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What Makes a Space Relatively Memorable? A Study on the Recollection of Spaces through Space Syntax and Imageability Theories

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Abstract

Space is a fundamental component of our existence, without which we cannot live or think. During our daily lives, we perceive various components of space concurrently and we build an understanding of the environment in our memories. The spatial properties/qualities of the environment have their own unique place in this context and have been studied in psychological and several non-psychological disciplines such as architecture, phenomenology, sociology and geography. In this frame, imageability theory focuses on the environment's visuo-spatial quality, whereas space syntax theory focuses on its spatial configuration, and they both enable the systematic evaluation of numerical data.
Starting with the question "What makes a space memorable among all its different components/features?", the research aims to investigate the effect of certain spatial qualities on spatial memory through quantitative research on an architectural scale. Within a multidisciplinary framework, the methodology presents a unique approach that integrates space syntax with memory data. Firstly, content analysis was applied to cognitive maps, and the obtained data were redefined according to the configurational (syntactic) and imageability qualities of the real environment they represent. Secondly, the redefined data was tested to evaluate the effect of spatial qualities on memory. 77 participants (age 23-75; 52M/25F) attended the case study and drew the plan schemas of the school building they graduated from. The relation between memory and (1) spatial units' imageability categories is searched through ANOVA tests, and (2) spatial units' syntactic values is searched through correlation tests. The significant results reveal that configurational and visual qualities of spaces are essential factors on what will be stored in memory depending on their lead of participants' spatial experience routines via their formal qualities. Furthermore, the case study presents multidisciplinary data that contributes to architectural design, environment and behavior, and space syntax theories and provides new insight into cognitive research on memory.

Keywords: *Architectural space, Cognitive map, Imageability, Space syntax, Spatial memory.*

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INTRODUCTION

Kant states that leaving space, time, and causality aside is out of the question in any given context (Akarsu, 1994). “Space” is a fundamental component of human existence that we cannot live or think without. From the first moment of birth, individuals perceive various components of space concurrently and build a total understanding of their environment. Human memory processes and stores various spatial information to maintain a consistent daily life in the environment and make sense of new spaces/spaces to be experienced in the future. However, individuals do not remember every place they have been or all the components of the places they remember. Then, what makes one place more memorable than others? Is it its components such as structural elements and plants, or users, features such as color, sound, temperature, or the events experienced there? Although all of these possible factors have been investigated separately within the scope of different research disciplines, still not enough clear findings have been presented as to why and how a space is recalled or unrecalled.

In this frame, three research fields come to the fore as they present valuable findings on how people's minds relate to places. Cognitive map research has presented valuable findings about participants' experiences, perceptions, and memories of their environment, mostly its configurational and formal qualities. On the other hand, imageability and space syntax theories have offered systematic evaluations of the built environments' physical qualities, configuration, and form and their relation to their users' social lives and perceptions. In tandem, the interdisciplinary findings obtained in these three fields offer researchers different perspectives to argue human-place relations through the lens of memory. Inspired by this observation, this study is structured on a multidisciplinary framework based on memory, cognitive map, imageability, and space syntax theories.

Starting with the question "What makes a space relatively memorable?", this study aims to systematically investigate the effect of specific qualities of spaces on memory by applying two well-known spatial analysis methods, space syntax and imageability, to memory research. In this context, the theory section presents the dynamics of human memory in regard to spatial information, the cognitive map concept, Lynch’s imageability theory and space syntax theory with the inclusion of related current research. The following sections present case study and methodology, results, discussion and conclusion.

THEORY

The transformative nature of memory

According to cognitive theories, every kind of information about the environment is data coded and stored in memory, which has been attributed with a meaning. The selective operations process these data, and only several components of that information are coded/stored to be recalled by memory (Smith & Kosslyn, 2014; Goldstein, 2011). Besides,

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memory has a transformational nature (Smith & Kosslyn, 2014; Nadel et al., 2008), and the coded information is not always the same as the recalled information. In unsuccessful recalls, the memories can be transformed, thwarted, or replaced with the effect of misleads (Goldstein, 2013) or affected by prejudice, misattribution, and infusion (Smith & Kosslyn, 2014); or the performance of memory may change by human factors (Rubin et al., 1999; Levine et al., 2002; Grysman & Hudson, 2013). Individuals tend to recall more number experiences if they repeatedly occurred (Wagner, 2006; Evans et al., 1981; Schouela et al., 1980), happened more recently (Rubin & Schulkind, 1997a), or belong to early adulthood and late adolescence, both under the effects of social and personal factors (Rubin, 2000; Levine et al.,2002; Piolino et al., 2009; Piolino et al., 2010; Conway & Pleydell-Pearce, 2000; Pillemer, 2001; Rubin et al., 1986). For instance, emotions serve as contextual cues for episodic memories (Allen et al., 2008; Reisberg & Hertel, 2003), and events that caused significant emotional responses are recalled in more detail (Goldstein, 2013; McGaugh, 2008). Moreover, the coding and recalling processes such as rehearsing, sharing, recurring, or replaying memories through thinking or talking lead to better recalling (Nelson, 1993; Nelson & Fivush, 2004; Piolino et al., 2009; Fivush, 1988).

Spatial information in memory and cognitive maps

Spatial information mostly derived from the visual perception of relatively constant, stable, and predictable environmental elements (walls, roads, trees, buildings) and has a formal reciprocity with them, whereas elements open to change and interpretation (wind, sound, people, animals) are omitted (Nadel et al., 2008). Similar elements and in-between relations in different environments support differentiating the spatial information and defining the context correlatively. Based on these basic qualities, it is possible to re-experience and re-consolidate the contextual information acquired from the environment, as opposed to the arbitrary/abstract conceptual information (Cooper & Lang, 1996; Nadel et al., 2008; Talarico, 2009).

The prementioned differentiations in memory are also valid for spatial/environmental information. Research indicates that the spatial scale and content of memories were found to change between children and adolescents depending on their relationship and dependence on their parents (Chawla, 1992). Memories that have more intense emotional effects include more number of perceptual (visual or auditive) and conceptual (time, place) details (Comblain et al., 2005); and individuals recall the places where they are informed/heard about an important public event more easily than the other places as an outcome of their raised feelings (Bauer et al., 2012; Brown & Kulik, 1977). On the contrary, in some cases spatial memories are not affected by manipulations towards episodic memory, and the spatial context is not transformed in the process of recalling (Nadel et al., 2008).

Apart from cognitive theories, the memory of spaces is argued via cognitive map concept in environment and behavior theories. Cognitive map theory is based on the schema concept in developmental psychology (Hart & Moore, 1973). Starting from infancy, human beings build up schemas in their minds through experience by collecting information about the world. These schemas are continuously formed, enriched with abstract thoughts and symbols after early adolescence, and reach an extensive content and complexity in adulthood (Norberg-Schulz, 1971). As a form of schema, cognitive maps include spatial information in a unique structure that develops over topological relations, and they have a web-like form in which every point is connected to the other (Kuipers, 1978; Penn, 2003; Long et al., 2007). Every cognitive map is unique, schematic, sketch like, unfinished, deformed, simplified, and open to change (Downs & Stea, 1973; Kaplan, 1973; Zimring & Dalton, 2003). For instance, complex configurations can deteriorate cognitive maps (Moeser,1988), and simple configurations are more legible and lead to more effective cognitive maps (Wang et al., 2019; O'Neill, 1991). In addition, they strengthen and organize memory and work as a solid lead to recall episodic memories (Gattis, 2001). Above all, they provide general information about the world and are requisite for human survival (Kaplan, 1973). Sketch maps presenting a previously experienced environment in drawing represent the cognitive comprehension of that environment and have been evaluated as the actual representation of a cognitive map on paper (Canter, 1977). In literature they are termed as cognitive maps (Tarcin Turgay et al., 2015; Karakus, 2007; Milgram 1972; Downs & Stea, 1973; Tuncok Sariberberoglu & Unlu, 2018; Sudas & Gokten, 2012) or mental maps (Tuan, 1975; Saarinen, 1988) by many researchers. Similar to spatial memory, every component of these sketch maps is reciprocal to a component or quality of the environment. Their ratios, scales, forms, contents, and drawing qualities differ depending on the participant's skills, but they still include valuable data about how an individual perceives and represents the environment (Haq & Girotto, 2003; Kim & Penn, 2004). Lynch (1960) has significantly contributed to the acceptance of the sketch map technique as a scientific method to analyze environmental elements and humans' perception of them for both architectural and urban research areas via his “imageability” theory (Göregenli, 2010).

Imageability

Lynch’s (1960) "imageability" concept is based on the qualities of environmental objects that give them a high probability of evoking a strong image in a perceiver. He focused on the visual qualities and stated that objects' shape, color, or arrangement facilitates vivid, powerful, and useful mental images. This powerful image ensures convenience in perception and priority and detail in recalling. Then, according to their goals, individuals structure a total environmental image focusing primarily on the ones that present potent images. During research Lynch

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asked the participants to draw a sketch map of their city and analyze which elements strongly shape an urban area's image in mind. According to the results, he defined five categories of urban elements based on their visual and formal qualities: paths, edges, districts, nodes, and landmarks. Paths are the movement axes that people use for going from one place to another; they are mostly predominant and arranged and relate to other urban elements. Edges are linear boundaries or breaks in continuity that work as lateral references; they are used for gathering generalized areas that could be penetrable or seamed. Districts are medium-to-large scaled, two-dimensional areas that have their own identity and significant inside-outside differences. Nodes are some strategic spots or symbolic areas that participants can enter, like the intersection points of transportation axes, a crossing of paths, and shifting points in which a function or symbol is condensed. Finally, landmarks are external reference points like buildings, signs, towers, or stores that fill the environmental image of the participants. Lynch theorized that an urban area is legible if its components can be easily identified and organized into a coherent pattern, and this pattern is structured with the synchronic and relational existence of elements belonging to all five imageability categories. This theory regarding the five basic urban element categories has been widely accepted and used by much urban research since (Al-Kodmany, 2001; Charles & Sorenson, 1985; Ökesli & Gürçınar, 2001).

There is an apparent distinction between architectural and urban spaces. First of all, cities are extensive in scale and can be perceived in more extended periods than buildings. Architectural spaces have continuous boundaries separating the inner space from the outer space and significant entrance points that transmit the user between them. On the other hand, urban areas have more porous boundaries defining an edge by combining multiple elements and several transition points serving as entrance points. Therefore, individuals always started to experience a building/a floor from its entrance point and move on to its other units. This movement is directed by and limited to the topological relations of the indoor spatial system, basically the adjacency and range of each unit. Despite these apparent differences, both cities and architectural objects are constructions in space (Lynch, 1960); therefore, architectural spaces can also be evaluated within imageability theory. Following that, Hunt (1985) argued the imageability of buildings and suggested a learning strategy that can enhance that, even in existing buildings. Danielsson (2005), on the other hand, argued for imageability in office environments to understand how employees perceive and use their office from a psychological perspective. Sachs (1999) also implemented Lynch's element categories to a school campus and defined the café and small theatre as landmarks and repetitious elements (like classrooms and family suites) as routes. Similarly, Lacanna et al. (2019) focused the design elements on a hospital layout and categorized corridors as paths, health zones as districts, zone boundaries as edges, intersection of paths as nodes, and architectonical/artistic elements as landmarks. Finally, Akan (2017) searched the effect of spatial configuration on participants' behavior and cognition in elderly institutions and categorized rooms as zones, commonly used spaces as landmarks, and corridors as roads.

Moreover, imageability categories are all strongly related to the spatial configuration of the city besides their visual qualities (Lynch, 1960; Charles & Sorenson, 1985; Todor et al., 2022; Abeynayake, 2022), which leads to an intersection between imageability and space syntax theories.

Imageability, cognitive maps and space syntax

Space syntax is a social space theory based on the configuration concept (Hillier, 2007). It divides spaces into two-dimensional units (convex space, axial line, isovist) and provides numerical equivalents of various relations between them. This enables the systematic evaluation of a configurational system or comparison of different systems with different scales and geometries via their configurational characteristics (Turner et al., 2001). In convex map and axial map analysis, the configuration can be transformed into "justified graphs" in which every unit is represented by a node, every connection between two nodes is represented by a line, and all nodes are organized relative to the defined root node (Bafna, 2003). Here, each connection between two nodes is regarded as a unit of depth, the primary measure of space syntax. The least number of connections between two nodes is the depth of one according to the other, and the number of connections of a node from a root node is its depth value in the configurational system. The sum of the depth values of each unit relative to the root node in a justified graph is the total depth value of the layout according to its defined root node (Hillier, 2007). The mean depth value is calculated by dividing the total depth value to the total number of nodes in the configurational system (Peponis & Wineman, 2002). This value represents the degree of accessibility of a layout independently of the number of nodes in it, and enables the accessibility values of different spatial systems, and therefore their syntactic structures, to be compared. Mean depth is inversely proportional to integration, the basic accessibility measure of space syntax. Therefore, a less integrated spatial system will have higher accessibility, while a more integrated system will have lower accessibility.

Dalton and Bafna (2003) have suggested that space syntax offers a sense of hierarchy to imageability elements, where paths could be regarded as axial lines, nodes as their intersections, and districts as intersecting paths with specific qualities. Research showed that landmarks are mostly located where they could be perceived from integrated paths with distinctive isovist areas (Dalton & Bafna, 2003; Güngör & Harman Aslan, 2020), streets with higher integration values are also significant paths in cognitive maps (Penn, 2003; Güngör & Harman Aslan, 2020), and the most significant nodes are usually located on the

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most integrated streets (Güngör & Harman Aslan, 2020), and have higher circularity values (Turner et al, 2001). Similarly, both the major landmarks, major nodes and paths of the city are mostly located at points with integration values well above the city average (Topcu et al., 2021).

Similar to imageability categories, some aspects of spatial cognition are implicit in space syntax as it investigates legibility, orientation, and wayfinding (Penn, 2003; Canakcioglu & Unlu, 2025). For instance, Long (2008) questioned the relationship between imageability categories and their configurational qualities. He correlated the frequency and accuracy of imageability elements drawn in cognitive maps with their syntactic values, and found a positive association between their cognitive representation and spatial configuration (global integration, local integration, and connectivity) values. Within the close period, some other research evaluated a different perspective and compared sketch maps' syntactic values and the spaces they represent. Kim and Penn (2004) and Zheng and Weimin (2011) implemented axial map analysis on cognitive maps and found that the configurational qualities of cognitive maps and the real environment are significantly similar. From a different perspective, Canakcioglu (2015) correlated the frequency of spaces in children's cognitive maps with their syntactic values and found a significant relationship between them.

The summarized literature shows that imageability and space syntax research's primary concerns are perception and cognition. However, both perception and cognition are cognitive operations that operate concurrently with and foster memory. From this perspective, literature on imageability also indicates that configurational and visual qualities are primarily perceived, coded, and stored in memory as they are significant aspects of cognitive maps. In addition, space syntax literature presents that, besides the imageability approach, it can also be regarded as a relatively new and effective tool for analyzing memory through cognitive maps. However, the literature does not provide evaluations that discuss how memory is affected by environmental factors despite the appropriate tools that have been generated within research. On the side, the memory literature strictly focuses on the participants' minds and does not concern the effects of the environmental elements or qualities on what is recalled or unrecalled. The lack of perspective across multiple fields has resulted in the absence of an approach examining the environment's effects on memory.

This study intends to bridge this apparent gap by combining previously presented tools and theories and to propose a new systematical method for memory researchers. Focusing on architectural scale, two primary research questions were specified: (1) "What makes an architectural space memorable among all its multiple components/characteristics?" and (2) "Can we reveal any spatial characteristic's effect on memory quantitively?". To address these inquiries, this study aims to systematically investigate the effect of specific qualities of an environment on human memory, and with a new approach, a unique methodology that adapts space syntax and imageability research tools to cognitive map analysis is proposed.

CASE STUDY AND METHODOLOGY

A simple methodology inspired by cognitive map theory and space syntax tools is designed to search for the effect of specific visuospatial qualities of architectural spaces on memory. To be more precise, measures derived from space syntax and imageability analyses have been instrumentalized to search the effects of configurational and visual qualities of an environment on its recall in cognitive maps. On the other hand, human factors such as age, gender, emotion, and recalling process are purposely left out of the scope to focus on the spatial factors on memory more clearly, even though preliminary studies indicated a strong relationship between spatial memory and human factors (Chawla, 1992; Bauer et al., 2012; Tarcin Turgay & Unlu, 2017). In this frame, this section presents the case study's participants, selected environment, and the proposed methodology in detail, respectively.

Participants

The case study is conducted with adults who were educated in the building of İstanbul Male High School. An average of 150 students have graduated from İstanbul Male High School annually since 1936. To rule out recent graduates' advantage on recall, the bottom age value is specified as 23 (the college graduation age) (Rubin & Schulkind, 1997a; Rubin, 2000), and to rule out the disadvantage of elderliness the top age value is limited to 75 (Old & Naveh-Benjamin, 2008; Hasher & Zacks, 1979). Approximately 7950 graduates were found to be in the age range. The case study includes 77 participants between the ages of 23 and 75 (25F/52M; M= 46.35, SD:1.579), that corresponds to the %0.96 of this target population and presents a generic frame of adulthood.

Case Study Environment

Research asserted that past experiences are recalled more and better if they occurred recently (Piolino et al., 2002; Rubin & Schulkind, 1997a), repeatedly (Wagner, 2006; Evans et al., 1981; Schouela et al., 1980), or in a certain period of life (Rubin, 2000; Levine et al.,2002; Piolino et al., 2009; Conway & Pleydell-Pearce, 2000; Pillemer, 2001), such as personal milestones (Conway & Pleydell-Pearce, 2000), or personally important events (Conway & Pleydell-Pearce, 2000). The middle and high school buildings experienced during adolescence, which is a turning point in life and where many important personal events take place, stand out as one of the public spaces promoting all these memory advantages. Accordingly, Istanbul Fatih (Male) High School, a historic educational institution, is selected as the case study environment (Figure 1 and 2).

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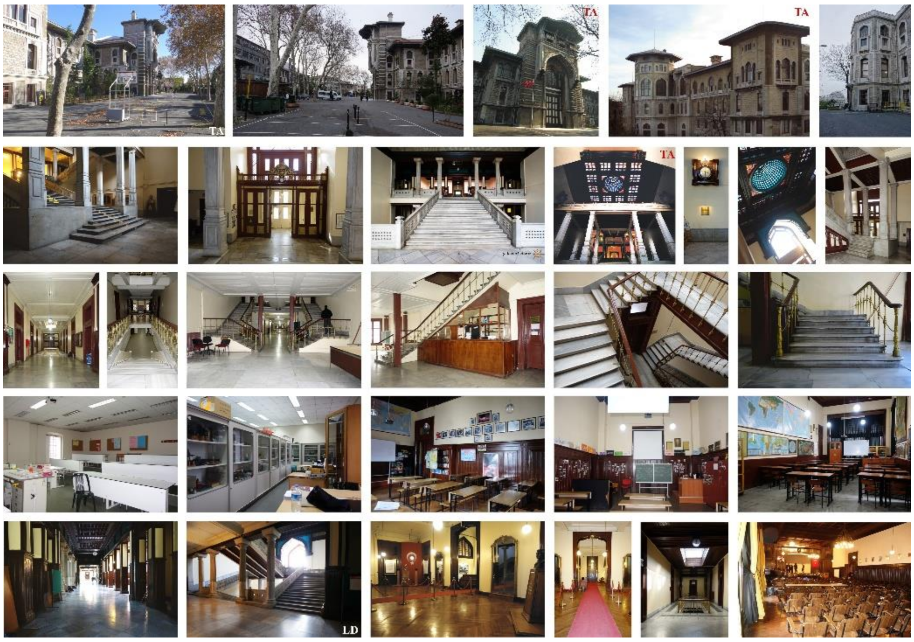

Figure 1. Visuals from the building (Photographs by the authors; Tansel Atasagun (TA) and Levent Deniz (LD).

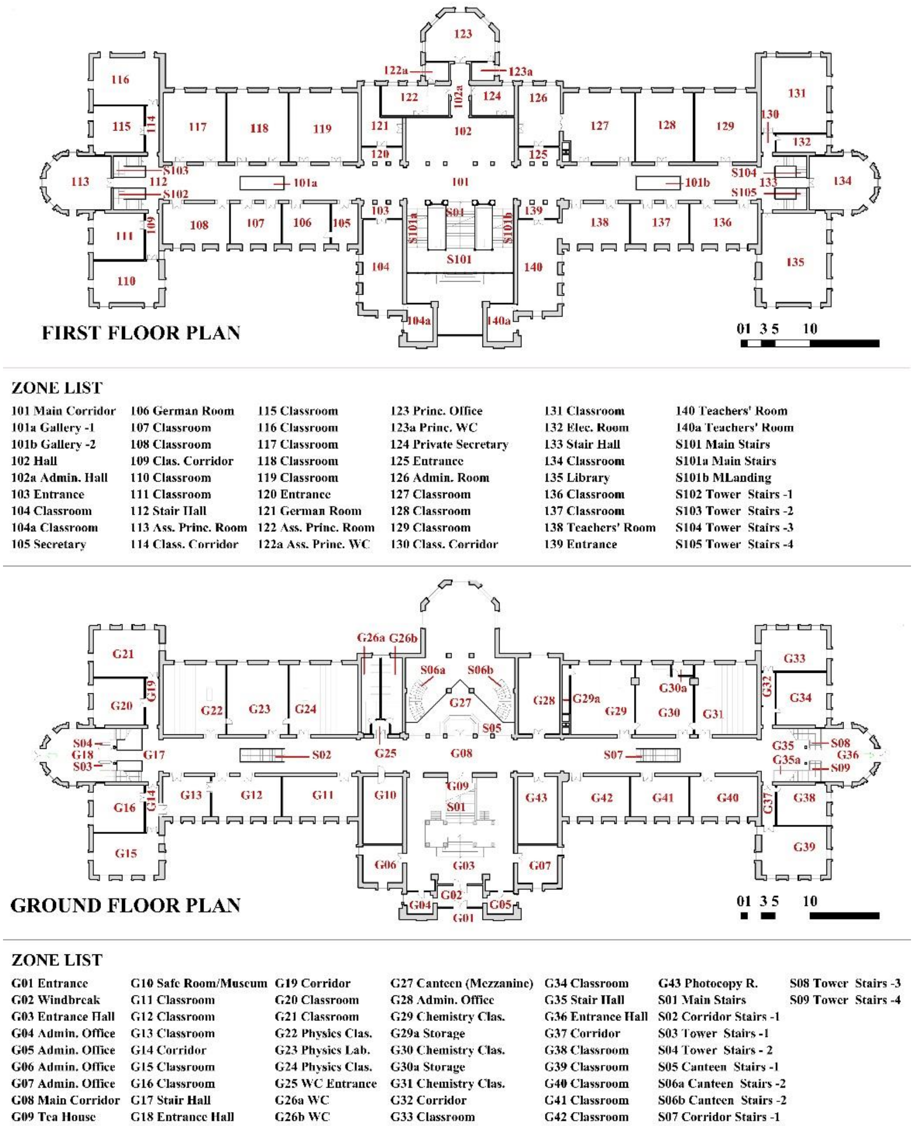

Figure 2. Plan drawings and zone lists, ground-floor and first-floor.

The building has a rectangular form of 24 meters to 106 meters, which expands to 48 meters to 120 meters with corner towers. Its symmetrical plan schema is defined by a main corridor parallel to the long edge of the building and two vast halls (entrance and main) that intersect with it at the center. There are classrooms, laboratories, wet cores, administrative rooms, and a conference hall lining up on both sides of the main corridor. The tower is used as a canteen on the ground-floor, administrative offices on the first-floor, and a lounge room on the second floor. At the two ends of the main corridor, there are stair halls on the ground-floor and octagonal classrooms on the first and second floors. Inside the four towers on the corners are two classrooms, an electrical room, and a library. There are two symmetrical gallery holes on the ground, first and second floors. The case study is conducted over the areas most used by students: the ground-floor and the first-floor (Figure 2).

Methodology

The procedure consists of four steps: (1) Generation of convex maps of each floor, (2) definition of configurational and visual measures via (2a) syntactic and (2b) imageability analysis of each floor, (3) data collection, (4) data generation and analysis according to the defined measures, and (5) statistical evaluation tests.

Step 1_Generating convex maps: Each floor plan schema is divided into convex spaces considering both the configuration and functional program of the building, regarding the fact that participants experience and give meaning to these spaces via both (Figure 3). In the following steps, each convex space is considered and expressed as a *node*.

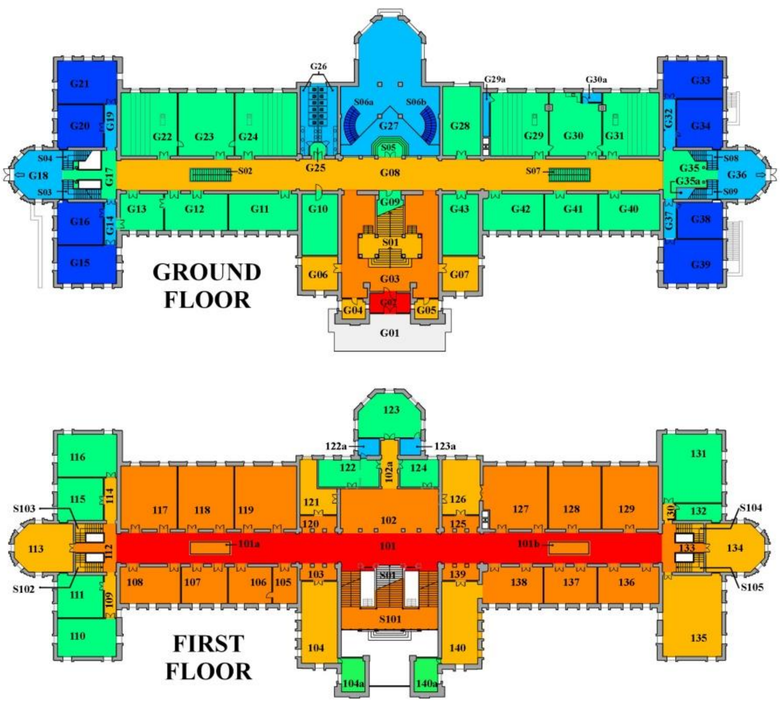

Figure 3. Convex maps presenting the convex space borders of each node (Colors are applied in accordance with Figure 4).

Step 2_Definition of measures: The configurational and visual measures are derived from two separate analysis.

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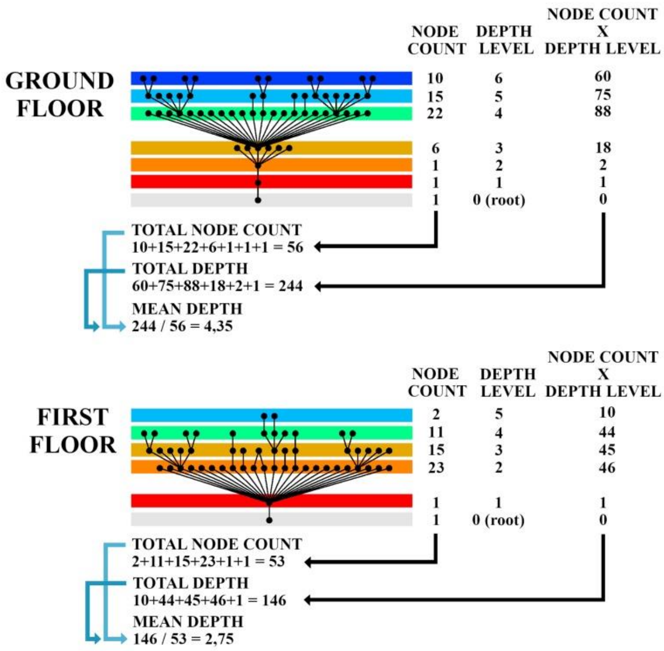
Step 2a_Generating configurational measures through syntactic analysis: Each floor's justified graphs are generated according to the convex maps. In these graphs every convex space is regarded as a syntactic node, and root nodes are identified as the entrances to the floor (G01 & S01). Then, each node's depth value is calculated as the number of connections between that node and the root node (Figure 4).



$$\text{TOTAL DEPTH} = \sum_{\substack{n=\text{number}\\ \text{of levels}}} \textit{node count on the level } x \textit{ depth value of the level}$$

$$\text{MEAN DEPTH} = \frac{\sum_{\substack{n=\text{number}\\ \text{of levels}}} \textit{node count on the depth level } x \textit{ depth value of the level}}{\textit{total node count}}$$

	NODE COUNT								SYNTACTIC VALUES	
	Root	Depth 1	Depth 2	Depth 3	Depth 4	Depth 5	Depth 6	Total	Total Depth	Mean Depth
Ground Floor	1	1	1	6	22	15	10	56	244	4,35
First Floor	1	1	23	15	11	2	-	53	146	2,75
Total	2	2	24	21	33	17	10	109	-	-

Figure 4. Justified Graphs presenting the syntactic analysis (Colors are applied in accordance with Figure 3). Syntactic formulas. Table presenting the distribution of node counts in each depth level, and syntactic values for both floors.

According to the justified graphs the ground-floor has six depth levels and 56 nodes, and the first-floor has five depth levels and 53 nodes (Figure 4). Both floors have only one node on the second depth level. However, most of these nodes belong to the fourth and fifth depth levels on the ground-floor, and the second and third depth levels on the first-floor (Figure 4). This is mainly due to the windbreak and the main hall in the ground-floor entrance that moved the ground-floor main corridor from the first depth level to the third, forming a deeper system. Two floors present two significantly different syntactic systems despite their node counts and depth levels being close to each other. Accordingly, first-floor's total depth and mean depth values (146; 2,75) are significantly lower than the ground-floor's (244; 4,35). This proves that the ground-floor has a less accessible, less integrated, and consequently more complex configurational system than the first-floor.

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Step 2b_Generating visual measures through imageability analysis: Every node's imageability category is defined according to Lynch's classification. In addition to the nodes, 8 edges are defined for the ground-floor (long edges of the main corridor, the canteen's outer wall, walls that frame the three exit doors, the boundaries of the main hall, and the facade line of the whole floor) and 6 edges are defined for the first-floor (long edges of the main corridor, short edges of the main corridor, boundaries of the main hall and façade line of the whole floor). Table 1 presents how the categories are introduced to architectural scale via the visual, spatial, figural, formal and functional qualities. Figure 5 shows each node's and element's category on the floor plans. According to the analysis, there are 23 paths, 66 districts, 9 nodes, and 11 landmarks in total, and their distribution is quite similar for both floors (Figure 5).

Table 1. Adaptation of imageability categories to the case study space (Photographs by the authors; Tansel Atasagun (TA) and Levent Deniz (LD))

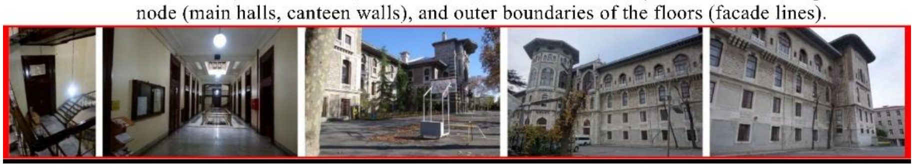
Paths: The horizontal and vertical circulation axes, corridors, and stairs.

Districts: Spatial units/areas that are enclosed with walls and have a significant identity defined by its function, as classroom, laboratory, canteen, toilet, storage, administrative room, assistant principle room, tea house, entrance hall, teachers' room, entrances.

Nodes: Spatial units/areas that are strategic as an entrance/exit to the building, as a crossing of paths, or with their significant function and visual character: halls, canteen, octagonal entrance halls, library, octagonal classrooms.

Landmarks: Spatial elements that serve as reference points have unique visual characteristics - depending on their shape, scale, material, and color- and are visible from many distances: main stairs, canteen stairs, corridor stairs, windbreak, museum, photocopy room and galleries.

Edges: The wall lines that define long planar borders (corridor walls), endings for a continuous movement (corridor walls, corridor ends, entrance hall walls), boundaries of a significant node (main halls, canteen walls), and outer boundaries of the floors (facade lines).



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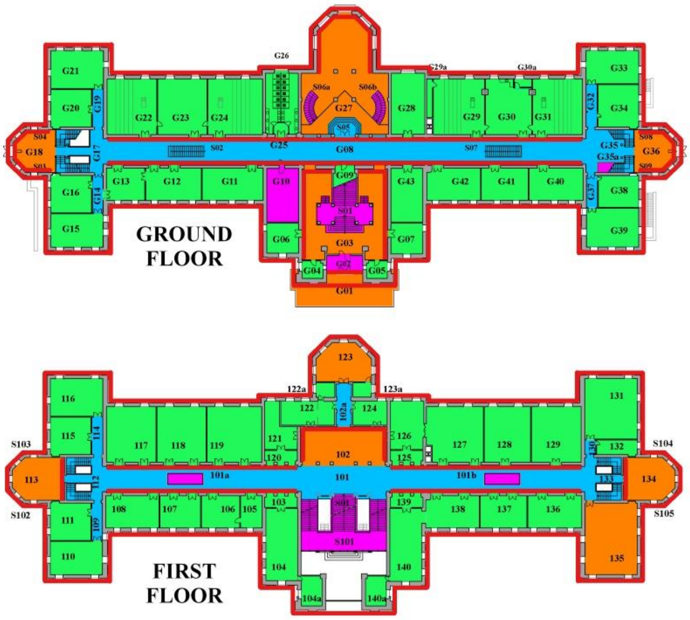

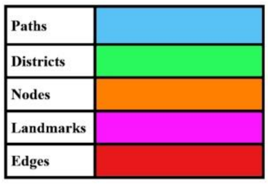

	Ground Floor	First Floor	Total
Paths	12	11	**23**
Districts	32	34	**66**
Nodes	4+1(G01)	4	**9**
Landmarks	7	3+1(S01)	**11**
Edges	8	6	**14**
Total	**63**	**58**	**123**

Figure 5. Convex maps presenting the imageability category of each convex space. Table presenting distribution of convex space counts in each category.

Step 3_Data collection: The participants were asked to 'draw the plan schema of the ground-floor and the first-floor respectively, in a maximum of 10 minutes for each drawing' in face to face interviews (77+77=154 cognitive maps[1]). All cognitive maps presented different characteristics in their drawing techniques of spatial units (Figure 6).

[1] The term cognitive map is preferred depending on the scope's relation with cognitive theories.

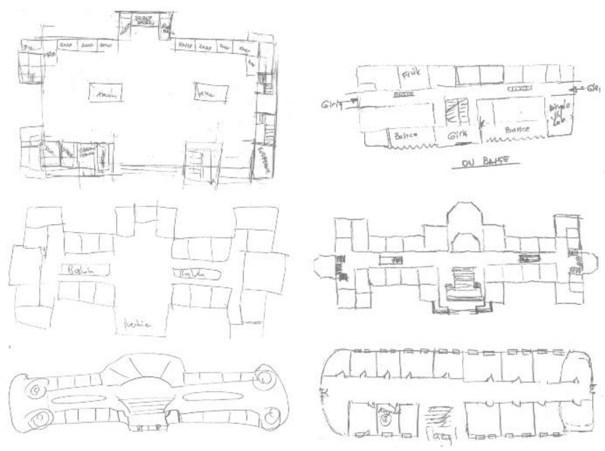

Figure 6. Sample Cognitive Maps (First-floor: F/34, M/41, M/29; Ground-floor: M/72, M/31, M/61)

Step 4_Data generation and analysis according to the defined measures: Due to the significant variation in the number of nodes/elements at each depth level and category in the real floor plans, nodes' appearance counts are not appropriate for a correct evaluation and comparison. To generate comparable numerical data, the appearance rate of each measure is derived from a data transformation process (Figures 4 and 5). The process is designed on the assumption that the appearance of each node in cognitive maps corresponds to the appearance of its depth value (Step 2a) and its imageability category (Step 2b). Accordingly, the appearance count of nodes and elements is regarded as the appearance count of syntactic depth levels and imageability categories over this correspondence. For instance, G02 windbreak was drawn by 17 participants, and this caused the appearance counts of the second depth level and the landmark category to increase by 17. Consequently, the appearance rate of each measure is derived as follows:

First of all, each cognitive map is analyzed through content analysis, and the appearance of each node and element in all cognitive maps is counted. Based on those counts, **the appearance count** of **(a) each depth level** is derived from *the sum of the appearance count of nodes on that level*, and **(b) each imageability category** is derived from *the sum of the appearance count of nodes/elements on that category* (Figure 7). Secondly, the **maximum potential appearance count** in the condition where each node or element is drawn by all participants is calculated by *multiplying the total number of participants by the total number of (a) nodes on the same depth level and (b) nodes/elements in the same category*. Finally, the **appearance rate** of each depth level and each imageability category are calculated by *dividing the appearance count to their maximum potential appearance count.*

CALCULATIONS ON CONFIGURATIONAL MEASURES
(FOR EACH DEPTH LEVEL)

$$\boldsymbol{appearance\ count} = \sum_{n=77} \begin{matrix} appearance\ count\ of\ nodes\ on\ the\ same\ depth\ level \\ in\ a\ cognitive\ map \end{matrix}$$

$$\boldsymbol{maximum\ potential\ appearance\ count}$$
$$= count\ of\ nodes\ on\ the\ same\ depth\ level\ in\ the\ floor\ plan\ \boldsymbol{X}\ count\ of\ participants$$

$$\boldsymbol{appearence\ rate} = \frac{appearance\ count}{maximum\ potential\ appearane\ count}$$

CALCULATIONS ON VISUAL MEASURES
(FOR EACH IMAGEABILITY CATEGORY)

$$\boldsymbol{appearance\ count} = \sum_{n=77} \begin{matrix} appearance\ count\ of\ nodes\ and\ elements \\ in\ the\ same\ category \\ in\ a\ cognitive\ map \end{matrix}$$

$$\boldsymbol{maximum\ potential\ appearance\ count}$$
$$= count\ of\ nodes\ and\ elements\ in\ the\ same\ category\ in\ the\ floor\ plan\ \boldsymbol{X}\ count\ of\ participants$$

$$\boldsymbol{appearence\ rate} = \frac{appearance\ count}{maximum\ potential\ appearane\ count}$$

Figure 7. Formulas for calculating appearance rate of depth levels and imageability categories

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Step 5_Statistical evaluation tests: The relation between the configurational characteristics and spatial memory is searched statistically via a correlation test between the nodes' depth values and appearance rates. In addition, the relation between visual characteristics and spatial memory is evaluated via One-Way ANOVA test between imageability categories and their appearance rates (Figure 8).

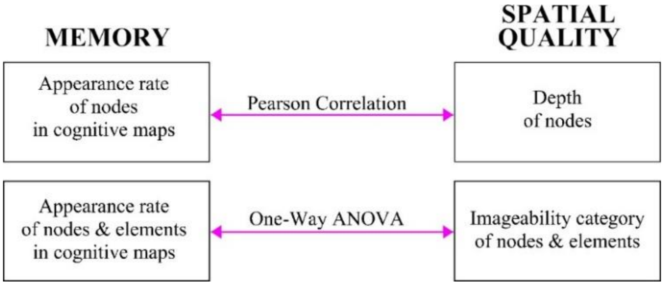

Figure 8. The correlations searching the relation of spatial memory to configurational and visual characteristics of nodes and elements.

FINDINGS AND RESULTS

The case study is conducted with 154 (77 ground-floor + 77 first-floor) cognitive maps. Four problematic areas that arose from expectable conflicts, such as human factors (age), spatial factors (the difference between floor schemas, building renovations, and space functions), and the study procedure are confirmed and evaluated as follows:

1. The first-floor is recalled more accurately than the ground-floor. This is interpreted over two factors. Firstly, the procedure in which the participants drew the ground-floor in the first order (a) raised the length of the recalling period of the first-floor and (b) enabled all participants to use the ground-floor map as a base in mind for the first-floor map. Current research indicates that replaying first-floor plan memory through thinking during the ground-floor plan drawing may lead to more accurate first-floor cognitive maps (Nelson, 1993; Nelson & Fivush, 2004; Piolino et al., 2009). Secondly, the entrance spaces on the ground-floor caused that floor to have a more complex configurational system than the first-floor. Based on previous research it is interpreted that the higher level of complexity of the ground-floor has led to the construction of more distorted cognitive maps that are likely to be less effective and less legible due to their lower compatibility with the actual layout (Moeser,1988; Wang et al., 2019; O'Neill, 1991).
2. 13 participants partially confused the ground-floor with the first basement floor, and 26 participants draw corridor and two classrooms on the second-floor instead of the library on the first-floor. Compatible with current research indicating memories can be transformed, thwarted, or replaced through various leads (Nelson, 1993; Goldstein, 2013) or human factors (Rubin et al., 1999; Levine et al., 2002; Grysman & Hudson, 2013; Smith & Kosslyn, 2014) these confusions are regarded as recall deficits at the target floor plan. Based on that, the first basement floor spaces represented (via naming) on the ground-floor, and the three extra spaces (a corridor

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and two classrooms) represented instead of library are ignored and left out of the data.

3. 18 participants drew two classrooms, G38 and G39, as one space representing their common functional feature (biology lab, geography lab). The unrepresented spaces (with lines or writing) are regarded as a recall deficit and not included in the data.
4. Some participants represented laboratory G23 and classrooms G22 and G24 on its sides as one space. Similarly, some participants represented laboratory G30 and classrooms G29 and G31 on its sides as one space. These are regarded as a recall deficit and the three spaces are acknowledged as one total space in the data.

The most and the least represented nodes in cognitive maps are strong factors over the results. The most represented nodes are the first-floor corridor 101 by 77 participants, the ground-floor corridor G08 by 76 participants, the main hall G03 by 76 participants, and the classrooms 108, 117, 129 at the end of the first-floor corridor by 72/73 participants. In contrast, the upper canteen stairs, S05, and the additional entrance halls in front of the classrooms/toilets, G25, 103, 120, 125, 139, are the least represented ones (less than 4 participants), followed by the tea house, G09, represented by 10 participants. On the side, the private toilets, 122a, 123a; and classroom storages, 104a, 140a, G29a, G30a, were not represented in any cognitive map (See Figure 2 for the node locations).

Analysis on configurational characteristics

107 nodes are evaluated in total, and the root nodes of both floors are left out of the data. Nodes 122a, 123a, G29a, G30a at the fifth depth level, and nodes 104a and 140a at the fourth depth level had not appeared in any cognitive map. The most appeared nodes were G02 (AC[(2)]: 17) and 101 (AC: 77) for the first depth level; G03 (AC: 76), 117 (AC: 73) , 108 (AC: 72), 129 (AC: 72) for the second depth level; G08 (AC: 76) and S01 (AC: 62) for the third depth level; 123 (AC: 69) and 122 (AC: 62) for the fourth depth level; G27 (AC: 61), G36 (AC: 56) and G18 (AC: 53) for the fifth depth level and G33 (AC: 47) for the sixth depth level.

The appearance rate of depth levels in ground-floor cognitive maps did not change respectively between the levels (Figure 9, Table 2). The highest appearance rate of the second depth level is %98,70 due to the recall count of G02. It is followed by the third depth level with %52,16, the fourth depth level with %47,34, the sixth depth level with %43,12, and the fifth with %40,17. Finally, G01, the only node at the first depth level on the ground-floor, was recalled only by %22,08 of the participants.

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Table 2. Configurational data

	Depth Value	Count On Layout	Appearance Count	Maximum Potential Appearance Count	Appearance Rate
Ground- floor	1	1	17	77	**22,08**
	2	1	76	77	**98,70**
	3	6	241	462	**52,16**
	4	22	802	1694	**47,34**
	5	15	464	1155	**40,17**
	6	10	332	770	**43,12**
First-floor	1	1	77	77	**100,0**
	2	23	1053	1771	**59,46**
	3	15	658	1155	**56,97**
	4	11	455	847	**53,72**
	5	2	0	154	**0,0**
Ground-floor + First-floor	1	2	94	154	**61,04**
	2	24	1129	1848	**61,09**
	3	21	899	1617	**55,60**
	4	33	1257	2541	**49,47**
	5	17	464	1309	**35,45**
	6	10	332	770	**43,12**

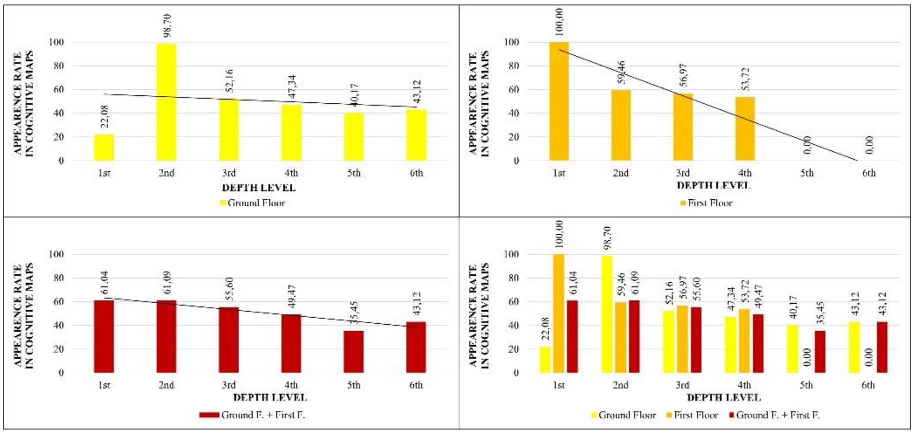

Figure 9. Appearance rate distribution graphic of depth levels.

On the other hand, the appearance rate of nodes on the first-floor declines respectively from the first depth level to the fifth depth level (Figure 8, Table 2). The main corridor 101 at the first depth level was recalled by all participants (%100). Following that, the appearance rate of the nodes at the second depth level is %59,46, the third depth level is %56,97, and the fourth depth level is %53,72. Neither of the participants recalled the two nodes at the fifth depth level.

When the two floors are evaluated together, a fairly regular decrease is observed from the first depth level to the fifth depth level. Nodes at the first two depth levels showed nearly equal appearance rates, 61.04% and 61.09%, although they had pretty different counts in the actual layouts as 2 and 24 (Table 2). Following that, the appearance rate of nodes at the third depth level was 55.60%, and at the fourth depth level was 49.47%, the sixth depth level was 43.12%, and the fifth depth level was 35.45%.

This distribution indicates that the appearance rates of nodes may decrease as the depth level increases, but this change is not linear and shows fluctuations between the two floors (Figure 8). This was investigated with Pearson Correlation tests between the appearance rate of nodes on a depth level and their defined depth value from the justified graph in Step 2 (Table 3).

Table 3. Pearson correlation between the appearance rate and depth value of nodes

Correlation (Pearson)	**Depth level – Appearance Rate** The appearance rate of each node in cognitive maps	
Ground-floor cognitive maps	r = - 0,149	p = 0,278 > 0,05
First-floor cognitive maps	**r = - 0,304**	**p = 0,028 < 0,05**
Both floors cognitive maps	**r = - 0,292**	**p = 0,002 < 0,05**

As shown in Table 3, the ground-floor correlation test presents an insignificant (p = 0, 278) low correlation (r = -0,149) between the depth values and appearance rates of nodes. On the other hand, the first-floor correlation test presents a medium correlation (r = -0,351) that is significant (p = 0,028) in the 0,05 level. However, the integrated analysis of both floor's data shows that the nodes' appearance rate and depth value have a significant (p = 0, 002) low correlation (r = -0,292) in a negative direction. The significant results indicate that the appearance rate of a node in cognitive maps decreases as the depth of that node increases.

Analysis on visual characteristics

The relationship between the appearance of defined nodes and elements (edges) in cognitive maps and their imageability categories are searched with 121 items (Figure 10, Table 4). The most represented **nodes** were G03 (AC: 76), G18 (AC: 56), G36 (AC: 53), G27 (AC: 61) in ground-floor cognitive maps, and 102 (AC: 58), 113 (AC: 49), 134 (AC: 48) and 135 (AC: 35) in first-floor cognitive maps. The most represented **paths** are G08 (AC: 76) for ground-floor, and 101 (AC: 77) for first-floor. The most represented **edges** are the main corridor walls on the ground-floor (AC: 72), the first-floor (AC: 73), and the main hall walls (AC: 57, AC: 59). Six **districts**, G29a and G30a on the ground-floor, and 104a, 140a, 122a and 123a on the first-floor were not drawn by any participants. On the side, most represented **districts** are 108 (AC: 73), 117 (AC: 73), 129 (AC: 72), 123 (AC: 69), 128 (AC: 68), 136 (AC: 67), 107 (AC: 65), 118 (AC: 64) and 137 (AC: 64) on the first-floor. All of the **landmarks** were represented by less than forty participants in the cognitive maps, except the most represented main stairs S01 (AC: 62) and gallery stairs S07 (AC: 45) and S02 (AC: 46) on the ground-floor.

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Table 4. Visual data

	Imageability Category	Count On Layout	Appearance Count	Maximum Potential Appearance Count	Appearance Rate
Ground-floor	Paths	12	414	924	**44,81**
	Districts	32	1059	2464	**42,98**
	Nodes	4	246	308	**79,87**
	Landmarks	7	213	539	**39,52**
	Edges	8	432	616	**70,13**
First-floor	Paths	11	579	847	**68,36**
	Districts	43	1372	3311	**41,44**
	Nodes	4	190	308	**61,69**
	Landmarks	3	102	231	**44,16**
	Edges	6	350	462	**75,76**
Ground-floor + First-floor	Paths	23	993	1771	**56,07**
	Districts	75	2431	5775	**42,10**
	Nodes	8	436	616	**70,78**
	Landmarks	10	315	770	**40,91**
	Edges	14	782	1078	**72,54**

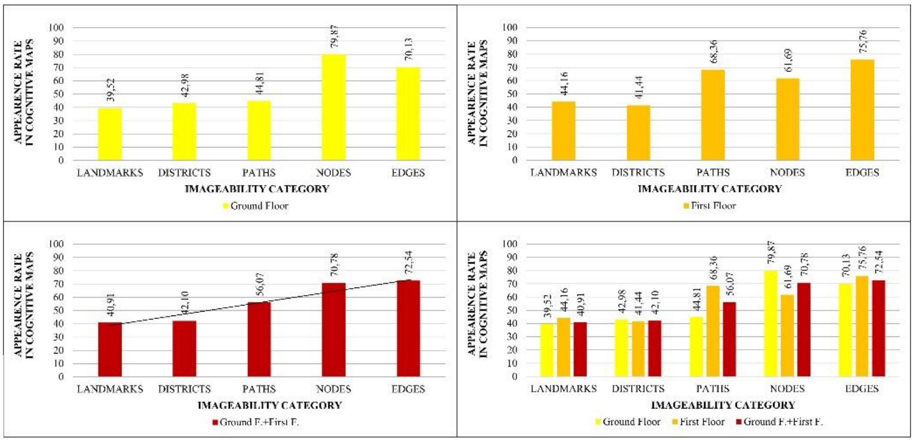

Figure 10. Appearance rate distribution graphic of imageability elements

The highest appearance rates are found for nodes (%79,87) and edges (%70,13) categories on the ground-floor, whereas paths (%44,81), districts (%42,98), and landmarks (%39,52) categories have the lowest rates in order (Table 4). Different from that, edges (%75,76) and paths (%68,36) categories have the highest appearance rates on the first-floor, followed by nodes (%61,69), landmarks (%44,16), and districts (%41,44) categories.

As both floors are evaluated together, **nodes** have the highest appearance rate as%70,78. Although **edges** have one common element (main corridors) with paths, their appearance rate is %72,54, which is much higher than the appearance rate of **paths**, %56,07. The districts' appearance rate is %42,10, whereas the landmarks' appearance rate is the lowest, %40,91. This gradation of the appearance rates is more similar to the ground-floor and the most recalled categories are edges, nodes, paths, districts, and landmarks, respectively (Table 4).

Even showing basic similarities, the distribution of appearance rates are different for each floor and their combination. One-Way ANOVA and post-hoc evaluation tests are applied to evaluate these differences and to specify which categories define the significant changes (Table 5, 6 and 7).

The mean appearance rates of imageability categories on the ground-floor changed between 30,42 and 61,50, and has shown a significant relation (F=4,387; p=0,002) (Table 5). The post-hoc test (Tukey) proved that the significant relations are between **nodes and districts (p=0,019), nodes and landmarks (p=0,036), edges and districts (p=0,021).**

Table 5. Statistical tests between the appearance rate and imageability categories, ground-floor

One-WAY ANOVA	Imageability Categories – Appearance Rate Ground-floor The appearance rate of each node & element in cognitive maps				
Imageability Category	**Node&Element Count (N)**	**Mean**	**Min.**	**Max.**	**Significance**
Paths	12	**34,50**	4	76	
Edges	8	**54,00**	31	72	df =62
Districts	32	**33,09**	0	60	F=4,913
Nodes	4	**61,50**	53	76	**p=0,002 < 0,05**
Landmarks	7	**30,42**	4	62	
Total	63	**37,52**	0	76	
POST-HOC (Tukey)	**Between Imageability Categories**				
Imageability Category	**Imageability Category**				**Significance**
Landmarks	Edges				**p=0,049**
Landmarks	Paths				**p=0,044**

The difference between the mean appearance rates of imageability categories of the first-floor change between quite close values (34 and 58,33) (Table 6). The ANOVA test presents an insignificant change between all categories (F=1,517; p=0,210), even though, the post-hoc test (Games-Howell) proved significant relation between **landmarks and paths (p=0,044), and landmarks and edges (p=0,049).**

Table 6. Statistical tests between the appearance rate and imageability categories, first-floor

One-WAY ANOVA	Imageability Categories – Appearance Rate First-floor The appearance rate of each node & element in cognitive maps				
Imageability Category	**Node&Element Count (N)**	**Mean**	**Min.**	**Max.**	**Significance**
Paths	11	**52,64**	43	77	
Edges	6	**58,33**	35	73	df =57
Districts	34	**40,35**	0	73	F=1,517
Nodes	4	**47,50**	35	58	p=0,210 > 0,05
Landmarks	3	**34,00**	27	38	
Total	58	**44,70**	0	77	
POST-HOC (Games-Howell)	**Between Imageability Categories**				
Imageability Category	**Imageability Category**				**Significance**
Landmarks	Nodes				**p=0,036**
Districts	Nodes				**p=0,019**
Districts	Landmarks				**p=0,021**

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In the integrated analysis of both floors, edges and nodes have significantly high minimum appearance counts, whereas landmarks have the lowest minimum appearance count and districts did not even appear in two cognitive maps (Table 7). Likewise, the maximum appearance rate for most paths, nodes, and edges is over %90, whereas it is around %78 for landmarks and districts. The difference between the closest mean values decreases with a pretty linear change and indicates a consistency. ANOVA tests presented a significant relation between the imageability categories and their appearance rate in cognitive maps (F=4,387; p=0,002) (Table 7), and post-hoc (Tukey) proved that the significant relations are between **edges and landmarks (p=0,011), and edges and districts (p=0,026).**

Table 7. Statistical tests between the appearance rate and imageability categories, combination of both floors

One-WAY ANOVA	**Imageability Categories – Appearance Rate** **Ground-floor and First-floor (combined)** The appearance rate of each node & element in cognitive maps				
Imageability Category	**Node&Element Count (N)**	**Mean**	**Min.**	**Max.**	**Significance**
Paths	23	**43,17**	4	77	
Edges	14	**55,86**	31	73	df =120
Districts	66	**36,83**	0	73	F=4,387
Nodes	8	**54,50**	35	76	**p=0,002 < 0,05**
Landmarks	10	**31,50**	4	62	
Total	121	**40,97**	0	77	

POST-HOC (Tukey)	**Between Imageability Categories**	
Imageability Category	**Imageability Category**	**Significance**
Edges	Landmarks	**p=0,011**
Edges	Districts	**p=0,026**

These significant results (ground-floor and both floors combined) indicate that the significant difference on the recall of these elements is mainly based on the most recalled edges category and least recalled landmarks category that both present significant relations in each test group. The following effective category is districts that have significant relations with nodes and edges on the first-floor, and with edges for the combination of both floors. The relation between nodes and districts and landmarks is also significant for the first-floor, still these relations are not enough to present a significant result between all categories on that floor. Paths, on the other hand, only have a significant relation with landmarks on the ground floor.

DISCUSSION

The results proved that architectural spaces' configurational and visual characteristics are significant factors on whether they are stored in cognitive maps.

To begin with, the outcome of the syntactic analysis proved a significant negative correlation between the depth and recall of architectural spaces: the recall rate of a space decreases as the depth level of that space in the configurational system increases. In this frame, the difference between two floors is evaluated via the first problematic area regarding the first-floor's longer recalling period with a base map (Nelson, 1993; Nelson & Fivush, 2004; Piolino et al., 2009), and its less complex and less deep configurational system (Moeser,1988; Wang et al., 2019; O'Neill, 1991). The significant result for both floors indicates that first-floor data is the main factor that leads to that result, and the ground-floor data enhanced that correlation despite having a clearly different node count distribution and no significant result. Moreover, the classrooms inside the corner towers are less represented in cognitive maps than the classrooms along the corridors, whereas the closed/authorized spatial units (the storage rooms and private toilets) were not represented in any of the cognitive maps. The entrance point of the floor is the starting point of the spatial experience in the building, whereas the least represented spaces are located apart from entrance areas and main circulation axes. This evidently presents that the spatial units far from the floor's entrance are recalled less, and spatial units close to the floor's entrance are recalled more by the participants. That could be evaluated from two different viewpoints: (1) the quantity of the experience and (2) the course of the experience.

For the quantity of experience, the spaces at the deeper points of a configurational system are bodily or visually less experienced during the daily routine, and based on that lack of experience, they are recalled less by participants. For the course of the experience, the spaces encountered at the beginning of a spatial experience are recalled more, and the spaces encountered later on are recalled less by participants. Both of these viewpoints prove that the storing of a space in cognitive maps is affected by (1) the distance of its location from the starting point of experience, that is, the entrance point of the layout, and accordingly, (2) how much it is experienced behaviorally and visually compared to other units (Wagner, 2006; Evans et al., 1981; Schouela et al., 1980). These evaluations prove that human cognitive maps have a syntactic structure, and the components distant from the central movement axes, focal points and entrances are more loosely connected to it.

On the side, the second analysis results proved that visual qualities are significant factors on the recall of spaces. The edges and nodes in an architectural layout are the most represented categories in cognitive maps. This indicates that (1) spatial elements that define long planar borders and lead participants for a continuous movement or stop and (2) spaces that exhibit strategic entrance/exit/crossing points via their locations and form are primarily stored in cognitive maps. (3) Spaces that connect other spaces along movement axes (paths) and (4) closed spaces with particular visual characters (districts) are also stored in cognitive maps; however, their recall rates are at the midlevel. Nevertheless, landmarks are the least recalled elements, indicating that the reference points in the scale of objects or building elements are not primarily stored

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in cognitive maps despite their unique visual characteristics. Accordingly, in cognitive maps representing a building’s layout, the primary structural elements are the continuous bordering walls of corridors, long and wide corridors connecting to multiple spaces, the halls at their intersections and entrance halls, whereas the secondary structural elements are the differentiated spaces via their location and form. On the other hand, building elements (such as statutes, columns, and wall clocks) that serve as reference points via their strong visual characteristics are insignificant structural components. This contradicts Lynch's (1960) theory, asserting a legible spatial organization is structured with the synchronic and relational existence of all five types of elements. Furthermore, it indicates that building layouts' legibility differentiates from urban layouts' legibility by using the main borders, axes and areas as references rather than singular visually compelling elements.

In the same frame, the statistical tests proved that the recall rate of imageability categories on cognitive maps significantly differs from each other and the edges, landmarks and districts have the strongest effect on this difference. Districts have appeared to be the second strongest factor by presenting significant relations with both of these categories. On the other hand, nodes are the third factor regarding their relation to landmarks and districts (on the first-floor), and paths appeared to be in a middle position which does not differentiate from any other categories. The significant correlations between the recall of edges and the recall of districts and landmarks indicate that cognitive maps are formed with the combined effect of edges that are recalled most and districts and landmarks that are recalled least, and nodes and paths have relatively less impact on this process.

CONCLUSION

The environments we experience possess a multicomponent and multidimensional nature that cannot be simply understood and evaluated. Similarly, our memory is a complex, multicomponent system running multiple concurrent operations such as perception, cognition, and memory. The complex structures of both systems necessitate the establishment of a narrow and clear framework when examining their relationships. Therefore, this study's theoretical background is structured on the well-known cognitive map, imageability, and space syntax theories, and the field study is limited to architectural scale. In addition, in order to obtain systematic and arguable results, the field study is focused on the measurable spatial components (spatial units), and accordingly, the most basic spatial analysis tools that can be adapted to cognitive map analysis were preferred. The results proved that the configurational and visual characteristics of spaces determine the selective processes of memory by leading participants' spatial experience routines and perception via their configurational, visual and formal qualities.

Still, the complex structure of architectural spaces' requires these predictions to be tested with more comprehensive studies in various contexts. Based on this study's findings, it seems possible to conduct more advanced cognitive research on space-memory relations through cognitive maps, with more detailed categorizations of space and with various quantitative methods like space syntax. Moreover, many other visual qualities, such as the floor height, color, lighting, patterns, and symbolic forms; nonvisual qualities, such as smells, echoes, covering textures, and sloped floors, or even social characteristics should be investigated in innovative ways in terms of how they relate to memory.

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Resume

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