chapter 13

SPATIAL LEARNING THROUGH LANDMARKS

Sehnaz Cenani[1] & Harry Timmermans[2]
[1]*(Assist. Prof. Dr.), Istanbul Medipol University, Turkey,*
e-mail: sdurmazoglu@medipol.edu.tr
ORCID: 0000-0001-8111-586X
[2]*(Prof. Dr.), Eindhoven University of Technology,*
e-mail: h.j.p.timmermans@tue.nl
ORCID: 0000-0002-8737-4632

1. INTRODUCTION

To understand the interaction between individuals and the built environment, relevant attributes, and filtering mechanisms of how individuals perceive the built environment and act within this environment should be investigated. According to Golledge and Stimson (1997), the main psychological variables intervening between an environment and human behavior are a combination of cognitive and emotional attitudes, values, emotions, perception and cognition, and learning. Moreover, these variables are connected to each other and take place within people's social and cultural networks. Spatial learning of a new route in an unfamiliar environment needs spatial decision-making processes, and in these processes, people use landmarks.

Saliency of a landmark depends on the nature of the landmark, and its uniqueness. Therefore, saliency of a landmark may change. Today, people depend on their navigation devices and smart phones for navigation and wayfinding. The importance and popularity of information and communication technologies is undeniable. What happens when individuals do not have an Internet connection or lose their smart phones? In several studies, the effects of landmarks on spatial learning in a virtual environment has beenin-vestigated (Steck & Mallot, 2000; Sturz & Bodily, 2010; Nys, Gyselinck, Orriols & Hickmann, 2015). Gramann et al. (2017) explored whether customized navigation directions support incidental spatial knowledge acquisition in a virtual driving environment. An examination of the literature shows that there are several studies focusing on comparing spatial learning from maps and navigation in the real world.Thorndyke and Hayes-Roth's study (1982), which is prepared for The Office of Naval Research, is one of the earliest studies in this research field. They investigate differences in spatial knowledge acquired from maps and navigation. Richardson, Montello and Hegarty'sstudy (1999) compares spatial knowledge acquisition from a map, from direct experience and by traversing through a virtual version of the building. Hirtle's study (2000) examines four case studies, such as you-are-here maps, information kiosks, an information browser in a virtual environment, and web-based browser for a library locator system. However, there is a lack of research focusing on cognitive aspects of landmarks such as which landmarks are more difficult to recall, or how navigation assistance systems affect an individual's spatial cognitive skills such as attention, perception, memory, learning and reasoning in the built environment. Therefore, the goal of the current study is to formulate a model to predict recollection of landmarks as a function of their saliency and the cognitive awareness levels of participants while navigating in the built environment. To that end, an experimental studydesigned by Wielens, Cenani, Kemperman and Borgers (2011) is used to investigate how navigation assistance systems influence the relationship between saliency of a landmark and the cognitive awareness of an individual. Gender-specific differences in the recollection of landmarks are expected to be found. Based on existing studies such as Sholl et al., 2000, Saucier et al., 2002, and Choi et al., 2006, it is assumed that female participants would be better at landmark recollection tasks. In addition, it is expectedthat there will be a difference in therecollection of landmarks between thepaper map group and thenavigation device group. Finally, it is expected to observe salient landmarks are recalled easier than other landmarks, since it is argued that there is a correlation between saliency of a landmark and cognitive awareness of an individual.

The remainder of this chapter is structured as follows: The following section reviews the literature on spatial learning. This is followed by a section describingthe proposed model of landmark recollection. The next sections present the experimental studyand results. Finally, the last section discusses the main findings and draws some conclusions.

2. SPATIAL LEARNING AND LANDMARKS

The literature on spatial learning is comprehensive. Studies on how individuals gain spatial knowledge and develop cognitive maps of the built environment have a long history (Evans, 1980; Richardson, Montello, & Hegarty, 1999; Gärling & Golledge, 2000; Tverksy, 2000; Ishikawa & Montello, 2006; Wang, Mou and Sun, 2014). Thorndyke (1980) stated that at the first (the lowest) level, individuals simply know a set of landmarks. They learn significant locations or objects such as an interesting façade or a sculpture. Landmarks are detected early in the learning process and can easily be remembered. If landmarks have any significance for individuals, it is easier for individuals to make assumptions as they construct their first mental map. At the second level, Thorndyke emphasizes that individuals are still not capable of connecting landmarks; however, they are able to point out landmark's direction relative to their positions. At the third level, individuals can memorize the sequence of locations. These sequences are still separated in their minds, but now they know several route alternatives. However, they are still unable to build new routes between different locations which belong to different groups. Finally, at the highest level, individuals succeed to develop a comprehensive representation of their environment. At this level, individuals can associate different locations and routes, and are able to develop a mental network representation of the city.

Golledge (1999) indicates that individuals' learning strategies in an unfamiliar environment are based on exploration according to some rules or heuristics, such as acquisition of a-priori knowledge about this environment from maps, sketches, verbal descriptions, or photographs. Peopleusually exhibit differences in their ability to recall different landmarks.A landmark plays animportant role in navigation. It helps us to identifya route and recall-learned routes. Anything can be a landmark, howeverit should be unique and easy to remember, so that it stands out as a reference point. Heth, Cornell and Alberts (1997) state that landmarks are essential for navigation for being unforgettable reference points that are selected along a route. They also indicate that landmarks mayhelpa person to determine spatial interactions between objects and routes, which consecutively make possible the development of a cognitive map of an area.

A landmark can be defined as an object or a feature of a city that is easily seen and recognized from a distance. A landmark can help individuals to be certain of their whereabouts. Lynch (1960) indicates that “a landmark is not necessarily a large object; it may be a doorknob as well as a dome”. Here, he points to the subjectivity of landmarks. Furthermore, landmarks must be visible;therefore, the location of a landmark is important. Lynch (1960) characterizes landmarks as external point references which may differ in size. He defines singularity and saliency as the importantcharacteristics of landmarks. According to him, singularity is connected to a clear shape; a landmark should create a contrast with its background and has a well-known location. In summary, buildings with distinct forms, buildings on decision-points and easily recognizable buildings due to their use types (e.g., hospitals, schools, military, or religious buildings, etc.) are expected to be noticed and recalled easily. If powerful cognitive reinforcements such as historical or personal associations are attached to an object, that object’s importance as a landmark increase. Dependent on these attributes, it is argued that a landmark may differ in terms of its saliency.

The role of landmarks in navigation has been investigated in several studies (Sorrows & Hirtle, 1999; Klippel & Winter, 2005; Gramann, Hoepner and Karrer-Gauss, 2017). Landmarks help individuals to identify their current positions in the built environment. Additionally, landmarks can indicate changes of direction, such as turning points or intersections. Landmarks can be used to maintain a course. If individuals do not use navigation devices or maps to navigate in an unfamiliar environment, they use landmarks to remember the route for their next trip. The most important feature of navigating in an unfamiliar environment is to maintain the spatial orientation. This means that an individual should be able to pinpoint his/her location relative to existing landmarks. Spatial orientation is the process of founding a link between spatial perception and spatial knowledge that is stored in one’s cognitive map or spatial knowledge acquired from a regular map (Peruch & Lapin, 1993). However, if an individual is familiar with the environment, then (s)he does not need landmarks for navigation, (s)he uses his/her cognitive map. Therefore, navigating in a familiar environment is rather easier than navigating in an unfamiliar environment.

3. THE MODEL

In this study, a model that predicts the probability that an individual recall a landmark as a function of two parameters is formulated: saliency of a landmark and the cognitive awareness level of an individual while navigating in the built environment. As stated before, a landmark plays an important role in wayfinding as well as in spatial knowledge acquisition. An individual (e.g., tourist, newcomer) who has insufficientinformation will need landmarks, given landmarks' importance for wayfinding and navigation. However, not all landmarks are equally distinctive (Cenani, 2013). Therefore, this study's purpose is to estimate a parameter for saliency that captures such discrimination. In principle, this parameter can be linked to explanatory variables such as the degree of uniqueness and the type of the landmark. For example, a hospital may be a less unique landmark than a palace. If a landmark is unique, the probability of recalling it will be high, and therefore the saliency will be high too.

Based on the discussed literature, it is assumed that the probability of an individual to recall a landmark is a function of (i) the saliency of a landmark, and (ii) the cognitive awareness of the individual. All other things being equal, the probability of an individual recollecting a particular landmark will increase with an increasing saliency of a landmark. Similarly, the probability will, ceteris paribus, increase with increasing awareness of an individual. Let δ denotes the saliency of a landmark j, and θ denotes the cognitive awareness of the individual i. It is assumed then that the probability of the individual i, recalling a landmark j is given by the following equation:

$$P_{ij} = \frac{\exp(\theta_i - \delta_j)}{1 + \exp(\theta_i - \delta_j)}$$

Please note that the structure of this equation is identical to the Rasch (1960) model originally introduced for measurement of certain attainment tests and intelligence tests in physiological and educational research (Kaiser & Keller, 2001; Evans et al., 2007).Also,the Rasch model has beenused in healthcare and marketing research (McHorney & Monahan, 2004; Salzberger & Sinkovics, 2006). The Rasch model can be applied to any type of discrete data for measuring a quantitative attribute. In the present study, the Rasch model is adapted into a cognitive task, to analyze the connection between the saliency of a landmark and the cognitive awareness of an individual while using a paper map or anavigation device.

4. METHOD

The experimental studywas originally designed and conducted in the context of a study by Wielens et al. (2011) and Wielens (2011). The details of this studycan be found in Cenani et al. (2017). Two circular routes (Route-A and Route-B) were chosen in Eindhoven, the Netherlands (see Figure 1). Both routes had similar features such as same number of turns (10 turns), length (1.6 km) and land-use type (mostly residential buildings along with several commercial buildings). Each participant walked one of the two predetermined routes, either with a paper map or anavigation device, during daytime. All participants were tested individually. Before the study, they were asked a series of questions to guaranteeminimumfamiliarity with these locations.

4.1. Participants

Forty male and 20 female undergraduate students from the Department of the Built Environment, Eindhoven University of Technology participated in this study. They received partial course credit for their participation. The mean age of participants was 21.1 years (SD = 3.99). Twenty male and ten female participantswere assigned to Route-A, and the other 30 participants were assigned to Route-B. Fifteen participants from each study location used the given navigation device and the rest of the participants performed the same task with a paper map.

4.2. Task and Apparatus

The navigation device used for the experimental studywas NAVIGON 2510 Explorer. The main reason of choosing this device was the pedestrian oriented navigation features. For example, the map was automatically oriented to the direction of the individual. This was an important feature because it eliminated the need of orienting the map. It was assumed that navigating in the built environment would be less time consuming, making a cartographic mistake would be minimal and the most important of it all, the need for landmarks to navigate in an unfamiliar environment would be less in navigation device users than paper map users. Therefore, it wasexpected that there would be a difference in the landmark recollection results between paper map users and navigation device users.

The participants used the navigation device in pedestrian mode. The route was uploaded before the field study. To restrict the visibility of the study area, the map on the screen was locked, so they could not zoom-in or zoom-out. Furthermore, all features of the device except for the names of the streets, the route and the North direction were turned off.

Figure 1. Tools Used in the Experimental Study. Navigon 2510 Explorer and A-4 Size Paper Maps

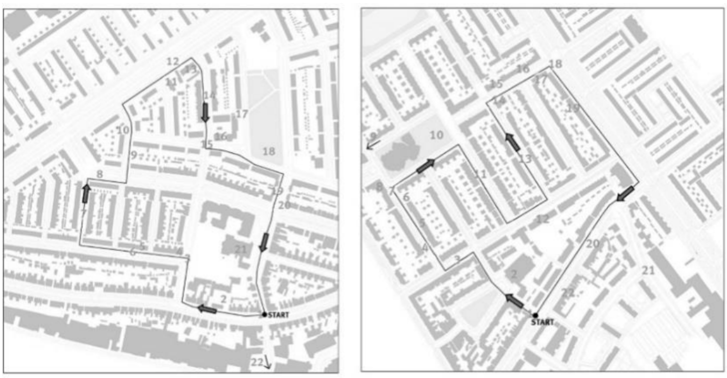

Figure 2. Landmarks (Green Numbers) on Route-A (Left) and Route-B (Right)

Paper map groups were given a printed map that was taken from www.maps.google.com. The route, the North direction and the street names were visible on the map, but information about landmarks, tagswereremoved. The tools used in the experimental studycan be seen in Figure 1. Figure 2 shows the locations of the landmarks (green numbers) and start/end point on both routes. Arrows indicate the direction of the route.

After the field study, 24 randomly numbered and placed cards containing photographs of landmarks of two test areas were given to the participants at the lab. They were asked if they recall these landmarks. Participants received a point for correct answers and received none for incorrect answers. If participants could not answer the question, it was assumed that they did not recall the landmark; therefore, they did not receive any points for unanswered questions.

4.3. Software

ConstructMap is used for the analyses. This software is chosen, because it provides a method for estimating respondent proficiency from assessment data and it also provides advanced interpretation of respondents' knowledge and behavior than test theory or item response theory (IRT) approaches (Kennedy, 2005).This software produces awareness estimates using expected a-posteriori (EAP), maximum likelihood (MLE), or plausible values (DPV) estimation algorithms. Kennedy (2005) indicates that the software produces these estimates using a multidimensional polytomous extension to the Rasch model known as the Multidimensional Random Coefficients Multinomial Logit (MRCML) Model (Adams, Wilson & Wang, 1997). Kennedy (2005) specifies that the EAP method provides a Bayesian analysis of observed events and it is a Bayesian estimation procedure using both the participants' scores and the distribution of the participants. In this study, the EAP method and the Monte Carlo method of integration are chosen for the analyses.

5. RESULTS

5.1. Saliency of a landmark

Based on the saliencyvalues calculated by *ConstructMap*, the comparison of two routes in terms of saliency of landmarks is shown in Figure 3. Please keep in mind that a higher (positive) value indicates a landmark with low saliency. According to this graph, L14 (house) on Route-A and L19 (house) on Route-B are the least salient landmarks, whereas L1 (church) on Route-A and L2 (playground) on Route-B are the most salient landmarks.

According to the findings, church and playground are more salient landmarks than rest of the landmarks. Since these landmarks create a contrast with their background and are easy to recall due to their architectural functions, these landmarks are the most salient landmarks in the landmark recollection task. These results are in line with initial expectations.

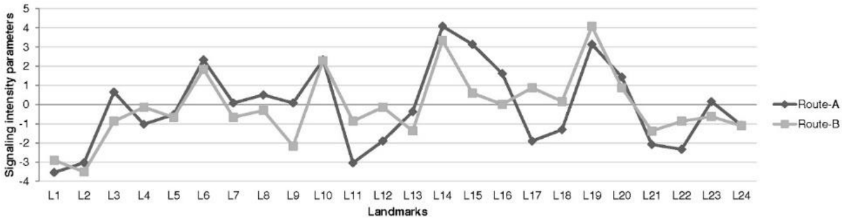

Figure 3. The Comparison of Saliency of Landmarks on Route-A & Route-B

5.2. Cognitive Awareness of an Individual

In this study, cognitive awareness represents the landmark-based spatial knowledge of an individual. Cognitive awareness of participants of Route-A and Route-B are shown in Table 1 and Table 2. Given that there are 24 landmarks in total in the landmark recollection task, the maximum score that can be achieved by a participant is 24. In the tables, a raw score represents the total number of the recollected landmarks by a participant. The next column indicates a participant's awareness estimate, and the last column shows the standard error for that estimate. Additionally, variance of the estimates (EAP Variance), the standard error of the mean value (SE of the Mean), the (given) model variance, and the marginal maximum likelihood (MML) reliability index are displayed at the bottom of each table.

As can be seen from Table 1, participant ID-4 (male) recalled 20 out of 24 landmarks; therefore, he achieved the highest score within his group. On the other hand, participant ID-26 (female) recalled 10 out of 24 landmarks; so, she achieved the lowest score in her group. In Table 2, participant ID-55 (male) achieved the highest score within his group, and participant ID-33 (male) and participant ID-49 (male) achieved the lowest scores in their groups. According to Table 1 and Table 2, male participants achieved the highest scores in their groups. The findings indicate that male superiority is observed in landmark recollection task. Surprisingly, these results are not matching with the initial assumption. It isassumedthat female participants would be better at landmark recollection task than male participants. Therefore, further statistical tests were conducted to confirm the significance of these results. In Table 3, independent samples test results (on number of correct answers) indicate that there is no significant gender difference for Route-A (Sig.: .659) and Route-B (Sig.: .290).

Table 1. Cognitive Awareness of Participants (Route-A)

Participant ID	Gender	Navigational aid	Raw score (max. score=24)	Est.	Std. Err.
1	M	map	13	0.31	0.26
2	M	map	12	0.24	0.26
3	M	map	13	0.31	0.26
4 [a]	M	map	20	0.79	0.26
5	F	map	15	0.45	0.26
6	F	map	15	0.45	0.26
7	F	map	16	0.52	0.25
8	M	map	12	0.24	0.26
9	F	map	14	0.38	0.26
10	M	map	15	0.45	0.26
11	F	map	12	0.24	0.26
12	M	map	17	0.58	0.25
13	M	map	13	0.31	0.26
14	M	map	15	0.45	0.26
15	M	map	15	0.45	0.26
16	M	nav. device	14	0.38	0.26
17	M	nav. device	14	0.38	0.26
18	M	nav. device	15	0.45	0.26
19	F	nav. device	15	0.45	0.26
20	F	nav. device	14	0.38	0.26
21	F	nav. device	14	0.38	0.26
22	F	nav. device	14	0.38	0.26
23	M	nav. device	17	0.58	0.25
24	M	nav. device	11	0.17	0.27
25	M	nav. device	15	0.45	0.26
26 [b]	F	nav. device	10	0.09	0.27
27	M	nav. device	16	0.52	0.25
28	M	nav. device	13	0.31	0.26
29	M	nav. device	13	0.31	0.26
30	M	nav. device	12	0.24	0.26
		Average	14	0.39	0.26
		Average EAP	0.39		
		EAP Variance	0.01		
		SE of the Mean	0.02		
		Model Variance	0.09		
		MML (EAP/PV)	0.21		

[a] Participant ID-4 is male and achieved the highest score.
[b] Participant ID-26 is female and achieved the lowest score.

Table 2. Cognitive Awareness of Participants (Route-B)

Participant ID	Gender	Navigational aid	Raw score (max. score=24)	Est.	Std. Err.
31	F	map	11	0.13	0.36
32	F	map	18	1.08	0.36
33 [b]	M	map	9	-0.11	0.36
34	M	map	15	0.68	0.37
35	M	map	17	0.95	0.36
36	M	map	15	0.68	0.37
37	M	map	18	1.08	0.36
38	F	map	17	0.95	0.36
39	M	map	10	0.00	0.35
40	M	map	14	0.54	0.37
41	M	map	16	0.81	0.36
42	M	map	18	1.08	0.36
43	F	map	17	0.95	0.36
44	F	map	15	0.68	0.37
45	M	map	16	0.81	0.36
46	M	nav. device	16	0.81	0.36
47	M	nav. device	13	0.40	0.37
48	F	nav. device	16	0.81	0.36
49 [b]	M	nav. device	9	-0.11	0.36
50	M	nav. device	18	1.08	0.36
51	F	nav. device	17	0.95	0.36
52	M	nav. device	14	0.54	0.37
53	M	nav. device	12	0.26	0.36
54	F	nav. device	17	0.95	0.36
55 [a]	M	nav. device	19	1.21	0.36
56	F	nav. device	14	0.54	0.37
57	M	nav. device	17	0.95	0.36
58	M	nav. device	17	0.95	0.36
59	M	nav. device	14	0.54	0.37
60	F	nav. device	18	1.08	0.36
		Average	15	0.71	0.36
		Average EAP	0.71		
		EAP Variance	0.13		
		SE of the Mean	0.06		
		Model Variance	0.26		
		MML (EAP/PV)	0.51		

[a] Participant ID-55 is male and achieved the highest score.
[b] Participants ID-33 and ID-49 are male and achieved the lowest scores.

Table 3. Results of the T-Tests

Group Statistics

			N	Mean	Std. Deviation	Std. Error Mean
1	Route-A	female	10	13.90	1.729	.547
		male	20	14.25	2.149	.481
2	Route-A	nav. device	15	13.80	1.821	.470
		map	15	14.47	2.167	.559
3	Route-B	female	10	16.00	2.160	.683
		male	20	14.85	2.996	.670
4	Route-B	nav. device	15	15.40	2.694	.696
		map	15	15.07	2.915	.753
5	Route-A & Route-B	route A	30	14.13	1.995	.364
		route B	30	15.23	2.763	.504

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	Df	Sig. tailed)	(2-Mean Difference	Std. Error Difference	Lower	Upper
1	Equal variances assumed	1.098	.304	-.447	28	.659	-.350	.784	-1.955	1.255
	Equal variances not assumed			-.481	22.046	.635	-.350	.728	-1.859	1.159
2	Equal variances assumed	.423	.521	-.912	28	.369	-.667	.731	-2.164	.830
	Equal variances not assumed			-.912	27.192	.370	-.667	.731	-2.166	.832
3	Equal variances assumed	1.542	.225	1.078	28	.290	1.150	1.067	-1.036	3.336
	Equal variances not assumed			1.202	24.084	.241	1.150	.957	-.824	3.124
4	Equal variances assumed	.000	.988	.325	28	.747	.333	1.025	-1.766	2.432
	Equal variances not assumed			.325	27.828	.747	.333	1.025	-1.766	2.433
5	Equal variances assumed	3.579	.064	-1.768	58	.082	-1.100	.622	-2.346	.146
	Equal variances not assumed			-1.768	52.783	.083	-1.100	.622	-2.348	.148

5.3. Frequency Distributions

Figure 4 and Figure 5 show the frequency distributions of participants' awareness values on 24 landmarks on both routes. Figure 4 illustrates the frequency distributions of the participants' awareness values filtered by gender, and Figure 5 shows the frequency distributions of the participants' awareness values filtered by the type of the navigational aid. In these figures, three ordered levels are used to define the logit ranges for each category: high (0.6 and more), medium (0.5-0.4), and low (0.3 and less).

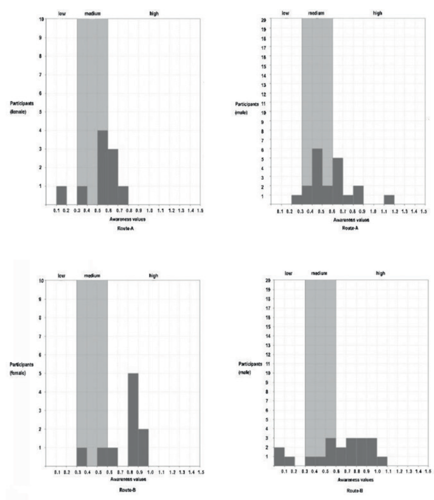

Figure 4. Frequency Distributions of Participants' Awareness Values (Filter. Gender)

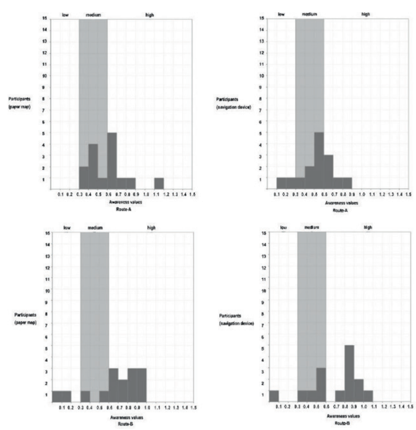

Figure 5. Frequency Distributions of Participants' Awareness Values (Filter. Navigational Aid)

Figure 4 shows that the number of male participants (n=9) with high awareness values is higherthan the number of female participants (n=4) with high awareness values forRoute-A. The number of male participants (n=12) with high awareness values is also higherthan the number of female participants (n=8) with high awareness values for Route-B. Similarly, in Figure 5, the number of paper map group's participants (n=8) with high awareness values is higherthan the number of navigation device group's participants (n=5) with high awareness values forRoute-A. The number of paper map group's participants (n=11) with high awareness values is also higherthan the number of navigation device group's participants (n=9) with high awareness values forRoute-B.

To summarize, based on these distribution graphs, contrary to the expectation, the number of male participants with high awareness values is higher than the number of female participants on both routes.Furthermore, the number of paper map group's participants with high awareness values is higherthan the number of navigation device group's participants forboth routes. The latter finding is in line with the expectation. However, as shown in Table 3, according to the independent samples test results, no significant navigational aid difference is found for Route-A (Sig.: .369) or Route-B (Sig.: .747). Having said that, of course these results hold for the current sample size; enlarging the sample and re-running the tests may lead to significant differences in the results.

6. DISCUSSION AND CONCLUSIONS

This study investigates the development of spatial learning through landmarks in an unfamiliar environment. The study focuses on how young adults (n = 60) identify and recall landmarks in visual-spatial tasks after walking a route. In this study, the Rasch model (1960) is used in a testthat includes visual-spatial tasks. The model is used to predict recognition of landmarks as a function of landmarks' saliency and the cognitive awareness levels of individuals while navigating in the built environment. To that end, an experimental study is designedto investigate how navigational aids (i.e., paper map and navigation device) influence the relation between saliency of a landmark and the cognitive awareness of individuals.

Two unexpected findings emerged from this study. First, in the landmark recollection task, male participants scored higher than female participants.

This means that male participants recalled more landmarks than female participants. However, various studies (Sholl et al., 2000; Saucier et al., 2002; Choi et al., 2006) have shown that men are more likely to use survey perspectives (e.g., cardinal directions and distances) in giving and following wayfinding directions, while women are more likely to use route perspectives (e.g., landmarks), and moreover, based on these studies, females use a landmark-biased strategy. If using landmarks for giving and following wayfinding directions is linked to the cognitive ability of recollection of landmarks then, one can assume that women would excel inthe landmark recollection task, given that existing studies indicate that women tend to pay more attention to landmarks. Therefore, it was expected that female participants would recollect landmarks to a greater extent. However, the findings showed that male participants are more successful than female participants inthe landmark recollection task (see Table 1 and Table 2). This result can be explained by gender-specific differences in cognitive skills. Although further study is required to gain a complete understanding of the spatial cognitive processes of individuals, the findings indicate that there may be some cognitive differences between spatial perception and recollection of landmarks among men and women.

A second unexpected finding that emerged from this study isthat contrary to the initial expectations, no significant difference can be found between the use of the paper map and the electronic navigation device (see Table 3). These findings can be caused by the small sample size, therefore; a larger sample size may give different results.

Furthermore, the results revealed that church (L1) and playground (L2) are the most recollected landmarks on both routes (Figure 3). In other words, these landmarks are the most salient landmarks of Route-A and Route-B. Lynch (1960) indicates that the singularity of a landmark is linked to a distinct form, contrast with nearby elements, and spatial prominence. If the singularity has an impact on saliency, a landmark such as a church is easy to recollect, due to its distinct form/architecture and spatial prominence. Similarly, a playground contrasts with nearby elements, makes it a salient object. In brief, this finding is consistent with the initial expectation.

It should be indicated that the sample contained undergraduate students who were very receptive to use information and communication technologies in their daily lives; therefore, in the future, a diverse socioeconomic and demographic sample will be included in the study. Finally, it is worth noting that the approach used in this paper can be improved by inclusion of more challenging cognitive tasks such as returning to the starting point without any navigational aid.

It is a fact that the use of electronic navigation devices is rapidly increasing. Moreover, most of the individuals do not pay attention to their surroundings while using a navigation device.As a result of using navigation devices, people do not learn the route they useand theirsurroundings. As discussed in this paper, landmarks and the level of cognitive awareness can be different from one individual to another; therefore, it may be better to consider these aspects while designing an intelligent navigation system. Intelligent navigation systems could include advices to support spatial learning and nurture spatial cognitive abilities. Today, with the help of advanced deep learning algorithms, it is possible to design intelligent navigation systems that learn users' interests, habits and improve their spatial knowledge acquisition. These navigation systems could advice users to plan their daily activities. For example, because of the rush-hour traffic or a traffic accident, the navigation systemmay suggest doing the grocery shopping first and then picking up the kid from the daycare. By receiving real-time information from systems such as travel, weather, or traffic systems, the advices about daily schedules might be modified. The quality of life of the users can be enhanced by the development of such advanced intelligent navigation systems.

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