

Spatial Ability Skills: A correlation between Augmented Reality (AR) and conventional way on wayfinding system

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Abstract

An urban design has become the latest technology in having a quality life for users. With increasing mobility of individuals, there is an increase in demand for a wayfinding system to people who are on the move. However, research regarding the use, evaluation and effect are limited. This research reviews on the conventional and Augmented Reality (AR) based wayfinding approaches and their correlation with the user's spatial ability. A set of questionnaires and research framework with the aid of AR prototype will be used to achieve results.

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1. Introduction

The ability to recognize visual-spatial world precisely and to achieve transformations on those perceptions are among eight parts that human intelligence embraces is spatial ability (Gardner, 1983). However, this is only one definition of the term "spatial ability". Frequently the terms "spatial ability" and "spatial skills" are used interchangeably irrespective of the distinction made between these terms in educational psychology (Sorby, 1999).

Spatial ability is defined as the natural ability to visualize, and the cognitive processes involved in locating target in space, perceiving distance, and directional relationships, and mentally transforming object with respect to their position or orientation in space before any formal training has occurred. Human naturally are born with this ability. It exists naturally and can be trained to strengthened the skills.

In everyday activities, spatial abilities are applied while finding a way at unfamiliar places. Hence, environmental graphic design (EGD) is playing an important role. One of the many practice areas that fall under the umbrella term of EGD is wayfinding system. Whether we realize it or not, wayfinding system is crucial and useful that will benefit us humans. Wayfinding system is

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the tools that help direct a person from one point to another. Therefore, it is a part of a larger and more holistic design theory that involves creating an atmosphere through the use of graphic design fundamentals. Wayfinding system exists to create an "experience" to users. Consequently, it is crucial to have an organized and proper system, for a greater positive experience to the users if it is interesting and functional.

According to Prall Derek (2014), in his article, it was mentioned that a wayfinding expert and president of Studio L'Image, Sue Labouvie, stated that wayfinding is about an information content and the analysis of the space or place that has been simplified, when one tries to move people through by coming up with a strategy to overcome complex device into a simple and comprehensible to the user. While EGD can be applied to private spaces and marketing, for instance, a shopping complex, wayfinding is exceptionally important in large, public spaces like urban areas such as housing estates, commercial buildings, roads, bridges and railways. Furthermore, in developing an effective wayfinding, one must consider the content that has to be readable and precise so that users will reach to the desired destination or places of interest safely and without difficulties.

Visitors come to a certain place with a broad range of motivations and expectations that can and do affect learning (Falk and Dierking, 2002). In fact, in many ways, by the time a visitor arrives at the front door, the nature and quality of the visiting experience have already been determined to a large degree (Falk and Dierking, 2002). Thus, the wayfinding design plays a critical role in visiting experience in outdoor or indoor places of interest, which affects visitors' learning experience directly.

In conjunction with this research, a wayfinding is an area that can be challenging to train without using the real environment. For example, there are particular difficulties in obtaining wayfinding knowledge in virtual environments. Many of these problems are due to limit navigational metaphors in these environments (Stanney and Salvendy, 1995).

Augmentation promises facilitation in enlightening wayfinding performance in numerous situations, where users are unfamiliar with a certain space, and may need external information to achieve an objective. For example, wayfinding is of contemporary interest for military, public safety agencies, travel industry, and the elderly. The availability of prototypical mobile Augmented Reality (AR) systems now can support studies in wayfinding using various AR strategies (Goldiez, Ahmad and Hancock, 2007).

In this study, spatial ability correlates with spatial comprehension, like verbal comprehension, comprises the capacity to perceive, understand, remember, and recall for future use (Darken and Peterson, 2001). This understanding of reading wayfinding needs to sustain a concept of space and the relative locations of objects and places. These items are essential to certain navigation for the use of users.

1.1. Background of the research

▪ Wayfinding

Wayfinding is the cognitive element of navigation. It does not involve a movement of any kind but only the planned and strategic parts that guide movement. It is not merely a planning stage that precedes motion. Wayfinding and motion are intimately knotted together in a complex negotiation that is navigation. The development and use of a cognitive map also referred to as a mental map, is a vital part of wayfinding. Even though it is still poorly understood, a cognitive map is a mental image of an environment. It has been called a "picture in the head" although there is substantial evidence that it is not purely based on imagery but somewhat has a symbolic quality. The representation of spatial knowledge in human memory that establishes a cognitive map will be a significant part of this research (Darken and Peterson, 2001).

▪ The map usage

Maps, photographs, videotape, verbal directions, and recently virtual environments are many secondary sources that have been used for spatial knowledge achievement. The most common of these is the map. For any map utilized in any environment, virtual or real, we need to know when the map is used, or more appropriately, what tasks the map is to be used for. The critical issue is whether or not the map is to be used preceding navigation or parallel with navigation. This issue is vital because maps that are used concurrently with navigation comprise the placement of oneself on the map. The first part of any task of this nature is, "Where am I? What direction am I facing?"

A transformation is required from the egocentric point of view to the geocentric viewpoint. If the map is used as a precursor to navigation, it is used only for planning and familiarization. No perspective transformation is required. Planning a journey is one example of such a geocentric navigation task. The planning is done outside of the environment, so there is no perspective transformation needed. However, the problem is more complicated when such a transformation is required, as in using a map during navigation. (Darken and Peterson, 2001).

- Augmented Reality (AR) based wayfinding

Wayfinding can be defined as spatial problem solving. It is about knowing where a person is in a building or an environment, knowing where a person desired location is, and knowing how to get there from a person present location. It is engaged in the idea of spatial knowledge. It considers the undertaking in question requiring that navigation (physical movement) take place. Passini (1984) has described;

'Spatial orientation and wayfinding ... allow people an idea of surrounding space, of their positions in that space, and they allow purposeful movement within that space.'

It explains that wayfinding leads or aids map reading. We will refer to navigation as a directed movement action and wayfinding as cognitive action connecting route determination. Therefore, augmentations such as direction indicators, maps, and path restriction can all greatly improve both wayfinding performance and overall user satisfaction (Darken, 1996).

- Spatial ability

Spatial ability is the capacity to understand and recall the spatial relations among objects. This skill can be perceived as a unique type of intelligence distinguishable from other forms of intelligence, such as verbal ability, reasoning ability, and memory skills. Spatial ability is not a monolithic and static trait but made up of numerous sub-skills, which are interrelated to each other and is developed throughout a person's life. Both men and women have assumed that men are somehow better able to solve so-described spatial problems than women. This obvious differentiation has been used to explain the differences in the numbers of men versus women in map reading.

1.2. Statement of the problem

Although AR technologies have been widely developed and commercialized, research about the use, evaluation and effect has just started (Yovcheva, et al., 2012; Dünser, Grasset, and Billinghamurst, 2008; Linaza, et al., 2012; Swan and Gabbard, 2005).

According to Anastassova, et al., (2005), most of the literature in AR has focused on usability issues. They suggested that there is a need for the implementation of user-based analysis regarding the creation of AR apps and the interactive experience they provide (Gabbard and Swan, 2008). The wayfinding process comprises knowing where you are, knowing your destination, following the best route to your destination, recognize your destination upon arrival, and finding your way back out (Carpman and Grant, 1993).

Previous research (Passini, 1992) proved that wayfinding in a complex environment often causes newcomers and occasionally frequent visitors uncertainty and stress, even with the assistance of wayfinding aids. Maps, landmarks and signs on walls are frequently confusing and not presented in appropriate position or logical sequence (Passini, 1992).

1.3. Research aim

This research aims to find the correlation between two types of wayfinding systems (conventional and Augmented Reality based) and the requirement of the spatial ability of the users. It also aims to investigate whether Augmented Reality (AR) based wayfinding can overcome the problems facing by the conventional wayfinding.

1.4. Research objectives

The research objectives are;

- to critically assess a group of people from a variety of categories (Age, gender, profession, etc.) in using a conventional map reading based wayfinding.
- to critically assess a group of people from a variety of categories (Age, gender, profession, etc.) in using an Augmented Reality (AR) based wayfinding.
- to assess the above respondent's spatial ability.
- to analyze the statistical association between the two types of wayfinding and the requirements of the spatial ability level.

1.5. Research questions

The research questions are derived from the above objectives:

- How the respondent respond towards conventional wayfinding (map reading)?
- How spatial ability help in conventional way of wayfinding
- Is AR required a certain level of spatial ability skills?
- What are the correlations between two types of wayfinding system that is conventional and Augmented Reality (AR) based and with the use of spatial ability skills?

2. Methodology

This research is to understand how the target audience embarks on the area of effective wayfinding, either the conventional type or augmented based type wayfinding. Some factors affecting wayfinding behavior among others, the human individual differences and environment factor (Montello, 2007). This study will provide further understandings into the complex relation between environment legibility and human individual differences (such as spatial abilities, sense of direction, and familiarity) on both types of wayfinding systems (conventional and AR based).

▪ Research design

A quantitative methodology incorporates with a proposed framework will be applied to obtain data and information. Findings from the framework will show correlational research information to investigate the wayfinding variables that will be implemented to achieve the research objectives. A purposive sampling strategy will be adopted, for example, using a prototype Augmented Reality (AR) based wayfinding to a group of selected user and a pencil-and-paper survey questionnaire will be provided in collecting data.

3. Significance of the research

This research will benefit user of a certain place or location in finding their way to their desired destination without hassle. Besides that, it will encourage the owner of the place or location such as theme park owner and local authority to implement or to improve their wayfinding system. As for a developer, this research will give guidance in designing an integrated wayfinding application. Therefore, AR based wayfinding will become a necessary device in wayfinding.

4. Literature review

A comparison of literature survey is needed to obtain results and explanation for the research. In one of the literature, conventional (map) and electronic device for wayfinding indicates that they have complementary strengths and weaknesses. Paper maps have no dynamics and lack of interactive properties compared to electronic map devices, it has high potential for the presentation of up-to-date dynamic content, easy to control and reliable (Paelke and Sester, 2010). Table 1 shows the comparison of conventional map and electronic devices.

Table 1. A comparison of conventional map and electronic devices (Paelke and Sester, 2010)

		Paper maps	Hand-held eMaps
Features	Size	Small to large, foldable, flexible	Small, fixed
	Power consumption	None	Significant; endurance hours to days
	Weight	Low	Wide range; typically several 100 g
	Price	Low	High
	Reliability	Very high	Limited
	Resolution (spatial)	Very high	Low
Content	Resolution (temporal)	Very limited (static depictions)	Potentially high (animation)
	Flexibility of content	No adaptation, difficult update	Easy if supported by software
	Content dimensions	Fixed, limited	Flexible, potentially unlimited
	Coverage	Fixed	Potentially unlimited

	Level-of-detail	Fixed, typically high (use specific)	Lower due to display resolution, flexible
	Readability	Very high	Lower
	Information access	Mostly push; serendipitous discovery common	Mostly pull; often lack of overview for discoveries if not explicitly supported
Use and interaction	Use, interaction	Well known interaction with paper; but learned	Special mechanisms, devices specific, only tasks
	Accessibility	map skills required High, but no support for visually impaired	supported by the software Lower, but special mechanisms for target groups
	Flexibility of use /adaptation to other uses	Very easy, common	can be implemented in software
	Annotation		Only if supported by the implementation, typically
	Query, search	Simple with pens, post-its etc.	limited
	Integration of GPS	Only pre-designed indices	Only if supported by the software
	Multi-user interaction	None	Full support possible in software
		Very easy, common	Full support possible in software Difficult due to device size

4.1. Spatial orientation and wayfinding

According to Darken and Peterson (2001), it is necessary to consider the fact that people are accustomed to navigation in physical spaces, whether or not a virtual environment attempts to simulate the real world. Undoubtedly, there are differences between regions of physical space that alter how navigation works, such as navigating in a forest versus navigating in a city, but there are assumptions that can be made based on experience in real environments that are useful in any real space. Darken and Peterson (2001) also mention, although this is not a satisfactory reason to blindly copy the actual world in every way it can, it certainly has to learn everything possible about how people relate to the physical world so that it can understand how to build better virtual environments.

4.2. Spatial ability and wayfinding

Although the behavioral, cognitive, and neural processes involved in wayfinding and navigation are typically treated as synonymous in the literature, important distinctions exist among these processes. Wayfinding is, aptly, the behavior of finding one's way from an origin to one or more destinations; in conventional terms, wayfinding relies on an existing understanding of an environment's spatial characteristics. In most other parts of the world, this understanding relies on existing spatial knowledge gathered from prior navigational experience, maps, or verbal descriptions.

4.3. Environmental cues

Wayfinding is based on "consistent use and organization of definite sensory cues from the external environment" (Lynch 1960). Wayfinding exhibits both decision-making and decision execution behavior (Passini, 1984). It is well assumed, to generate knowledge about further actions, and people rely on cues that can be retrieved from the environment (Raudal and Worboys, 1999). Cues are objects within or of environments that people engage in generating mental representations.

Environmental cues fall into several familiar types:

- Signs (e.g. directional signs and informational signs) (Weisman, 1981; Passini, 1984);
- Maps (e.g. You-are-here (YAH) maps and layout maps) (Levine Marchon and Hanley, 1984);
- Landmarks, certain objects that are more prominent than others; (Shanon, 1983; Sorrows and Hirtle, 1999; Denis et al., 1999; Allen, 2000; Michon and Denis, 2001);
- Architectural features that are not landmarks (Lynch, 1960);

- Layout and structure of the environment (Weisman, 1981; Seidel, 1982; O'Neill, 1991);
- Verbal cues (e.g. communication with other people and/or available help centers). (Freundschuh et al., 1990; Allen Miller and Ondracek, 1997; Denis et al., 1999).

Of these, signs provide the most straightforward wayfinding information (direction, location or confirmation of location). Maps have the capacity to offer all possible information to help the way-seeker. However, as every person has a different ability for comprehending information, compounded further by design and alignment matters associated with maps (Levine, 1982; Levine Machon and Hanley, 1984), a map may also delay wayfinding.

Further, people tend to seek landmarks (often 3 Dimensional), to construct mental representations of unaccustomed environments (Shanon, 1983; Michon and Denis, 2001), especially in the circumstances, when the navigated target is near a known landmark.

When a way-seeker fails to either find the necessary cues (Braaksma and Cook, 1980; Dada and Wirasinghe, 1999; on the viewability of cues), or comprehend conveyed information from a cue, the often consequent behavioral response is to seek help, where available, from information desks or others (Freundschuh et al., 1990; Allen, Miller and Ondracek, 1997; Denis et al., 1999).

4.4. Wayfinding variables

This graphical construct gives identity to six wayfinding variables, considered at the node, node-pair and route levels (Braaksma and Jordan, 1980; O'Neill, 1991; Denis, Pazzaglia, Cornoldi and Bertolo, 1999; Dada and Wirasinghe 1999; Allen, 2000). The six wayfinding variables are;

- The number of exit paths
- The Confirmation of informational sign in destination
- Spatial viewability
- Imaginary viewability
- Length in distance
- Length of segments

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4.5. Wayfinding in large-scale virtual worlds

As important as navigation is to human performance in virtual worlds, support for effective navigation is often overlooked in the design process. An experiment intended to show that real-world wayfinding and environmental design principles are effective in designing virtual worlds, which support skilled wayfinding behavior.

The design principles are adapted from both the cognitive psychology literature and urban and architectural design methodologies. There are two categories of design principles; those that guide the organizational structure of the environment, and those that guide the use and presentation of maps. (Darken, 1996).

The study measures subject performance on a complex searching task in some virtual worlds with differing environmental cues. The environments are enormous and consist of open sea, land, and ships, which are used as targets for search tasks. The worlds are augmented with a radial grid, a map, both, or neither. For each trial, the subject's viewpoint position and orientation were sampled approximately once per second. A verbal protocol with accompanying video was used to elicit information about the search strategies employed. A map drawing exercise followed each trial to gain insight into the subject's spatial knowledge (i.e. cognitive map) of the environment. (Darken, 1996).

The results show that subjects in the treatment without any additional cues were often disoriented and had extreme difficulty completing the task. The grid was shown to provide superior directional information, but both treatments using the map were superior overall due to the geocentric perspective provided. Behaviors associated with each treatment indicate that the cues had a strong effect on both search performance and search strategy. The results suggest that users of large-scale virtual worlds require a structure to navigate effectively. Augmentations such as direction indicators, maps, and path restriction can all greatly improve both wayfinding performance and overall user satisfaction (Darken, 1996).

4.6. Augmented reality

Augmented reality (AR) involves overlaying the real world with information from computer-generated displays. Current AR technologies support limited mobility, although this is expected to change in the future. This paper presents experimental results of effects of various AR display strategies on human performance in a simulation-based analog of a "search and rescue" navigation task (Goldiez, Ahmad and Hancock, 2007).

The augmentation scheme was a spatially and temporally registered map that was overlaid onto a corresponding real-world maze. The experiment required the participants to cross the maze, periodically answer orientation questions, obtain a target object, and exit the maze as quickly as possible. One hundred twenty participants were evaluated in six different conditions. There were two control conditions (paper map or compass prior to entering the maze), and four experimental conditions (combinations of egocentric and exocentric maps, and continuously on or on-demand map display) (Goldiez, Ahmad and Hancock, 2007).

Performance measures involved of the duration of time to traverse the maze and percentage of maze covered. AR resulted in better performance than the control conditions in terms of accuracy by facilitating the participants' coverage of the maze. Results demonstrate that the better performance with respect to time was in the map control condition. This outcome may be due to the small size of the maze, which could be memorized. (Goldiez, Ahmad and Hancock, 2007).

According to Bimber (2012), earlier research on AR focused on head-mounted displays and backpack computers, currently it includes a variety of enabling technologies, such as camera phones and other handhelds, advanced projector-camera systems, and AR-extended professional devices, such as x-ray scanners. Therefore, AR is now a possible evolution that is used in our everyday routine.

While AR's practical applications have not yet come to the level that many people involved in the field have dreamed of, the number of these applications is gradually increasing (Bimber, 2012).

5. Conclusion

In conclusion, the aim of the study presented in this paper is to obtain the correlation between two types of wayfinding systems, conventional and Augmented Reality (AR) based, and the requirement of the spatial ability of the users. An investigation whether AR based wayfinding can overcome the problems facing by the conventional wayfinding are being tested to the respondents.

The results from this research showed that the evolution of AR over the course of nearly 50 years has finally made it possible to use this technology in our daily lives (Bimber, 2012). AR is expected to exhibit better performance compared to a conventional wayfinding when more complex environments are employed. These results demonstrate promising benefits in mobile AR usage in specific navigation tasks. Design guidelines were extracted to guide future AR systems continued progress in enhancing performance. However, these conclusions need to be verified in a larger and more detailed experiment.

The results of the research may encourage the development of methods for analyzing the factors that are affecting wayfinding behavior, the human individual differences, and environment factor. Therefore, more detailed research is needed to investigate the differences in conventional and AR based wayfinding by integrating with various types of variables in wayfinding and spatial ability skills in their influence on wayfinding performance. Such result could aid in the design of more legible wayfinding systems.

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