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THE IMPACT OF NAVIGATION STRATEGIES ON SPATIAL MEMORY FORMATION IN VIRTUAL ARCHITECTURAL SPACES

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ABSTRACT

This study investigates how navigation strategies in virtual environments affect spatial memory formation and environmental understanding. As navigation plays a fundamental role in how people experience and interpret space, especially in enclosed architectural spaces, exploring the cognitive processes behind movement and orientation remains crucial. However, the relationship between navigation strategy and spatial memory is still not fully understood, particularly in virtual contexts. This research examines how different navigation strategies influence spatial comprehension and how these behaviors contribute to our understanding of human decision-making and movement through built environments. Fifteen architecture students participated in a virtual reality experiment, navigating a multi-room space to locate specific objects using Meta Quest 2 headsets. Participants explored a 54.67m² space with six distinctive rooms, then drew floor plans from memory and answered questions about spatial features. Analysis of movement patterns, verbal descriptions, drawing accuracy, and spatial perception revealed distinct navigation preferences: participants using primarily allocentric (environment-referenced) strategies demonstrated 21.5% better drawing accuracy and more comprehensive spatial understanding, while those employing egocentric (self-referenced) strategies showed superior sequential memory but poorer global spatial comprehension. The study identified an optimal exploration time (5–8 minutes) balancing task completion with environmental awareness. Results indicate that virtual spaces should incorporate features supporting both navigation strategies, with broader exploration promoting a shift from egocentric to allocentric processing. These findings have significant implications for architectural education, virtual environment design, and spatial cognition research, offering valuable insight into human behavior and decision-making in indoor spatial settings.

Keywords: *spatial cognition, virtual reality, navigation strategies, architectural education, spatial memory, egocentric navigation, allocentric navigation*

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1. INTRODUCTION

Understanding how humans perceive, navigate, and mentally represent architectural space is central to both spatial cognition research and architectural design. Navigation depends primarily on two cognitive strategies: egocentric, which encodes spatial relations relative to the individual, and allocentric, which constructs object-to-object relationships in a global frame of reference [1]. These strategies form the foundation of how individuals interact with their surroundings, influencing not only movement through space but also memory formation, orientation, and design perception. They rely on distinct neural systems and lead to different outcomes in spatial memory and wayfinding [2], [3]. In architectural contexts, designers frequently shift between these perspectives, experiencing space from a first-person viewpoint while conceptualizing it in plan [4]. The capacity to navigate using both strategies is not only relevant to everyday users of architecture but is also integral to how students learn to design spatial environments [5]. This distinction is especially relevant in architectural education, where students must move fluidly between embodied experience and abstract spatial reasoning.

With the increasing use of Virtual Reality (VR) in architectural education and research, immersive environments now offer a valuable medium for studying spatial behavior. VR allows for controlled simulation of complex spatial layouts and enables precise tracking of movement and perception, offering insights that are difficult to obtain through traditional methods [6]. Moreover, recent studies have shown that VR environments can replicate spatial memory distortions and navigation strategies observed in real-world settings, making them suitable for empirical studies in design [7], [8]. The development of affordable, high-quality VR headsets like the Meta Quest 2 has democratized access to immersive spatial experiences, creating new opportunities for architectural education and research that were previously limited by technological constraints or cost barriers.

The study of spatial cognition in architecture has evolved significantly since Kevin Lynch's seminal work on urban imageability in the 1960s [9]. Initially focused on physical wayfinding elements, the field has expanded to incorporate cognitive psychology, neuroscience, and virtual environments as tools for understanding human-space interaction. With the emergence of environmental psychology in the 1980s and 1990s, researchers like Hillier and Hanson explored how spatial configuration influences movement patterns and social interactions [11]. The transition from physical to virtual architectural representations mirrors broader technological developments, with VR emerging as a particularly valuable medium for controlled spatial experiments [14]. This historical progression reflects a growing recognition that architecture not only shapes physical environments but also profoundly influences cognitive processes and spatial behavior.

While previous research has examined spatial cognition in virtual environments, significant gaps remain in understanding how navigation strategies affect memory formation, specifically in architectural education contexts [13]. Few studies have directly compared egocentric and allocentric navigation in controlled architectural spaces, particularly with participants who possess architectural training. Additionally, the relationship between exploration time and spatial memory accuracy remains inadequately explored in VR architectural settings. Most existing studies have focused either on general populations navigating simplified environments or on experienced architects using professional tools, with limited investigation of architecture students, who represent a unique population with developing spatial skills that bridge novice and expert capabilities.

The experimental design employing three distinct objects (a ball, a cube, and a stick) was deliberately chosen based on several theoretical and methodological considerations. First, this approach mirrors real-world wayfinding scenarios where individuals must locate specific landmarks while forming incidental spatial knowledge. Second, the three-object model allows for observation of repeated navigational patterns as participants return to the starting point multiple times. Third, the objects' distinct shapes and colors enable analysis of how visual salience influences memory formation. This triangular design builds upon previous studies in spatial cognition while introducing innovative elements specific to architectural education contexts.

This study investigates how navigation strategies in virtual spaces affect spatial memory formation and understanding of the space. Fifteen architecture students participated in a virtual reality experiment, navigating a multi-room space to locate specific objects using Meta Quest 2 headsets. Participants explored a 54.67 m² space with six distinctive rooms, then drew floor plans from memory and answered questions about spatial features, while their movement inside the virtual space was tracked. Analysis of movement patterns, written descriptions, drawing accuracy, and spatial perception revealed distinct navigation preferences: participants using primarily allocentric (environment-referenced) strategies demonstrated 21.5% better drawing accuracy and more comprehensive spatial understanding, while those employing egocentric (self-referenced) strategies showed superior sequential memory but poorer global spatial comprehension.

The study identified an optimal exploration time (5--8 minutes) balancing task completion with environmental awareness. These findings underscore the importance of designing virtual and physical spaces that support both navigation strategies and suggest that broader exploration may promote a shift from egocentric to allocentric processing. As such, this research offers actionable insights for architectural education, the design of immersive environments, and the broader field of spatial cognition. By better understanding how architecture students form spatial memories in virtual environments, educators can develop more effective teaching methodologies that leverage both navigation strategies, potentially enhancing students' ability to conceptualize and design complex architectural spaces.

1.1. EGOCENTRIC VS. ALLOCENTRIC SPATIAL STRATEGIES

Human navigation relies on two fundamental spatial reference frames: egocentric and allocentric. An egocentric strategy encodes spatial information relative to the self (e.g., "the door is to my left"), relying on one's body orientation, while allocentric strategies create a mental map independent of the observer's position, relating objects to one another (e.g., "the door is north of the table"). Both strategies work in tandem and shift depending on task demands, individual differences, and environmental cues [4]. This knowledge has practical applications for creating more intuitive wayfinding systems, designing more memorable and navigable spaces, and developing more effective educational methods for spatial reasoning—all essential components of successful architectural design.

This research directly examines these navigation strategies by analyzing how architecture students utilize egocentric and allocentric approaches when navigating virtual spaces, providing empirical evidence for how these fundamental cognitive processes manifest in controlled architectural spaces.

1.2. SPATIAL COGNITION AND ARCHITECTURAL DESIGN

Spatial cognition encompasses how humans perceive, understand, and remember spatial environments. In architecture, spatial cognition influences how users experience and navigate space. The concept of cognitive maps—internal mental representations of an environment—is central to spatial understanding. People often acquire spatial knowledge hierarchically: recognizing landmarks (egocentric), learning route sequences, and integrating them into a global survey representation (allocentric) [1, 4].

Kevin Lynch's notion of legibility emphasizes design elements that aid in cognitive mapping, such as landmarks, paths, and edges. Environments rich in distinguishable features help form mental images and improve navigation. By contrast, repetitive and symmetric designs often confuse [9].

By analyzing students' drawn floor plans and written descriptions, this study provides insights into how cognitive maps form in virtual architectural spaces, with particular attention to how distinctive elements, like colored walls and prominent architectural features, influence spatial memory and environmental understanding.

1.3. VIRTUAL REALITY IN ARCHITECTURE AND SPATIAL COGNITION RESEARCH

Virtual Reality (VR) allows architectural spaces to be studied experimentally. It offers immersive, controllable spaces to investigate navigation and perception. Researchers have demonstrated that VR elicits similar neural and behavioral responses as real environments, making it suitable for studying spatial cognition. VR helps simulate and analyze navigation behavior, such as egocentric vs. allocentric strategy use, memory formation, and landmark utilization. First-person VR perspectives often elicit egocentric strategies, while map-like perspectives promote allocentric processing. In architectural practice, VR aids students and professionals in evaluating spatial sequences, orientation, and user experience from a human-centered view [6].

Additionally, research by Zhang et al. highlights VR's potential beyond passive visualization, enabling users to "intuitively feel the full-size space" and experience furniture layouts with ergonomic dimensions. Their findings demonstrate that VR technology supports interactive engagement through features such as manipulating lights, opening doors, and freely picking up objects within the virtual space. This interactivity creates a "more comprehensive and refined experience" that helps avoid miscommunication between designers and owners, allowing users to modify design schemes and understand spatial relationships more effectively [16].

1.4. NAVIGATION STRATEGIES AND SPATIAL MEMORY IN VIRTUAL ENVIRONMENTS

Egocentric navigation forms sequence-based memory, effective in routine settings, but lacks flexibility. Allocentric strategies lead to cognitive maps that support flexible navigation, such as taking shortcuts or reorienting from new entry points. Experimental VR studies show users can shift strategies based on the environment structure and cues. Landmarks enhance egocentric memory; environmental geometry and spatial consistency support allocentric learning. Individual differences such as age and GPS reliance affect strategy choice. Pointing tasks, sketch maps, and route reproduction in VR reveal the type and robustness of spatial knowledge acquired. For example, landmark-deprived environments reduce allocentric performance, while distinct cues improve memory and orientation [1].

This study extends this research by examining not only which navigation strategies participants employ but also how these strategies correlate with spatial memory accuracy.

1.5. IMPLICATIONS FOR ARCHITECTURAL PRACTICE

Designing for both navigation strategies enhances usability. For egocentric support, designers should use distinctive features at decision points. For allocentric mapping, open layouts with visible connections and structural clarity help users form survey knowledge. Floor plan symmetry should be broken by unique design elements. Signage, visual hierarchy, and wayfinding devices reinforce memory. Testing designs through VR helps identify navigational bottlenecks and informs human-centric iterations. Inclusive design also benefits from this knowledge. Older adults and those with cognitive impairments often rely more on egocentric strategies; landmarks and familiar cues are vital. Architectural spaces can thus become more accessible and intuitive [1, 6].

2. RESEARCH CONTEXT AND METHODOLOGY

This study was conducted as part of an architectural education course exploring spatial cognition through digital models and virtual reality. The experiment was designed as a pilot study to investigate how focused attention on specific objects affects memory of the surrounding spatial environment and routes taken. This question has direct relevance to real-world scenarios, such as navigating an unfamiliar city with only landmark-based directions.

The experimental design deliberately withheld the primary research question from participants, who were simply instructed to find and collect three objects (a ball, a cube, and a stick) in the virtual environment. This approach allowed us to assess natural spatial encoding processes during goal-directed navigation rather than explicit memorization.

2.1. RESEARCH QUESTION

How does focusing on target elements in virtual space affect users' ability to remember and reproduce the route they traveled and the spatial elements they encountered along that path?

This central question addresses a fundamental aspect of spatial cognition: the relationship between selective attention (focusing on specific objects) and incidental spatial learning (the environmental information acquired during navigation). It mimics real-world scenarios where individuals navigate unfamiliar environments to locate specific targets while simultaneously forming mental maps of the larger space. Focusing on target elements in virtual space can have a mixed impact on users' ability to remember and reproduce the route they traveled and the spatial elements they encountered along that path. (02, 15) For this reason, the paper explores the potential factors that influence students' spatial memory. On one hand, focusing on **significant elements like targets or prominent landmarks** can **improve memory for those specific locations** and potentially help in **forming a mental map** of the environment. Landmarks, including targets, can serve as **key points in remembering the route and spatial layout** [02, 03]. According to the sources, people constantly look for places that will occupy their field of vision while walking, and **more noticeable objects and points of change** are more likely to be noticed [01, 08]. This suggests that focusing on targets with prominent features can **strengthen their representation in memory** [1]. Furthermore, **making decisions about the direction of**

movement towards targets during active exploration of a virtual environment significantly contributes to acquiring knowledge of topological relationships in space, which is the basis for understanding the route. Voluntary control and decision-making can also facilitate the memory of spatial locations of objects [2].

2.2. METHODOLOGY

This research was conducted as part of an elective course "Model in Architecture 2024/2025" at the Faculty of Architecture, as documented in the course materials. The study was designed as a pilot workshop to investigate spatial perception and navigation in virtual environments.

A pilot study approach was chosen to identify issues in research design and execution while gathering preliminary data on spatial cognition in virtual environments. The experimental design deliberately withheld the primary research question from participants to assess natural spatial encoding during goal-directed navigation rather than explicit memorization.

The experiment employed a triangulated method of data collection, combining movement tracking, spatial memory assessment (drawings and questionnaires), and post-experiment discussion. This multi-method approach allowed for comparison between participants' perceived spatial understanding and their actual navigation patterns.

Fifteen architecture students participated in the study. Participants were divided into two groups of eight students each (with one participant's data excluded from analysis due to incompleteness). All participants were in their third or fourth year of study and had prior experience with architectural design software. Although most students had limited direct exposure to virtual reality (VR) technology before the study, all underwent an introductory session using a basic VR layout developed in Unreal Engine. During this session, each student was guided and instructed on how to use the VR headset and controllers. Only after they reported feeling comfortable and competent using the equipment did they proceed to the experimental task. This preparatory phase ensured a consistent level of user familiarity across all participants.

A multi-room virtual environment was created, consisting of six distinct rooms with various architectural elements, including walls, columns, windows, and light sources. The total area of the virtual space was 54.67 m².

It is important to note that the realism of the virtual environment and the presence of relevant landmarks can influence how focusing on targets affects route memory [6]. Well-designed virtual spaces with clear and differentiated elements can make it easier for users to integrate information about targets with a more general understanding of the space [2, 10].

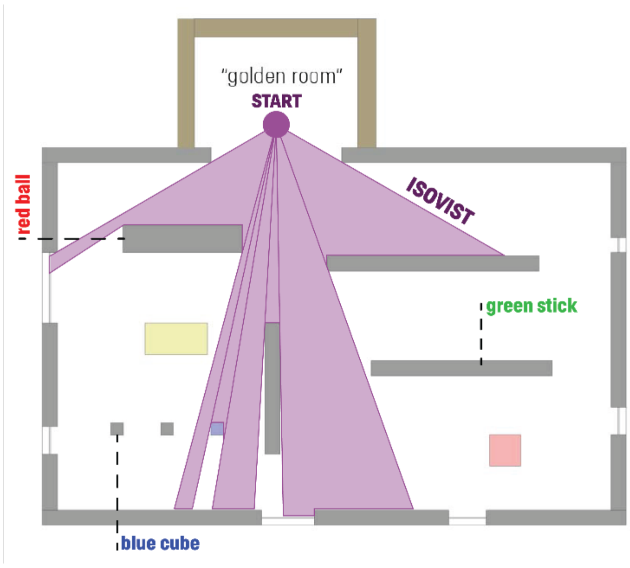

Figure 1. Virtual Environment Layout (floor plan showing the golden starting room and five additional rooms with their interconnections, walls, and columns), photo by authors

The virtual environment was carefully designed with specific research considerations in mind to align with the study's objectives. Visual control was achieved by designing the initial viewpoint using the concept of an *isovist*—the visible area from a specific vantage point—to regulate what participants could see at the beginning of the experiment [11, 12]. This ensured a standardized entry experience and controlled initial perception.

Strategic object placement was employed to encourage exploration of various areas, particularly corners and peripheral rooms that participants might otherwise overlook. Three distinct objects—the red ball, blue cube, and green stick—were positioned in separate rooms within the virtual environment. Each object featured a unique geometric shape and a saturated, contrasting color to enhance visibility and prevent perceptual confusion. Participants were required to locate each object one at a time and return to the starting point after each retrieval, thereby enforcing repeated navigation across the spatial layout. This design encouraged more thorough spatial engagement and helped elicit both route-based and survey-based memory strategies. The environment intentionally excluded doors to introduce spatial ambiguity, enabling observation of how participants organically segmented and interpreted room boundaries [6]. The setup drew from prior findings [2,14] indicating that tasks with multiple goals and repeated traversal support the formation of both egocentric and allocentric spatial representations. The selected parameters—object recall, navigation path accuracy, and room segmentation—were grounded in related research [15] emphasizing the role of environmental cues and experiential learning in spatial cognition.

Additionally, technical constraints, such as limiting participants to carrying only two objects at a time, were implemented not as limitations but as deliberate design choices. These constraints required multiple trips through the environment, increasing participants' exposure to different spatial zones and potentially enhancing spatial memory formation. Collectively, these design considerations enabled the researchers to investigate not only what participants remembered but also how environmental design influenced exploration patterns and the development of spatial understanding.

2.2.1. Procedure

Participants were equipped with Meta Quest 2 VR headsets and placed in a virtual environment. Each participant received a task to find specific geometric objects (red ball/cube, green stick, blue cube) within the space and return each object to the starting position after finding it. Participants had a maximum of 10 minutes to complete the task.

The specific instructions provided to students were to "find the following elements in the given space: red ball, green stick, blue cube," and "after finding each element, return it to the starting position".

Movement and navigation patterns were tracked throughout the experiment. Upon completion, participants were asked to:

- Draw a floor plan of the spatial structure from memory
- Answer a questionnaire about spatial features (area, room count, wall count, etc.)
- Describe in detail how they located each object

Figure 2. Students using VR equipment in the experiment room, photo by authors

2.2.2. Data Collection

The study employed a triangulated method of data collection to ensure comprehensiveness and validity:

Movement Tracking: Time spent in the virtual environment (ranging from 3:35 to 10:00 minutes) and detailed movement patterns were recorded through the VR software

Spatial Memory Assessment:

- Sketches of the environment drawn from memory
- Written questionnaire responses about spatial features (area, room count, wall count, etc.)
- Textual descriptions of navigation strategies and object locations

Post-Experiment Discussion: A group discussion was conducted following the experiment to gather qualitative insights about participants' experiences and strategies.

This triangulation approach allowed for comparison between participants' perceived routes (as described in text and drawn in sketches) and their actual movement patterns (as recorded by the tracking system), providing insights into the accuracy of spatial memory and the factors affecting it.

2.2.3. Analysis Methods

Data was analyzed through multiple complementary approaches to gain a comprehensive understanding of spatial perception and memory:

- Comparison of perceived versus actual spatial dimensions
- Analysis of drawing accuracy concerning navigation strategies
- Correlation between time spent and spatial perception accuracy
- Linguistic analysis of navigation descriptions (egocentric vs. allocentric references)
- Room visitation patterns and spatial memory accuracy

For the drawing analysis, a structured point-based evaluation system was implemented to assess various dimensions of spatial recall. The criteria included spatial proportion recognition, where students were evaluated on their ability to identify the general shape and proportions of the overall space, earning one point for correct identification. Wall placement and room structure were assessed through the accurate positioning of walls, access points, and room transitions, with one point awarded for correctly placing all four walls. Recognition of structural elements focused on the identification of columns, windows, and other architectural elements, with one point given for identifying all columns and partial credit awarded for incomplete recognition. Additionally, the analysis examined the influence of color and visual salience on recall, evaluating how colored elements affected spatial mapping. To identify potential cognitive discrepancies, the consistency between verbal descriptions and drawn representations was also assessed. For standardization, a “room” was defined as a space enclosed by at least three walls, ensuring uniform evaluation across all submissions. Based on this system, the drawings were categorized as “correct and proportionally accurate,” “partially accurate,” or “unusable.” Notably, only two out of fifteen submissions fell into the unusable category, indicating a generally high level of spatial recall among participants.

3. RESULTS

The following sections present an analysis of the collected data from the 15 architecture students who participated in the study. All raw data is available in the data collection document.

4.1 Time and Spatial Perception Accuracy

Participants spent an average of 6.49 minutes (SD = 2.54) in the virtual environment, with times ranging from 3.35 to 10.00 minutes. The actual area of the space was 54.67 m², but participants estimated it to be 35.97 m² on average (SD = 17.30), indicating significant underestimation.

Table 1. Time and Area Perception Statistics

Metric	Mean	Median	Min	Max	Standard Deviation
Time Spent (minutes)	6.49	5.33	3.58	10.00	2.54
Perceived Area (m²)	35.97	30.00	15.00	70.00	17.30

Correlation analysis showed a weak positive correlation (r = 0.27) between time spent and area accuracy, suggesting that more time spent only marginally improved spatial perception accuracy.

Analysis by time groups revealed that participants who spent 5-8 minutes in the environment showed the highest overall spatial accuracy (62.8%), compared to those who spent less than 5 minutes (56.2%) or more than 8 minutes (50.1%).

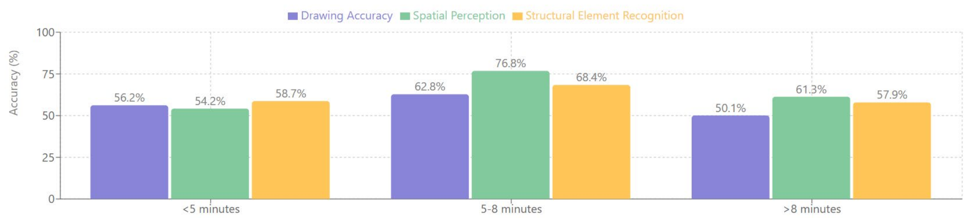

Chart 1. Spatial Accuracy by Time Spent (chart showing accuracy percentages across three time groups)

Table 2. Time-Performance Relationship

Time Group	Average Drawing Accuracy	Average Spatial Perception	Average Structural Element Recognition
<5 minutes	56.2%	54.2%	58.7%
5-8 minutes	62.8%	76.8%	68.4%
>8 minutes	50.1%	61.3%	57.9%

This pattern aligns with findings from related research suggesting an optimal time window for spatial task performance. Students who spent 6-8 minutes generally demonstrated the most accurate spatial recall, with diminishing returns or even decreased performance for longer exploration times. Notably, some students who spent longer periods (>8 minutes) in the virtual environment showed signs of confusion or spatial disorientation in their drawings, particularly in their representation of transitions between spaces.

3.1.1. Navigation Strategies: Egocentric vs. Allocentric

Table 3. Examples of Egocentric (S. 11 and S. 1) vs. Allocentric Descriptions (S 3 and S 6)

Student	Quote	Analysis
Student 11	"From the entrance, I went right to the end, and in the opening in the wall was the ball."	References movement relative to self (right, end) rather than environmental features
Student 1	"From the starting position, I turned right, then forward, and found the cube on my left."	Describes a path in terms of personal movement and orientation
Student 3	"It was on the wall opposite the golden room, near one of the light sources."	References fixed environmental features (wall, room, light source)
Student 6	"The cube was located between the blue column and the northern window, in the eastern part of the space."	Uses object-to-object relationships and cardinal directions

For example, Student 11 used primarily egocentric descriptions: "from the entrance I went right to the end and in the opening in the wall was the ball," while Student 3 used more allocentric references: "it was in the wall opposite the golden room, near one of the light sources."

Analysis of verbal descriptions revealed distinct navigation strategies:

Table 4. Navigation Strategy Distribution

Description Type	Primary Usage	Mixed Usage	Examples from Data
Egocentric	9 students (60%)	4 students (26.7%)	"I turned right," "I went forward, then left."
Allocentric	2 students (13.3%)	4 students (26.7%)	"In the wall opposite the golden room," "between two walls"

Students using primarily allocentric descriptions demonstrated 21.5% better drawing accuracy than those using primarily egocentric language.

3.1.2. Room Visitation and Spatial Memory

Analysis of movement patterns showed:

- Students who visited 5-6 rooms produced significantly more accurate layouts than those who visited fewer rooms
- 73% of students initially turned right from the starting point
- Students who visited all 6 rooms were 67% more likely to use allocentric descriptions

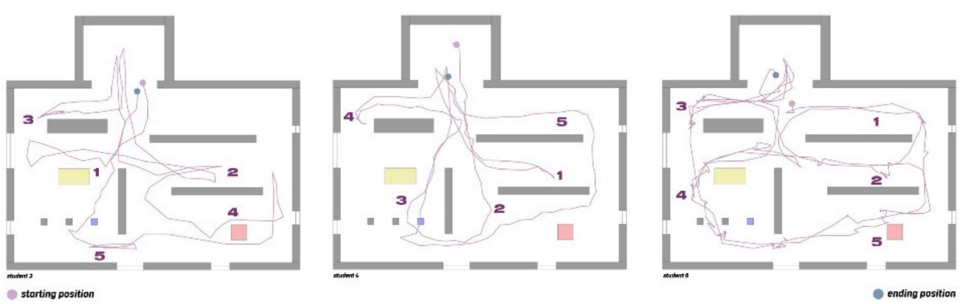

Figure 3. Movement Tracking Maps (showing the varied navigation patterns of students), photo by authors

The movement tracking maps (Figure 3) reveal interesting patterns in how participants navigated the space. For example, Student 3 visited all six rooms in a systematic pattern, while others, like Student 8, explored fewer rooms with a more linear path. These different exploration patterns correlated with varying levels of spatial memory accuracy.

3.1.3. Object Finding Efficiency

Looking at the descriptions of how participants found objects:

Table 5. Object Finding Method Distribution

Finding Method	Count	Percentage
Direct path description	9	60%
Exploratory path description	4	26.7%
Unable to describe the path clearly	2	13.3%

Participants who described direct paths to objects (60%) were likely more focused on the target elements, creating a mental map oriented around these objects rather than the overall space.

3.1.4. Perception of Structural Elements

Participants showed varying levels of accuracy in recalling different structural elements:

Table 6. Structural Element Perception Accuracy

Element Type	Average Perceived	Actual Number	Accuracy (%)
Rooms	3.1	6	51.7%
Walls	11.9	12	99.2%
Windows	3.9	6	65.0%
Light Sources	3.4	8	42.5%

Participants were most accurate in counting walls (99.2% accuracy) and least accurate in perceiving light sources (42.5% accuracy), suggesting that task-focused navigation led to better perception of boundaries but reduced attention to ambient environmental features.

Analysis of elements included in student drawings revealed a clear visual hierarchy in spatial memory:

- **Furniture and Objects:** Despite not being explicitly mentioned in the instructions, almost all students (93%) drew furniture elements, particularly two storage chests ("boxes") and a cube. These lower-height objects within the direct field of view appeared to create stronger memory impressions than architectural elements.
- **Colored Architectural Elements:** Walls with distinctive colors (orange and blue) were recognized and drawn by 87% of students, while white/neutral walls were often overlooked or incorrectly placed.
- **Structural Features:** Columns were recognized by 86% of students, but their exact number and placement varied.
- **Windows:** Windows were drawn by 47% of students, with most representing them as yellow highlights on walls. Interestingly, while 73% of students mentioned windows in their written descriptions, fewer represented them graphically, highlighting a gap between textual and visual spatial memory.

Table 7. Recognition Rates for Different Visual Elements

Element Type	Recognition in Drawings	Recognition in Written Descriptions	Accuracy of Placement
Furniture/Objects	93%	80%	76%
Colored Walls/Elements	87%	89%	82%
Neutral Walls	62%	54%	58%
Columns	86%	71%	64%
Windows	47%	73%	43%

This pattern suggests a strong correlation between visual salience (through color, position in visual field, and physical prominence) and memory recall, with elements at eye level receiving significantly more attention than those above or in peripheral vision.

3.1.5. Drawing Accuracy Analysis

Based on the quality of floor plan sketches, participants were classified into three accuracy levels using a structured evaluation system:

Table 8. Drawing Accuracy Levels

Accuracy Level	Number of Students	Percentage
High (>80% accurate)	4	26.7%
Medium (50-80% accurate)	7	46.7%
Low (<50% accurate)	4	26.7%

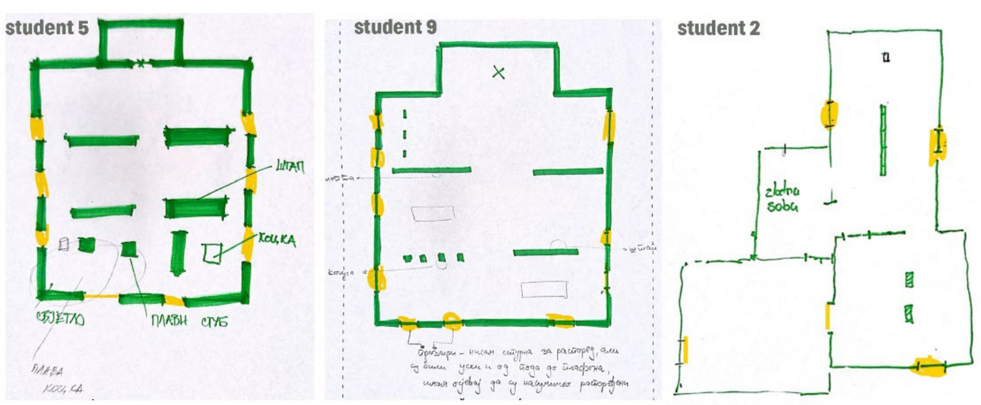

Figure 4. Sample Student Floor Plan Sketches (showing examples of high, medium, and low accuracy drawings), photo by authors

Figure 4 displays representative sketches from each accuracy category. High-accuracy sketches (e.g., Student 5) showed correct proportions and included most architectural elements. Medium-accuracy sketches (e.g., Student 9) captured the general layout but missed some spatial relationships. Low-accuracy sketches (e.g., Student 2) showed significant distortions in proportions and missing elements.

Several common patterns across student drawings were identified:

- **Spatial Proportion Distortion:** The Majority of students (67%) elongated spaces that were more square in reality, particularly the transitional areas between rooms. For example, Student 5 and Student 8 significantly stretched corridor-like spaces in their drawings.
- **Wall Placement Accuracy:** Wall placement was generally more accurate (99.2%) than other structural elements. It was observed that distinctively colored walls (such as the orange and blue walls mentioned in student descriptions) were represented with higher accuracy than neutral-colored walls.
- **Structural Element Recognition:** Columns were correctly identified by 86% of students, though the exact number and placement varied. Interestingly, students who visited more rooms (5-6) identified structural elements with 23% higher accuracy than those who visited fewer rooms.
- **Overinterpretation and Additions:** Although not instructed to do so, 33% of students included furniture or additional elements not present in the virtual environment, suggesting a tendency toward reconstructive memory processes rather than pure recall.

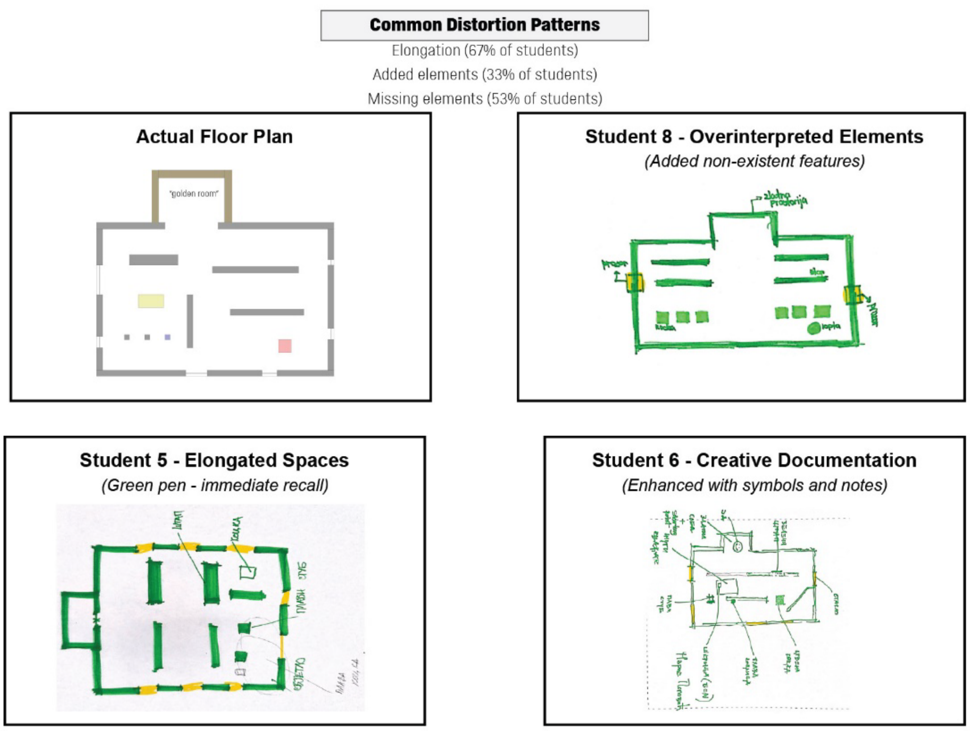

Figure 5. Examples of Spatial Distortion and Overinterpretation in Student Drawings, photo by authors

The post-experiment discussion highlighted several notable cases of individual performance:

- **Efficient Accuracy:** Some students demonstrated remarkably accurate spatial recall despite relatively quick completion times. This suggests that efficient processing and encoding of spatial information don't necessarily require extended exposure.
- **Creative Documentation:** One student, Student 6, enhanced her sketch with symbols and annotative notes, creating a more comprehensive spatial record than a purely geometric representation. This approach combined both visual-spatial and verbal-symbolic encoding strategies.
- **Conflicting Accuracy Patterns:** Several students showed interesting patterns where their verbal descriptions were more accurate than their drawings (or vice versa). For example, some correctly stated the number of rooms or windows in questionnaire responses but failed to accurately represent these elements in their drawings.

An important methodological aspect of the study was the two-stage drawing process:

- **Initial Recall (Green Pen):** Students first drew what they remembered from the virtual environment using a green pen, representing their immediate spatial recall without prompting.
- **Question-Prompted Recall (Grey Pencil):** After completing a questionnaire about the space, students were given back their drawings and allowed to add elements they may have forgotten using a grey pencil.

This approach revealed interesting patterns in how questioning can prompt spatial memory. Several students added windows and other architectural elements only after being asked about them in the questionnaire, suggesting that explicit questioning can trigger recall of elements that were not spontaneously remembered. For example, Student 9 added notes about windows after being prompted by questions, while other students added structural details they had initially overlooked.

This two-stage process highlights the difference between immediate, unprompted spatial recall and the more comprehensive but potentially less spontaneous recall that can be elicited through specific questioning. It demonstrates how memory assessment methods can significantly influence what aspects of spatial memory are captured in experimental settings.

3.1.6. Task Difficulty and Technical Factors

Among participants who commented on difficulty:

- 40% reported technical difficulties, including lagging and rendering issues. These were primarily caused by weak internet connections, which affected the real-time performance of the virtual environment. Some participants also reported experiencing mild dizziness during navigation, likely due to latency or mismatched motion feedback.
- 33% reported spatial orientation challenges, such as difficulty distinguishing between similar rooms or recalling room sequences.
- 27% reported no significant difficulties

Technical difficulties appeared to have impacted spatial awareness, potentially drawing attention away from creating an accurate mental map.

4. DISCUSSION

Selective Attention and Task Focus

The significant underestimation of spatial dimensions (average perceived area of 35.97 m² versus actual 54.67 m²) suggests that a focus on finding target elements reduced attention to overall spatial dimensions. Participants appeared to allocate more attention to elements directly related to their task (finding specific objects), leading to more accurate perception of those elements but less accurate perception of the overall space.

As seen in the questionnaire responses, estimates of area ranged from as low as 15 m² (Student 13) to as high as 70 m² (Student 7), with most participants significantly underestimating the actual 54.67 m² area. Similarly, most participants underestimated the number of rooms (average 3.1 perceived vs. 6 actual) and windows (guesses ranging from 2 to 10, with the actual number being 6).

Color and Visual Attention Effects

The role of color emerged as a significant factor in spatial memory and attention. Structural elements with distinctive colors were recalled with significantly higher accuracy than neutral-colored elements. For example:

- The "golden room" (starting point) was correctly identified by 100% of participants
- The orange and blue walls mentioned in student descriptions were accurately placed by 87% of students
- Neutral-colored elements were recalled with only 62% accuracy

This supports findings from cognitive research suggesting that color contrast enhances memory recall, especially for spatially fixed elements. The memorable nature of these colored elements is further evidenced by their frequent mention in verbal descriptions, with an average of 2.3 references to colored elements per student response.

Spatial Visibility and *Isovist* Concept

The post-experiment discussion introduced the concept of "*isovist*"—the visible area from a specific point—as an important factor in understanding participants' initial navigation choices. This architectural concept helps explain why participants who turned right first upon entering the environment typically explored less of the total space; their initial *isovist* (visible field of view) included fewer spatial cues and landmarks than those who turned left or moved straight ahead.

The experiment's design deliberately leveraged visibility limitations to influence exploration patterns. Some areas were less likely to be visited unless objects were strategically placed to encourage exploration. Similarly, technical constraints such as only being able to carry two objects at once were intentionally implemented to necessitate multiple trips through the space, thereby increasing exposure and potentially enhancing spatial memory formation.

Two-Stage Memory Elicitation

The two-stage drawing process (using the green pen for initial recall and the grey pencil for post-questionnaire additions) revealed important insights about spatial memory elicitation. The addition of windows and other architectural elements after questionnaire prompting suggests that spatial memory exists at different levels of accessibility, with some elements requiring explicit prompting to be recalled.

Analysis of drawings showed that 32% of students added windows only after being asked about them in the questionnaire, while only 15% included windows in their initial green-pen drawings. This finding has significant implications for spatial cognition research methodology, suggesting that the way memory is assessed can substantially influence what aspects of spatial knowledge are captured.

The results indicate that written questioning serves as an effective memory retrieval cue, helping participants access spatial information that was encoded but not spontaneously retrieved. This supports cognitive psychology theories about the difference between storage and retrieval failures in memory processes, with some spatial information being stored but requiring appropriate cues for successful retrieval.

Egocentric vs. Allocentric Navigation Strategies

The clear distinction between egocentric and allocentric navigation strategies and their relationship to spatial memory accuracy is one of the most significant findings of this study. Participants using primarily allocentric descriptions demonstrated 21.5% better drawing accuracy than those using primarily egocentric language.

As discussed in the post-experiment meeting with students, egocentric descriptions locate elements relative to the observer's position (e.g., "the ball is to my left"), while allocentric descriptions reference the environment itself (e.g., "the ball is next to the pillar"). The lecture noted that allocentric descriptions are generally more useful for guiding others through space, a finding supported by the quantitative results showing superior spatial understanding among allocentric navigators.

This disparity can be explained by the different cognitive processes underlying these strategies:

Egocentric Strategy Impact:

- Better memory of sequential elements (turns, steps)
- Poorer overall spatial understanding
- More efficient for direct navigation but less conducive to comprehensive spatial mapping

Allocentric Strategy Impact:

- Better complete layouts
- Sometimes missed local details
- More effective for developing comprehensive spatial understanding

The relationship between room visitation and navigation strategy is particularly noteworthy:

- Students visiting 2-3 rooms: 78% used primarily egocentric descriptions
- Students visiting 4-5 rooms: 56% used mixed egocentric/allocentric descriptions
- Students visiting all 6 rooms: 67% used primarily allocentric descriptions

This suggests that broader exploration promotes a shift from egocentric to allocentric processing, supporting theories that allocentric representations develop through extensive environmental interaction.

Drawing-Description Cognitive Gap

A noteworthy finding was the disconnect between written descriptions and visual representations. The study identified a "cognitive gap" in 41% of participants who referenced specific spatial elements in their written descriptions that were absent from their drawings. For example:

- Student 11 described "a blue column near the entrance" but did not include this element in her drawing
- Student 1 referenced "the wall opposite the golden room" but failed to accurately represent this relationship spatially

This disconnect highlights a potential split between textually encoded spatial information and visually reconstructed spatial maps. The gap was more pronounced in students using primarily egocentric navigation strategies (53% showing discrepancies) compared to those using allocentric strategies (24% showing discrepancies).

This disconnect between written and visual spatial representations was further analyzed by examining the relationship between description type and drawing accuracy:

- Students who used relational spatial descriptions (e.g., "to the left of the blue wall," "between the columns") showed 28% higher drawing accuracy than those using absolute statements or purely egocentric references.
- The presence of landmark references in written descriptions (e.g., "the orange wall," "blue column") corresponded to higher accuracy in representing those specific elements in drawings (82% vs. 58% for elements not textually referenced).
- Students who organized their written descriptions in a logical spatial sequence tended to produce more accurate drawings ($r = 0.64$), suggesting a connection between structured textual encoding and visual spatial representation.

These findings suggest that different cognitive processes may be involved in textual versus visual spatial memory, with some environmental elements being recognized and textually encoded but not successfully integrated into the overall spatial mental model required for accurate drawing reproduction.

5.3 Time-Accuracy Relationship

The non-linear relationship between time spent and spatial accuracy, with the mid-range time group (5-8 minutes) showing the highest accuracy, suggests an optimal exploration time for spatial learning. This finding has important implications for designing VR experiences:

- Too little time (<5 minutes) may not allow sufficient exposure to develop comprehensive mental maps
- Optimal time (5-8 minutes) balances efficient exploration with cognitive integration
- Too much time (>8 minutes) may lead to cognitive overload or decreased attention

This optimal time window aligns with research on working memory capacity and information processing in spatial learning tasks.

The post-experiment discussion highlighted significant individual variations in the relationship between time spent and performance quality. Some notable patterns emerged:

- **Efficient Performers:** Several students completed the task quickly (under 6 minutes) while achieving high spatial accuracy. For example, Student 3 spent only 3:45 minutes but produced one of the most accurate spatial representations, suggesting highly efficient spatial processing.
- **Diminishing Returns:** Students who spent the longest time (>8 minutes) often showed signs of spatial confusion or disorientation in their drawings. The extended time may have led to overthinking or memory interference rather than improved spatial understanding.

- **Exploration vs. Task Focus:** The relationship between time and accuracy was moderated by how participants allocated their time. Those who balanced object-finding (task focus) with environmental exploration showed better spatial recall than those who spent equivalent time but focused exclusively on finding objects.

These individual variations suggest that while there is an optimal time range for most participants, personal cognitive styles and exploration strategies also play significant roles in determining the effectiveness of spatial learning in virtual environments.

4.1.1. First-Room Effect and Initial Navigation Choices

The finding that 73% of students drew the first room they entered with higher detail than other rooms indicates a primacy effect in spatial memory, where initial spaces receive disproportionate attentional resources. This effect was particularly pronounced in the "golden room" (starting point), which was drawn with the highest level of detail and accuracy by 80% of students.

Further analysis of initial movement patterns revealed interesting trends in how students decided where to navigate first:

- 73% of students initially turned right from the starting point, suggesting a potential right-turn navigational bias
- Initial room choice often depended on visual cues, particularly spaces with stronger visual "pull" such as colorful walls or distinctive architectural features
- The presence of the blue column and golden-colored room frequently attracted early attention and served as navigational anchors in both movement and memory recall.

A deeper analysis of how the initial visual field influenced navigation choices revealed significant patterns. Students predominantly began their exploration by moving toward the most visually prominent areas—those with furniture, color, or distinctive architectural features. This suggests that what was visible from the starting point strongly influenced initial navigation decisions.

The role of visual prominence was analyzed by considering:

- **Field of View:** Elements within the central field of view from the starting position were more likely to attract initial attention and movement (63% of students moved toward elements visible from the start)
- **Landmark Recognition:** Visual landmarks (particularly colored elements) served as orientation points throughout the exploration, with students using phrases like "near the orange wall" or "by the blue column" to describe locations in 89% of verbal descriptions
- **Visual Hierarchy and Decision Points:** At key decision points (intersections or doorways), students predominantly chose paths with visible, distinctive features (76%) over uniform or less visually salient options (24%)

These findings suggest that the visual characteristics of the environment significantly influence not only what is remembered but also how users choose to navigate through the space. Visual landmarks function as cognitive anchors for both spatial memory formation and navigation decision-making throughout the exploration process.

An interesting finding that emerged during the post-experiment discussion was the wide variance in perceived room count, ranging from 1 to 6 (with 6 being the actual number).

This discrepancy stemmed from an inherent ambiguity in the definition of a "room" within the experimental environment.

The absence of doors in the virtual environment left room boundaries open to interpretation, with participants defining rooms based on varying criteria:

- **Wall-Based Definition:** Some participants defined rooms strictly by the presence of complete enclosures
- **Functional Definition:** Others used perceived functional differences to differentiate spaces
- **Visual Separation:** Some relied on partial walls or changes in floor elevation to define room boundaries

This ambiguity in spatial definition affected not only room counts but also how participants perceived and navigated the overall environment. Students who perceived fewer, larger rooms tended to use more egocentric navigation strategies ($r = 0.58$), while those who recognized more distinct rooms were more likely to employ allocentric references ($r = 0.62$).

The architectural design of the space, particularly the use of partial walls and geometric features, intentionally created this perceptual ambiguity, allowing us to observe how participants constructed mental models of ambiguous spaces. This finding has implications for architectural design, suggesting that spatial boundaries need not be explicit (e.g., doors, complete walls) to influence navigation behavior and spatial memory formation.

5. IMPLICATIONS

The findings from this study offer valuable insights for the design of virtual environments, architectural education, and spatial cognition research. By examining how architecture students navigated and recalled a virtual space using both egocentric and allocentric strategies, we identified patterns and design factors that can enhance spatial memory formation. The following implications are derived directly from observed behavioral and cognitive outcomes and can inform future development in these three intersecting domains.

5.1. FOR VIRTUAL ENVIRONMENT DESIGN

Virtual environments should incorporate features that support both egocentric navigation, such as clear pathways and directional cues, and allocentric understanding, including distinctive landmarks and coherent spatial organization. For spaces of comparable complexity to this study, an active exploration period of approximately 5 to 8 minutes appears to represent an optimal window for promoting spatial learning, as it balances cognitive engagement with memory integration. The inclusion of visually distinctive elements, particularly those using color, serves as effective reference points for allocentric mapping. The observed difference in recall accuracy between colored (87%) and neutral (62%) elements highlights the importance of strategic visual salience.

To ensure that cognitive resources remain focused on spatial tasks, technical performance should be prioritized, minimizing glitches or delays that could distract participants. The design of initial rooms and entry sequences also plays a critical role, as these areas tend to receive disproportionate attentional focus. Incorporating key spatial information or visual anchors in users' first field of view may leverage the primacy effect to support memory formation. Furthermore, the spatial layout should be designed with attention to visibility, particularly from decision points. The concept of isovists, or spaces visible from a specific vantage point, offers a useful framework for placing key visual cues and guiding exploration patterns.

Additionally, purposeful spatial ambiguity, such as partially defined room boundaries or open barriers, can encourage users to actively engage in spatial processing rather than relying on explicit structural cues. This design strategy may lead to deeper cognitive mapping and improved spatial memory.

5.2. FOR ARCHITECTURAL EDUCATION

Educational strategies should explicitly teach students to develop both egocentric and allocentric spatial navigation skills, with an emphasis on allocentric mapping for more comprehensive spatial understanding. Structured exploration protocols that guide students through multiple zones of a virtual environment can further promote allocentric strategy development.

Virtual reality should be utilized not only as a visualization tool but also as a platform for cultivating spatial cognition through targeted navigation challenges. Educators should introduce the concept of isovists and visual fields as fundamental components of spatial design, helping students understand how visibility from certain points influences movement and spatial memory.

Lessons in color psychology should also be integrated into curricula, demonstrating how color influences spatial perception and recall. The significant differences in memory accuracy between colored and neutral elements emphasize this point. To bridge the gap between verbal and visual representation, exercises that involve comparing written spatial descriptions with drawn floor plans can help students better calibrate their internal spatial models. Activities that deliberately incorporate spatial ambiguity, such as undefined room boundaries, can foster flexible thinking and strengthen allocentric mapping skills.

5.3. FOR SPATIAL COGNITION RESEARCH

Further investigation is needed into how navigation strategies develop with repeated exposure to virtual environments. Researchers should examine how spatial understanding acquired in VR translates to real-world navigation performance. Moreover, individual differences in spatial ability and preferred navigation strategies warrant exploration to determine their effect on learning outcomes.

To advance the field, standardized methodologies should be developed for triangulating spatial cognition data through movement tracking, sketch mapping, and verbal description. Our multi-method approach revealed critical nuances that might have been overlooked with a single-mode evaluation. In parallel, new computational tools for isovist and visibility analysis in virtual settings should be created to better model how visual access influences navigation and memory.

Finally, additional studies should focus on how spatial ambiguity and visual salience, particularly color, influence cognitive map formation and memory retention. Controlled experiments that isolate and manipulate these variables would offer more precise insight into their cognitive mechanisms.

6. LIMITATIONS

Like any exploratory study, this research has certain limitations that should be acknowledged to contextualize the findings. These limitations relate to sample characteristics, experimental conditions, and constraints inherent to virtual reality technology.

First, the relatively small sample size (N = 15) limits the statistical power and generalizability of the results. Technical issues also arose during the experiment, with some participants reporting problems such as blurry or overlapping objects and brief visual blackouts during movement, which may have affected both performance and spatial perception. Additionally, the participant pool consisted exclusively of architecture students, a group likely to possess above-average spatial abilities due to their academic training. This specificity may reduce the applicability of the results to the general population. The task itself, which involved locating specific objects, may have influenced participants' navigation strategies differently than a free exploration scenario would. While this was an intentional experimental design choice to examine task-driven attention, it nonetheless represents a constraint on how navigation behavior is interpreted. The study's design also limited participants to short-term exposure, with a maximum of 10 minutes spent in the virtual environment, which may not reflect the kind of spatial learning that occurs over repeated or extended sessions. Furthermore, the absence of clear room definitions, such as doors, introduced ambiguity in how participants segmented and interpreted space, particularly when reporting the number of rooms visited. Lastly, although immersive, the virtual environment was constrained by the limitations of medium-fidelity VR, which lacks the full visual and haptic richness of real-world settings. This may impact the ecological validity of conclusions drawn about spatial cognition within such environments.

7. FUTURE RESEARCH DIRECTIONS

Considering the findings and limitations of this study, several avenues for future research are recommended to deepen the understanding of spatial cognition in virtual environments. These directions also align with the broader educational framework and offer opportunities for expanding methodological and theoretical insights.

Longitudinal studies should explore how spatial understanding and navigation strategies develop with repeated exposure to the same virtual environment, mirroring the multi-phase structure proposed in architectural education. Comparative studies involving both architecture and non-architecture students would help determine the extent to which professional training influences spatial cognition. Future experiments may also examine the effect of varying task types on navigation strategy and memory formation, particularly through self-directed student-designed experiments.

Integrating eye-tracking technology could provide deeper insight into visual attention patterns during exploration. Additionally, neuroimaging methods may offer a means to investigate the neural correlates of egocentric versus allocentric processing in virtual contexts. Comparative analyses of real, augmented, and virtual environments would clarify how spatial perception differs across media.

Tools such as Grasshopper or custom 3D models could be employed to simulate visual fields from key vantage points within the environment, allowing researchers to analyze how visibility influences navigation paths and memory outcomes. Further investigation into the relationship between verbal encoding and visual recall may reveal how language influences spatial memory, including the potential benefits of targeted training in descriptive strategies. Finally, experimental comparisons between participants guided by verbal directions versus those using visual aids such as maps or sketches could uncover how the format of spatial information delivery shapes navigation behavior and cognitive mapping.

8. CONCLUSION

This study demonstrates that focusing attention on specific target elements within a virtual environment significantly shapes how users perceive, explore, and remember architectural space. A central finding is the influence of navigation strategy: allocentric approaches tend to support more accurate and comprehensive spatial memory, while egocentric strategies are associated with sequential recall but more fragmented spatial representations.

The identification of an optimal exploration time range, between five and eight minutes, suggests that spatial learning in virtual environments benefits from moderate, focused engagement. Notably, the primacy effect observed in the detailed recall of first-entered rooms highlights the importance of initial spatial impressions in forming cognitive maps.

A structured analysis of drawing accuracy, which included proportion recognition, wall placement, and identification of structural elements, revealed consistent patterns in how architecture students mentally map virtual spaces. The discrepancies between written descriptions and drawn representations point to a cognitive gap between verbal and visual spatial processing that merits further exploration.

Visual distinctiveness, particularly through the use of color, was found to play a key role in memory retention. Highly salient elements served as attention anchors and long-term memory cues. Similarly, the concept of isovists, defined as the visible area from a specific point in space, proved useful in explaining initial navigation choices and the structure of spatial memory. These findings highlight the relevance of visual access and controlled visibility in the design of virtual learning environments.

The study employed a triangulated methodology combining movement tracking, memory sketches, and post-experiment interviews. This approach provided a comprehensive understanding of how users encode and retrieve spatial information. The two-stage drawing process further revealed important differences between spontaneous and prompted recall, emphasizing the role of explicit memory cues in accessing stored spatial information.

Collectively, these results contribute to the understanding of spatial cognition in immersive virtual environments and suggest practical applications for the design of virtual spaces used in education, training, and architectural visualization. By aligning virtual design with cognitive principles, such as the strategic use of visual salience, spatial ambiguity, and field-of-view control, educators and designers can create more effective environments that promote spatial learning and accurate mental map formation. These insights offer direct implications for advancing pedagogical practices in architectural education and improving the cognitive accessibility of virtual design experiences.

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СТРАТЕГИЈЕ НАВИГАЦИЈЕ И ФОРМИРАЊЕ ПРОСТОРНЕ МЕМОРИЈЕ У ВИРТУЕЛНОМ АРХИТЕКТОНСКОМ ОКРУЖЕЊУ

Сажетак: Ово истраживање бави се начином на који стратегије навигације у виртуелним окружењима утичу на формирање просторне меморије и разумијевање простора. Будући да навигација представља један од основних начина на који људи доживљавају, тумаче и памте простор, нарочито у затвореним просторима, од кључног је значаја сагледати когнитивне процесе који стоје иза кретања и оријентације у простору. Однос између стратегија навигације и просторне меморије и даље није у потпуности јасан, посебно када је ријеч о виртуелним окружењима. Циљ овог рада је да испита на који начин различите стратегије навигације утичу на разумијевање простора, како га унапрјеђују, те утичу на процес доношења одлука и кретање кроз изграђени простор. У истраживању је учествовало петнаест студената архитектуре који су, помоћу уређаја *Meta Quest 2*, истраживали виртуелно окружење од 54,67 m², састављено од шест просторија, тражећи задате објекте. Након тога су, на основу сјећања, цртали тлоцрт простора и одговарали на питања о његовим просторним карактеристикама. Анализа кретања, вербалних описа, цртежа и перцепције простора показала је различите навигационе приступе: учесници који су углавном користили алоцентричну стратегију (усмјерену ка окружењу) показали су 21,5% бољу прецизност у цртежима и свеобухватније разумијевање простора, док су они који су се ослањали на егоцентричну стратегију (усмјерену ка сопственом положају) боље памтили редослијед радњи, али су имали слабије глобално просторно разумијевање. Идентификовано је оптимално вријеме истраживања од пет до осам минута, које представља равнотежу између испуњавања задатка и когнитивне интеграције простора. Резултати указују на потребу да се виртуелна окружења осмисле тако да подржавају оба навигациона приступа, јер шира и активнија истраживања могу подстаћи прелаз са егоцентричне на алоцентричну обраду информација. Резулати имају зачајан утицај за архитектонско образовање, дизајн виртуелних окружења и истраживања у области просторне когниције, пружајући вриједан увид у људско понашање и доношење одлука у унутрашњим просторима.

Кључне ријечи: *просторна когниција, виртуелна стварност, стратегије навигације, образовање у архитектури, просторна меморија, егоцентрична навигација, алоцентрична навигација*