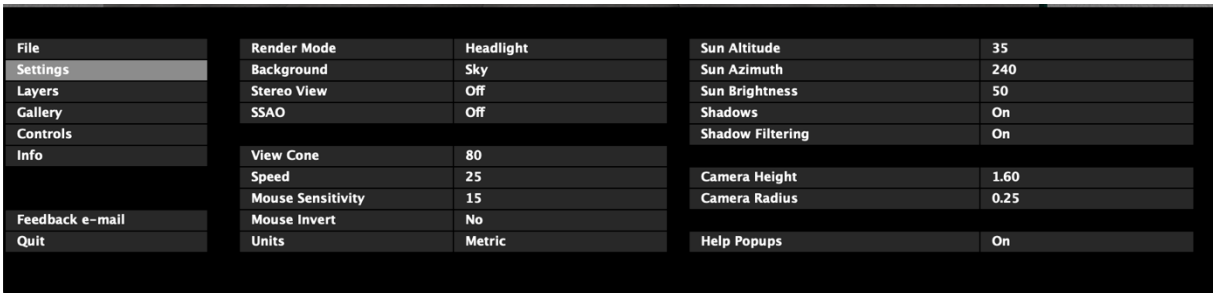


Figure 12. A screenshot captured in the BIMx used in the virtual study that shows the values in the settings menu.

To obtain the environments involving the physical maps (N_QRC) and the QR codes (QRC), we did not generate two separate BIMx models; instead, we utilized the layer feature. The layers created in ArchiCAD could be transferred to the BIMx model, and the users had the ability to turn the layers on and off (Figure 12). Thus, while generating the model in ArchiCAD, we created two layers named “Physical Maps” and “QR Codes” and assigned the physical maps and the QR code tags created in the ArchiCAD to these layers, respectively. As a result, to switch the conditions, we turned the relevant layer on or off before starting the tasks. When we turned on the "Physical Maps" layer, the scene was obtained for the N_QRC. When we turned on the "QR Codes" layer, the scene was obtained for the QRC (Figure 13).

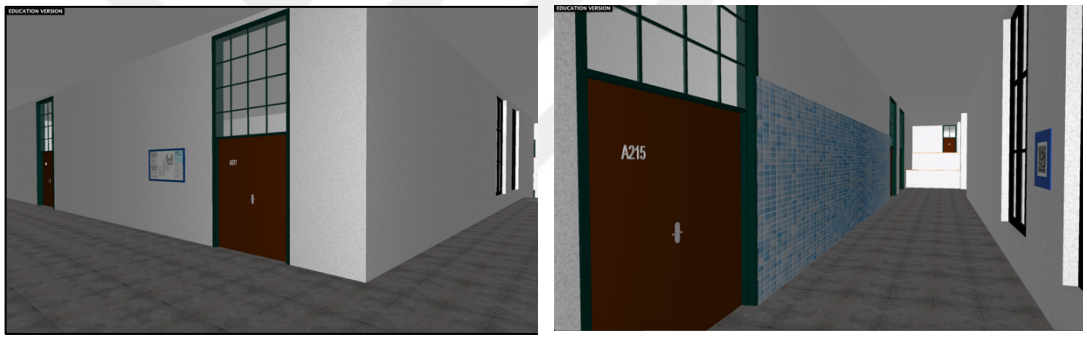


Figure 13. Perspectives from the virtual environment, showing a physical map in NQRC (left) and a QR code in QRC (right).

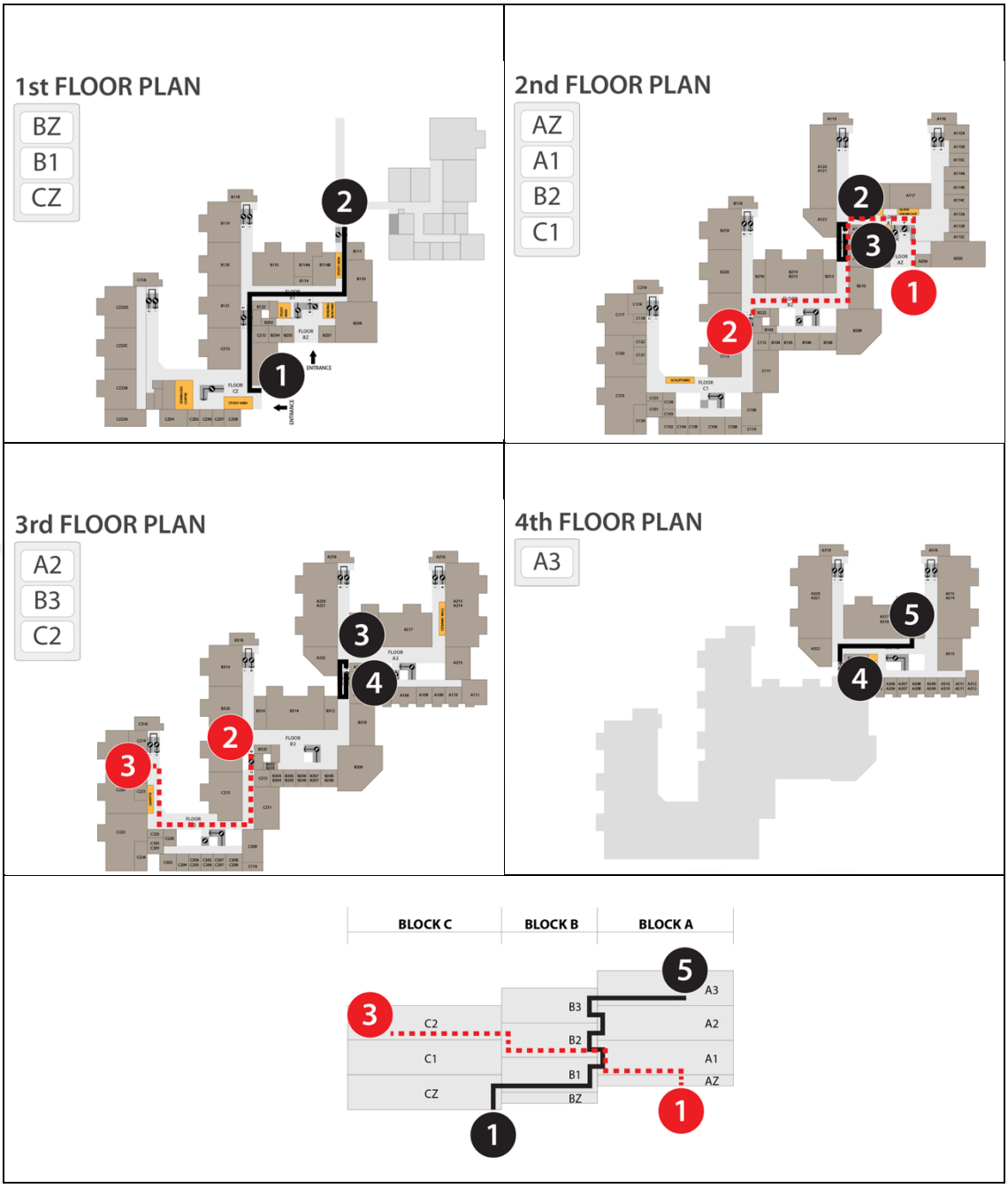


Figure 14. Path-1 (indicated by dashed red lines) and path-2 (indicated by continuous black lines) used in the virtual study shown on the floor plans and section of the building.

We used the same model in both conditions. However, to avoid the learning effect, we did not use the same path in N_QRC and QRC; we chose two partially intersecting paths at different levels in the building (see Figure 14) as we did in the physical study. We determined the paths to have similar lengths, number of

decision points, branches at the decision points, level changes, turns, and block changes considering the optimal paths (Richter & Klippel, 2002) (Table 7).

Table 7. Optimal path length, number of decision points, branches, level changes, turns, and block changes for the optimal paths in the virtual study.

| Path Number | Paths | Optimal Path Length (m) | Decision Points | Branches | Level Changes | Turns | Block Changes |
|---|---|---|---|---|---|---|---|
| Path-1 | A → C217 | 142 | 11 | 23 | 3 | 6 | 2 |
| Path-2 | C → A317 | 131 | 12 | 24 | 6 | 8 | 2 |

Note: The letters A, B, and C refer to the block names the task starts; e.g., A means "starting from the entrance of block A".

### 6.3. Participants

Seventy-two undergraduate students (36 men, 36 women) with an average age of 23 (range: 20-29 years) volunteered to participate in the study. Similar to the physical study, they were interior architecture and architecture undergraduate students from Çankaya University and were selected through quota sampling. Because we used a 3D model of an actual building at Bilkent University, which we used in the physical study, only the participants who were unfamiliar with the building took part in the study. None of them had a prior wayfinding experience with QR codes.

### 6.4. Materials

#### 6.4.1. Maps

Similar to the previous study, the maps used in N_QRC and QRC had similarities in design but differed in the amount of information they contained. While the physical maps showed the floor plan the map was located on only (Figure 15), the digital map showed all the floor plans of the building from the highest to the lowest (Figure 16). The floor levels in each block were different, and thus, the floor levels

of the blocks were different on the same floor plans. Due to that reason, naming the floor plans as ground, first, second, and third could be confusing. To avoid this, next to the floor plan, we specified which floor levels the blocks had on that floor plan. For example, as the second-lowest floor plan included the ground floor in block A, the first floors in blocks A and C, and the second floor in block B, the floor levels were listed as AZ, A1, C1, and B2 next to that floor plan under the floor name, “Floor Plan 2”.

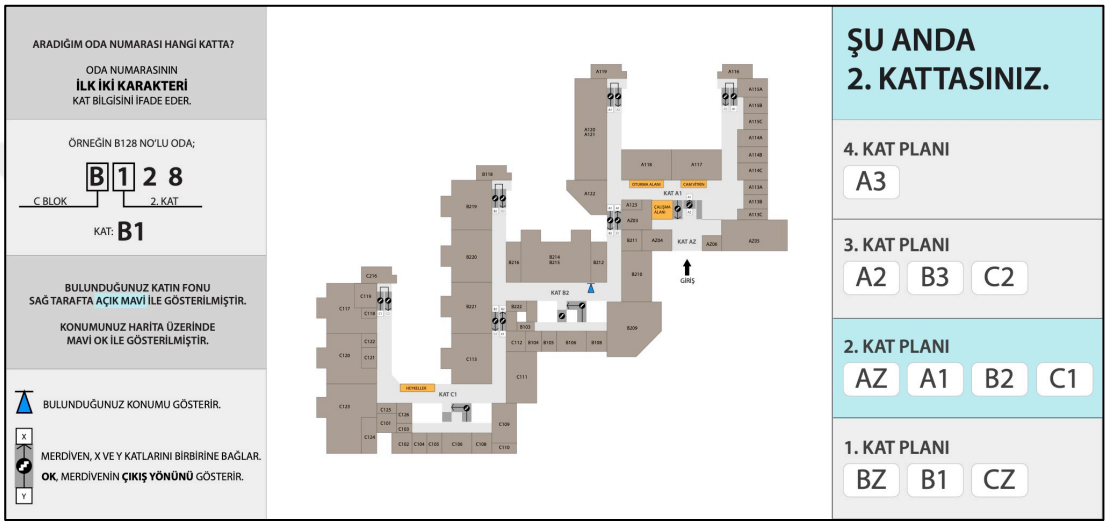


Figure 15. A sample physical map located on B2 (on the second floor in block B), used in the virtual study.

Besides, the maps showed brief information about particular icons used on the map and its working system for a more conscious map reading experience. Those explanations were available on the left and right sides of the current floor plan on the physical maps (see Figure 15) and at the top of the page before displaying the floor plans on the digital maps (Figure 16). Both maps gave information about the relation of the room numbering with the block name and its relevant floor level, the blue arrow showing the current position and direction of the participants, the stair icon showing its ascending direction and the floor levels the stair was connected, name of the floor plan the participant was currently standing on, and a description that helps the users to find the floor plan they were currently on among all of the floor plans.

Because the students might have difficulty understanding which blocks and floor levels the stairs connected, we devised a method to illustrate the stairs. The stairs were depicted with a rectangle, and a universal staircase icon was placed at its midpoint. We put a square at each end of the rectangle, and in these squares, we specified the names of the floor levels to which the staircase was connected. Thus, participants could understand whether the staircase they wanted to use was connected to the area they wanted to go. Additionally, we added an arrow aligned with the rectangle to indicate the stairs' ascent direction. This information enabled them to notice whether they were above or below the floor level they wanted to go. Last but not least, the floor plan a participant was currently standing on was highlighted with a light blue background that was applied behind the relevant floor plan on the digital maps and behind the relevant floor plan name on the physical maps. In addition, the floor plans indicated a variety of information, including the entrances to the building, floor levels, room numbers, stairs, and landmarks. We depicted landmarks on the floor plans with an orange rectangle containing the name of the landmark. Applying Levine's (1982) principles described in the methodology of the physical study, we used the same YAH symbol as in the physical study, but this time in blue.

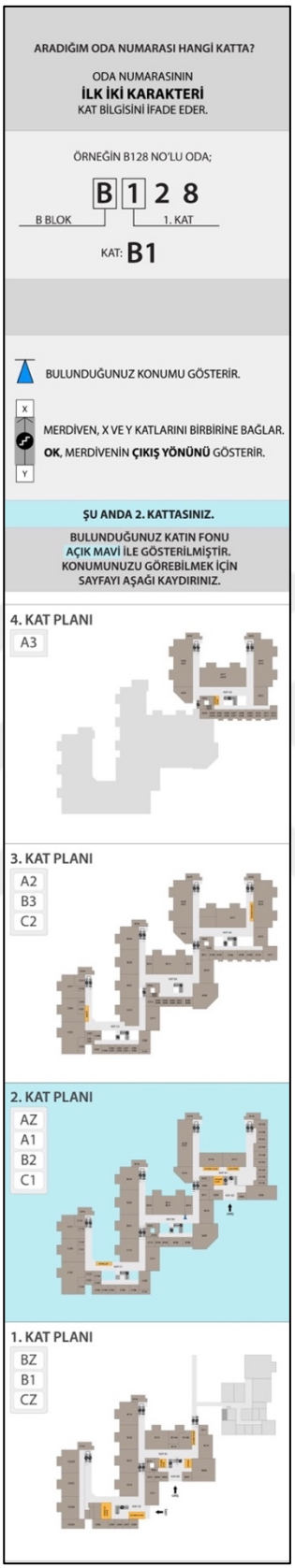


Figure 16. A sample digital map, located on B2 (on the second floor in block B), used in the virtual study.

In the conventional environment with the physical maps, we aimed to simulate an everyday wayfinding situation where maps are situated at the decision points with heavy foot traffic and where people need wayfinding cues at most such as near entrances of the buildings, the stairs, or elevators. For this reason, we used the physical maps at the points where the stairs in the middle of each block meet the main floors (Figure 17). We used one physical map on each main floor in each block, leading to the use of nine physical maps in total.

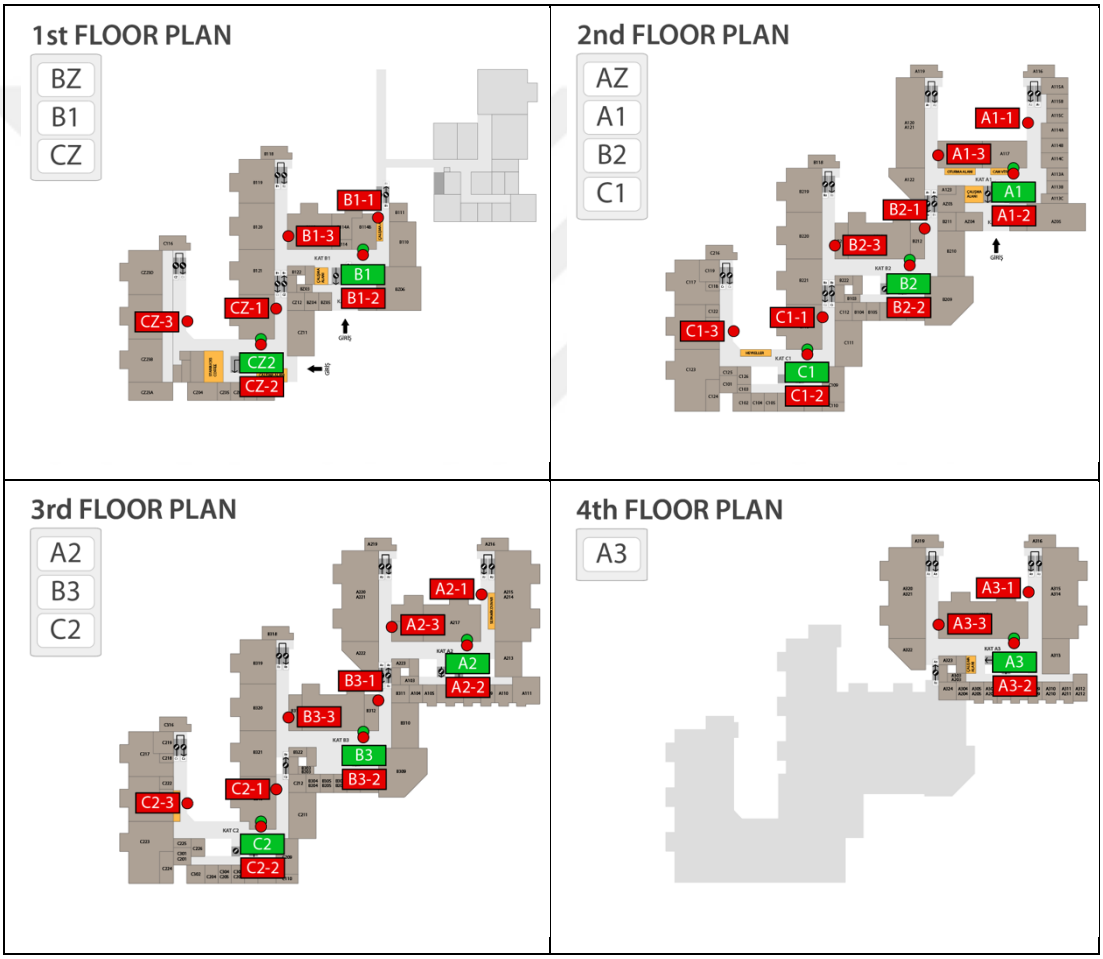


Figure 17. The location of the QR codes (shown as red circles) with their names (shown in red rectangles) and the physical maps (shown as green circles partially behind the red circles) with their names (shown in red rectangles) used in the virtual study shown on the floor plans.

### 6.4.2. QR Codes

We followed the same method to create dynamic QR codes for the VE, just as we did in the physical study using Google Drive (see Figure 9). Also, we utilized the same naming procedure with a slight difference. In the physical study, we used a three-character naming for the QR codes to locate them systematically. In the virtual study, we revised the second and the third characters. While the second character in the physical study referred to the location of the QR code on the related floor plan, in the virtual study, it referred to the floor level where the QR code is located on the relevant block. While the third character in the physical study referred to the side where the QR code is pasted on the 3D sign, it referred to the location of the QR code on the related floor plan. For example, in the virtual study, a QR code named "A3-1" meant that the QR code was located in Block A; was on the third floor of Block A; and the first QR code tag based on a systematic order defined above. Furthermore, because we converted QR codes from an angled 3D sign to a flat sign for the VE, we only had one QR code on one sign. As a result, we omitted the left and right options. As a result, there was a slight change in tag naming. When these arrangements were completed, QR codes were saved in pdf format using these names and located in the VE.

In the proposed environment, we offered the QR code tags near the decision points by taking advantage of their compact size. As we used three QR code tags on each main floor in each block, there were twenty-seven digital maps in total. The center points of the physical maps and QR code tags were located at eye level, 160 cm. To achieve contrast and perceive them better on the white wall surface in VE, we used a thick blue edge at the edges of QR code tags (Arthur & Passini, 1992) (Figure 18).

Figure 18. A QR code tag used in the virtual study that reveals the digital map in Figure 16.

Additionally, we applied the same method to locate the QR codes within the setting as we did in the physical study. Benefiting from the compact size of the QR codes, we located them at the decision points where two or more corridors intersected and people most need help (Arthur & Passini, 1992) (See Figure 17). We used three QR code tags on each main floor in each block which led to the use of 27 digital maps in total.

### 6.4.3. Equipment

The current study was conducted online during quarantine time, employing a desktop-based VR system. As a result, all software and hardware required to complete the tasks were provided by the participants under the supervision of the researcher. As the first tool, the participants were requested to use their personal computers with a stable internet connection, microphone, and camera that function properly. The computers were expected to have a web browser installed to view the questionnaires and powerful hardware to run the virtual environment, BIMx, and to be plugged in to prevent sudden/unexpected shutdowns.

As the second tool, we used Zoom, a video conferencing tool, to visually and audibly meet and communicate with participants from a distance. This platform supported

advanced features such as chatting with other participants, turning on/off the microphone or camera, sending documents to others, and sharing and recording the screen. While a free account had a meeting time limit of 40 minutes, the paid options we used in this study had no time limit. Zoom enabled us (1) to access the relevant links sent via the chat window, (2) to allow the researcher to view the participants' screens while performing using the screen share feature, (3) to track the participants' faces to reveal whether they looked at their computer screen or their smartphone, and (4) to save their task performance for the analysis phase using the record feature.

As the third tool, the participants used their own smartphones to scan the QR codes in the environment. The devices they owned were expected to have a camera capable of detecting and decoding a QR code; an internet connection, either Wi-Fi or cellular; and a web browser to display the digital maps. To avoid a possible shutdown during the task, the smartphones were expected to have at least an 80 percent charge. If the participants had a problem with the phone's battery that could cause an immediate drop in the charge, they were permitted to use a charging cable that did not restrict their mobility while sitting. Before the task in QRC, the participants activated "airplane mode" and "do not disturb mode" to avoid potential interruptions such as incoming calls or any other notifications.

As the fourth tool, the participants used a software application to detect and decode a QR code. While some of the smartphones on the market included a QR code scanning feature embedded into their default camera application, others required the use of an additional QR code scanning application. For instance, while this feature was available on all Apple devices running iPhone Operating System (iOS) 11 and later, its availability on Android devices may vary. Indeed, even if the default camera application had this feature, users needed to ensure that it was enabled on their phones. For this reason, we recommended a free and small-size application for each operating system to participants whose default camera application did not support the QR code scanning feature. We suggested "QR Code

Reader & QR Scanner" for iOS (iPhone) users and "QR Reader and Barcode Scanner" for Android (Samsung, Xiaomi, Huawei, Oppo, Honor, Meizu, Reeder, etc.) users.

As the fifth tool, we used a screen recorder application to save the actions on the participants' smartphones, such as opening the camera application, scanning the QR code, and waiting for the map to load. While the iOS users were requested to install the "Record it!" application, the Android users installed either the "Vidma Recorder" or "X Recorder" application we suggested.

As the sixth tool, the researcher gave the participants a "Pre-Task Participant Information Text" before the study. This text contained instructions for scheduling an appointment for the task day, communicating with the researcher, the hardware and software applications the participants should have, and the Zoom link that enabled the researcher to meet the participant whose appointment time had arrived.

### 6.5. Questionnaires

The study included two questionnaires given before and after the task. Here, we mentioned the essential sections and questions from both questionnaires. As a result, the section and question numbers listed below may not match their equivalents in the questionnaire. Pre-task and post-task questionnaires, including all the questions, can be seen in APPENDIX I and APPENDIX J, respectively.

#### 6.5.1. Pre-Task Questionnaire

The pre-task questionnaire consisted of two sections. In the pre-task questionnaire, in Section 1, the participants were asked to rate their navigational abilities using the Santa Barbara Sense of Direction Scale (SBSOD), which was explained in detail in the pre-task questionnaire of the physical study. In Section 2, we aimed to examine the participants' interest levels in QR codes, asking a 7-point scale question ("What is your interest level in QR codes?").

### 6.5.2. Post-Task Questionnaire

The post-task questionnaire consisted of eight sections. In Section 1, we requested the participants to rate their spatial presence (sense of being there) in the VE using Igroup Presence Questionnaire (IPQ) (*Igroup*, 2016). The questionnaire included 14 items divided into four parts: (a) one general item ("In the computer-generated world I had a sense of being there"); (b) 'spatial presence' consisting of five items (e.g.," Somehow I felt that the virtual world surrounded me", "I had a sense of acting in the virtual space, rather than operating something from outside"); (c) 'involvement' consisting of four items (e.g., "I still paid attention to the real environment), "I was not aware of my real environment"); (d) 'realness' consisting of four items (e.g., "How real did the virtual world seem to you?", "How much did your experience in the virtual environment seem consistent with your real-world experience?"). The questionnaire used a 7-point Likert scale with options ranging from -3 to 3. However, we adapted this scale to be 1 to 7 for this study to ensure consistency with all questions using a 7-point Likert scale. Among all the questions, three of them were negative statements. Before calculating the average score, the negative statements were reversed. Higher scores referred to a higher sense of presence.

In Section 2, the participants rated their perceived ease of task and comfort levels in both conditions using a 7-point scale (1 = strongly disagree, 7 = strongly agree), which was mentioned in the post-task questionnaire of the physical study in the section "4.5.2 Post-Task Questionnaire".

In Section 3, the participants assessed the usability of the proposed model using a different and more widely used usability scale than they did in the physical study. In the virtual study, the participants used System Usability Scale (SUS), a tool for measuring usability. It consists of a 10-item questionnaire with five positive (odd-numbered questions) (e.g., "I think that I would like to use this system frequently", "I would imagine that most people would learn to use this system very quickly") and negative (even-numbered questions) (e.g., "I found the system unnecessarily

complex", "I think that I would need the support of a technical person to be able to use this system") statements using a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*), which was originally created by Brooke (1996). This questionnaire allows for evaluating a wide variety of products and services, including hardware, software, mobile devices, websites, and applications.

Calculating the SUS score required a series of steps. In the first step, we needed to calculate the sum of the scores for all odd-numbered questions (X) and the sum of the scores for all even-numbered questions (Y) separately. In the second step, we reached X0 by subtracting five from X and Y0 by subtracting Y from 25. We summed X0 and Y0 and achieved a SUS score ranging between 0 and 40. Thus, in the last step, we multiplied the sum of X0 and Y0 by 2.5 to achieve a usability score ranging between 0 and 100. The average SUS score is 68; put differently, a score of 68 is at the 50th percentile. SUS scores can be graded and rated with adjectives (Table 8). While the SUS scores lower than 51 refer to an awful usability score, the SUS scores higher than 80.3 refer to an excellent usability score.

However, to continue the consistency between the questions, we converted the options of the questions to a 7-point Likert scale. Therefore, while calculating the SUS score of the participants, we converted X and Y values rated on a 7-point Likert scale to a new X and Y values rated on a 5-point Likert scale with the method of direct proportion.

Table 8. SUS scores with their corresponding grades and adjective ratings.

| **SUS Score** | **Grade** | **Adjective Rating** |
|---|---|---|
| > 80.3 | A | Excellent |
| 68 - 80.3 | B | Good |
| 68 | C | Okay |
| 51 - 68 | D | Poor |
| < 51 | F | Awful |

In Section 4, we asked the participants to rate their willingness to use QR codes for indoor wayfinding in the future using a 7-point scale as we did in the physical study in two parts: by (1) revealing their intentions to use the proposed model in the future ("If available, I would prefer to use QR code-based wayfinding tools inside buildings") and their reactions to the buildings with QR codes and (2) assessing nine wayfinding situations with complex buildings in which the QR codes could be useful. A detailed explanation of this section can be found in the post-task questionnaire of the physical study in the section "4.5.2 Post-Task Questionnaire".

In the first part of Section 5, the participants rated the equipment used in the QRC to understand the feasibility of the proposed model in its current form via multiple choice questions that allowed for more than one selection. We asked them to evaluate the internet speed, the performance of their smartphone, the QR code scanner application, and the availability of the QR codes in need. In the second part, the participants indicated the map features they found beneficial while performing the tasks by choosing one or more of the following options: "being able to see which floor I'm on among all floors"; "being able to see which floor levels the floor plans contain"; "being able to see the floors the stairs were connected"; "faint display of the floors levels, which were not included in the floor plan I was on"; "maps placed/displayed in the same direction as the environment/the way I looked at the map"; "specifying landmarks/fields (Starbucks Coffee, workspaces, etc.)"; and "being able to see all the floor plans on the digital map viewed on the smartphone".

In Section 6, the participants evaluated possible scenarios regarding the distribution of physical maps and QR codes in the environment using a 7-point scale with the following statements: "It would be sufficient to have a QR code in the areas where the stairs meet the floor", "As in the environment without QR code in this study, it would be sufficient to have a physical map only in the areas where the staircase meets the floor, where there is no QR code", "As in the QR code environment in this study, it would be sufficient to have a QR code in each corridor", "In the areas where the staircase meets the floor, it would be sufficient to use the QR code and the physical map together", "It would be sufficient to use a QR code in each

corridor and the physical map in the areas where the stairs meet the floor". In the second part, the participants were asked to choose one of the scenarios listed above that would best meet their needs.

In Section 7, the participants rated their interest level in QR codes ("What is your interest level in QR codes after the study?") on a 1-7 Likert scale (1 = strongly disagree, 7 = strongly agree). Finally, in Section 8, the participants were asked to make a suggestion for the development of the QR Code application they had experienced in this study or any method that might be useful in wayfinding.

### 6.6. Procedure

At the appointment time, the participants met the researcher via Zoom using the invitation link mentioned in the "Pre-Task Participant Information Text". At the very beginning of the meeting, the researcher checked whether the participant's:

- face was visible enough on the camera to track their movements,
- computer (1) had a microphone and camera that functions properly, (2) was plugged in, (3) had a stable internet connection, a web browser, and BIMx installed and ready to use,
- smartphone (1) had a stable internet connection, (2) at least 80 percent charge or was plugged-in,
- smartphone had a default QR code scanning feature in the default camera application
    - If this feature was unavailable on their smartphone, we checked if they installed the QR code scanner application we suggested.
- QR code scanning feature worked properly by sending them a Google Drive link containing a sample pdf with the same page size as the digital maps,
    - In this way, we checked if the content embedded in the QR codes was revealed properly and demonstrated how to scan a QR code.
- smartphone had one of the screen recording applications we suggested,
- screen recording application functioned properly by performing a demo by requesting them to (1) launch the screen recording application, (2) began to

record, (3) took several photos with their default camera application, (4) spent some time in the web browser, (5) turned back to the screen recording application and stopped recording, and (6) checked the record was saved to the default photo/gallery application.

- In this way, we checked if the screen recorder application functioned properly and demonstrated how to use the application and save the recording to the default photos/gallery application.

After the equipment check, the researcher shared the online pre-task questionnaire link with the participants via the chat window of Zoom, and the participants viewed the questionnaire on their web browsers. Following the completion of the pre-task questionnaire, the researcher shared the Google Drive link of the BIMx model containing the VE via Zoom and requested the participants to download and open the file. From this moment on, the participants were asked to sit approximately 50 cm away from their computers and to share their BIMx desktop viewer screen using the screen share feature in Zoom. Then, following the researcher's instructions, they opened the VE, which involved either physical maps or QR codes based on the task type in the first phase. The participants were then given three minutes to become familiar with the VE and adapt to keyboard and mouse controls in a practice environment. When the participants felt comfortable and ready to begin the task, the researcher directed them to the starting point of the relevant path (the entrance door of the relevant block) based on their task type in the first phase.

After that, we conducted a wayfinding study performed in the form of an experiment based on a 2 (gender) x 2 (condition: N_QRC, QRC) design with repeated measures on the last variable (Table 9). We divided the participants into four groups based on gender to have an equal number of male and female participants in both conditions. In the first phase, the participants in the first and the second group performed path-1 in N_QRC and QRC, respectively. The participants in the third and fourth groups performed path-2 in N_QRC and QRC,

respectively. In the second phase, the participants switched the path and the condition they performed to control for order effects.

Table 9. Research design of the virtual study.

| | Number of Participants | | | Phase I | | Phase II | |
|---|---|---|---|---|---|---|---|
| **Task Type** | **Total** | **Men** | **Women** | **Condition** | **Path** | **Condition** | **Path** |
| A | 18 | 9 | 9 | N_QRC | 1 | QRC | 2 |
| B | 18 | 9 | 9 | N_QRC | 2 | QRC | 1 |
| C | 18 | 9 | 9 | QRC | 1 | N_QRC | 2 |
| D | 18 | 9 | 9 | QRC | 2 | N_QRC | 1 |
| | N=72 | N=38 | N=38 | | | | |

While performing in N_QRC, the participants used the physical maps located near the vertical circulation on the main floors in each block. They were allowed to go back to the building entrance if they needed to look at the physical maps while performing in N_QRC. On the other hand, in QRC, the participants were expected to scan the QR codes. In both conditions, the participants had to use the physical/digital map within the setting at least once and more as needed. The participants were told they had no time limit to complete the task and could look at the maps as long as they wanted. We mentioned that they could not talk to the researcher while performing and requested them to activate the 'Airplane' and 'Do Not Disturb' modes to avoid possible interruptions. The participants began the first wayfinding task; once (1) they understood the task rules, (2) the first target was announced, and (3) the researcher began recording the Zoom screen shared by the participants via the screen record feature.

As the participants completed the first wayfinding task, the researcher paused the screen recording, and the participants exited and relaunched the BIMx. Thus, they returned to the location they were in the first task. However, since the settings were back to the default values when exiting the software application, the participants readjusted the walking speed and layer visibility. The researcher (1) oriented the participants to the starting point of the second wayfinding task

considering their task type, (2) gave information relevant to the second task, (3) revealed the target room to start the task, (4) started to record the screen and (4) stopped it as the participants reached the second target. Just before and after the tasks performed in QRC, the participants started and stopped recording the screen of their smartphones, respectively, and sent the record to the researcher via a cloud-based online platform, WeTransfer, after the researcher ended the Zoom meeting with the participant.

### 6.7. Measuring the Task Performances

All the task performances of the participants were analyzed after the study by watching the participants' Zoom records while performing. The task completion times of the participants were recorded in seconds using a timer. Travel distance was measured in meters by tracing the path they walked on AutoCAD and calculating the path length with the add-on command "TLEN". The travel speed of the participants was calculated in m/s (meter per second) by dividing the travel distance by the task completion time. For both measurements, we started measuring as they entered the building and stopped when they reached the target.

In both conditions, we measured the time spent looking at maps as the duration that started from when they began looking at maps and ended when they looked elsewhere or continued walking. In QRC, however, the time spent looking at maps did not include the time spent accessing the digital maps, which involved the actions of opening the camera application, scanning a QR code, and waiting for a digital map to load.

While traveling, the participants sometimes stopped and looked at a map, their environment, and the map again before restarting walking. Each of these sets was counted as one act of looking at a map. However, if the participant looked at the same map successively until a new map was used, we considered the number of maps used as one. We measured the number of digital maps used in QRC by

counting the number of QR code scans while performing in QRC, as the digital maps referred to the QR codes.

# CHAPTER VII

# RESULTS OF THE VIRTUAL STUDY

The data gathered from the virtual study, similar to the physical study, were analyzed using separate 2 (gender) X 2 (condition: N_QRC, QRC) analysis of variance (ANOVAs) for factorial designs with repeated measures on the last variable. Results involving the dependent variables of sense of direction, wayfinding performance, perceived ease of task and comfort level, and the evaluations of the proposed model are as follows. We also included the correlations between the variables.

## 7.1. Sense of Direction

The participants' mean score of sense of direction was 4.7 points out of seven (*SD* = 1.1). The results of the independent samples t-test revealed that there was a significant difference between the sense of direction scores of men (*M* = 5.1, *SD* = 0.9) and women (*M* = 4.4, *SD* = 1.1), $t(70) = 2.87$, $p = .005$.

## 7.2. Wayfinding Performance

As shown in Table 10, ANOVA results involving task completion time revealed a significant condition main effect, which indicated that the participants completed the wayfinding tasks in N_QRC at a shorter time compared to QRC. Gender main effect showed that men (*M* = 199.1, *SD* = 75.6) spent less time to complete the

given task compared to women (*M* = 316.4, *SD* = 138.0), *F*(1, 70) = 32.35, *p* < .001, *η2* = .32. Besides, there was a statistically significant interaction between the effects of gender and condition on the task completion time, *F*(1, 70) = 4.097, *p* < .001, *η2* = .06. Follow-up Bonferroni post hoc tests revealed that women spent significantly more time in QRC compared to N_QRC which was similar to the men's performance.

Table 10. ANOVA results involving condition main effects and post hoc comparisons of the wayfinding performance in the virtual study.

| **Variable** | ***N*** | **N_QRC Mean (*SD*)** | **QRC Mean (*SD*)** | ***F* statistics** | **Significance** | **Effect Size** |
|---|---|---|---|---|---|---|
| Task completion time | 72 | 218.0 (94.2) | 297.5 (157.2) | *F* (1, 70) = 20.58 | *p* < .001 | *η2* = .23 |
| Men | 36 | 177.1 (69.6) | 221.1 (81.7) | | *p* = .023 | |
| Women | 36 | 258.9 (98.6) | 373.9 (177.4) | | *p* < .001 | |
| Travel distance (in meters) | 72 | 290.7 (78.3) | 267.6 (101.7) | *F* (1, 70) = 2.12 | *p* = .15 | *η2* = .03 |
| Men | 36 | 271.0 (90.3) | 229.4 (68.2) | | *p* = .041 | |
| Women | 36 | 310.4 (118.5) | 305.8 (115.4) | | *p* = .85 | |
| Travel speed (m/s) | 72 | 1.4 (0.4) | 1.0 (0.3) | *F* (1, 70) = 98.34 | *p* < .001 | *η2* = .58 |
| Men | 36 | 1.6 (0.4) | 1.1 (0.3) | | *p* < .001 | |
| Women | 36 | 1.3 (0.3) | 0.9 (0.3) | | *p* < .001** | |

Note. *N* = sample size; N_QRC = no-QR condition; QRC = QR condition; *SD* = standard deviation; ***p* < .01; **p* < .05.

Furthermore, the participants spent 11.8 (*SD* = 6.4) seconds to reach a digital map. However, when we consider the total number of times QR codes were used in a task in QRC, the results revealed that the participants spent 30.7 (*SD* = 27.7) seconds to reach the digital maps during a wayfinding task in QRC (Figure 19).

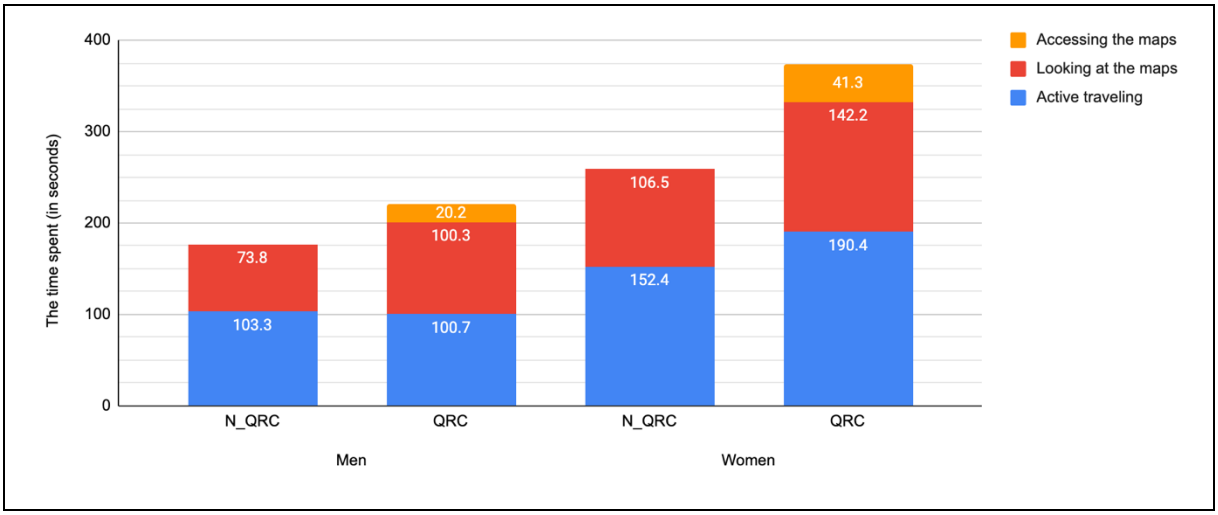


Figure 19. The time spent for the actions performed in N_QRC and QRC by gender in the virtual study.

According to the ANOVA results involving the travel distance, the condition main effect revealed no significant difference between the participants' travel distances in both conditions. Gender main effect showed that men ($M$ = 250.2, $SD$ = 70.2) had a shorter travel distance compared to women ($M$ = 308.1, $SD$ = 117.0), $F(1, 70)$ = 10.93, $p < .001$, $\eta 2$ = .14. Data revealed that gender effect on the travel distance was independent of the condition effect. However, the Bonferroni post hoc test indicated that although women's travel distance revealed no significance between the two conditions, men had a shorter travel distance in QRC compared to N_QRC.

The participants' travel speed, however, indicated a significant difference between N_QRC and QRC. Gender main effect revealed that men ($M$ = 1.4, $SD$ = 0.4) traveled faster compared to women ($M$ = 1.1, $SD$ = 0.3), $F(1, 70)$ = 18.84, $p < .001$, $\eta 2$ = .21. The interaction effect between gender and condition, however, indicated no significant difference in travel speed. The follow-up Bonferroni post hoc test showed that both men and women walked slower during QRC compared to NQRC.

### 7.3. Use of Maps

All the descriptive and inferential statistics results can be found in Table 11. The condition main effect for the number of maps used indicated that the participants

used the physical maps 3.9 times (*SD* = 1.9) in N_QRC and the digital maps 2.6 times (*SD* = 1.6) in QRC, indicating a significant difference (Figure 20). According to the gender main effect, men (*M* = 2.9, *SD* = 1.4) completed the wayfinding tasks using fewer maps compared to women (*M* = 3.6, *SD* = 2.0), *F*(1, 70) = 6.68, *p* = .012, *η2* = .09. ANOVA results revealed that there was not a significant interaction between gender and condition on the number of maps used. The follow-up Bonferroni post hoc test showed that both men and women used more maps in N_QRC in comparison to QRC. Moreover, the data showed that after the participants attempted to use a map for the first time, the number of following attempts in QRC began to decline faster.

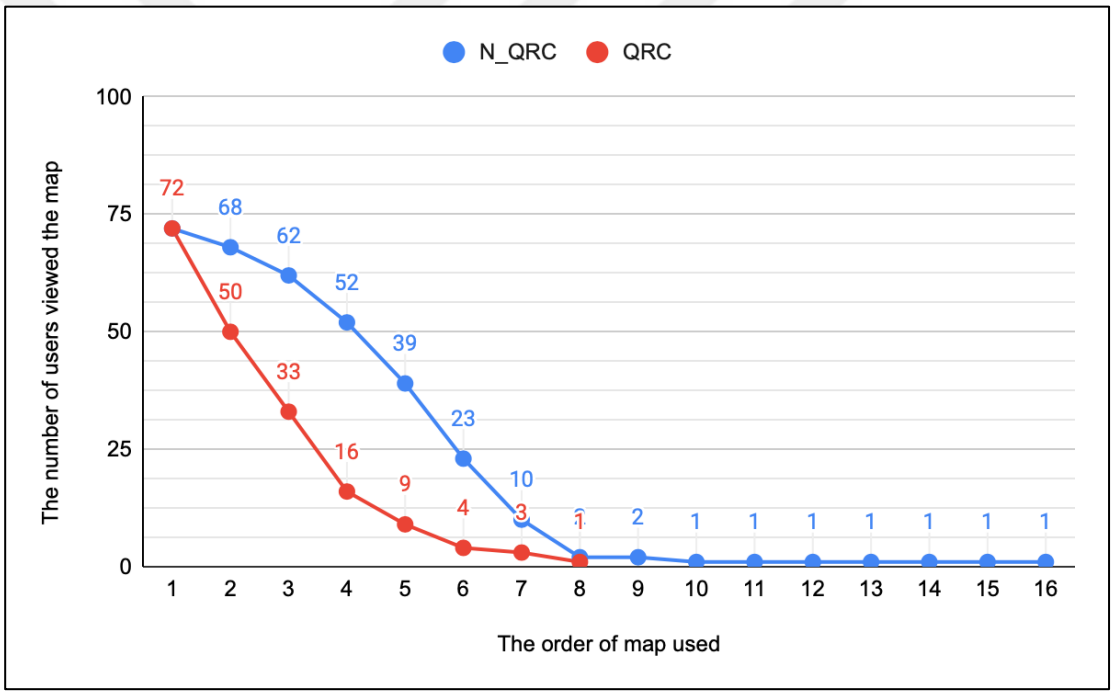


Figure 20. The number of maps used based on the order of maps the participants used in N_QRC and QRC in the virtual study.

According to the ANOVA results, including the number of times looking at the maps, the data indicated that the participants viewed the maps more frequently in QRC compared to N_QRC. The main effect for the gender revealed that women (*M* = 11.0, *SD* = 6.3) looked at the maps more often than men did (*M* = 8.4, *SD* = 4.8), *F*(1, 70) = 5.31, *p* = .024, *η2* = .07. Moreover, the gender effect on the number of times

looking at the maps had a significant interaction with the condition effect $F(1, 70) = 4.65$, $p = .035$, $\eta 2 = .06$. According to the Bonferroni post hoc test, both men and women looked at the maps more often in QRC in comparison to N_QRC.

The condition main effect for the time spent looking at the maps showed that the participants spent more time to look at the maps in QRC compared to N_QRC (Figure 21). According to the results involving the gender main effect, the data revealed that men ($M = 97.1$, $SD = 53.2$) spent less time to view the maps than women did ($M = 145.0$, $SD = 86.5$), $F(1, 70) = 12.69$, $p = .001$, $\eta 2 = .15$. However, there was not a significant interaction between gender and condition for the time spent looking at the maps. Follow-up Bonferroni post hoc test pointed out that both men and women spent more time to view the maps in QRC compared to N_QRC.

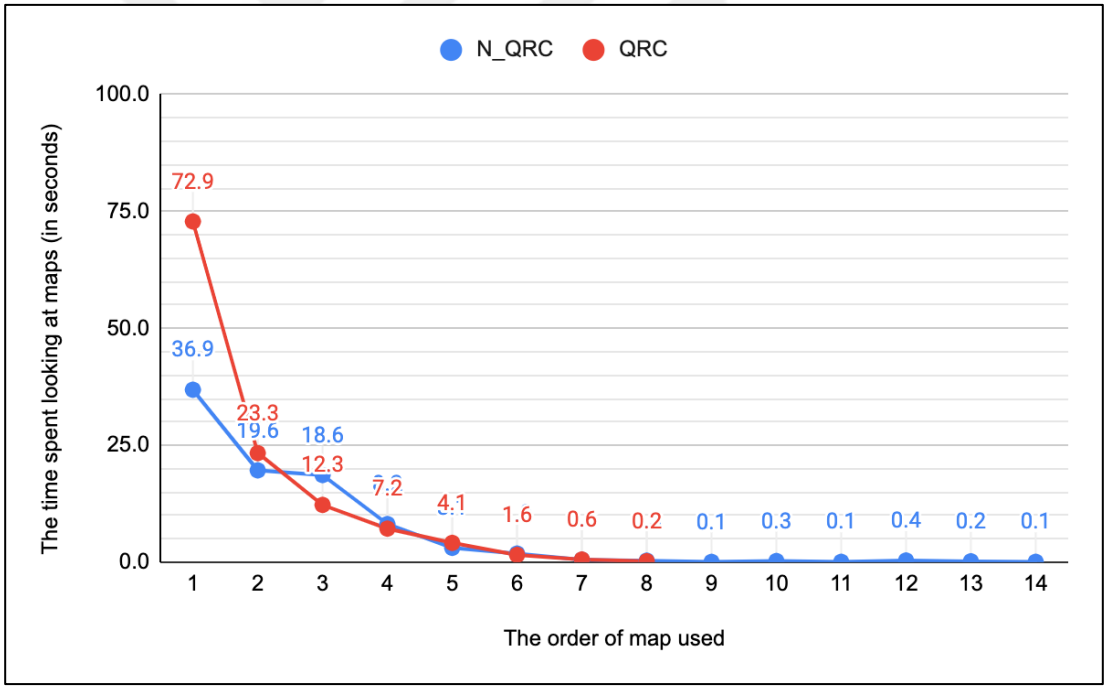


Figure 21. The time spent looking at maps based on the order of maps the participants used in N_QRC and QRC in the virtual study.

According to the ANOVA results, including the time spent looking at a map, the data indicated that the participants spent more time to view a map in QRC compared to N_QRC. Gender main effect and interaction main effect demonstrated no significant

difference. Bonferroni post hoc test, however, revealed that both men and women spent more time to look at a map in QRC compared to N_QRC.

The data containing the condition main effect of the time spent at every instance of viewing a map indicated a significant difference between N_QRC and QRC. The gender main effect between men and women and the interaction between gender and condition effect revealed no significant difference. Nevertheless, the gender effect indicated a significant interaction with the condition effect $F(1, 70) = 10.86$, $p = .002$, $\eta 2 = .13$. Bonferroni post hoc test showed that both men and women spent more time to look at a map in N_QRC in comparison to QRC.

When we analyzed the time spent looking at the first map, the condition main effect revealed that the participants viewed the first map longer in QRC compared to N_QRC (see Figure 21). The gender main effect and interaction main effect pointed out no significant difference. The follow-up Bonferroni post hoc test, however, revealed that both men and women spent more time to look at the first map in QRC compared to N_QRC.

We also investigated the participants' map usage according to the task type and the location of the maps/QR codes in the building. The results revealed that the participants most often used the closest physical map/QR code to them when they entered the building. The closest physical map to the entrance of block A and block C was used 38 and 33 times, respectively. Similarly, the closest QR code to the entrance of block A and block C was used 36 and 35 times, respectively.

Table 11. ANOVA results involving condition main effects and post hoc comparisons of the participants' map use in the virtual study.

| Variable | *N* | N_QRC Mean (*SD*) | QRC Mean (*SD*) | *F* statistics | Significance | Effect Size |
|---|---|---|---|---|---|---|
| Number of maps used | 72 | 3.9 (1.9) | 2.6 (1.6) | $F$ (1, 70) = 21.40 | $p < .001$ | $\eta 2 = .23$ |
| Men | 36 | 3.6 (1.4) | 2.1 (1.3) | | $p < .001$ | |
| Women | 36 | 4.1 (2.2) | 3.1 (1.8) | | $p = .029$ | |
| Number of times looking at maps | 72 | 4.7 (2.2) | 14.8 (9.2) | $F$ (1, 70) = 95.71 | $p < .001$ | $\eta 2 = .58$ |
| Men | 36 | 4.5 (1.9) | 12.4 (7.6) | | $p < .001$ | |
| Women | 36 | 4.9 (2.5) | 17.2 (10.1) | | $p < .001$ | |
| The total time spent looking at maps (in sec.) | 72 | 90.1 (57.5) | 121.2 (81.8) | $F$ (1, 70) = 30.54 | $p < .001$ | $\eta 2 = .30$ |
| Men | 36 | 73.8 (50.4) | 100.3 (53.1) | | $p = .001$ | |
| Women | 36 | 106.5 (60.1) | 142.2 (99.2) | | $p < .001$ | |
| The time spent looking at a map (in sec.) | 72 | 25.0 (14.8) | 61.4 (51.3) | $F$ (1, 70) = 36.24 | $p < .000$ | $\eta 2 = .34$ |
| Men | 36 | 21.9 (15.7) | 66.7 (53.1) | | $p < .000$ | |
| Women | 36 | 28.0 (13.4) | 56.1 (49.6) | | $p = .001$ | |
| The time spent at every instance of viewing a map (in sec.) | 72 | 20.6 (12.2) | 10.9 (10.8) | $F$ (1, 70) = 39.93 | $p < .001$ | $\eta 2 = .36$ |
| Men | 36 | 16.9 (9.9) | 12.3 (13.5) | | $p = .032$ | |
| Women | 36 | 24.3 (13.3) | 9.5 (7.0) | | $p < .001$ | |
| The time spent looking at the first map (in sec.) | 72 | 36.9 (26.1) | 72.9 (60.0) | $F$ (1, 70) = 22.36 | $p < .000$ | $\eta 2 = .24$ |
| Men | 36 | 36.7 (30.8) | 76.5 (53.3) | | $p < .000$ | |
| Women | 36 | 37.1 (20.8) | 69.2 (66.6) | | $p = .007$ | |

Note. *N* = sample size; N_QRC = no-QR condition; QRC = QR condition; *SD* = standard deviation; $^{**}p < .01$; $^{*}p < .05$.

### 7.4. Perceived Ease of Task and Comfort Level

The ANOVA results revealed that there was not a significant difference in the participants' perceived ease of task (N_QRC: $M = 5.8$, $SD = 1.4$; QRC: $M = 5.9$, $SD = 1.3$) and comfort level (N_QRC: $M = 5.7$, $SD = 1.6$; QRC: $M = 5.9$, $SD = 1.5$) between N_QRC and QRC, as well as men (N_QRC: $M = 5.9$, $SD = 1.2$; QRC: $M = 6.1$, $SD = 1.2$) and women (N_QRC: $M = 5.6$, $SD = 1.6$; QRC: $M = 5.8$, $SD = 1.4$) (Table 12).

Table 12. ANOVA results involving condition main effects and post hoc comparisons of the participants' perceived ease of task and comfort level in the virtual study.

| Variable | *N* | N_QRC Mean (*SD*) | QRC Mean (*SD*) | *F* statistics | Significance | Effect Size |
|---|---|---|---|---|---|---|
| Perceived ease of task | 72 | 5.8 (1.4) | 5.9 (1.3) | $F(1, 70) = 0.81$ | $p = .37$ | $\eta 2 = .01$ |
| Men | 36 | 5.9 (1.2) | 6.1 (1.2) | | $p = .59$ | |
| Women | 36 | 5.6 (1.6) | 5.8 (1.4) | | $p = .48$ | |
| Comfort level | 72 | 5.7 (1.6) | 5.9 (1.5) | $F(1, 70) = 0.70$ | $p = .41$ | $\eta 2 = .01$ |
| Men | 36 | 5.9 (1.3) | 5.9 (1.4) | | $p = .87$ | |
| Women | 36 | 5.5 (1.8) | 5.8 (1.5) | | $p = .33$ | |

Note. *N* = sample size; N_QRC = no-QR condition; QRC = QR condition; *SD* = standard deviation; $^{**}p < .01$; $^{*}p < .05$.

### 7.5. Evaluations of the Proposed Model

The participants rated the System Usability Scale (SUS) for QRC with a score of 83.3 out of 100. In other words, our proposed model reached the highest usability grade, "A", with an adjective rating of "excellent usability" (Bangor et al., 2009; Brooke, 1996). The participants rated their willingness to use QR codes for indoor wayfinding in the future with a score of 6.0 (*SD* = 1.5) out of seven. The data revealed no significant difference between men's (*M* = 5.9, *SD* = 1.5) and women's (*M* = 5.9, *SD* = 1.5) evaluations.

The participants also assessed the possible wayfinding situations with complex buildings where the proposed application could be a method for indoor navigation (See Table 10). According to the data, finding a car in parking garages/multi-story car parks appeared as the most needed wayfinding situation to use the proposed model with a score of 6.4 (*SD* = 1.1). Finding a section/product in a market or store received the lowest score by the participants with 5.4 (*SD* = 1.8) points. On average, their ratings ranged from 6.5 to 5.4 points, with a mean score of 6.2 (SD = 0.8). No gender difference was found between men's (*M* = 6.2, *SD* = 0.8) and women's (*M* = 6.2, *SD* = 0.9) ratings.

The data showed that the tools used in QRC worked well for most participants. According to the results, QR code scanner application, availability of QR codes, internet speed, and smartphone performance revealed no issues for 99%, 97%, 90%, and 89% of the participants, respectively. According to the participants' evaluations of the map features (Table 13), the data revealed that 91.67% of the participants considered "seeing which floor I am on between all floors" the most beneficial feature for them during navigation. The feature of "being able to see all the floor plans on the digital map viewed on the smartphone", which was related to the digital maps used in QRC, was evaluated as the second most useful feature by 87.50% of the participants. However, the faint display of the floor levels linked to the stairs and the display of landmarks on the maps were rated by half (50%) and less than half (45.83%) of the respondents, respectively.

Table 13. The participants' ratings of the map features in the virtual study, which were found useful and ranked from highest to lowest.

| Map Features | Male | Female | Total | Percentage |
|---|---|---|---|---|
| Being able to see which floor I'm on among all floors | 32 | 34 | 66 | 91.7% |
| Being able to see all the floor plans on the digital map viewed on the smartphone (QRC only) | 31 | 32 | 63 | 87.5% |
| Being able to see the floors the stairs were connected | 28 | 29 | 57 | 79.2% |
| Maps placed/displayed in the same direction as the environment/the way I looked at the map | 28 | 28 | 56 | 77.8% |
| Being able to see which floor levels the floor plans contain | 26 | 29 | 55 | 76.4% |
| Faint display of the floors levels, which were not included in the floor plan I was on | 20 | 16 | 36 | 50.0% |
| Specifying landmarks/fields (Starbucks Coffee, workspaces, etc.) | 18 | 15 | 33 | 45.8% |

Additionally, the participants rated the possible scenarios regarding the distribution of the physical maps and QR codes in the environment (Table 14). The option offering the use of wayfinding aids at most, which was the combination of the settings applied in N_QRC and QRC, received the highest score (*M* = 5.4, *SD* = 1.5).

This option was followed by the setting in QRC with a score of 5.2 (*SD* = 1.7). The scenario that received the lowest score (*M* = 4.0, *SD* = 1.9) was the only option without QR codes, which was applied in N_QRC. We also asked the participants which one they would prefer if they had to choose only one of the scenarios. Their responses were similar to the previous question, such that the scenario offering the combination of N_QRC and QRC was rated by 26 participants (36.1%) that was followed by the setting in QRC, which was rated by 16 participants (22.2%). Similarly, the option rated with the lowest score was the setting in N_QRC, which was preferred by 7 participants (9.7%).

Table 14. The participants' ratings of the possible scenarios in the virtual study for the distribution and the availability of the physical maps and the QR codes ranked from highest to lowest.

| **Scenario** | **Men Mean (*SD*)** | **Women Mean (*SD*)** | **Average** |
|---|---|---|---|
| It would be sufficient to use a QR code in each corridor and the physical map in the areas where the stairs meet the floor together (Combination of N_QRC and QRC) | 5.3 (1.7) | 5.5 (1.4) | 5.4 (1.5) |
| It would be sufficient to have a QR code in each corridor (The same with the QRC used in this study) | 5.0 (1.9) | 5.4 (1.4) | 5.2 (1.7) |
| In the areas where the staircase meets the floor, it would be sufficient to use the QR code and the physical map together | 5.2 (1.7) | 4.6 (2.0) | 4.9 (1.8) |
| It would be sufficient to have a QR code in the areas where the stairs meet the floor | 4.9 (1.8) | 4.5 (1.9) | 4.7 (1.9) |
| it would be sufficient to have a physical map only in the areas where the staircase meets the floor (The same with the N_QRC used in this study) | 3.9 (1.7) | 4.1 (2.1) | 4.0 (1.9) |

### 7.6. Correlations

The Pearson correlation coefficients (r values) between the variables in N_QRC and QRC can be seen in Table 15. The correlational analyses revealed that, in both conditions, the participants who viewed more maps were more likely to spend

more time reading them and completing their wayfinding tasks. They also traveled more and walked more slowly. As would be expected, a decrease in task completion times, travel distances, and the time spent looking at the maps increased the perceived ease of task. In addition to these, in QRC, the participants reporting higher perceived ease of task and comfort level and traveling faster tended to rate the proposed model more usable. Besides, the variables positively associated with usability and negatively with the task completion time seemed to be associated with a stronger likelihood of using the proposed model in the future.

Table 15. Correlations between the measures in N QRC and QRC in the virtual study.

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| N_QRC | | | | | | | | | | |
| 1. | Sense of direction | | | | | | | | | |
| 2. | Task completion time | –.14 | | | | | | | | |
| 3. | Travel distance | –.18 | .65** | | | | | | | |
| 4. | Travel speed | .03 | –.57** | .15 | | | | | | |
| 5. | Number of maps used | –.03 | .61** | .63** | –.13 | | | | | |
| 6. | Time spent to look at maps | .03 | .85** | .27* | –.77** | .49** | | | | |
| 7. | Perceived ease of task | .24* | –.32** | –.39** | .13 | –.17 | –.24* | | | |
| 8. | Comfort level | .15 | –.12 | –.21 | .03 | –.16 | –.04 | .64** | | |
| QRC | | | | | | | | | | |
| 1. | Sense of direction | | | | | | | | | |
| 2. | Task completion time | –.22 | | | | | | | | |
| 3. | Travel distance | –.19 | .73** | | | | | | | |
| 4. | Travel speed | .20 | –.62** | –.03 | | | | | | |
| 5. | Number of maps used | –.16 | .61** | .54** | –.29* | | | | | |
| 6. | Time spent to look at maps | –.14 | .93** | .58** | –.69** | .47** | | | | |
| 7. | Perceived ease of task | .01 | –.45** | –.39** | .28* | –.42** | –.42** | | | |
| 8. | Comfort level | .04 | –.29* | –.27* | .23 | –.22 | –.32** | .75** | | |
| 9. | Usability (USE) score | .01 | –.10 | .03 | .27* | –.09 | –.19 | .67** | .75** | |
| 10 | Willingness for future use | –.08 | –.23* | –.11 | .23* | –.21 | –.30* | .62** | .74** | .79** |

Note. N_QRC = no-QR condition; QRC = QR condition; **$p < .01$; *$p < .05$.

# CHAPTER VIII

# DISCUSSION

This section presents the interpretation of the results obtained from the physical and virtual study. The results of the two studies are discussed together in a single chapter rather than in two separate chapters to avoid repetition and to have a comparative interpretation of the results.

## 8.1. Wayfinding Performance and Use of Maps

In both studies, the results emphasized that the participants spent more time in QRC compared to N_QRC. The difference could be attributed to the number of maps used, which was also positively correlated with task completion time, a common finding in the correlations of both studies. In the physical study, the participants used more maps in QRC, whereas in the virtual study, they used more maps in N_QRC. The opposite finding between the studies was probably because of the distribution of the physical maps in the setting. In the physical study, the maps on the walls were only located at building entrances and only five participants returned to the building entrance to look at the maps for a second time. There might be two possible explanations for this finding. First, while performing the task, the participants had to walk a considerable distance to get to the entrance, which could be deterring. Second, the participants may have perceived returning to the

entrance of a complex building they are unfamiliar with as an additional spatial problem.

In the virtual study, however, the participants used fewer maps in QRC compared to N QRC, which was the opposite result obtained in the physical study. There might be two factors for achieving this result. First, in the virtual study, the maps on the walls were placed near the vertical circulation points, resulting in a more even map distribution than in the physical study. Thus, the participants benefited from the physical maps they encountered while navigating, leading to an increase in the use of those maps compared to the physical study. Second, the use of maps displayed on the smartphone, including all of the building's floor plans, and the near-constant availability of these maps might have influenced this finding. In both conditions, the participants predominantly started their task by using the first map to understand their position with respect to the building layout. While there was a gradual decline in the use of physical maps in N_QRC after the first map use, there was a sharp decrease in the use of digital maps in the second attempt, followed by a gradual decline. We found that only a few participants scanned two or more QR codes. This was probably due to the difference in the amount of information the maps contained in both conditions. Unlike the QR codes in the physical study, which included the current floor plan only, all the QR codes in the virtual study included the same map containing the building's all floor plans. Because of that, most participants might have ignored scanning additional QR codes in the virtual study as the maps provided the same content. On the other hand, the maps embedded in QR codes differed only in the direction of the map, the floor level on which the participant was located, and the participants' position on the relevant floor plan, as determined by the QR code scanned. Thus, the participants in the virtual environment might have scanned a new QR code to verify that they were on the right track or to reassess their position if they felt disoriented in the building.

Despite using fewer maps, in the virtual study, the participants spent more time looking at maps in QRC, resulting in longer task completion times, probably because

of the near-constant availability of the maps. The results indicated that after accessing a map on the smartphone, they looked at the maps they accessed many times while navigating but spent less time at every instance of viewing the map. This was most likely due to performing a more cautious traveling style in QRC. In the proposed condition, they stopped and looked at the maps on their smartphones more often, frequently matching their position and the environment with the setting, leading to a slower walking speed and a longer task completion time. This finding is congruent primarily with Gerber and Kwan's (1994) cautious map reading approach when you have the opportunity to carry the map with you and look at it while navigating. They indicated that individuals applying this approach heavily depend on their maps to find their route as they located it on their maps and proceed by matching the map with the environmental information they encountered. The regularity of behavior indicates that these people do not plan far ahead on their maps. Instead, they prefer to take each leg of the route as it occurred. In the virtual study, another factor that may contribute to longer task completion times in QRC was the initial interaction with the maps. The participants spent nearly twice the time looking at the first map they used in QRC compared to N_QRC. This was most likely due to the amount of information and the relative complexity introduced by the maps displayed on the smartphone, which included all the floor plans. Thus, paying attention to and comprehending the entire configuration of the building while studying the first map may have required more cognitive effort, possibly resulting in longer map reading times. This is parallel to the previous finding by Meilinger et al. (2006). They discovered that the complexity of maps increases the time spent using maps.

Besides, the method of accessing the maps in QRC could be a common factor contributing to longer task completion times in both studies. While using the proposed model, the participants performed a series of actions that required additional time to access a map, such as launching the camera application, taking a photo of a QR code tag, and waiting for the digital map to load. In addition, the participants had the flexibility to look at, zoom in/out, rotate, and pan the maps in

QRC as opposed to the N_QRC, in which these actions were unavailable. Thus, the alternative way to interact with the maps in QRC might have increased the total travel time in that condition.

Overall, reaching a longer task completion time in QRC compared to N_QRC contradicts the findings of studies performing similar comparisons (Pearson et al., 2017; Zhang et al., 2021). The difference was probably because of the proposed models' way of working. Users benefiting from their models follow a predefined path or a set of directions to the target, which reduces the human workload for cognitive tasks in wayfinding (Tadepalli et al., 2021). Nevertheless, the condition we proposed was grounded on YAH maps, necessitating the use of survey knowledge. Thus, understanding the spatial configuration of all the floor plans, matching them with the spatial information gathered from the environment, and creating a route to the target require more learning effort (Mulloni et al., 2009). According to Butler et al. (1993), following a route can minimize energy expenditure and may not affect the memory load. However, schematic maps, such as our you-are-here map, necessitate the development of a holistic cognitive schema. When studying a map, a person must look for cues in the map to help them decide what to do at decision points (e.g., hallway intersections) and then locate those cues in the actual environment, resulting in a substantial memory load. On the other hand, a predefined route guides each wayfinding decision.

Even though reaching a longer task completion time seems to conflict with the adoption of a potentially useful recent technology, we expected it due to issues related to adapting to a novel process. Because the conventional environment we employed in this study simulated the most common wayfinding models currently used in complex buildings, the participants were already familiar with that condition and knew how to navigate it. On the other hand, the proposed condition introduced them to the near-constant availability of an indoor map, a level of flexibility they had probably never experienced before. Since the participants were not accustomed to a wayfinding model where they could carry all the floor plans with

them, they might not have developed a practical method for using maps and could not fully benefit from the features of the multi-map model (Ishikawa et al., 2008). However, as the model we developed becomes widespread and used more frequently, especially by enthusiastic early adopters (Rogers, 2003), people are expected to gain the ability to use an interface with multiple maps more effectively, thus improving the wayfinding time.

Gender seemed to be a crucial factor affecting wayfinding performance. In line with the studies pointing to gender differences in spatial ability favoring men over women (Chen et al., 2009; Lawton, 1994, 1996), our findings in both studies indicated that men completed the tasks in less time and travel distance with higher travel speed compared to women in both conditions. In terms of map use, men used fewer maps in both studies and spent less time looking at maps in the virtual study by viewing the maps fewer times. In addition, the male participants' performance in using maps may promote the finding that men are likely to be better at reading maps (Lawton, 2010).

### 8.2. Perceived Ease of Task and Comfort Level

We also inquired about how the participants felt about the different conditions of the study, namely ease of wayfinding, comfort level, and evaluations of the proposed model. In both studies, no significant differences were observed in the perceived ease of task between the conditions. In other words, although the proposed model necessitated a series of additional actions performed with a smartphone and was associated with a longer task completion time, the participants' ratings revealed no difference in the ease and comfort of wayfinding between the two conditions. As mentioned previously, this was probably because of the flexibility provided by the model that allowed the participants to transfer the map onto their smartphone and carry it with them, giving instant access to view all the floor plans in the building and looking at the map whenever they needed. If they wanted to update their location to orient themselves, they knew another QR code would be nearby. Those advantages could be the reason why they did not

seem to mind the longer task completion times of QRC and evaluated both conditions similarly in terms of ease and comfort. However, our finding conflicts with the literature (Pearson et al., 2017) comparing QR code and no-QR code conditions and examining the ease of task. The reason, again, could have been the use of predefined routes that diminish users' workload, easing the wayfinding process.

The correlations of both studies revealed that the participants with longer task completion times tended to perceive the task as more difficult regardless of the condition. In addition, the perceived ease of task was positively correlated with the comfort level, which agrees with previous literature (Chang, 2013). Therefore, once they have adapted to using the proposed model, they may have better wayfinding performance, resulting in easier and more comfortable wayfinding experiences.

### 8.3. Evaluations of the Proposed Model

The usability score was essential to understand whether the proposed model worked as intended (Bangor et al., 2009; Brooke, 1996; Torrado et al., 2016). We employed a different usability test in each study but based on the participants' ratings within each test, the proposed model was rated to be highly useful in both studies. In other words, the participants' ratings confirm that the proposed model worked well and fulfilled its purpose. The participants rated the use of the proposed model in complex structures positively and wanted to use it in the future. Correlations revealed that the participants' perceived ease of task and comfort level in QRC were positively associated with their usability scores. Therefore, the improvement of these factors and the factors associated with them might play a key role in increasing the usefulness of the proposed model.

We also found that the interest level in the QR codes increased significantly after the present study. This might be because they found the general use of QR codes useless in the applications they have encountered so far (McGowan, 2021). However, their opinion on the QR codes may have changed as they experienced an

effective use of QR codes benefiting their lives (Demir et al., 2015), as in this study. Another important finding was that there was no gender difference in the positive evaluations of the proposed model, even though women's performances were significantly lower compared to those of men. This could imply that the feeling of control provided by the instant access to locations with the use of QR codes was likely seen as a good trade-off for the extra time spent during wayfinding.

According to the evaluations of map features used in the virtual study, the participants, at most, preferred to know where and on which floor they were in an unfamiliar building. In the second place, they preferred to see all the floor plans of the building, an option only available in QRC. The reason for this could be to examine all of the existing spaces in the building, locate the target, and generate a route to this target. In addition, we asked the participants to evaluate some possible scenarios obtained by combining the settings in N_QRC and QRC to understand whether the map distribution we presented in QRC was sufficient. The participants most preferred the combination in which the settings in N_QRC and QRC were presented together. The answers given to open-ended questions may explain the reason for this finding. Many respondents noted that scanning a QR code every time to access a map can be inconvenient, especially for those not interested in technology, such as the elderly.

Among the combinations, the setting we presented in QRC was the second most preferred option by the participants. This could imply that the participants found the setting adequate for indoor wayfinding. On the other hand, the setting we presented in N_QRC was the least preferred option by the participants. This may indicate that although the participants experienced an environment based on QR codes for the first time for indoor wayfinding, they found the proposed model more functional than the traditional wayfinding method based on physical YAH maps. This was most likely due to the amount of memory load differed in both conditions. In N_QRC, after looking at a map, they had to remember the spatial configuration or the route they planned until viewing the next map, which relied solely on their

cognitive map. However, in QRC, they could view the maps whenever they wanted and update their position before each decision point, resulting in less short-term memory load (Giannopoulos et al., 2014).

### 8.4. The Comparison of the Physical and the Virtual Study

In terms of recording the participants' task performances, the virtual study provided an advantage over the physical study (Dombeck & Reiser, 2012; Morganti et al., 2007; Rey & Alcañiz, 2010). In the physical study, we followed the participants to trace the path they walked and recorded the time they spent accessing the maps using a screen recorder on the smartphone we provided them. However, we were not able to measure the number of times they looked at maps and the time they spent looking at maps. We only measured the time they spent looking at the physical maps at building entrances since studying a map located on the door is quite rare and obvious. On the other hand, in the virtual study, we recorded the participants' (1) movements in the three-dimensional building model, (2) faces using the screen record feature in Zoom, and (3) smartphone screens. Monitoring all the recordings of the participants simultaneously after synchronizing them, we were able to measure the number of times the participants looked at maps and the amount of time they spent looking at maps, which were the variables we could not examine in the physical study.

Regarding the degree of realism, the physical study was undeniably superior to the virtual study as it was conducted in a real environment (Rey & Alcañiz, 2010; Witmer & Singer, 1998). The virtual environment could not include all the features available in the real environment, such as background noise/sound (Dalirnaghadeh & Yilmazer, 2022), lighting (Hidayetoglu et al., 2012), and people moving around (Dalton et al., 2019; H. Li et al., 2019; Yang et al., 2018). Additionally, the participants navigating in the VEs did not move physically (self-motion) and lacked accurate kinesthesia (movements of the muscles) (Jansen-Osmann & Wiedenbauer, 2004; Vilar & Rebelo, 2010). Thus, as the participants moved in the VE using a

keyboard and mice, they may have walked distances they would not normally be willing to walk in real life.

In both studies, the equipment we used and the research setting revealed no issues, allowing us to accurately measure the task performances and test the proposed model; as a result, there were no problems with the validity of the studies (Hammersley, 1987; Heale & Twycross, 2015; Schultheis et al., 2002). However, the uneven distribution of the maps located on the walls (physical maps) and the QR code tags on the walls (digital maps) might be questioned. Although we increased the number of maps in N_QRC in the virtual study to reduce signage misdistribution between the two conditions, the number of maps remained unequal. Aside from that, we obtained similar results from both studies, which varied slightly in their methodology. This could imply that both studies achieved high reliability (Hammersley, 1987; Heale & Twycross, 2015; Jansen-Osmann & Wiedenbauer, 2004).

From the researcher's point of view, each study has its own set of limitations and benefits. In the physical study, meeting the participants in the experiment setting required effort due to obtaining the necessary permissions for them to enter the university campus and assisting them in finding the building on the campus where the experiment was conducted. Moreover, as the study was employed over several days, locating and removing the YAH maps on building entrances and 3D signs on the walls each day took significant time and energy (Krathwohl, 1998). In the virtual study, however, meeting the participants and adapting the virtual environment to each condition was relatively simple and quick, whereas generating the virtual model was the most difficult, demanding substantial time and effort (Jansen-Osmann & Wiedenbauer, 2004). Besides, there was a major difference in the experiment durations of the two studies. While the experiment in the physical study took nearly 30 minutes, including answering questionnaires, the experiment in the virtual study took approximately one hour as we checked all the tools and the

software the participants provided one by one to ensure they functioned as expected.

### 8.5. Preliminary Design Guidelines for the Proposed Model

As previously stated, the proposed model in the physical environment functioned well. However, based on our observations and the participants' evaluations, we improved the model and tested it in a virtual environment, which also performed well. On top of that, we requested them to express their opinion about using the proposed model. In light of the saturated information obtained through this process and experiments, we offer preliminary design guidelines to those who want to adopt our QR code-based indoor navigation model to their institutions and thus provide their visitors with a positive user experience. Below, we listed our suggestions for the design of (1) the building's floor plans, (2) maps that include all the floor plans, (3) QR code tags, and (4) the placement of QR codes. Detailed versions of the proposed items can be found in the methodology section of both studies conducted within the scope of this dissertation.

***Floor plan design***

1. The map should be simple to understand (Klippel et al., 2006; Passini, 1984). Details on the drawing, such as annotations, dimensions, furniture, and so on, should be removed. Indication of rooms (offices, classes, restrooms, rooms, etc.) together with horizontal (corridors) and vertical circulation (stairs, elevators) paths would be sufficient for the abstraction of the floor plans.

2. Common use areas, such as restrooms, vertical circulation spots (e.g., stairs, escalators, and elevators), information desks, and so on, may be emphasized with universal symbols to be recognized quickly (Klippel et al., 2006; Phillips & Noyes, 1982).

3. To match the map with the environment, (1) the name of the rooms should be provided on the corresponding areas on the floor plan; (2) building entrances could be shown with an arrow together with the text ‘Entrance’; (3) if available, landmarks could be shown on the floor plan with a text or icon describing the landmark (Levine, 1982; O’Neill, 1999).

4. If a floor plan consists of two or more floor levels, (1) the name of the floor levels should be indicated on the relevant circulation paths; and (2) on the drawing of the relevant stairs, it could be helpful to indicate which two floors the user is connected to by those stairs.

5. The spaces and circulation paths might be differentiated with color coding (Arthur & Passini, 1992; Montello, 2010). Using light or tinted colors for the circulation paths and dark or shaded colors for rooms may emphasize the circulation paths where the users navigate.

6. The relevant floor plan needs to involve the You-Are-Here (YAH) symbol according to the position of the person scanning the QR code (Levine, 1982). The YAH symbol may only consist of an arrow showing the location and direction of the user. Another option is to add a line to the arrow, which provides additional information by depicting the map’s position and direction. The YAH symbol should be large enough on the digital map to be visible without zooming in on the first look.

7. The floor plans should be oriented or aligned with the setting considering the scanning direction of the relevant QR code (Aretz, 1991; Levine, 1982; Montello, 2010).

***Map design***

1. This proposal envisions a map presenting all of the building’s floor plans along with the necessary descriptions. The building's floor plans should

be provided in a logical order, preferably from the highest to the lowest floor, from top to bottom of the page. To distinguish the floor plans, a separator element or a design method, like a line, should be considered between the floor plans.

2. The name of the floor level (e.g., "1st Floor") should be provided next to the relevant floor plan (Arthur & Passini, 1992; Jeamwatthanachai et al., 2016).

3. Among all the floor plans, the map should highlight the current floor plan where the scanned QR code is located, such as using a different background color, depicting a thick frame around the current floor plan, or placing an arrow pointing to the current floor plan.

4. The map should include usage instructions for the proposed model and the map (Klippel et al., 2006). The instructions at the top of the page may assist beginners in understanding how to use the maps. Furthermore, if the instructions appear before the maps at the top of the page, we may prevent the user from skipping that information.

5. Maps should be crisp and clear and maintain their resolution while zooming to avoid detail loss. Thus, they might be generated with a vector-based software application rather than a pixel-based one and should be saved in PDF format.

***QR Code Design***

1. Type: QR codes should be dynamic. In other words, their content needs to be adaptable to changes while using the same QR codes (Aulya et al., 2016). As a result, if one of the floor plans needs to be revised, the QR code tags in the environment remain the same while their content is updated.

2. Generation: Dynamic QR codes could be generated using online QR code service providers, possibly creating a paid account. Another option for creating a QR code is to use online cloud-based file-sharing platforms, which provide free use until users reach a certain storage size. for creating a QR code is to use online cloud-based file-sharing platforms, which offer free use until the users reach a specific storage size. The platforms enable users to assign a unique Uniform Resource Locator (URL), created specifically for that file. The file's content can be changed using the same URL, which is then embedded in QR codes using free QR code generators or bulky QR code generator add-ons, available for spreadsheets.

3. Visibility: QR codes should be clearly visible against the background on which they are placed. To do so, a thick frame around the QR code or adding a background, all in a contrasting color (Arthur & Passini, 1992) may aid in noticing the QR code.

4. QR codes should be large enough to be easily perceived, considering the size or foot traffic of the space in which they are located (Arthur & Passini, 1992). Larger QR code tags may be used near building entrances or vertical circulations to ease their perception in crowds.

5. In low-light conditions, where it is hard to see QR codes, such as indoor parking areas, QR code tags could be illuminated, or the frame around the QR code could be luminous/phosphoric (Rodrigues et al., 2019; Rousek & Hallbeck, 2011).

6. The material of the QR code tag should be durable against possible friction. If needed, these tags could be covered by another layer of durable material.

***QR Code Placement***

1. QR codes should be named systematically before installation because understanding the differences between them with the human eye is nearly impossible. Only in this way can one understood which QR code will be placed where.

2. Utilizing the compact size, QR codes should be located near the decision points (Klippel et al., 2006; Zhang et al., 2021) at one end of a wall surface, running along the corridor. Thus, each corridor may include one QR code tag. If QR codes are used on the same side of a circulation path as possible to be consistent, users will have no confusion about which surface to look for these tags. If there is a long corridor, the number of QR code tags may be increased to assist users in updating their location. Similarly, if QR code tags located on the walls in a large space, such as atriums, have a long distance between them, additional tags might be provided at the center of the space by hanging them. Figure 22 introduces a suggestion for locating the QR codes based on the typography of the building forms adapted from Dogan et al. (2015).

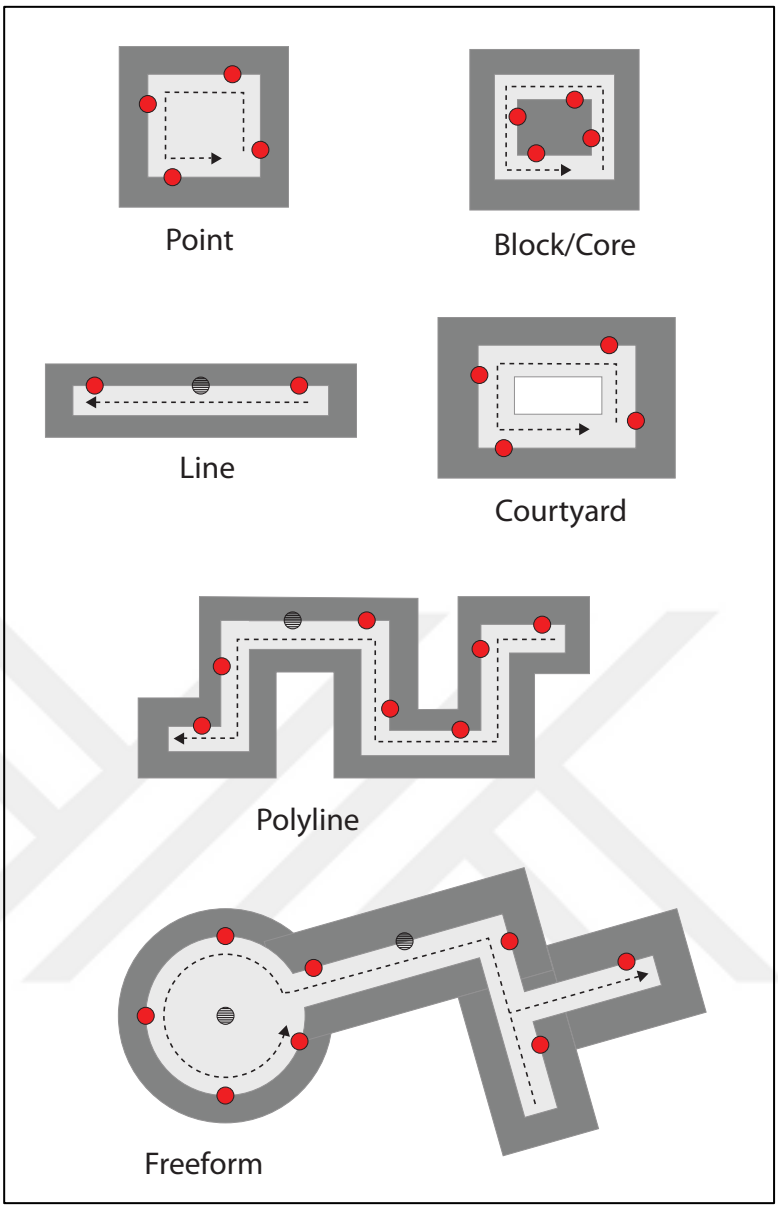


Figure 22. Suggestions for the placement of QR codes according to the typography of building forms.

(Red circles indicate the location of QR code tags, whereas black hatched circles refer to the possible use of additional QR code tags on demand, considering the distance)

3. In addition to the general distribution of QR codes in the setting, a special effort might be given to the areas with dense foot traffic, such as near building entrances and vertical circulations (Klippel et al., 2006). At least one QR code must be visible from the building entrance because

visitors want to obtain information about the environment's configuration as soon as possible when they enter the building. Likewise, since vertical circulation areas are the points where the visitor decides to go up or down, large QR code tags can be provided so that visitors can scan them from a certain distance without approaching them. This may also avoid possible crowds and queues to scan QR codes in busy areas.

4. QR code tags should be positioned near one end of the wall surfaces. Placing the QR codes/maps asymmetrically in the setting helps users match the map with the setting more efficiently and faster and better position themselves (Levine, 1982). Besides, visitors who approach a decision point where two or more corridors intersect could see the QR code near one end of the wall before they arrive intersection.

5. While placing the QR codes, their geometric center should be at eye level, 160 cm, approximately (Panero & Zelnik, 1979).

6. For those who have difficulty accessing or using technology, a physical map of the environment could be provided alongside QR code tags (Czaja & Sharit, 1998; Heinz et al., 2013).

# CHAPTER IX

# CONCLUSION

This doctoral thesis proposed a QR code-based indoor navigation model based on You-Are-Here (YAH) maps and compared it with commonly used wayfinding models, conducting two studies. Our first research question was if there was a difference between the task performances in both conditions. Based on the statistical analyses of both studies, it is revealed that condition type is an essential factor that affects individuals' task performances. The proposed model's flexibility seems to become an essential determinant of users' wayfinding behavior. Being able to view all floor plans at once causes using fewer maps, but the opportunity to carry the map while navigating increases the number of times to look at maps and the time spent looking at maps, particularly at the first look at the map. Overall, the proposed condition yields longer task completion times. Gender differences supported the prior findings in the literature that men are better than women in terms of task completion time, distance traveled, number of maps used, and time spent looking at maps.

The second research question examined the effect of condition on the perceived ease of task and comfort level. Results gathered from both studies indicated that

the type of condition does not influence wayfinding difficulty and stress level. We can conclude that the proposed model is as easy and comfortable as the conventional wayfinding model. In point of fact, based on our hypothesis, we expected the condition with the proposed model to be easier and more comfortable than the condition with the conventional wayfinding model. However, according to the correlations, it seems that map interaction impacts the wayfinding experience negatively. Contrary to our hypotheses, we could not achieve consistent results based on gender. The third question investigated evaluations of the proposed model. In line with our hypothesis, we discovered a willingness to use the model in the available buildings, even in its current form, reaching a high usability score.

***Limitations and Future Studies***

Results contrasting with our hypotheses, such as longer task completion time and similar ease and comfort levels in the proposed environment, need further exploration. Since the model introduced in the conventional setting is a configuration they routinely use, the issue in the proposed environment is probably related to adapting a new technology that requires managing the use of maps effectively. Thus, adaptation to the proposed model could be examined with additional studies. In a two- or three-stage study where the same participants used similar routes, it could be questioned whether there is an improvement in the participants' task performance and experience during the use of the proposed model.

Future studies may also investigate additional measurements such as the frequency of hesitations and errors, route memorization, cue recognition, object recall, pointing tasks, and sketch-mapping tasks. These measurements may help us comprehend the degree of spatial knowledge obtained from the environment and its accuracy under the proposed conditions.

One of the limitations of the present study is the uneven distribution of QR codes and YAH maps in the two conditions. To compare the QR code-based wayfinding method to an everyday indoor wayfinding configuration, we utilized YAH maps, which are typically found near vertical circulations. However, we placed QR codes in each corridor to take advantage of their compact size. If we had placed the QR codes only near vertical circulations, the conditions would have been more similar, but we took advantage of the technology and thus preferred a more realistic way of distributing QR codes.

Another limitation of this study is that our sample comprised university students aged between 20 and 28. Because people in this age range are likely to be more tech-savvy, giving them an advantage over older people, future studies could involve more diverse age ranges. In addition, as the participants were students of architecture departments, their backgrounds in design education may have an affirmative effect on wayfinding (Groat, 1982; Nasar and Purcell, 1990; Purcell et al., 1998). People from various fields of education may use different navigation strategies while navigating (Saku, 1992). Thus, considering the potential differences between architects and non-architects, future studies may include participants from various fields.

In the present study, we did not check if the participants had visual deficiencies or color blindness and wore glasses. Future studies may test those factors and design QR code tags and maps, and choose colors based on the results of the tests. Similarly, the proposed model could be reconsidered for people with cognitive disabilities. Besides, upcoming research may examine (1) the sample group by age and (2) the effect of other people's presence in the environment on wayfinding.

Using a non-immersive virtual system could be another drawback of the current study. Since people navigating in the VEs do not move physically (self-motion) in the real world and do not have accurate kinesthesia (movements of the muscles) (Jansen-Osmann & Wiedenbauer, 2004; Vilar & Rebelo, 2010), a further study may

test the improved form of the proposed model in a physical setting to prevent the lack of self-motion.

***Benefits of the Proposed Model***

This research is a proof-of-concept attempt to show that the model we improved could be useful as a low-cost and easy-to-implement indoor wayfinding tool. As mentioned earlier, the strength of the proposed model is that it functions with current standard smartphones and does not require the use of location-aware technologies, mobile applications, and programming language. Visitors could carry the maps, view them when necessary, and update their position and orientation by scanning a new QR code. Compared to other models requiring additional equipment and knowledge of scripting that cause such models not to be widely used, our model has a much better potential to be used in practice as it is low-cost, easy to adopt, and free of a service provider, which are essential factors for those who would like to adopt a model.

With the proposed model that complies with the post-pandemic life standards, we may contribute to using QR codes in wayfinding. Given the constant rise in smartphone ownership, internet connection availability, and the QR code experience due to the pandemic, the proposed model could be applied to buildings with complex layouts, such as campuses, hospitals, terminals, shopping malls, and parking garages. In parking garages, people view their vehicle's location on the building's floor plans by scanning a QR code tag near their vehicle. In supermarkets, they can scan a QR code at the entrance to view the location of the shelves and the categories of the products on those shelves (meat products, dairy products, etc.) on the floor plan. As a result, visitors can go directly to the relevant shelf without having to search. Besides, by scanning QR codes in terminals/airports, visitors could see the location of ticket offices categorized by companies and gates where vehicles are approaching. Therefore, passengers whose vehicle’s departure time is approaching could plan their route from the entrance to the gate before entering the building, which may diminish their anxiety. Alternatively, the proposed model

could be used to find the location of (1) departments or doctors' rooms in hospitals, (2) classes on campuses, (3) seminar rooms in conference halls, (4) stores in shopping malls, and (5) artworks in museums.

The use of compact-sized QR code tags may result in more spacious and aesthetically pleasing environments. Institutions that adopt dynamic QR codes can easily update their maps in case of a change in floor plans without having to change QR code tags. As people would spend more time in a building offering a good wayfinding experience, institutions using this technology may attract more visitors/customers and grow their profits.

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**APPENDICES**

## APPENDIX A. Ethics Committee Approval

**Bilkent Üniversitesi**
**Akademik İşler Rektör Yardımcılığı**

**Tarih** : 12 Haziran 2019

**Gönderilen** : Çetin Tünger

**Tez Danışmanı** : Çağrı İmamoğlu

**Gönderen** : Fatma Taşkın
İnsan Araştırmaları Etik Kurulu Başkanı

**Konu** : *"Use of Quick ..."* çalışması etik kurul onayı

Üniversitemiz İnsan Araştırmaları Etik Kurulu, 12 Haziran 2019 tarihli görüşme sonucu, *"Use of Quick Response (QR) Codes for Indoor Wayfinding"* isimli çalışmanız kapsamında yapmayı önerdiğiniz etkinlik için etik onay vermiş bulunmaktadır. Onay, ekte verilmiş olan çalışma önerisi, çalışma yürütücüleri, ve bilgilendirme formu için geçerlidir.

Bu onay, yapmayı önerdiğiniz çalışmanın genel bilim etiği açısından bir değerlendirmesine karşı gelmektedir. Çalışmanızda, kurulumuzun değerlendirmesi dışında kalabilen özel etik ve yasal sınırlamalara uymakla ayrıca yükümlüsünüz.

Etik Kurul Üyeleri:

| Ünvan / İsim | Bölüm / Uzmanlık | İmza |
|---|---|---|
| 1. Doç.Dr. Fatma Taşkın | İktisat | |
| 2. Prof.Dr. Erdal Onar | Hukuk | |
| 3. Prof.Dr. Haldun Özaktaş | Elektrik ve Elektronik Müh. | |
| 4. Doç.Dr. Işık Yuluğ | Moleküler Biyoloji ve Genetik | |
| 5. Dr. Öğr. Üyesi Gül Günaydın | Psikoloji | |
| Yd.1.Doç.Dr. Çiğdem Gündüz Demir | Bilgisayar Mühendisliği | (yedek üye) |
| Yd.2. Dr. Öğr. Üyesi A.Barış Özbilen | Hukuk | (yedek üye) |

Kurul karar/toplantı No: 2019_06_12_03

Bilkent Üniversitesi, 06800 Bilkent, Ankara • Telefon: (312) 290 12 13 • (312) 290 12 14 • Faks: (312) 266 41 52

## APPENDIX B. All differences between the physical and the virtual study

| Content | Physical Study | Virtual Study |
|---|---|---|
| Setting | FADA building in Bilkent University<br>Limited to two floors | 3D model of the same building<br>Includes all the floors |
| Task | Task 1: A → C113<br>Task 2: B → CZ23D<br>All the participants used an iPhone 6 given by the researcher. | Task 1: A → C217<br>Task 2: C → A317<br>All the participants used their own smartphones. |
| Questionnaire | Answered by an iPad given by the researcher<br>---- | Answered by the participants' web browser installed on their computers<br>Added questions to improve the model in the future |
| QR Codes | V-shape 3D form<br>Includes two QR codes on one tag<br>Colored in green<br>Located at 2.10 meters above the ground | Flat design<br>Includes one QR code on one tag<br>Colored in blue<br>Located at 1.60 meters above the ground |
| Maps (Physical & Digital) | Indicates the current floor only<br>---<br>---<br>Indicates four categories based on function<br>Lists room numbers under the relevant categories<br>Indicates the north sign<br>Floor naming based on main floors such as Z, 1, 2 | Indicates all floor plans and the current floor level among them<br>Includes an explanation about understanding the room's floor level<br>Indicates all the floor names with the relevant floor levels in each block<br>---<br>---<br>---<br>Floor naming based on blocks such as A1, B2, CZ |
| Physical maps | Physical maps located at building entrance doors<br>--- | Physical maps located on each main floor in each block facing the main stairs<br>Includes a YAH symbol |
| Digital maps | Shows the current floor only<br>Includes YAH symbol in red | Shows all the floors<br>Includes YAH symbol in blue |
| Floor plans | --- | Includes landmarks |

| Content | Physical Study | Virtual Study |
|---|---|---|
| | Coloring based on function for the rooms | One-type coloring for the rooms |
| | Coloring based on blocks for the transition area | One-type coloring for the transition area |
| | V-form indicator of stair ascent direction | Arrow-type indicator of stair ascent direction |
| | --- | Floor level indicator the stair is connected to |
| | --- | Includes stair icon |
| | Includes door icon | --- |

## APPENDIX C. Comparison of the results obtained from the two studies

| | The Physical Study | The Virtual Study | Similarity in Statistical Results | Gender Difference | |
|---|---|---|---|---|---|
| | | | | PS | VS |
| ***Wayfinding performance*** | | | | | |
| Task completion time | N_QRC < QRC | N_QRC < QRC | Yes ✓ | M<W | M<W |
| Men | N_QRC = QRC | N_QRC < QRC | No | | |
| Women | N_QRC < QRC | N_QRC < QRC | Yes ✓ | | |
| Travel distance | N_QRC = QRC | N_QRC = QRC | Yes ✓ | M<W | M<W |
| Man | N_QRC = QRC | N_QRC > QRC | No | | |
| Women | N_QRC = QRC | N_QRC = QRC | Yes ✓ | | |
| Travel speed | N_QRC > QRC | N_QRC > QRC | Yes ✓ | M=W | M>W |
| Man | N_QRC > QRC | N_QRC > QRC | Yes ✓ | | |
| Women | N_QRC > QRC | N_QRC > QRC | Yes ✓ | | |
| Number of maps used | N_QRC < QRC | N_QRC > QRC | No | M=W | M<W |
| Man | N_QRC < QRC | N_QRC > QRC | No | | |
| Women | N_QRC < QRC | N_QRC > QRC | No | | |
| ***Perceived ease of task and comfort level*** | | | | | |
| Perceived ease of task | N_QRC = QRC | N_QRC = QRC | Yes ✓ | M=W | M=W |
| Man | N_QRC = QRC | N_QRC = QRC | Yes ✓ | | |
| Women | N_QRC = QRC | N_QRC = QRC | Yes ✓ | | |
| Comfort level | N_QRC = QRC | N_QRC = QRC | Yes ✓ | M=W | M=W |
| Man | N_QRC < QRC | N_QRC = QRC | No | | |
| Women | N_QRC = QRC | N_QRC = QRC | Yes ✓ | | |
| ***Evaluation of QRC*** | | | | | |
| Usability* | %89.9 | %83.26 | --- | M=W | M=W |
| Willingness for future use (out of seven) | 6.4 | 6 | --- | M=W | M=W |
| Interest level in QR codes | 3.95 → 6.45 | 4.61 → 6 | Yes ✓ | M=W | M=W |

| | The Physical Study | The Virtual Study | Similarity in Statistical Results | Gender Difference | |
|---|---|---|---|---|---|
| | | | | PS | VS |
| ***Variables measured in QRC in the Virtual Study*** | | | | | |
| Number of times looking at maps | --- | N_QRC < QRC | --- | --- | M<W |
| Man | --- | N_QRC < QRC | --- | | |
| Women | --- | N_QRC < QRC | --- | | |
| Total time spent looking at maps | --- | N_QRC < QRC | --- | --- | M<W |
| Man | --- | N_QRC < QRC | --- | | |
| Women | --- | N_QRC < QRC | --- | | |
| Time spent at every instance of viewing the map | --- | N_QRC > QRC | --- | --- | M=W |
| Man | --- | N_QRC > QRC | --- | | |
| Women | --- | N_QRC > QRC | --- | | |
| Time spent looking at the first map | --- | N_QRC < QRC | --- | --- | M=W |
| Man | --- | N_QRC < QRC | --- | | |
| Women | --- | N_QRC < QRC | --- | | |
| Time spent looking at a map | --- | N_QRC < QRC | --- | --- | M=W |
| Man | --- | N_QRC < QRC | --- | | |
| Women | --- | N_QRC < QRC | --- | | |

Note. *Usability score was conducted using the USE test in the physical study and SUS test in the virtual study; PS = physical study; VS = virtual study; M = men; W = women.

## APPENDIX D. Observation sheet used in the physical study

**OBSERVATION SHEET**

**Date:** ____ / ____ / _____

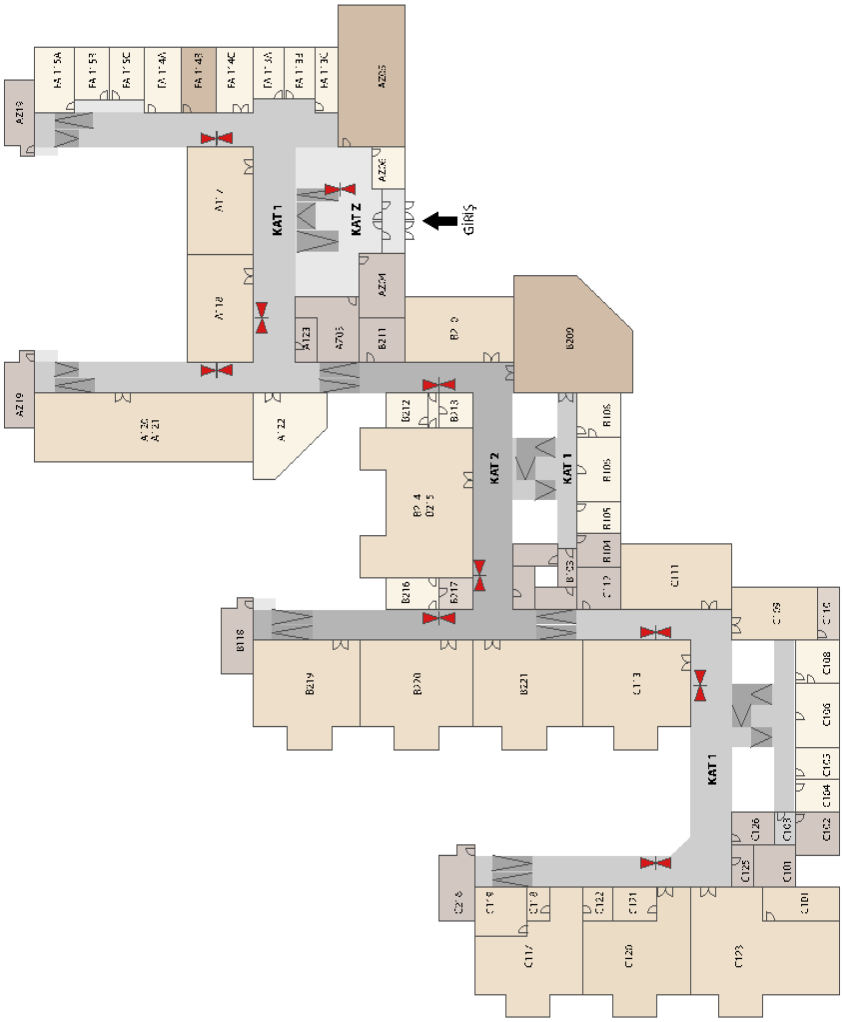
**Reference Code:** _____

**Task Type:** ▫ **(A)** A QR B NQR ▫ **(B)** A NQR B QR
▫ **(C)** B QR A NQR ▫ **(D)** B NQR A QR

**Target:** ▫ Block A → C113 ▫ Block B → CZ 23D

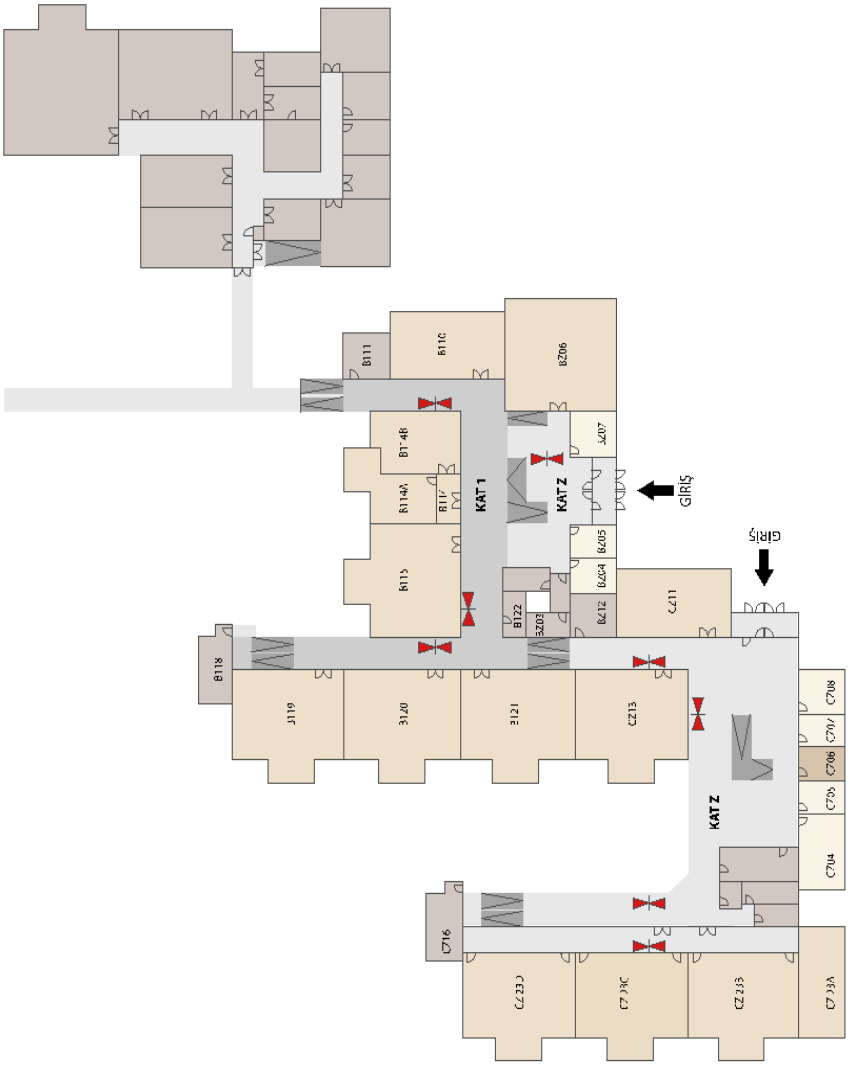
| | TASK 1 | TASK 2 |
|---|---|---|
| **Environment:** | ▫ Code ▫ No Code | ▫ Code ▫ No Code |
| **Finishing Time:** | _____:_____ | _____:_____ |
| **Duration:** | _____ min. _____ sec. | _____ min. _____ sec. |
| **Looking at Phy. Map** | _____ sec. + _____ sec. | _____ sec. + _____ sec. |
| **Screen Record S. Time** | _____:_____ | _____:_____ |
| **Screen Rec. Problem** | ▫ Yes ▫ No | ▫ Yes ▫ No |

**Map (**Block A → C113)**:**




1.

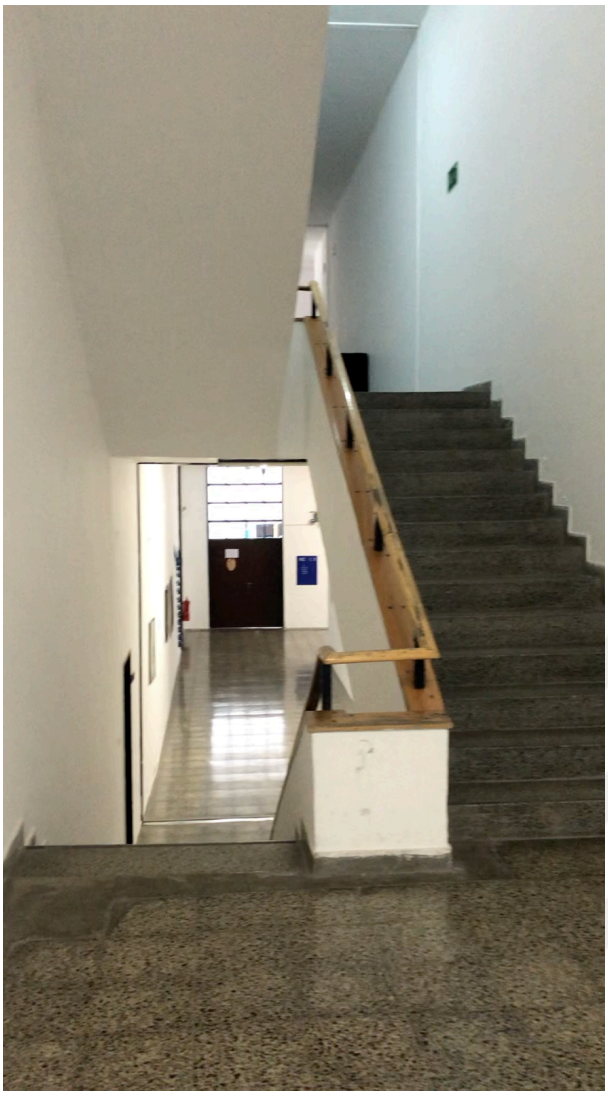
**Map (**Block B → CZ 23D**):**



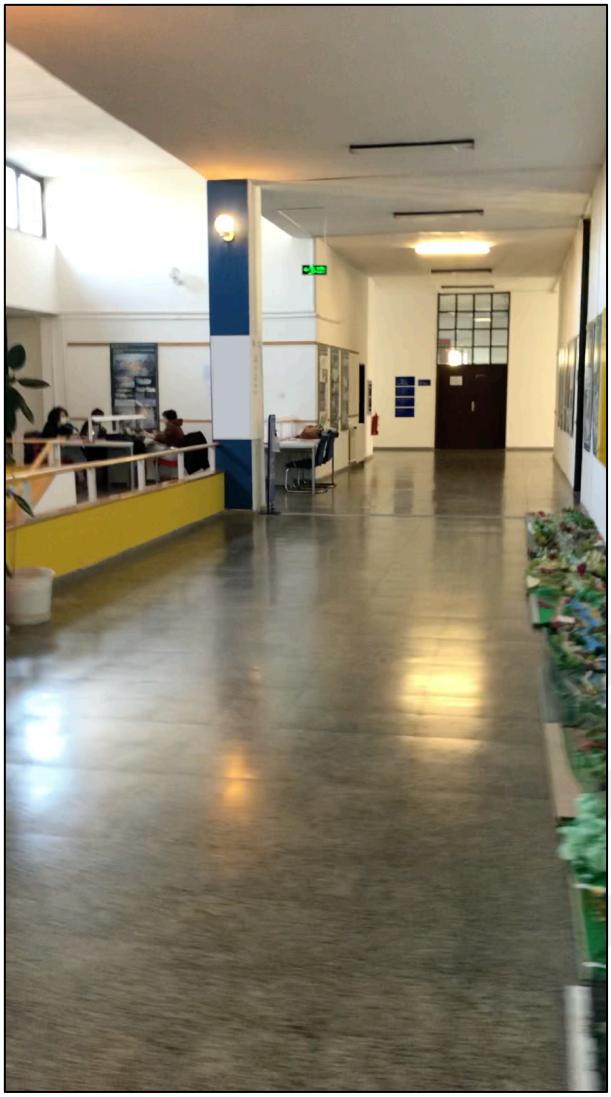
**APPENDIX E. Photographs captured from the physical environment**

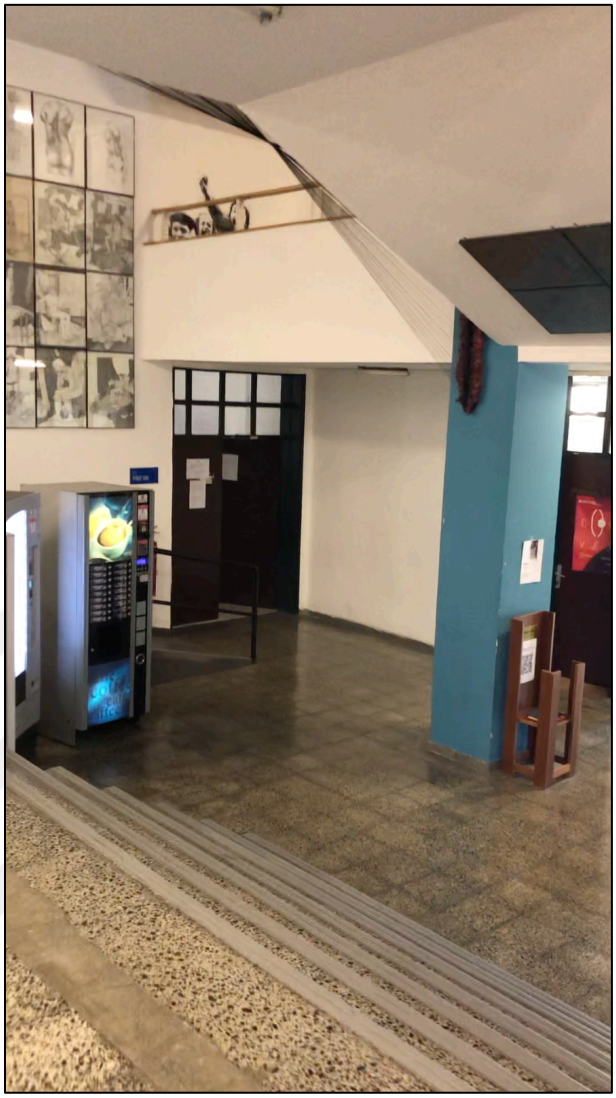
Perspectives showing the study area located on floor B1 (on the first floor in block B) (left) and the sculptures located on floor C1 (on the first floor in block C) (right).

Perspectives showing the glass showcase located on floor A1 (on the first floor in block A) (left) and the Starbucks Coffee located on floor CZ (on the ground floor in block C) (right).



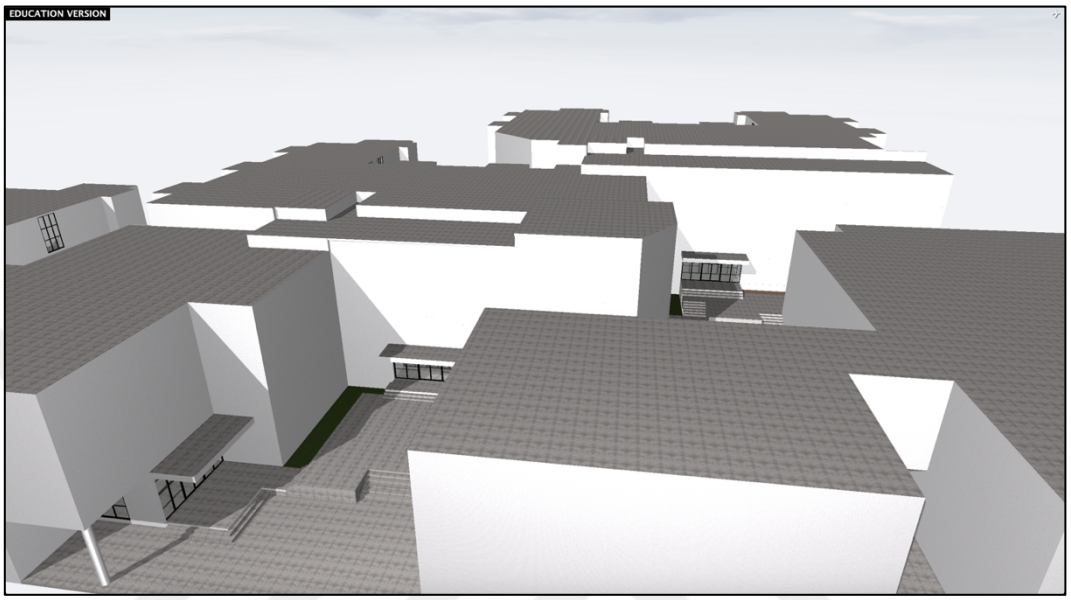
Perspectives showing the corridors and stairs on floor B2 (on the second floor in block B) (left) and on floor A3 (on the third floor in block A) (right).



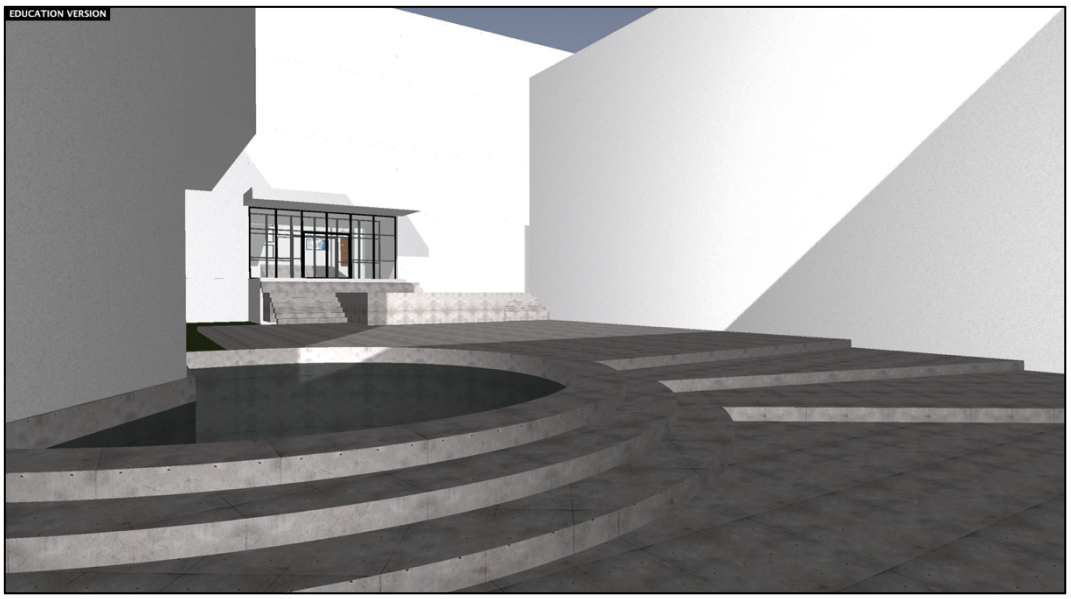


Perspectives showing study area located on floor A3 (on the third floor in block A) (left) and the vending machines located on floor BZ (on the ground floor in block B) (right).

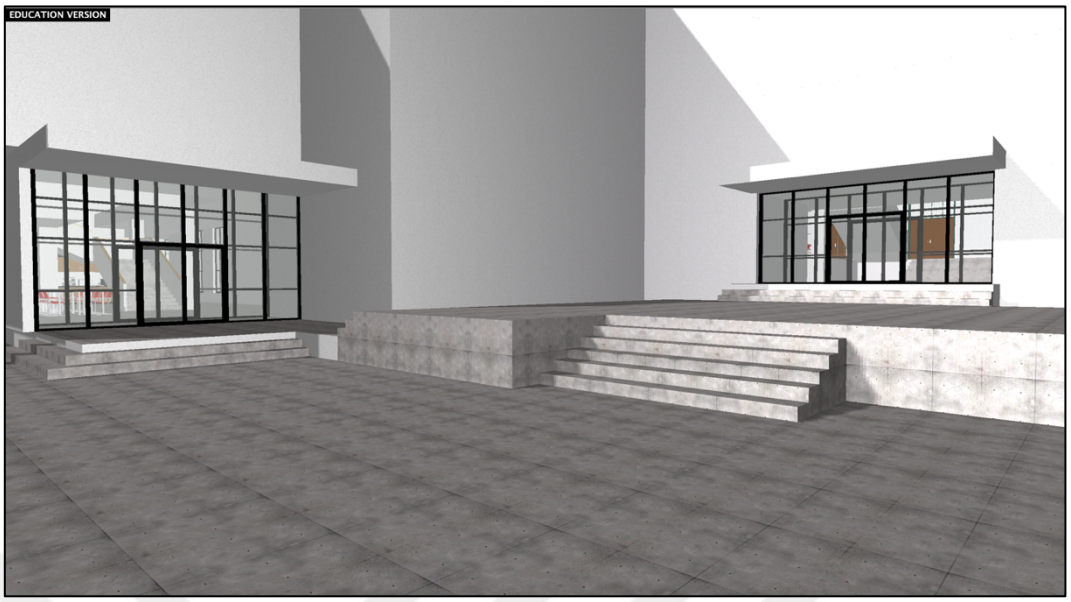
## APPENDIX F. Screenshots captured from the virtual environment




A perspective showing the overall view of the building indicating the entrances to block A (right), B (middle), and C (left).




A perspective showing the entrance to Block A.




A perspective showing the entrance to Block B (right) and C (left).

A perspective from the entrance of block A.

A perspective from the entrance of block B.

A perspective from the entrance of block C.

A perspective showing the target of path-1, C217.

A perspective showing the study area located on floor CZ (on the ground floor in block C).

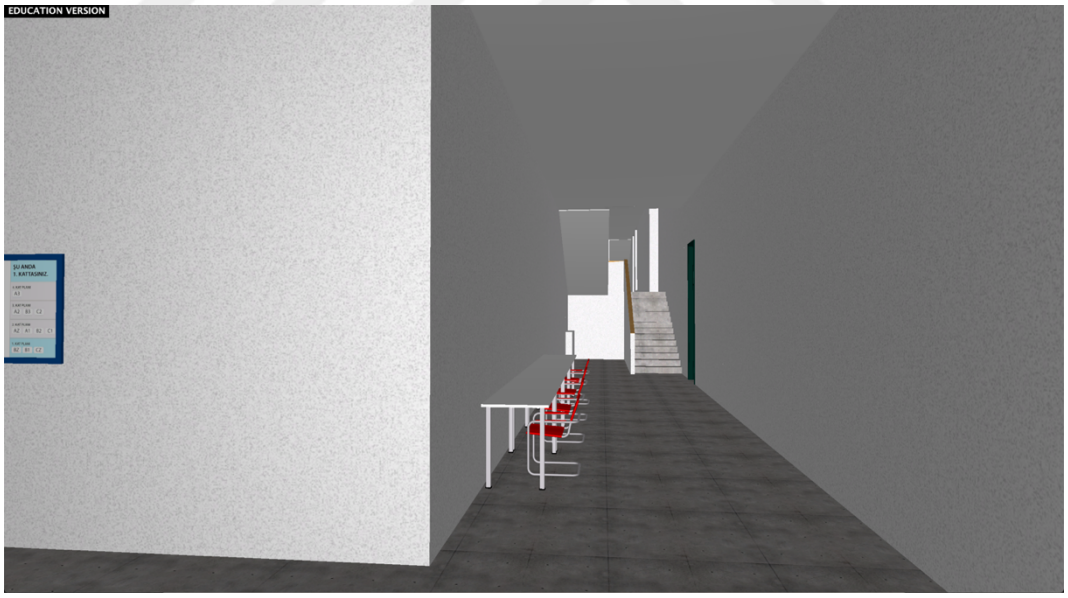
A perspective showing the Starbucks Coffee located on floor CZ (on the ground floor in block C).

A perspective showing the sculptures located on floor C1 (on the first floor in block C).

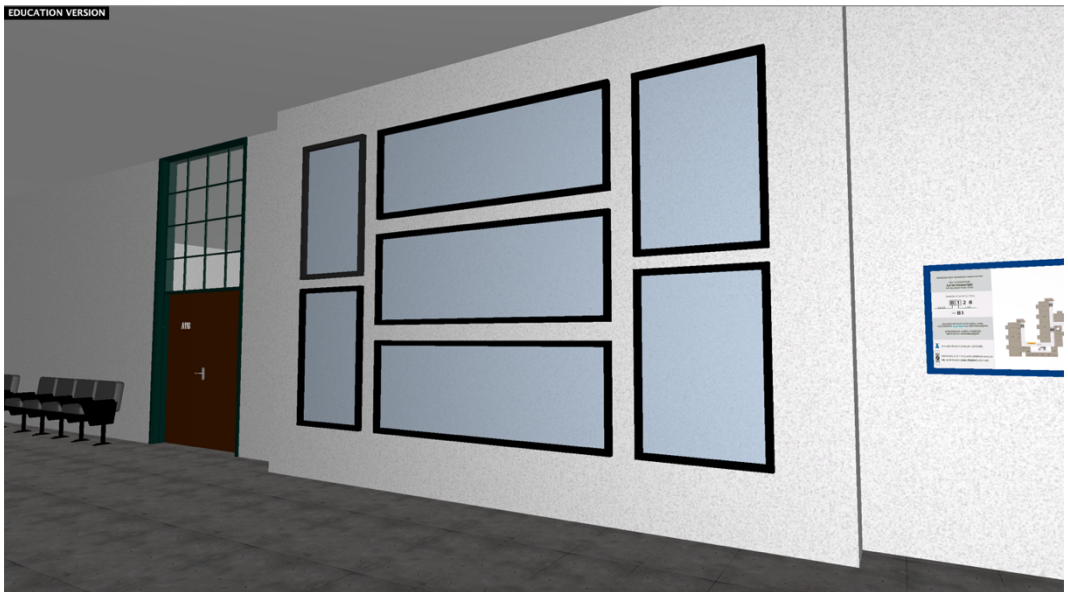
A perspective showing the graffiti located on floor C2 (on the second floor in block C).

A perspective showing the vending machines located on floor BZ (on the ground floor in block B).

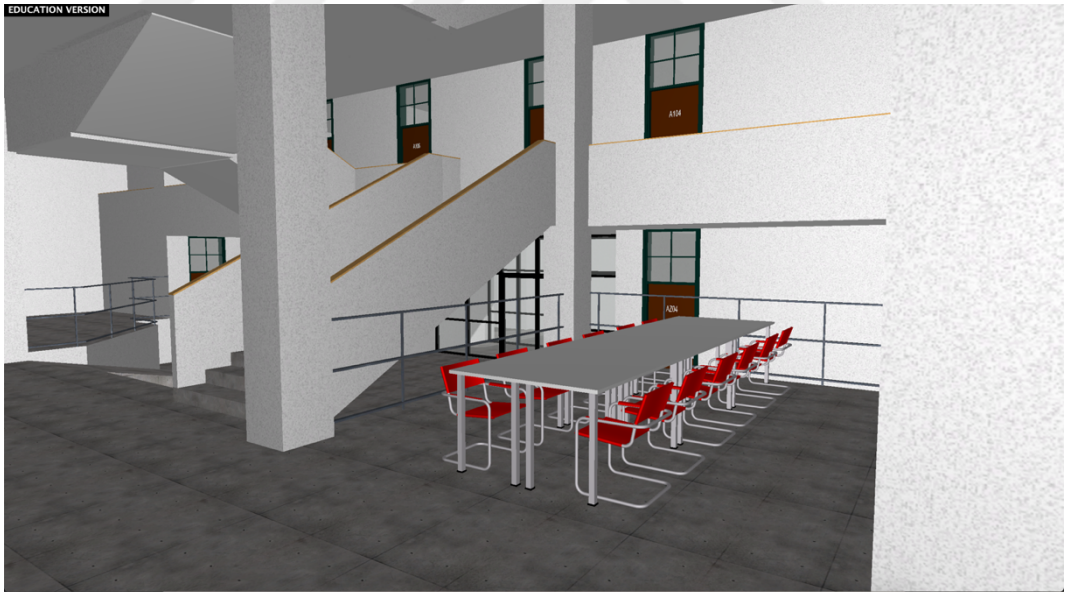
A perspective showing the study area located on floor B1 (on the first floor in block B).




A perspective showing the study area located on floor B1 (on the first floor in block B).




A perspective showing the glass showcase located on floor A1 (on the first floor in block A).




A perspective showing the study area located on floor A1 (on the first floor in block A).

A perspective showing the sitting area located on floor A1 (on the first floor in block A).

A perspective showing the study area located on floor A3 (on the third floor in block A).

# Çalışma Öncesi Anketi

* Gerekli

Bölüm 1: Bilgilendirilmiş Gönüllü Onam Formu

ÇALIŞMA BAŞLIĞI:
İç Mekanlarda Yön Bulma Amaçlı Kare Kod Kullanımı

ARAŞTIRMACI:
Çetin Tünger

İhsan Doğramacı Bilkent Üniversitesi, Ekonomi ve Sosyal Bilimler Enstitüsü, İç Mimarlık ve Çevre Tasarımı doktora öğrencisiyim. Sizin de katılmanızı istediğim bir araştırma çalışması yürütmekteyim. Bu form, bu çalışmanın neden yapıldığı, çalışmaya katılmanız haline sizden yapılması istenenler, ve bilgilerinizin nasıl kullanılacağıyla ilgili detaylı ve önemli bilgiler içermektedir.

## 1. Çalışmanın İçeriği

ÇALIŞMANIN AMACI:

Bu çalışmanın amacı, teknolojik gelişmelerin/araçların, yön bulma etkisini ortaya çıkarmaktır.

ÇALIŞMA PROSEDÜRÜ:

Katılımcılar:
1. çalışma hakkında kısaca bilgilendirilecekler,
2. çalışma öncesi, dijital bir ankete tabi tutulacaklar,
3. iki farklı yön bulma çalışmasına katılacaklar,
4. çalışma sonrası, ikinci bir dijital ankete tabi tutulacaklar.

ÇALIŞMA SÜRESİ:

Çalışmanın bir katılımcı için yaklaşık 15-20 dakika sürmesi beklenmektedir.

ÇALIŞMANIN YAPILACAĞI YER:

Tüm çalışmalar, Bilkent Üniversitesi Merkez Kampüsü içerisinde yer alan Güzel Sanatlar, Tasarım ve Mimarlık Fakültesi'ne (GSTMF) bağlı olan FA, FB, ve FC bloklarında gerçekleşecektir.

## 2. Çalışmaya Katılım ve Katılımcılar Hakkında

ÇALIŞMAYA KATILIM ŞARTI

Çalışmaya katılabilmek için 18 yaşından büyük olmak gerekmektedir.

OLASI RİSKLER VE SORUNLAR

Bu çalışmaya katılımınız, günlük yaşamın ötesinde oluşabilecek herhangi bir fiziksel veya duygusal risk içermemektedir. Bu çalışmaya katılım tamamen gönüllülük esasına dayanmaktadır.

ÇALIŞMANIN KATILIMCIYA OLASI FAYDALARI

Bu araştırma çalışmasında bulunmanın, size doğrudan bir yararı yoktur. Bu çalışma, teknolojik araç kullanımının yön bulma sürecine etkisi hakkında daha fazla bilgi edinmek için tasarlanmıştır. Çalışmanın sonuçları gelecekte topluma yardımcı olmak için kullanılabilir ve kampüs binası, hastane, alışveriş merkezi, havaalanı vb. alanların iç mekanlarında kullanıcılara faydalı olabilecek yeni bir yol bulma uygulamasının oluşturulmasına katkıda bulunabilir. Size de güncel yön/konum bulma teknolojileri açısından bilgi verebilir ve çevrenize daha bilinçli bakmanıza yardımcı olabilir.

KATILIMCI VERİLERİNİN GİZLİLİĞİ

Bu çalışmada, analizler toplu olarak ele alınacak, bireysel isimler veya kişisel tanımlanabilir bilgiler bu çalışmada kesinlikle kullanılmayacaktır. Çalışmada elde edilen veriler sadece bilimsel yayınlarda ve sunumlarda rapor edilecektir.

FİNANSAL BİLGİLENDİRME

Bu çalışmaya katılımın size hiçbir maliyeti olmayacaktır. Çalışmaya katılımınız durumunda size herhangi bir ödeme yapılmayacaktır.

İLETİŞİM

Sorunuz varsa, şimdi belirtiniz. Çalışma sonrasında sorularınız olursa, ilgili mail adresi üzerinden araştırmacıyla iletişime geçebilirsiniz.

Email: cetin.tunger@bilkent.edu.tr

## 3. Kabul

Bilgilendirilmiş Gönüllü Onam Formu'nu kabul ettiğinizi belirtmek için kutucuğu işaretleyiniz.

1. *

*Uygun olanların tümünü işaretleyin.*

☐ Yukarıda açıklanan araştırma çalışmasına katılmayı kabul ediyorum.

2. *

Lütfen tarihi belirtiniz.

*Örnek: 7 Ocak 2019*

3. Bu formun kayıtlarınıza geçmesini isterseniz, bir kopyası aşağıda belirteceğiniz e-posta adresi'ne gönderilecektir.

## Bölüm 2: Katılımcı Referans Kodu

4. Lütfen araştırmacının size belirttiği "Katılımcı Referans Kodu"nu giriniz. *

## Bölüm 3: Demografik Bilgiler

5. Yaş *

6. Cinsiyet *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Kadın
- ◯ Erkek
- ◯ Belirtmek istemiyorum

## Bölüm 4: Aşinalık

7. Bilkent Üniversitesi - Güzel Sanatlar, Tasarım ve Mimarlık Fakültesi (GSTMF) F binasının FA, FB ve FC bloklarının iç mekan yerleşimine aşinayım. *

*Yalnızca bir şıkkı işaretleyin.*

hiç katılmıyorum

1 ◯
2 ◯
3 ◯
4 ◯
5 ◯
6 ◯
7 ◯

kesinlikle katılıyorum

## Bölüm 5: Kare Kod Bilgisi ve Kare Koda Olan Reaksiyonlar

8. Daha önce aşağıdaki gibi bir görselle karşılaştınız mı? *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Evet
- ◯ Hayır *10. soruya gidin*

9. Görselin ne olduğunu/ismini söyleyebilir misiniz? *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Evet
- ◯ Hayır *10. soruya gidin*

10. Aşağıdaki tanımlamalardan hangilerini duyduğunuzu belirtiniz. *

*Uygun olanların tümünü işaretleyin.*

- ☐ Quick Response Code
- ☐ QR Code
- ☐ Kare Kod
- ☐ Hiçbirini bilmiyorum

11. Kare Kod'ları gördüğünüz yerleri belirtiniz. *

*Uygun olanların tümünü işaretleyin.*

- ☐ Gazete reklamı
- ☐ Dergi reklamı
- ☐ Ürün paketleme
- ☐ Kupon
- ☐ Katalog
- ☐ Televizyon
- ☐ Dış mekan/Açık hava Reklamı
- ☐ Dış Mekan İçin Yön/Konum Bulma
- ☐ İç Mekan İçin Yön/Konum Bulma
- ☐ Diğer

12. Kare kodu hiç kullandınız mı? *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Evet, kullandım.
- ◯ Hayır, kullanmadım. *14. soruya gidin*

13. Kare Kod'ları hangi amaçla kullanmıştınız? *

*Uygun olanların tümünü işaretleyin.*

- ☐ Websiteleri/uygulamalar aracılığıyla ek bilgilere erişim
- ☐ Satın alma / Mobil ödeme
- ☐ ATM'den kartsız para çekme
- ☐ Sosyal medyayla etkileşim kurma
- ☐ Kupon, indirim veya kampanya alımı
- ☐ Dış Mekan İçin Yön/Konum Bulma
- ☐ İç Mekan İçin Yön/Konum Bulma
- ☐ Diğer

14. Lütfen aşağıdaki işlemler için şu andaki ve gelecekteki Kare Kod kullanımı ilgi düzeyinizi belirtiniz. *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç ilgilenmiyorum | 2 | 3 | 4 | 5 | 6 | 7 ilg |
|---|---|---|---|---|---|---|---|
| **Websiteleri/uygulamalar aracılığıyla ek bilgilere erişim** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | |
| **Satın alma / Mobil ödeme** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | |
| **ATM'den kartsız para çekme** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | |
| **Sosyal medyayla etkileşim kurma** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | |
| **Kupon, indirim veya kampanya alımı** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | |
| **Dış Mekan İçin Yön/Konum Bulma** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | |
| **İç Mekan İçin Yön/Konum Bulma** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | |

15. Genel olarak, Kare Kod kullanımıyla ilgileniyorum. *

*Yalnızca bir şıkkı işaretleyin.*

hiç ilgilenmiyorum

1 ◯
2 ◯
3 ◯
4 ◯
5 ◯
6 ◯
7 ◯

oldukça ilgileniyorum

Bölüm 6: Akıllı Telefon Kullanımına Yönelik Tutum

16. Akıllı telefonunuz var mı? *

*Yalnızca bir şıkkı işaretleyin.*

◯ Evet
◯ Hayır *22. soruya gidin*

17. Akıllı telefonunuzun hangi platformu kullandığını belirtiniz. *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ iOS (Tüm iPhone'lar)
- ◯ Android (Samsung, Huawei, Xiaomi, Lg, Lenovo, HTC, Meizu, Honor, Asus, Sony, Vestel, Turkcell)
- ◯ Windows (Microsoft)
- ◯ Diğer: _____

18. Akıllı telefonunumu kullanmada becerikliyimdir. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| hiç katılmıyorum | |
| 1 | ◯ |
| 2 | ◯ |
| 3 | ◯ |
| 4 | ◯ |
| 5 | ◯ |
| 6 | ◯ |
| 7 | ◯ |
| kesinlikle katılıyorum | |

19. Akılı telefonumda yüklü olan uygulamaları sık sık kullanırım. *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç katılmıyorum | 2 | 3 | 4 | 5 | 6 | 7 - kesinlikle katılıyorum |
|---|---|---|---|---|---|---|---|
| **Arama / Mesaj** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Sosyal medya** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kamera** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Haritalar** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **İnternet tarayıcısı** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

20. Akıllı telefonunuzu daha önce açık alanda yön/konum bulma için kullandınız mı? (Örnek: Google Maps) *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Evet
- ◯ Hayır

21. Akıllı telefonunuzu daha önce iç mekanlarda yön/konum bulma için kullandınız mı? *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Evet
- ◯ Hayır

Bölüm 7: Santa Barbara Yön Algısı Ölçümü

22. Aşağıdaki ifadeleri değerlendiriniz. *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç katılmıyorum | 2 | 3 | 4 | 5 | 6 | 7 - kesinlikle katılıyor |
|---|---|---|---|---|---|---|---|
| Yön belirtmekte/yol tarifi vermekte çok iyiyimdir. | | | | | | | |
| Eşyaları bıraktığım yerleri hatırlamada zorlanırım. | | | | | | | |
| Mesafeleri analiz etmede/tahmin etmede çok iyiyimdir. | | | | | | | |
| "Yön algım" çok iyidir. | | | | | | | |
| Çevremi, coğrafi/ana yönler (Kuzey - Güney - Doğu - Batı) açısından düşünmeye eğilimliyim. | | | | | | | |
| Yeni bir şehirde çok kolay kaybolurum. | | | | | | | |
| Harita okumayı severim. | | | | | | | |
| Yönleri anlamakta zorlanırım. | | | | | | | |
| Harita okumada çok iyiyim. | | | | | | | |
| Arabada yolcu olarak seyahat ederken rotaları çok iyi hatırlamam. | | | | | | | |
| Yol tarifi vermekten hoşlanmam. | | | | | | | |
| Nerede olduğumu bilmek benim için önemli değildir. | | | | | | | |
| Uzun yolculuklar için gezi planlamasını / dolaşım planını genellikle başkasına bırakırım. | | | | | | | |
| Yeni bir yere sadece bir kez seyahat ettikten sonra, o rotayı hatırlayabiliyorum. | | | | | | | |
| Çevrem hakkında, kafamda oluşturduğum haritama / zihinsel haritama çok güvenmem. | | | | | | | |

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Google Formlar

# Çalışma Sonrası Anketi

* Gerekli

Bölüm 1: Katılımcı Referans Kodu

1. Lütfen araştırmacının size belirttiği "Katılımcı Referans Kodu"nu giriniz. *

Bölüm 2: Görev Zorluğu Algısı 1/2

Kare Kod Uygulaması Olmadan Yön Bulma

2. Binanın Kare Kodsuz bölümünde yönümü kolayca buldum. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

3. Binanın Kare Kodsuz bölümünde yön bulurken rahat hissettim. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

Bölüm 2: Görev Zorluğu Algısı 2/2

Kare Kod Uygulaması ile Yön Bulma

4. Binanın Kare Kodlu bölümünde yönümü kolayca buldum. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

5. Binanın Kare Kodlu bölümünde yön bulurken rahat hissettim. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

Bölüm 3: Kare Kod'la Yön Bulma Uygulaması Değerlendirmesi 1/3

6. Katılmış olduğunuz çalışmadaki Kare Kod uygulamasının, binalarda yön bulma açısından kullanılabilirliğini değerlendiriniz. *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç katılmıyorum | 2 | 3 | 4 | 5 | 6 | 7 - kesinlikle katılıyorum |
|---|---|---|---|---|---|---|---|
| **Yön bulmada daha etkili olmamı sağlıyor.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Daha üretken olmamı sağlıyor.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kullanışlı.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Hayatımdaki faaliyetler açısından bana daha fazla kontrol sağlar.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Başarmak istediğim şeyleri yapmamı kolaylaştırır.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kullandığımda bana zaman kazandırır.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Yön bulmamı sağlar.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Beklenileni yerine getirir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

Bölüm 3: Kare Kod'la Yön Bulma Uygulaması Değerlendirmesi 2/3

7. Katılmış olduğunuz çalışmadaki Kare Kod uygulamasının, binalarda yön bulma açısından kullanılabilirliğini değerlendiriniz. *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç katılmıyorum | 2 | 3 | 4 | 5 | 6 | 7 - kesinlikle katılıyorum |
|---|---|---|---|---|---|---|---|
| **Kullanımı kolaydır.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kullanması basittir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kullanıcı dostudur.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Yapmak istediğimi mümkün olan en az adımla yapmamı sağlar.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Esneklik sağlar.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kullanımı zahmetsizdir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Yazılı talimatlar olmadan kullanılabilir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kullanım anında herhangi bir tutarsızlık meydana gelmiyor.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Düzenli kullanıcılar uygulamayı sevecektir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Hatalardan hızlı ve kolay bir şekilde kurtulabilirim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Her seferinde başarılı bir şekilde kullanabilirim.** | | | | | | | |

Bölüm 3: Kare Kod'la Yön Bulma Uygulaması Değerlendirmesi 3/3

8. Katılmış olduğunuz çalışmadaki Kare Kod uygulamasının, binalarda yön bulma açısından kullanılabilirliğini değerlendiriniz. *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç katılmıyorum | 2 | 3 | 4 | 5 | 6 | 7 - kesinlikle katılıyorum |
|---|---|---|---|---|---|---|---|
| **Kısa sürede kullanmayı öğrendim.** | | | | | | | |
| **Kullanmasını öğrenmek kolay.** | | | | | | | |
| **Nasıl kullanacağımı kolayca hatırlıyorum.** | | | | | | | |
| **Kullanımını çabucak kavrayabildim.** | | | | | | | |
| **Kullanımından memnunum.** | | | | | | | |
| **Arkadaşıma tavsiye ederim.** | | | | | | | |
| **Kullanımını eğlenceli buluyorum.** | | | | | | | |
| **İstediğim şekilde çalışıyor.** | | | | | | | |
| **Harika.** | | | | | | | |
| **Sahip olmam gerektiğini düşünüyorum.** | | | | | | | |
| **Keyif alarak kullanıyorum.** | | | | | | | |

Bölüm 4: Pilot Çalışma: Araştırma Düzenini ve Ekipmanlarını Test Etme 1/2

Kare Kod Düzeni

Çalışma esnasında, bina içerisinde gördüğünüz kare kod'lar için aşağıdaki maddeleri değerlendiriniz.

9. Kare Kod Büyüklüğü *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Şu anki hali iyi/uygun
- ◯ Daha küçük olmalı
- ◯ Daha büyük olmalı
- ◯ Diğer: _____

10. Kare Kod Sayısı *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Şu anki hali iyi/uygun
- ◯ Daha az sayıda olmalı
- ◯ Daha fazla sayıda olmalı
- ◯ Diğer: _____

11. Kare Kod'ların Yerden yüksekliği *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Şu anki hali iyi/uygun
- ◯ Daha alçakta olmalı
- ◯ Daha yüksekte olmalı
- ◯ Diğer: _____

12. Kare Kod'ların konumlandığı duvara göre açısı *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Şu anki hali iyi/uygun (Açılı)
- ◯ Duvara hemzemin/yapışık olmalı
- ◯ Duvara dik olmalı
- ◯ Diğer: _____

13. Kare Kod'ların algılanabilirliği *

*Uygun olanların tümünü işaretleyin.*

- ☐ Şu anki hali iyi/uygun
- ☐ Aydınlatmalı olmalı
- ☐ Başka bir renk olmalı
- ☐ Diğer: _____

Bölüm 4: Pilot Çalışma: Araştırma Düzenini ve Ekipmanlarını Test Etme 2/2

Dijital Araçlar/Ortam

Çalışma esnasında, dijital araç/ortam kullanımıyla ilişkili olan aşağıdaki maddeleri değerlendiriniz.

14. Akıllı Telefon - Harita - İnternet Bağlantısı *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç katılmıyorum | 2 | 3 | 4 | 5 | 6 | 7 - kesinlik katılıyoru |
|---|---|---|---|---|---|---|---|
| **Telefonun ekran büyüklüğü yeterliydi.** | | | | | | | |
| **Telefonun performansı yeterliydi.** | | | | | | | |
| **Haritanın okunabilirliğinden memnun kaldım.** | | | | | | | |
| **Haritanın tasarımından memnun kaldım.** | | | | | | | |
| **İnternet hızından memnun kaldım.** | | | | | | | |
| **İnternet bağlantısında kopma yaşamadım.** | | | | | | | |

Bölüm 5: Gelecekteki Kullanım Davranışı 1/2

15. Araştırma çalışması sonrasındaki görüşlerinizi, çalışması öncesi görüşlerinizle kıyaslayarak aşağıdaki ifadeleri değerlendiriniz. *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç katılmıyorum | 2 | 3 | 4 | 5 | 6 | 7 - kesinlikle katılıyorum |
|---|---|---|---|---|---|---|---|
| **Kare Kod'a olan ilgim arttı.** | | | | | | | |
| **Kare Kod'u daha sık kullanmayı düşünüyorum.** | | | | | | | |
| **Kare Kod'un diğer kullanım biçimlerinden de yararlanmayı düşünüyorum.** | | | | | | | |
| **Kare Kod'la yön bulma uygulaması olan bir iç mekanda Kare Kod'ları kullanırdım.** | | | | | | | |
| **Kare Kod'la yön bulma uygulaması olan binaları daha prestijli bulurum.** | | | | | | | |

Bölüm 5: Gelecekteki Kullanım Davranışı 2/2

16. Kare Kod ile yön/konum bulma teknolojisinin aşağıdaki mekanlarda faydalı olacağını düşünüyorum. * 

Parantez içinde, potansiyel olarak görülen örnek kullanım alanlarını belirtmektedir

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 - hiç katılmıyorum | 2 | 3 | 4 | 5 | 6 | 7 - kesinlikle katılıyorum |
|---|---|---|---|---|---|---|---|
| **Üniversite kampüsü binalarında / Orta öğretim binalarında (sınıf bulma)** | | | | | | | |
| **Hastanelerde (muayene alanı bulma)** | | | | | | | |
| **Alışveriş merkezlerinde (mağaza bulma)** | | | | | | | |
| **Havaalanlarında, Otobüs terminallerinde, Tren garlarında (peron, firma bulma)** | | | | | | | |
| **Müzelerde / Büyük ölçekli ören yerlerinde (alan, eser bulma)** | | | | | | | |
| **Kongre merkezlerinde (salon bulma)** | | | | | | | |
| **Süper market / Yapı market / Teknoloji mağazalarında (ürün bulma)** | | | | | | | |
| **Kapalı/Çok katlı otoparklarda (araç bulma)** | | | | | | | |
| **Büyük binalarda (tuvalet, merdiven, asansör vb. servis alanı bulma)** | | | | | | | |

Bölüm 6: Çalışma Hakkındaki Görüşleriniz

17. Binalarda kolayca yön/konum bulmaya yönelik önerileriniz varsa lütfen belirtiniz. Önerileriniz, deneyimlemiş olduğunuz Kare Kod uygulamasının geliştirilmesine veya yön bulmada faydalı olabileceğini düşündüğünüz herhangi bir metoda yönelik olabilir.

Bu içerik Google tarafından oluşturulmamış veya onaylanmamıştır.

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# Çalışma Öncesi Anketi

* Gerekli

Bölüm 1: Bilgilendirilmiş Gönüllü Onam Formu

ÇALIŞMA KONUSU:
İç Mekanlarda Yön Bulma

ARAŞTIRMACI:
Çetin Tünger

Araştırmacı, İhsan Doğramacı Bilkent Üniversitesi, Ekonomi ve Sosyal Bilimler Enstitüsü, İç Mimarlık ve Çevre Tasarımı doktora öğrencisidir ve katılmak üzere olduğunuz çalışmayı yürütmektedir. Bu form, bu çalışmanın neden yapıldığı, çalışmaya katılmanız haline sizden yapılması istenenler, ve bilgilerinizin nasıl kullanılacağıyla ilgili detaylı ve önemli bilgiler içermektedir.

## 1. Çalışmanın İçeriği

ÇALIŞMANIN AMACI:

Bu çalışmanın amacı, teknolojik gelişmelerin/araçların, yön bulmaya etkisini ortaya çıkarmaktır.

ÇALIŞMA PROSEDÜRÜ:

Katılımcılar:
1. çalışma hakkında kısaca bilgilendirilecekler,
2. çalışma öncesi, dijital bir ankete tabi tutulacaklar,
3. snal ortamda iki farklı yön bulma çalışmasına katılacaklar,
4. çalışma sonrası, ikinci dijital bir ankete tabi tutulacaklar.

ÇALIŞMA SÜRESİ:

Çalışmanın bir katılımcı için yaklaşık 15-20 dakika sürmesi beklenmektedir.

ÇALIŞMANIN YAPILACAĞI YER:

Tüm çalışmalar, Bilkent Üniversitesi Merkez Kampüsü içerisinde yer alan Güzel Sanatlar, Tasarım ve Mimarlık Fakültesi'ne (GSTMF) bağlı olan FA, FB, ve FC bloklarının modellendiği sanal masaüstü bir ortamda gerçekleşecektir.

## 2. Çalışmaya Katılım ve Katılımcılar Hakkında

ÇALIŞMAYA KATILIM ŞARTI

Çalışmaya katılabilmek için 18 yaşından büyük olmak gerekmektedir.

OLASI RİSKLER VE SORUNLAR

Bu çalışmaya katılımınız, günlük yaşamın ötesinde oluşabilecek herhangi bir fiziksel veya duygusal risk içermemektedir. Bu çalışmaya katılım tamamen gönüllülük esasına dayanmaktadır.

ÇALIŞMANIN KATILIMCIYA OLASI FAYDALARI

Bu araştırma çalışmasında bulunmanın, size doğrudan bir yararı yoktur. Bu çalışma, teknolojik araç kullanımının yön bulma sürecine etkisi hakkında daha fazla bilgi edinmek için tasarlanmıştır. Çalışmanın sonuçları gelecekte topluma yardımcı olmak için kullanılabilir ve kampüs binası, hastane, alışveriş merkezi, havaalanı vb. alanların iç mekanlarında kullanıcılara faydalı olabilecek yeni bir yol bulma uygulamasının oluşturulmasına katkıda bulunabilir. Bunun yanı sıra, size de güncel yön/konum bulma teknolojileri açısından bilgi verebilir ve çevrenize bu açıdan daha bilinçli bakmanıza yardımcı olabilir.

KATILIMCI VERİLERİNİN GİZLİLİĞİ

Araştırmacı, çalışma boyunca katılımcının ses ve görüntüsünü kayıt edecek, katılımcıdan da bir süreliğine telefonunun ekran kaydı almasını (kamera, kare kod tarayıcı ve web tarayıcı uygulaması) ve bu kaydı araştırmacıya iletmesini talep edecektir. Elde edilecek veriler toplu olarak analiz edilecek, bireysel isimler veya tanımlanabilir bilgiler bu çalışmada kesinlikle kullanılmayacaktır. Çalışmada elde edilen veriler sadece bilimsel yayınlarda ve sunumlarda anonim olarak rapor edilecektir.

FİNANSAL BİLGİLENDİRME

Bu çalışmaya katılımın size hiçbir maliyeti olmayacaktır. Çalışmaya katılımınız durumunda size herhangi bir ödeme yapılmayacaktır.

İLETİŞİM

Araştımacı
Sorunuz varsa, şimdi belirtiniz. Çalışma sonrasında sorularınız olursa, ilgili mail adresi üzerinden araştırmacıyla iletişime geçebilirsiniz.

Email: cetin.tunger@bilkent.edu.tr

3. Kabul

Bilgilendirilmiş Gönüllü Onam Formu'nu kabul ettiğinizi belirtmek için kutucuğu işaretleyiniz.

1. *

*Uygun olanların tümünü işaretleyin.*

- [ ] Yukarıda açıklanan araştırma çalışmasına katılmayı kabul ediyorum.

2. *

Lütfen bugünün tarihini belirtiniz.

_____

*Örnek: 7 Ocak 2019*

Bölüm 2: Katılımcı Kaydı

3. Lütfen araştırmacının size belirttiği "Katılımcı Referans Kodu"nu giriniz. *

_____

4. Lütfen araştırmacının size belirttiği "Görev Tipi Kodu"nu giriniz. *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ A
- ◯ B
- ◯ C
- ◯ D

Bölüm 3: Demografik Bilgiler

5. Doğum Yılı *

_____

6. Cinsiyet *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Kadın
- ◯ Erkek
- ◯ Belirtmek istemiyorum

Bölüm 4: Yön Algısı Ölçümü

7. Aşağıdaki ifadeleri değerlendiriniz. *

(1) hiç katılmıyorum (7) kesinlikle katılıyorum

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Yön belirtmekte/yol tarifi vermekte çok iyiyimdir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Eşyaları bıraktığım yerleri hatırlamada zorlanırım.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Mesafeleri analiz etmede/tahmin etmede çok iyiyimdir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **"Yön algım" çok iyidir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Çevremi, coğrafi/ana yönler (Kuzey - Güney - Doğu - Batı) açısından düşünmeye eğilimliyim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Yeni bir şehirde çok kolay kaybolurum.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Harita okumayı severim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Yönleri anlamakta zorlanırım.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Harita okumada çok iyiyim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Arabada yolcu olarak seyahat ederken rotaları çok iyi hatırlamam.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Yol tarifi vermekten hoşlanmam.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Nerede olduğumu bilmek benim için önemli değildir.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Uzun yolculuklar için gezi planlamasını / dolaşım planını genellikle başkasına bırakırım.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Yeni bir yere sadece bir kez seyahat ettikten sonra, o rotayı hatırlayabiliyorum.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Çevrem hakkında, kafamda oluşturduğum haritama / zihinsel haritama çok güvenmem.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

Bölüm 5: Kare Kod Kullanımı Genel İlgi Düzeyi

8. Daha önce herhangi bir işlev için kare kod kullandınız mı? *

Aşağıda örnek bir kare kod görseli verilmiştir.

*Yalnızca bir şıkkı işaretleyin.*

◯ Evet

◯ Hayır

9. Kare Kod kullanımı genel ilgi düzeyinizi belirtiniz. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç ilgilenmiyorum |
| 1 | ○ |
| 2 | ○ |
| 3 | ○ |
| 4 | ○ |
| 5 | ○ |
| 6 | ○ |
| 7 | ○ |
| | oldukça ilgileniyorum |

Bu içerik Google tarafından oluşturulmamış veya onaylanmamıştır.

Google Formlar

## APPENDIX J. Post-task questionnaire of the virtual study

# Çalışma Sonrası Anketi

* Gerekli

Bölüm 1: Katılımcı Kaydı

1. Lütfen araştırmacının size belirttiği "Katılımcı Referans Kodu"nu giriniz. *

2. Lütfen araştırmacının size belirttiği "Görev Tipi Kodu"nu giriniz. *

*Yalnızca bir şıkkı işaretleyin.*

- A
- B
- C *7. soruya gidin*
- D *7. soruya gidin*

Bölüm 2: Yön Bulma Deneyimi 1/2

Görev Tipi: A veya B

Kare Kod Uygulamasının Kullanılmadığı Görev
Birinci Görev

3. Kare Kod uygulamasının kullanılmadığı görevde yönümü kolayca buldum. *

*Yalnızca bir şıkkı işaretleyin.*

| | hiç katılmıyorum | | | | | | kesinlikle katılıyorum |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

4. Kare Kod uygulamasının kullanılmadığı görevde yön bulurken rahat hissettim. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

5. Kare Kod uygulamasının kullanıldığı görevde yönümü kolayca buldum. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

Bölüm 2: Yön Bulma Deneyimi 2/2

Görev Tipi: A veya B

Kare Kod Uygulamasının Kullanıldığı Görev
İkinci Görev

6. Kare Kod uygulamasının kullanıldığı görevde yön bulurken rahat hissettim. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

*11. soruya gidin*

Bölüm 2: Yön Bulma Deneyimi 1/2

Görev Tipi: C veya D

Kare Kod Uygulamasının Kullanıldığı Görev
Birinci Görev

7. Kare Kod uygulamasının kullanıldığı görevde yönümü kolayca buldum. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

8. Kare Kod uygulamasının kullanıldığı görevde yön bulurken rahat hissettim. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

9. Kare Kod uygulamasının kullanılmadığı görevde yönümü kolayca buldum. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

Bölüm 2: Yön Bulma Deneyimi 2/2

Görev Tipi: C veya D

Kare Kod Uygulamasının Kullanılmadığı Görev
İkinci Görev

10. Kare Kod uygulamasının kullanılmadığı görevde yön bulurken rahat hissettim. *

*Yalnızca bir şıkkı işaretleyin.*

| | |
|---|---|
| | hiç katılmıyorum |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| | kesinlikle katılıyorum |

Bölüm 3: Kare Kod'la Yön Bulma Uygulaması Değerlendirmesi

11. Katılmış olduğunuz çalışmadaki Kare Kod uygulamasının, binalarda yön bulma açısından kullanılabilirliğini değerlendiriniz. *

(1) hiç katılmıyorum (7) kesinlikle katılıyorum

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Bu sistemi sıklıkla kullanmak isteyeceğimi düşünüyorum.** | | | | | | | |
| **Bu sistemi gereksiz bir şekilde karmaşık buldum.** | | | | | | | |
| **Bu sistemin kullanımının kolay olduğunu düşündüm.** | | | | | | | |
| **Bu sistemi kullanabilmek için daha teknik bir kişinin desteğine ihtiyaç duyacağımı düşünüyorum.** | | | | | | | |
| **Sistemdeki değişik fonksiyonların bir bütün olarak çalıştığını düşünüyorum.** | | | | | | | |
| **Bu sistemde çok fazla tutarsızlık olduğunu düşünüyorum.** | | | | | | | |
| **Çoğu insanın bu sistemi kullanmayı kolayca** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **öğrenebileceğini düşünüyorum.** | | | | | | | |
| **Bu sistemin kullanımını çok ters/sıkıntılı buldum.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Bu sistemi kullanırken kendimden çok emin hissettim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Bu sistemde bir şeyler yapabilmek için öncelikle bir çok şey öğrenmem gerekti.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

Bölüm 4: Kare Kodlu Ortamda Kullanılan Ekipmanların Değerlendirilmesi

12. Eğer var ise, çalışma esnasında problem yaşadığınız maddeleri işaretleyiniz.
Bir problem yaşamadıysanız bir sonraki soruya geçebilirsiniz.

*Uygun olanların tümünü işaretleyin.*

- ☐ Telefon performansı
- ☐ İnternet hızı
- ☐ Kare kod tarayıcı uygulaması
- ☐ Ekran kaydedici uygulaması
- ☐ BIMx model görüntüleyici uygulaması
- ☐ Zoom uygulaması
- ☐ İhtiyaç halinde kare koda ulaşım

13. Yön bulmada, harita üzerinde size faydası olduğunu düşündüğünüz özellikleri seçiniz.
Birden fazla seçim yapabilirsiniz.

*Uygun olanların tümünü işaretleyin.*

- ☐ Tüm katlar arasında hangi katta olduğumu görmek
- ☐ Kat planlarının hangi katları içerdiğini görmek
- ☐ Merdivenin bağladığı katları görebilmek
- ☐ Bulunduğum kat planında yer almayan katların silik gösterilmesi
- ☐ Haritaya bakma yönüm ile aynı yönde olacak şekilde yerleştirilen/açılan haritalar
- ☐ Sembol yapıların/alanların belirtilmesi (Starbucks Coffee, Çalışma Alanları, vb.)
- ☐ Akıllı telefonda açılan dijital haritada tüm katları görebilmek

Bölüm 5: Gelecekteki Kullanım 1/2

14. Araştırma çalışması sonrasındaki görüşlerinizi, çalışması öncesi görüşlerinizle kıyaslayarak aşağıdaki ifadeleri değerlendiriniz. *
(1) hiç katılmıyorum (7) kesinlikle katılıyorum

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Kare Kod'la yön bulma uygulaması olan bir iç mekanda Kare Kod'ları kullanırdım.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kare Kod'la yön bulma uygulaması olan binalara daha olumlu bakmamı sağlar.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

Bölüm 5: Gelecekteki Kullanım 2/2

15. Kare Kod ile yön/konum bulma teknolojisinin aşağıdaki durumlarda faydalı olacağını düşünüyorum. *

(1) hiç katılmıyorum (7) kesinlikle katılıyorum

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Kapalı/Çok katlı otoparklarda (araç bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Alışveriş merkezlerinde (mağaza bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Havaalanlarında, Otobüs terminallerinde, Tren garlarında (peron, firma bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Üniversite / okul binalarında (sınıf bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Hastanelerde (muayene alanı bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kongre/ Performans merkezlerinde (salon bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Büyük binalarda (tuvalet, merdiven, asansör vb. servis alanı bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Müzelerde / Büyük ölçekli ören yerlerinde (alan, eser bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Marketlerde / Mağazalarda (reyon/ürün bulma)** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

## Bölüm 6: Kare Kod Kullanımı Genel İlgi Düzeyi

16. Çalışma sonrasında, Kare Kod kullanımı genel ilgi düzeyinizi belirtiniz. *

*Yalnızca bir şıkkı işaretleyin.*

hiç ilgilenmiyorum

1 ◯
2 ◯
3 ◯
4 ◯
5 ◯
6 ◯
7 ◯

oldukça ilgileniyorum

## Bölüm 7: İç Mekanda Yön Bulma Deneyimi 1/2

17. Bu çalışmadan önce akıllı telefonunuzu iç mekanlarda yön/konum bulma için kullandınız mı? *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Evet
- ◯ Hayır *19. soruya gidin*

18. Akıllı telefonunuzu iç mekanlarda yön/konum bulmak için nasıl kullandınız? Kısaca belirtiniz. *

Bölüm 7: İç Mekanda Yön Bulma Deneyimi 2/2

19. Bu çalışmadan önce iç mekanda yön/konum bulmak için Kare Kod kullandınız mı? *

Örnek: Bir kare kodu taratarak kare kodda yer alan bina kat planının/kat şemasının görüntülenmesi.

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Evet, kullandım.
- ◯ Hayır, kullanmadım. *21. soruya gidin*

20. Daha önce iç mekanda yön/konum bulmak için Kare Kodu nasıl kullandınız? Kısaca belirtiniz. *

Bölüm 8: Sanal Ortamda Bulunma Hissi

21. Aşağıdaki ifadeleri sanal ortamdaki deneyiminize göre değerlendiriniz. *

(1) hiç katılmıyorum (7) kesinlikle katılıyorum

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Sanal ortamda, "orada bulunma" hissine sahip oldum.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Sanal dünyanın beni bir şekilde çevrelediğini hissettim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Programa girdiğimde sadece bazı resimler algıladığımı hissettim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kendimi sanal ortamda mevcut/bulunmuş hissetmedim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Dışarıdan bir şeyi çalıştırıyormuş hissi yerine, sanal ortamda aktif rol aldığımı hissettim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Kendimi sanal ortamda mevcut/bulunmuş hissettim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Sanal ortamda gezinirken gerçek dünyanın (sesler, oda sıcaklığı, diğer insanlar vb.) hemen hiç farkına varmadım.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Şu an içinde bulunduğum gerçek ortamın (odamın, ofisimin, vb.) farkında değildim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Hala bulunduğum gerçek ortama (odama, ofisime, vb.) dikkatimi veriyordum.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Tam anlamıyla sanal ortamın içine çekilmiştim.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Sanal ortam bana tamamen gerçekçi göründü.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Sanal ortamdaki deneyimim gerçek dünya deneyimime çok benziyordu.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Sanal dünya bana gerçek dünyadan ayırt edilemeyecek kadar gerçekçi göründü.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Sanal dünya, gerçek dünyadan daha gerçekçi görünüyordu.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

Bölüm 9: Olası Koşulların Değerlendirilmesi 1/2

(1) hiç katılmıyorum (7) kesinlikle katılıyorum

22. Aşağıdaki koşulların bir iç mekanda yön bulmanıza yeterli olma durumunu değerlendiriniz. *

*Her satırda yalnızca bir şıkkı işaretleyin.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Bu çalışmada yer alan kare kodlu ortamdaki gibi her koridorda bir kare kod olması yeterli olurdu.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Bu çalışmada yer alan kare kodsuz ortamdaki gibi kare kodun olmadığı sadece merdivenin kat ile buluştuğu alanlarda fiziksel harita olması yeterli olurdu.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Her koridorda bir kare kod ve merdivenin kat ile buluştuğu alanlarda fiziksel haritanın birlikte kullanımı yeterli olurdu.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Merdivenin kat ile buluştuğu alanlarda kare kod ve fiziksel haritanın birlikte kullanımı yeterli olurdu.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| **Merdivenin kat ile buluştuğu alanlarda kare kod olması yeterli olurdu.** | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

Bölüm9: Olası Koşulların Değerlendirilmesi 2/2

(1) hiç katılmıyorum (7) kesinlikle katılıyorum

23. Az önceki koşulların birini tercih etmek zorunda olsaydınız tercihiniz hangisi olurdu? *

*Yalnızca bir şıkkı işaretleyin.*

- ◯ Bu çalışmada yer alan kare kodlu ortamdaki gibi her koridorda bir kare kod olması yeterli olurdu.
- ◯ Bu çalışmada yer alan kare kodsuz ortamdaki gibi kare kodun olmadığı sadece merdivenin kat ile buluştuğu alanlarda fiziksel harita olması yeterli olurdu.
- ◯ Her koridorda bir kare kod ve merdivenin kat ile buluştuğu alanlarda fiziksel haritanın birlikte kullanımı yeterli olurdu.
- ◯ Merdivenin kat ile buluştuğu alanlarda kare kod ve fiziksel haritanın birlikte kullanımı yeterli olurdu.
- ◯ Merdivenin kat ile buluştuğu alanlarda kare kod olması yeterli olurdu.

Bölüm 10: Çalışma Hakkındaki Görüşleriniz

24. Binalarda kolayca yön/konum bulmaya yönelik öneriniz varsa lütfen belirtiniz. Önerileriniz, deneyimlemiş olduğunuz Kare Kod uygulamasının geliştirilmesine veya yön bulmada faydalı olabileceğini düşündüğünüz herhangi bir metoda yönelik olabilir.

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