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Methods of Investigating Spatial-Visual Cognition in Urban Environments: An Integrative Literature Review

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Abstract

Investigating visual cognition is essential for understanding how individuals consciously view and respond to urban environments, facilitating the desired outcomes in urban design. This literature review explores various methods for studying spatial-visual cognition to uncover how individuals navigate, perceive, and engage with their surroundings. A systematic search was conducted across three databases—Egyptian Knowledge Bank, Google Scholar, and ResearchGate—to identify 31 relevant papers that met the inclusion criteria from an initial set of 1,000 articles. Drawing from these scholarly sources, the review analyzes different approaches to studying visual cognition, focusing on methods such as free recall, cued recall, and estimation tasks, each offering unique insights into cognitive processing. Additionally, the review examines mobile eye-tracking, a more recent and advanced method that provides real-time data on visual attention during navigation. By comparing these methods, the review emphasizes the value of employing multiple techniques simultaneously to gain a comprehensive understanding of spatial-visual cognition, which is vital for effective urban design and planning.

Keywords: Urban navigation, Wayfinding; Visual Attention; Spatial Knowledge; Cognitive Map.

طرق استكشاف الإدراك المكاني-البصري في البيئات العمرانية: مراجعة تكاملية للدراسات السابقة.

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الملخص

يعد التحقيق في الإدراك البصري أمرًا ضروريًا لفهم كيفية مشاهدة الأفراد للبيئات الحضرية واستجابتهم لها بوعي، مما يسهم في تحقيق النتائج المرجوة في تصميم المدن. تستعرض هذه المراجعة الأدبية أساليب مختلفة لدراسة الإدراك البصري المكاني بهدف الكشف عن كيفية تنقل الأفراد وإدراكهم وتفاعلهم مع محيطهم. تم إجراء بحث منهجي عبر ثلاث قواعد بيانات: بنك المعرفة المصري، جوجل سكولار، وريسرش جيت، حيث تم تحديد

31 ورقة بحثية ذات صلة استوفت معايير الاشتمال من أصل 1000 مقالة. استنادًا إلى هذه المصادر الأكاديمية، تحلل المراجعة أساليب مختلفة لدراسة الإدراك البصري، مع التركيز على طرق مثل الاستدعاء الحر، الاستدعاء الموجه، ومهام التقدير، حيث يقدم كل منها رؤى فريدة حول معالجة الإدراك. بالإضافة إلى ذلك، تستعرض المراجعة تقنية تتبع حركة العين عبر الأجهزة المحمولة، وهي طريقة حديثة ومتقدمة توفر بيانات لحظية حول الانتباه البصري أثناء التنقل. من خلال مقارنة هذه الأساليب، تؤكد المراجعة على قيمة استخدام تقنيات متعددة بشكل متزامن للحصول على فهم شامل للإدراك البصري المكاني، وهو أمر حيوي لتصميم وتخطيط حضري فعال.

الكلمات المفتاحية: العثور على الطريق؛ الانتباه البصري؛ المعرفة المكانية؛ الخريطة الإدراكية.

INTRODUCTION

Spatial-visual cognition involves how individuals perceive and interact with the visual aspects of their environment. Various research methods are used to study spatial-visual cognition, with visual attention playing a significant role as an indicator of the potential effectiveness of a spatial feature (Tang, 2020). In the field of wayfinding, several studies have explored spatial-visual cognition, such as Lynch (1960), Downs and Stea (1973, 1977), and Kaplan (1976). Tolman (1948) first introduced the concept of cognitive mapping through experiments with rats, showing their ability to create mental maps by adapting to new routes when encountering previously unexplored dead ends. Lynch (1960) found that constructing a mental representation of an environment is essential for interpreting information and guiding actions, as it merges immediate sensory input with memories.

Downs and Stea (1973) proposed that individuals use cognitive maps to navigate their surroundings. Mental mapping is the main source of environmental information for wayfinding in a familiar environment. However, in unfamiliar environments, external maps become necessary. Before acting on external maps, people still need to analyse the environmental information. Therefore, the mental images of the environment in people's minds help guide their actions (Downs & Stea, 1977). Kaplan (1976) further explains that successful navigation from point A to point B involves recognizing key decision points along the route. These concepts collectively contribute to understanding wayfinding as a cognitive map.

In the field of wayfinding, numerous studies have investigated spatial-visual cognition by comparing wayfinding in familiar and unfamiliar environments (Huang et al., 2012; 2013). Additionally, research has examined the effectiveness of different navigation aids in the wayfinding process (Ahmadpoor & Heath, 2018; Ben-Elia, 2021; Ishikawa et al., 2008; Wang & Worboys, 2016).

Assessing the quality of urban design requires considering parameters such as perception, attention, retention, comprehension, and deduction. Therefore, understanding spatial-visual cognition is crucial for urban development. Various studies have employed different methods and tasks to measure and explore visual perception. This article aims to identify and analyse these methods in order to compare and classify their techniques, applications, and results based on previous research. This review sheds light on the evolution of these methods, particularly in the era of technology, and examines the impact of different navigation aids on wayfinding quality and cognitive map accuracy. It also helps to indicate the most effective urban elements in the navigation process and spatial recall.

RESEARCH METHOD

According to the methodology proposed by Abusaada & Elshater (2022), this review follows a five-stage process: framing the research topic and identifying gaps, formulating logical queries, establishing inclusion and exclusion criteria, conducting content analysis and grouping, and finally extracting results from the texts. To identify the objectives and explore the gaps in prior research, the review begins by addressing five key research questions: (1) What methods have previous studies employed to examine spatial-visual cognition in human wayfinding within urban environments? (2) How have traditional methods of recalling cognitive maps, as proposed by Lynch, evolved over time? (3) In what ways has the digital age influenced the methods used to investigate spatial-visual interactions? (4) What is the influence of various navigation aids on wayfinding accuracy and cognitive map precision? (5) Which urban elements play the most significant role in facilitating navigation and enhancing spatial memory recall?

Figure 1 shows the research steps process. A systematic search of online research databases, including the Egyptian Knowledge Bank, Google Scholar, and ResearchGate, was carried out to identify relevant papers using the search terms "wayfinding", "navigation", and "perception". The search was conducted between January and December 2023. The inclusion criteria were: (1) studies focusing on wayfinding; (2) studies investigating visual attention and environmental cognition; (3) studies conducted exclusively in urban environments; (4) studies published between 1960 and 2023; and (5) studies published in refereed journals. The exclusion criteria were: (1) articles written in languages other than English; and (2) studies addressing special cases such as visual impairments, physical disabilities, or mental disabilities. After eliminating duplicate articles and those that did not meet the inclusion criteria, 98 studies remained. Following a content analysis, it was determined that only 31 studies addressed the research questions.

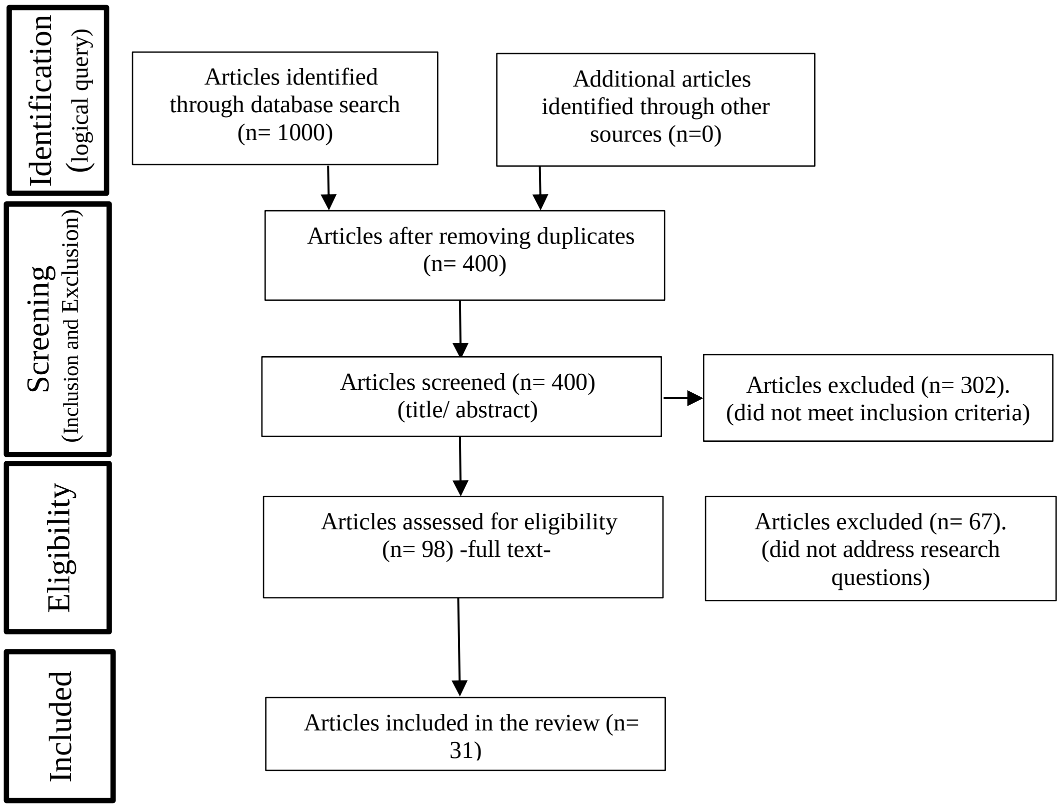


Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for the research (Authors).

1. LITERATURE REVIEW

According to the review of the 31 studies, visual attention, cognitive mapping, and mental imagery were investigated across various disciplines including planning, urban design, environmental psychology, human geography, psychology, and computer science.

1.1. Planning and Urban Design

Urban planners and designers use the wayfinding process to establish design principles for cities and study how people interact with the urban environment. In 1960, Lynch employed tasks such as sketching maps, recording, and photographic recognition to capture individuals' mental images. His method focused on asking people to draw the city's mental images, which were then analyzed through visual comparison. This analysis revealed the level of recognition of five main urban elements: paths, edges, districts, nodes, and landmarks. Appleyard in his study (1969) used three tasks to assess the recall of buildings and other landmark cues: free verbal recall, map recall, and trip recall.

Ishikawa and Montello (2006) conducted a study to explore how individuals acquire spatial knowledge while navigating unfamiliar locations in Santa Barbara, California, USA, over ten sessions. The study area featured different route types: straight routes with perpendicular turns, curve routes with fewer turns, and combined routes. Participants' spatial knowledge was assessed after each session through direction/distance estimation tasks and map sketching. The results showed that participants had a lower error in direction estimation for the curve routes than the straight and combined routes. Errors decreased across all routes by the end of the final session. Map sketching also indicated that participants had a better understanding after completing the sessions.

Ishikawa et al. (2008) conducted a study in which participants were required to navigate an unfamiliar residential area in Kashiwa, Japan. Their performance was analyzed to investigate the effectiveness of using the Global Positioning System (GPS) versus paper maps and direct experience. After completing the navigation task, the researchers assessed the participants' knowledge through direction estimation and map sketching tasks. In the direction estimation task, participants drew an arrow from the center of a circle to indicate the start direction. In addition to the map sketching task, participants used paper to draw spatial relations. Results revealed that the GPS group had a higher error in direction estimation than the direct-experience group. Additionally, the map sketching task showed that the topological accuracy of sketch maps was lower in the GPS group than in the direct-experience group.

Abou El-Ela (2018) studied the impact of GPS on college students' spatial awareness. Participants were asked to sketch a map of their daily commute from college to home, and the analysis focused on the spatial features represented in the maps. The study revealed that streets and landmarks were the most frequently depicted elements, followed by districts and nodes, while edges were rarely included. The findings suggest that navigation apps can strengthen users' familiarity with urban spaces.

Ahmadpoor and Heath (2018) conducted a study in which participants were asked to navigate an unfamiliar area in the central district of Nottingham City, UK. Some participants used GPS applications, while others did not. After the navigation task, the researchers assessed the participants' landmark knowledge while they recognized 68 photos of buildings in the area. Participants rated their level of remembrance for each building on a five-point Likert scale ranging from 1 (remember) to 5 (don’t remember at all). The researchers analyzed the results and found that non-GPS users performed significantly better in recalling 41 building photos, and both groups performed equally well in 20 buildings. Additionally, both groups performed poorly in recalling 7 building photos.

In another study conducted by Ahmadpour et al. (2020). First-year undergraduate and postgraduate students were asked to navigate an unfamiliar area in Nottingham, UK, using GPS or without it. The study aimed to investigate the impact of environmental legibility in the age of portable digital maps. After the navigation task, participants completed a recognition memory task. That involved full-screen color photographs of urban scenes of the routes they had navigated. The study analyzed three types of environmental features: landmark memory, node memory, and path memory. The total number of correct responses per participant was calculated for each condition. The study also examined the physical properties of urban features, such as path length, number of turns, presence, and placement of landmarks. As well as node properties and node legs.

The study compared the influence of navigation aids on spatial knowledge acquisition between the GPS and non-GPS groups. The analysis revealed significantly higher recognition accuracy in the non-GPS group for all features. Path recognition accuracy was unaffected by the number of turns or path length but was influenced by the presence of internal or external landmarks. The number of node legs did not significantly impact recognition accuracy, but the presence of landmarks at nodes did. Furthermore, the non-GPS group exhibited a significant correlation between landmark accuracy and visual factors, while the GPS group did not. In conclusion, the non-GPS group demonstrated better recognition memory than the GPS group.

In Tang's (2020) study, eye-tracking (ET) technology was used to examine how the placement of signs affects visual attention during wayfinding. Fixation and saccade data were collected from participants using wearable ET devices. Fixations indicate periods of relatively stable eye movement, allowing detailed information about the focus of visual attention to be processed. Saccades are quick eye movements that shift focus from one point to another. The fixation and saccade sequences were analyzed using Tobii analytical software based on specific filter and threshold settings. The results indicated that aligning signage with the edge of the façade could improve wayfinding efficiency.

Vaez et al. (2021) conducted a study to indicate the influence of urban form and navigational aids on spatial cognition and wayfinding behavior. The study compared three groups: participants using a paper map, the Google Maps app, and those relying solely on local signage for navigation. After completing the navigation task, participants were asked to draw map sketches, undergo interviews, and perform a distance estimation task. The analysis of responses revealed significant differences in spatial knowledge acquisition among the three groups. Results from the sketch map task indicated variations in the number of remembered landmarks, route accuracy, relative object relations, and map quality. Participants in the local-signage-only group recalled a significantly higher number of landmarks compared to the other groups. The paper map group outperformed other groups in route accuracy. In addition, the local-signage-only group performed better in relative object positioning compared to the GPS group. The paper map group also exhibited higher map quality than the GPS group. In the distance estimation task, the local-signage-only group had slightly higher mean correct distance estimations, with the GPS group showing the lowest, but the difference was not statistically significant. Interview results emphasized the significance of landmarks and buildings in shaping a memorable route for all groups. The most cited reason for a landmark's memorability was its eye-catching characteristics, such as color, height, or size.

1.2. Environmental Psychology

Environmental psychologists often overlook the physical environment and conduct tests under unrealistic conditions. These tests examine the interaction between individuals and their physical surroundings, with both parties influencing each other (Nasar, 2011). One significant study in this field is the research conducted by Evans et al. (1984), where participants watched a simulated environment, and their performance was compared in noisy and quiet conditions. The researchers analyzed how route configurations and landmarks affect cognition by comparing two types of route patterns (grid and non-grid) with and without landmarks.

The study also examined how differences in stress levels affect participants' performance in tasks such as incidental memory, route mapping, and photo order and relocation. In the incidental memory task, participants were given a list of 10 items (e.g., bench, fountain, flower box) and asked to select five items they recalled from the environment. The accuracy of recognition was assessed based on the number of correctly identified items. Route maps were evaluated by instructing participants to sketch a map of the routes they navigated, and the accuracy of sketches was assessed by comparing them to the actual routes in terms of layout and left-right sequencing. In the photo ordering and relocation tasks, participants were asked to indicate their recognition of various photos from the environment, arrange them in sequence, and place them in their correct location.

The results of the incidental memory task revealed no significant effects of environmental conditions or stress on recognizing items in their surroundings, with participants remembering an average of 3.43 out of 5 items. In the route maps task, stress did not impact the number of bends drawn, but participants in the grid pattern drew more accurate route configurations with fewer bends than those in the non-grid pattern. Environmental conditions and stress did not significantly affect scene identification, but stress did impact photo ordering and relocation. The study also concluded that the grid route pattern enhances route recall accuracy but has little impact on recalling actual locations of places or spatial order. Landmarks, on the other hand, improve the recognition of place-specific locations.

1.3. Geography

In the study by Tu Huynh and Doherty (2007), which is related to the geography field and focused on Lynch's five elements, participants used a tablet PC with a wireless pencil to draw map sketches of the environment. The initial software used was CorelDraw, enabling participants to create sketches saved in a (.dxf) format compatible with CorelDraw and the GIS package used for analysis. The second software used was Camtasia Studio, a video-capture package that recorded all computer screen activities and the user's sound in Audio-Video Interleaved format (.avi). This provided a sequence of a participant's drawing process, explaining the order in which elements were drawn. Analysis of the sketches revealed that paths and landmarks were frequently drawn, while nodes, edges, and districts were less depicted. Analysis of the videos showed that participants initially focused on drawing paths, which accounted for 65% of the elements drawn, but gradually shifted to drawing more landmarks, which increased to 60%. Nodes were consistently included in the sketches, while edges and districts were not represented well. The study suggested that using a tablet PC does not significantly impact the appearance of sketch maps.

Huang, Schmidt, and Gartner conducted two studies in Salzburg City, Austria, to assess spatial knowledge acquisition during navigation in familiar and unfamiliar environments. Participants utilized different interface technologies, including mobile maps, augmented reality, or voice in GPS-based pedestrian navigation. In their first study titled "Spatial Knowledge Acquisition in the Context of GPS-based Pedestrian Navigation" (2012), participants engaged in a pointing task and sketching map activity. The pointing task required participants to estimate the direction to the starting point using degrees with a digital compass on their mobile phones. The results indicated that mobile map-only and voice users performed better in pointing accuracy than AR users. In the sketching maps task, voice users depicted more landmarks, while mobile map users made fewer errors in sketching turns.

In their second study titled "Spatial Knowledge Acquisition with Mobile Maps, Augmented Reality, and Voice in the Context of GPS-based Pedestrian Navigation

System: Results from a Field Test" (2013), the researchers conducted four tasks: a pointing task, a landmark recognition task, a route direction task, and a landmark placement task. In the landmark recognition task, participants were asked to select images they believed were located along the routes, and their performance was evaluated based on the number of accurately chosen images. In the route direction task, participants were assessed on their ability to acquire and use route knowledge while navigating. Scores were based on the number of incorrect turning directions in their responses. In the landmark placement task, participants had to write or place the IDs of selected pictures on a printed map of the area. Spatial knowledge acquisition was evaluated by measuring the distance (deviation) between the placed position and the actual position of scenes on the paper map in centimetres, converted to meters on a real-world scale. Results indicated that participants using interface technology in an unfamiliar environment acquired less spatial knowledge than those in a familiar environment. Additionally, participants using three interface technologies performed less effectively.

Schwering et al. (2017) conducted three studies related to wayfinding. The first study investigated the influence of different navigational aids on spatial knowledge acquisition. Three aids were tested: Google Maps, verbal route descriptions, and verbal landmark descriptions. After the navigation, participants completed a sketch map task and estimated directions and distances. The results showed that the group using verbal landmark descriptions had the lowest spatial knowledge, while the Google Maps group had significantly larger pointing errors on average. The second study examined the role of global and local landmarks in human wayfinding. Participants were asked to describe routes in a familiar area using sketch maps and verbal explanations. The findings indicated that local landmarks were the most frequently referenced spatial features in verbal descriptions and sketch maps. Furthermore, all participants incorporated global landmarks in their route descriptions. The third study focused on effective visualization techniques for landmarks on small screens, like mobile phones. After completing a wayfinding task, participants were asked to face north and perform a pointing task towards the landmarks they had visited. The average pointing error was minimal, indicating the effectiveness of map-supported navigation.

In a study by Ben-Elia (2021), participants were asked to navigate unfamiliar residential areas. The study compared participants' performance using the Google Maps app on their mobile phones with those using paper maps. After completing the navigation task, the researcher assessed the spatial knowledge of the participants in terms of orientation awareness, landmark recognition, and route recognition. The researcher evaluated participants' orientation awareness by asking them to identify the direction of the starting point. Their responses were assessed based on the absolute error in degrees from the correct angle. In the landmark recognition task, participants were required to identify pictures of landmarks along the navigation route. Their responses were evaluated based on the error percentage. In the route recognition test, participants were asked to recall the correct turn directions at decision points (left, right, or straight). The results indicated that participants who used Google Maps performed poorly (made more errors) in route recognition, pointing accuracy (degrees of deviation), and landmark recognition compared to those who used paper maps.

Karkasina et al. (2021) studied drivers' geospatial abilities in unfamiliar environments. Participants were given two types of verbal route descriptions during navigation: references to landmarks or street names. After completing the navigation task, participants were assessed by sketching maps, estimating distances, and estimating directions. The study revealed that verbal cues based on landmarks helped drivers construct a more accurate cognitive map of the route. However, the type of verbal cues used did not impact participants' estimates of distance or direction.

Dong et al. (2021) utilized eye-tracking technology, sketch maps, and interviews to compare the effectiveness of augmented reality (AR) navigation with traditional 2D map usage. The researchers found differences in visual behavior that reflect distinct cognitive traits. AR users exhibited shorter fixation durations, larger saccade amplitudes, and increased pupil sizes compared to users of 2D maps. Furthermore, AR users tended to focus on people rather than building landmarks. These findings suggested that AR navigation could potentially result in lower spatial memory performance, as evidenced by the analysis of sketch maps.

Xu et al. (2022) conducted a study to examine the effects of voice-assisted digital maps, digital maps without voice instructions, and paper maps on spatial knowledge. The researchers examined spatial knowledge acquired with eye tracking, sketch maps, questionnaires, and interviews. The study revealed that voice-guided digital maps can save pedestrians time, but they are less effective than paper maps in helping people remember routes.

Kapaj et al. (2023) examined how various landmark visualization styles affect navigation and spatial knowledge. The study used distance and direction estimations to measure spatial knowledge acquisition. Findings showed that participants using digital maps with 2D graphics had the lowest performance in estimation tasks.

1.4. Psychology

Psychologists focus more on studying mental processes, brain functions, and behavior during the wayfinding process. Munzer et al. (2006) conducted a notable study in this field, where participants were asked to navigate Saarbrucken Zoo in Germany using GPS and paper maps. After completing the wayfinding task, participants underwent a photographic recall test where they had to click on a marked box to indicate the correct placement and direction of each photo on the route. Route recognition was assessed by calculating the percentage of incorrectly identified photos. In the survey knowledge test (replacement task), participants were required to drag and drop images of intersections onto a map to assess their knowledge. Survey knowledge was evaluated based on the accuracy of the replacement at the correct locations. The study found that GPS users demonstrated good route knowledge but poor survey knowledge. In contrast, map users exhibited better survey and route knowledge.

In a study by Jansen-Osmann and Heil in January 2007, the researchers examined the effects of circular and square mazes on spatial knowledge acquisition in a virtual environment. The study revealed that direction estimation was more accurate in a circular environment. In another study by Jansen-Osmann et al. (March 2007), the impact of regular and irregular mazes on spatial knowledge in adults and children was examined. The study revealed that participants' age significantly influenced direction estimation, with younger children showing less accuracy. Maze type, however, did not have a significant effect. Furthermore, younger children on map correctness scored lower than older children and adults, irrespective of maze type.

Lukas et al. (2014) studied how marked routes in "You-are-Here" Maps affect navigation performance and cognitive mapping. Participants were randomly assigned to view one of four "You-are-Here" map types: marked route with a long map presentation, marked route with a short map presentation, no marked route with a long map presentation, and no marked route with a short map presentation. After completing a wayfinding task in a virtual environment, participants sketched. The sketch maps were evaluated based on map quality, route accuracy, and relative object positioning, which refers to the correct placement of objects on the map, including landmarks like trees, rocks, and mountains. The results indicated that navigation time and deficiency score were lower when the route was not marked on the map compared to when it was marked. This suggests that marking routes early during map viewing impairs navigation performance, while maps without marked routes facilitate the construction of a cognitive map and improve navigation performance. The sketch maps supported the idea that a more elaborate cognitive map was developed when the route was not marked. However, route accuracy was the best in the condition where the route was marked, as it directed participants' attention to the route.

Wenczel et al. (2017) studied landmark selection and route learning in wayfinding. They used a mobile eye-tracking device, a landmark recognition task, and a landmark placement task to investigate how participants perceived landmarks. Findings revealed that landmarks with greater visual salience tended to receive more fixation time and were recognized more easily.

Smith et al. (2022) conducted a study on the influence of interface digital map design on navigation in urban areas. Participants were assigned to use either Google Maps, a static symbols map, or a dynamic symbols map (an interactive thematic map that utilizes changing symbols to represent data that varies over time or by magnitude). During the navigation task, participants had stopping points where they were asked to point in the direction of the previous stopping point. Following the wayfinding task, participants were required to indicate the route taken and recall landmarks using the base map. The findings revealed that participants using the dynamic map demonstrated greater accuracy in orientation judgments, although there were no significant differences in their overall spatial knowledge.

Jaeger et al., (2023) conducted a study to examine the impact of visual representation (maps) and verbal representation (verbal instructions) on the development of spatial knowledge in a complex virtual environment. They assessed spatial knowledge acquisition with a route-pointing task and replacement recall task. In the pointing task, there was no evidence of improved spatial knowledge. In addition, the replacement recall task, there were no appreciable differences between the groups' accuracy in recreating a map of the target landmarks.

1.5. Computer Science

A notable study in the field of computer science was conducted by Burnett and Lee (2005), where participants were asked to navigate a virtual town. Some participants used a traditional paper map with highlighted routes, while others used turn-by-turn voice guidance. After completing the navigation task, the researchers examined participants' cognitive maps using photo recognition, scene ordering, and map sketching techniques. The study found that participants who used turn-by-turn voice guidance remembered fewer scenes, were less accurate in ordering them, and sketched simpler maps with fewer landmarks.

In a study by Willis et al. (2009), participants navigated a large-scale environmental setting to examine their spatial knowledge acquisition. They were provided with information through a traditional map or a mobile device. Following the wayfinding task, spatial knowledge acquisition was assessed through estimation tasks and sketching maps. The results showed that mobile map users had lower performance in acquiring spatial knowledge than traditional map users.

Wang and Worboys (2016) conducted a study to examine the impact of pedestrian navigation aids, such as GPS and Legible London signs (a comprehensive system of wayfinding signs in London), on users' spatial knowledge compared to direct route experience. They evaluated spatial knowledge acquisition using tasks and map sketching. The study revealed that the Legible London group acquired local knowledge by examining signage maps but had a limited understanding of their surroundings. The Google Maps group depended on automatic route guidance, which was fast and reliable, but faced challenges in linking their current position to the destination due to the small screen size. Google Maps users showed the lowest level of attention to their routes and surroundings, resulting in the least spatial knowledge compared to the other two groups.

Löwen et al. (2019) conducted a study to study the impact of GPS maps that emphasize different environmental features on spatial learning. They evaluated spatial knowledge acquisition using sketch map drawing and direction estimation tasks. The study revealed that emphasizing local features helps people acquire route knowledge while emphasizing global features helps people acquire survey knowledge (i.e., an overall mental representation of the spatial environment). These findings enhance our understanding of spatial knowledge acquisition in wayfinding tasks and propose that future navigation systems could improve spatial knowledge by integrating local and global landmarks and features in wayfinding maps.

Sugimoto et al. (2021) studied individuals' spatial memory when learning an environmental route using a smartphone map versus a paper map. They assessed this through scene recognition and landmark identification tasks and found that participants identified more landmarks than using a paper map.

Table 1 compares the reviewed research papers according to their research objectives, the type of environment (real, virtual, familiar, and unfamiliar), the navigation aids utilized, and the methods and tasks employed to investigate spatial-visual cognition.

Table 1. Analysis and comparison of reviewed research papers

NO	Author, year	Methods of Investigating Spatial-Visual Cognition														
		Conventional approach (Recalling mental image)														Recent approach (Eye tracking)
		Free recall				Cued recall							Estimation			
								Photographic cues								
		Questions with text answers	Map sketching	Interviews	Verbal route descriptions (record)	Wordy cues	Map mark-up task	Objects or Scenes Recognition Task	Identify cues task	Scene ordering task	Replacement recalls task	The route direction recalls task	Estimation direction (Pointing task)	Straight-line distance	Route distance	
Architecture/ Planning / Urban																
1	Lynch, (1960)	*	*		*			*	*	*	*		*			
2	Appleyard, (1969)		*	*	*											
3	Ishikawa & Montello, (2006)		*										*	*	*	
4	Ishikawa, et al., (2008)		*										*	*	*	
5	Abou El-Ela, (2018)		*													
6	Ahmadpoor, (2018)							*								
7	Ahmadpoor et al., (2020)							*								
8	Tang, (2020)															*
9	Vaez et al., (2021)	*	*					*	*					*		
Environment psychology																
10	Evans et al., (1984)	*	*			*		*		*	*					
Geography																
11	Tu Huynh & Doherty, (2007)		*													
12	Huang et al., (2012)		*										*			
13	Huang et al., (2013)										*	*	*			
14	Schwering et al., (2017)		*										*	*	*	
			*		*											
													*			
15	Ben-Elia, (2021)							*				*	*			
16	Karkasina et al., (2021)		*										*	*	*	
17	Dong, et al., (2021)	*	*													*
18	Xu et al., (2022)	*	*	*												*
19	Kapaj et al., (2023)												*	*	*	
Psychology																
20	Münzer, et al., (2006)										*	*				
21	Jansen-Osmann & Heil, (2007)												*			
22	Jansen-Osmann et al., (March 2007)		*										*			
23	Lukas, et al., (2014)		*													
24	Wenczel et al., (2017)							*			*					*
25	Smith et al., (2022)						*						*			
26	Jaeger et al., (2023)										*		*			
Computer since																
27	Burnett & Lee, (2005)		*					*		*						
28	Willis, et al. (2009)		*										*	*	*	
29	Wang & Worboys, (2016)		*										*			
30	Löwen et al., (2019)		*										*			
31	Sugimoto et al., (2021)							*								

Source: The Authors

2. Findings

After reviewing previous studies, it was found that there are two approaches to investigating visual-spatial cognition: the conventional approach, which involves recalling mental images, and the recent approach, which utilizes new technologies like eye-tracking technology to capture human gaze behavior and level of visual attention. The conventional methods are free recall, cued recall, and estimating distance and direction. Table 2 outlines various methods within each task. For example, the free recall method includes tasks like answering questions with text, sketching maps, conducting interviews, and describing routes verbally. The cued recall involves word cues, map mark-up tasks, and photographic cues for object and scene recognition and path recognition tests. The estimation method includes pointing and distance estimation tasks.

Table 2. Methods of investigating spatial-visual cognition

Methods of Investigating Spatial-Visual Cognition		Tasks		Sources
Conventional Approach (Recalling Mental Image)	**Free recall**	Questions with text answers		(Lynch, 1960; Vaez et al., 2021)
		Map Sketching		(Ishikawa et al., 2008; Evans et al., 1984; Lynch, 1960)
		Interviews		(Appleyard, 1969)
		Verbal route descriptions (record)		(Lynch, 1960; Appleyard, 1969)
	Cued recall	Wordy cues		(Evans et al., 1984)
		Map mark-up task		(Smith et al., 2022)
		Photographic cues	Objects or Scenes Recognition Task	(Lynch, 1960; Ahmadpoor et al., 2020; Ahmadpoor, 2018; Ben-Elia, 2021)
			Identify cues task	(Lynch, 1960)
			Scene ordering task	(Lynch, 1960; Evans et al., 1984; Burnett & Lee, 2005)
			Replacement recall task	(Lynch, 1960; Evans et al., 1984; Münzer et al.2006)
			The route recognition test	(Ben-Elia, 2021; Huang et al., 2013; Münzer et al., 2006)
	Estimation	Pointing task		(Ishikawa & Montello, 2006; Willis et al., 2009; Huang et al., 2012; 2013; Ben-Elia, 2021; Karkasina et al., 2021)
		Straight-line distance		(Willis et al., 2009; Ishikawa & Montello, 2006; Karkasina et al., 2021; Vaez et al., 2021; Kapaj et al., 2023)
		Route distance		
Recent Approach		Eye tracking		(Tang, 2020; Dong, et al., 2021; Xu et al., 2022; Wenczel et al., 2017)

Source: The Authors

The review revealed that most papers employed multiple tasks for extracting mental images. Figure 2 indicates the frequency or ratio of each task's usage in all the reviewed papers. The most frequently utilized tasks for each method are as follows:

(1) Free map sketching is the most commonly used type of free recall, with a ratio of 65%.
(2) Recognition of objects or scenes is the most frequently used type of cue recall (photographic), with a ratio of 29%.
(3) The pointing task is the most commonly used type of estimation, with a ratio of 55%.

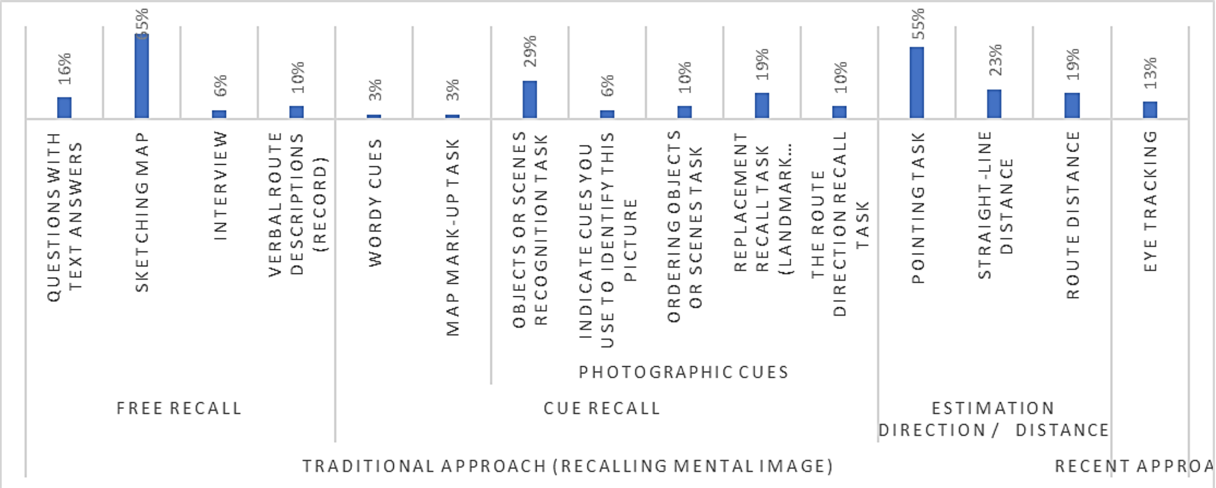


Figure 2. The ratio of using each task in the reviewed papers (Authors).

Furthermore, the relationships between different tasks were calculated and analyzed in the matrix shown in Figure 3. The numbers in the cells indicate the number of articles that used intersecting tasks together. The analysis reveals that map sketching is commonly paired with estimation tasks, sometimes complemented by object or scene recognition tasks, and occasionally by questions.

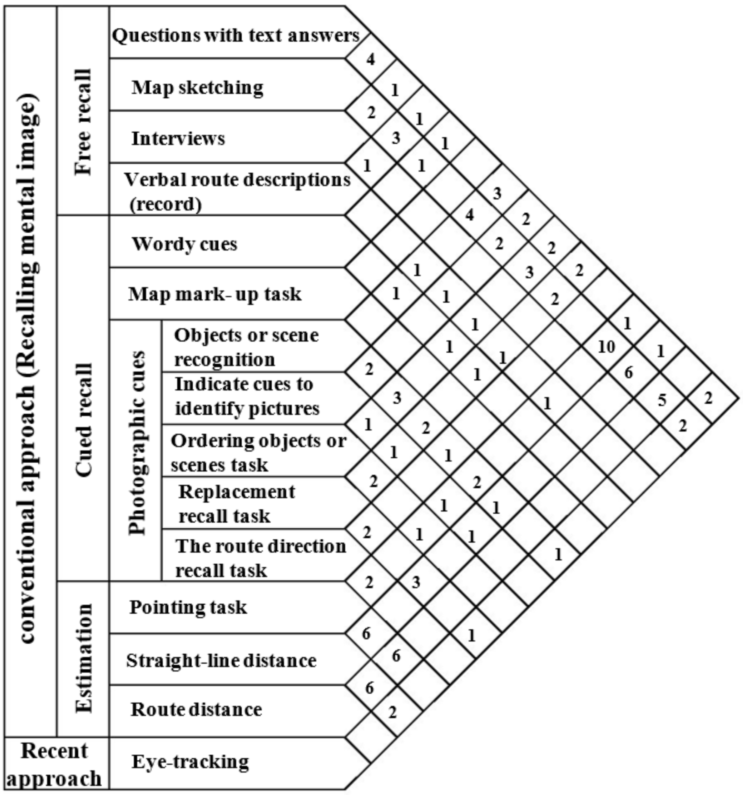


Figure 3. Relationships between different tasks. The numbers in the cells indicate the number of research articles that utilized both intersecting tasks together (Authors).

Based on the above, it is important to understand how each method and their respective tasks can be used to investigate spatial-visual cognition:

2.1. The Conventional Approach (Recalling Mental Image)

The conventional approach involves using long-standing techniques such as free recall, cued recall, and estimating distance and direction:

2.1.1. The free recall method

In the free recall method, no hints are given to assist memory retrieval. This method involves four types of tasks: free questions, free map sketching, interviews, and free trip recall. Two types of measurements are used to assess free recall: accurate item recall and item order. Accurate item recall involves remembering the correct elements in the environment, while item order accuracy pertains to recalling items in their specific locations.

2.1.1.1. Questions with text answers

In this task, participants are required to provide text answers to a series of questions to evaluate their spatial knowledge acquisition following a wayfinding task (Lynch, 1960; Vaez et al., 2021). Table 3 shows sample questions and their respective scoring criteria.

Table 3. Examples of the questions used in the reviewed papers

N	Questions to investigate spatial knowledge acquisition	Scoring criteria	Papers used these questions
	Questions focusing on remembering items		
1	What first comes to mind—what symbolizes the navigation area for you?	The accuracy of item recall	(Lynch K. , 1960)
2	Describe the sequence of things you would see, hear, or smell on the way, including landmarks that have become significant to you.	The accuracy of item recall / Accuracy of item order	(Lynch K. , 1960)
3	Could you please tell us which elements in the navigation area are most recognizable and easiest to recall? (A minimum of two or three elements.)	The accuracy of item recall	(Lynch K. , 1960)
	Questions focusing on indicating environmental cues		
1	What general physical characteristics would you give to the navigation area?	indicating environmental cues	(Lynch K. , 1960)
2	Why did you remember those elements (i.e., what were the features that made them memorable)?	indicating environmental cues	(Lynch K. , 1960; Vaez et al., 2021)

Source: The Authors

2.1.1.2. Free map sketching

Map sketches have been utilized to explore how individuals perceive, internalize, and apply spatial knowledge of space (Lynch, 1960). After participants complete a wayfinding task, they are asked to draw a mental image of the area and add any features that come to mind (Appleyard, 1969). In earlier research, prior to the prevalence of technology, researchers relied on basic tools such as pencils and paper for map sketching. Lynch (1960) highlights that the researcher would observe participants and take notes to document the sequence of elements drawn. More recently, with the advancement of technology, Tu Huynh and Doherty (2007) employed tablets and wireless pencils for map sketching, with software capturing the sequence of elements drawn in real time.

In addition to the quality of map drawing, two factors are used to evaluate all map sketches: item recall accuracy and item ordering (Lukas, et al., 2014). Figure 4-A shows the assessment of a map sketch in terms of item recall accuracy, where the sketch map has undergone segmentation and structural recognition of objects. The landmarks, nodes, and street segments on the sketch map are identified, labelled, and compared to the metric map of the area shown in Figure 4-B (Schwering et al., 2014).

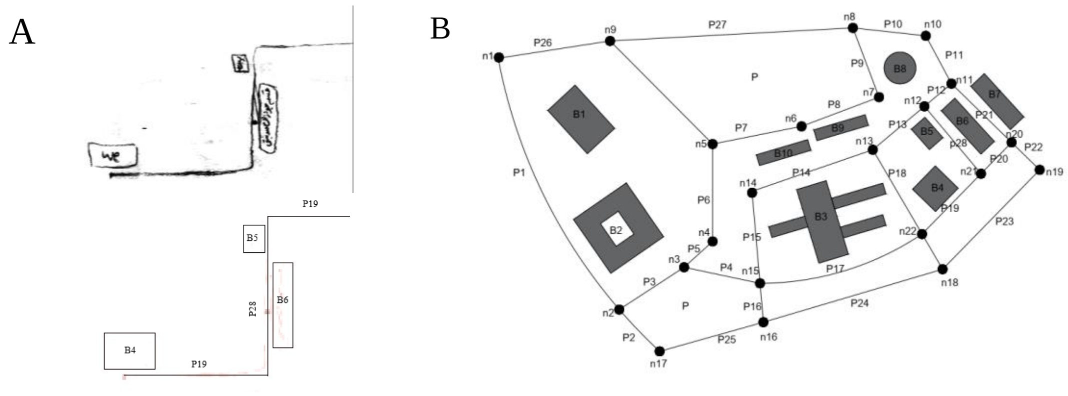


Figure 4. Evaluation of a sketch map involves: (A) Analysing and segmenting the sketch to identify and label paths, nodes, and landmarks. (B) comparing the sketch to a metric map of the same area. (Authors, based on Schwering et al., 2014 and Abou El-Ela, 2018)

The analysis of map sketches is typically conducted using Lynch's five elements: paths, landmarks, nodes, edges, and districts, as illustrated in Table 4.

(1) Each path in the drawing is assessed based on path recall accuracy and path order. Path recall accuracy is determined by the number of correct segments drawn (Lynch, 1960; Burnett & Lee, 2005) and correct bends or curves (Evans et al., 1984), while path order is determined by the sequence of turns and directions (Ishikawa et al., 2008; Evans et al., 1984; Vaez et al., 2021).
(2) The accuracy of landmark recall depends on the number of landmarks included in the map, such as transportation stations, restaurants, shops, religious buildings, police stations, and banks, in addition to the correct placement (Burnett & Lee, 2005).
(3) The accuracy of node recall depends on the number of nodes drawn and the precision of their locations (Abou El-Ela, 2018; Lynch, 1960).
(4) The accuracy of district recall depends on the ability to indicate groups of buildings with similar heights, architectural styles, and shapes inside the navigation area (Lynch, 1960).
(5) The accuracy of edge recall depends on the number and locations of elements being drawn, such as rivers, bridges, or train tracks.

Table 4. Analysis of map sketching based on Lynch's five elements: paths, landmarks, nodes, districts, and edges

Elements to be examined	Scoring criteria	Indicators	Papers used these methods
Paths	Accuracy of path recall	The number or ratio of recognized paths	(Burnett & Lee, 2005; Lynch K. , 1960)
	Accuracy of path order		(Ishikawa et al., 2008; Evans et al., 1984; Lynch, 1960)
landmarks	Accuracy of landmark recall	The number or ratio of recognized landmarks	(Burnett & Lee, 2005; Lynch K. , 1960; Vaez et al., 2021)
	Accuracy of landmark order		(Burnett & Lee, 2005; Lynch K. , 1960)
Nodes	Accuracy of node recall	The number or ratio of recognized nodes	(Abou El-Ela, 2018; Lynch K. , 1960)

Districts	Accuracy of district recall	The number or ratio of recognized districts	(Lynch K. , 1960; Abou El-Ela, 2018)
Edges	Accuracy of edge recall	The number or ratio of recognized edges	(Lynch K. , 1960; Abou El-Ela, 2018)

Source: The Authors

The primary challenge in free map sketching is the limited drawing skills of individuals, which hinders the accurate representation of their spatial knowledge (Tu Huynh & Doherty, 2007; Vaez et al., 2021). Therefore, the accuracy of a map drawing is determined by its level of quality and details according to its type. Vaez et al. (2021) identified three types of free maps: a top-down view (Figure 5-A), a side perspective (Figure 5-B), and a combination of both views (Figure 5-C).

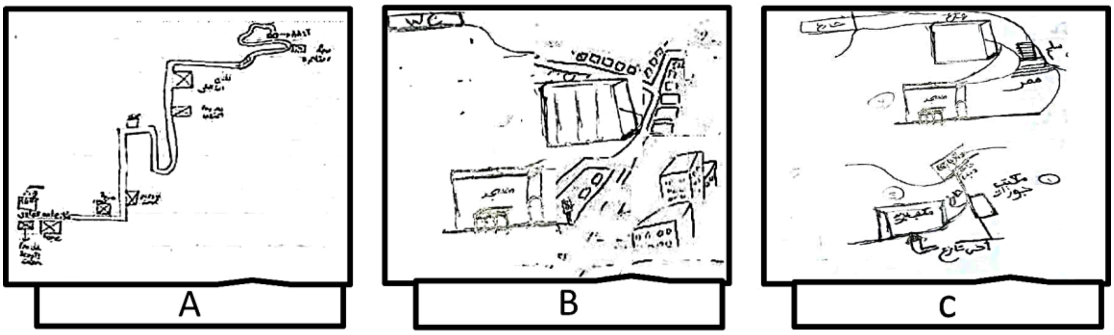


Figure 5. Types of free maps: (A) A top-down view, (B) A side perspective view, (C) A combination of both views (Adapted from Abou El-Ela, 2018 based on the classification of Vaez, Burke & Yu, 2021).

Map sketches are classified based on their degree of complexity, ranging from simple to complex (Figure 6). Simple maps are spatially scattered and sequentially fragmented. Spatially scattered maps lack connections between elements, like maps focusing mainly on landmarks, while sequentially fragmented maps lack integration or order between parts. On the other hand, complex maps are either sequentially branched and looped or sequentially netted, with a higher level of details and integration between elements (Burnett & Lee, 2005).

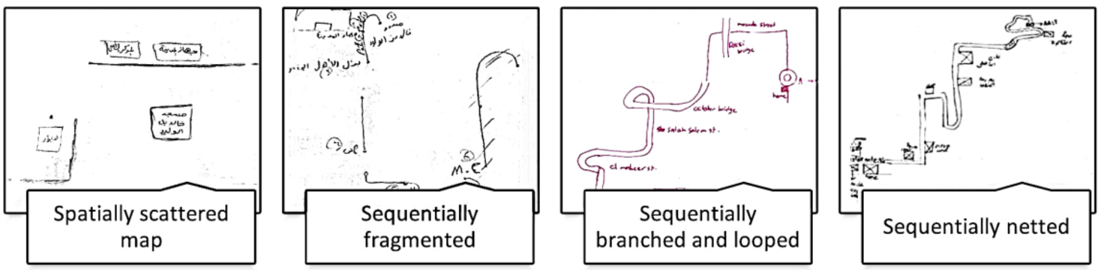


Figure 6. The degrees of map complexity (Adapted from Abou El-Ela, 2018 based on the classification of Burnett & Lee, 2005; Abou El-Ela, 2018).

2.1.1.3. Interview

After the wayfinding task, participants are usually interviewed and asked questions such as: "Would you be able to tell us which points or places in the navigation area you remember best?" They typically respond verbally (Appleyard, 1969). Previous studies have relied on the number of locations, buildings, or features remembered to assess the accuracy of item recall.

2.1.1.4. Verbal route descriptions (record)

After completing the wayfinding task, participants are usually asked to describe the route, the order of the sights, sounds, smells, and any landmarks they may have noticed along the way. Their responses are typically recorded to be easily analysed and investigated later to assess the accuracy of item recall and item order (Lynch, 1960; Appleyard, 1969).

2.1.2. Cued recall method

In the cued recall method, hints in the form of words or photographs are provided to aid memory. Participants are given a group of words or pictures from within and outside the navigation area and asked to identify which ones were seen inside the environment. The tasks of this approach enable researchers to assess how individuals identify the correct items and how they order and place them accurately in their correct locations (Lynch, 1960; Evans et al., 1984; Burnett and Lee, 2005; Ahmadpoor & Heath, 2018; and Ahmadpoor et al., 2020).

2.1.2.1. Wordy cues

In this task, participants are given a written list of items, with approximately half of them found in the navigation area and the other half from a different urban setting. The list includes common urban items like benches, fountains, and flower boxes. The accuracy of recall is assessed based on the number of items correctly remembered (Evans et al., 1984).

2.1.2.2. Map mark-up task:

After completing the wayfinding task, participants are asked to mark the route and significant landmarks they remembered on a blank map. This method helps avoid issues with participants' drawing quality. The route in each sketch is scored based on the percentage of accurately marked paths between turns or decision points, as well as the accuracy of included landmarks and their correct placement (Smith et al., 2022).

2.1.2.3. Photographic cues

Several studies such as (Lynch, 1960; Evans et al., 1984; Burnett & Lee, 2005; Huang et al. 2013; Münzer et al., 2006; Ben-Elia, 2021) have utilized photographic cues in various recalling tasks, such as object or scene recognition and route recognition tests.

2.1.2.3.1. Object or scene recognition task

This task is also called the photograph recall test (Lynch, 1960; Ahmadpoor et al., 2020), the landmark recognition test (Ahmadpoor, 2018; Ben-Elia, 2021), and the spatial recognition test (Vaez et al., 2021). In this task, participants are shown colour photos of urban elements or scenes within and outside the study area to assess their environmental recognition. Participants are evaluated using different scales, including "select," "yes/no," or "Likert." scales. In the "select" scale, correct responses are based on the number of accurately selected photos. In the "yes/no" scale, correct responses require indicating 'yes' for photos within the study area and 'no' for photos outside the study area. On the Likert scale, the correct response involves recalling scenes from the study area and not recalling scenes outside it, using a five-point Likert scale ranging from (remember) to (don’t remember at all). Table 5 illustrates how to indicate the degree of recognition for each urban element.

Table 5. Scoring criteria and indicators for object or scene recognition tasks

Elements to be examined	Scoring criteria	Indicators	Source
Scene	The accuracy of selecting a correct scene	The number or ratio of recognized scenes	(Lynch K. , 1960; Vaez et al., 2021; Ben-Elia, 2021)
	Level of recognizing the scene on a Likert scale		(Evans et al., 1984)
Path	The accuracy of path recall (yes/no)	The number or ratio of recognized paths	(Burnett & Lee, 2005; Ahmadpoor et al., 2020; Ben-Elia, 2021; Vaez et al., 2021)
	Level of recognizing the path on a Likert scale		
landmarks	The accuracy of landmark recall (yes/no)	The number or ratio of recognized landmarks	(Burnett & Lee, 2005; Ahmadpoor et al., 2020; Ben-Elia, 2021; Ben-Elia, 2021; Vaez et al., 2021)
	Level of recognizing the landmarks on a Likert scale		(Ahmadpoor & Heath, 2018)
Nodes	The accuracy of node recall (yes/no)	The number or ratio of recognized nodes	(Ahmadpoor et al., 2020; Ben-Elia, 2021)
District	The accuracy of district recall (yes/no)	The number or ratio of recognized buildings with similar heights, architectural styles, and shapes.	(Ben-Elia, 2021; Vaez et al., 2021)
Edge	The accuracy of edge recall (yes/no)	The number or ratio of recognized edges	(Lynch K. , 1960)

Source: The Authors

After scene identification, participants are asked to perform one or more of the following:

- Cue Identification: Participants are asked to identify cues that helped them remember the scene (Lynch, 1960).
- Scene Ordering: Participants are asked to arrange the scenes in a logical sequence, which is then compared to the actual order (Lynch, 1960; Evans et al., 1984; Burnett & Lee, 2005).
- Replacement Recall Task: Participants are instructed to place each photograph in its corresponding spatial location. This can be done either by physically arranging the pictures on a table or floor, as described in the studies of Lynch (1960) and Evans et al. (1984), or by digitally dragging and dropping them onto a map using electronic devices (Münzer et al., 2006).

2.1.2.3.2. The route recognition test

In this test, participants are required to remember actions at decision points and identify the directions they turned (Ben-Elia, 2021). Participants can indicate the correct direction by selecting one of the marked or coded routes (Münzer et al., 2006). The score is determined by the number of incorrect turning directions, representing the percentage of errors made (Huang et al. 2013).

2.1.3. Estimation method

In this method, researchers guide participants to the starting point and ask for two types of estimates: one for direction and one for distance:

2.1.3.1. Estimation of direction (Pointing task)

Lynch (1960) was the first to introduce directionality in mental image studies by asking participants to identify the north direction in the navigation area. Subsequent researchers, such as Ishikawa and Montello (2006), Willis et al. (2009), Huang et al. (2012, 2013), Ben-Elia (2021), and Karkasina et al. (2021), have utilized a pointing task where participants are instructed to imagine themselves at a starting point (any location) and visually point towards any other nearby destination. Participants draw an arrow from the center of a circle to the destination on paper (see Figure 7), allowing researchers to measure the average angular error between the actual direction and the pointed direction.

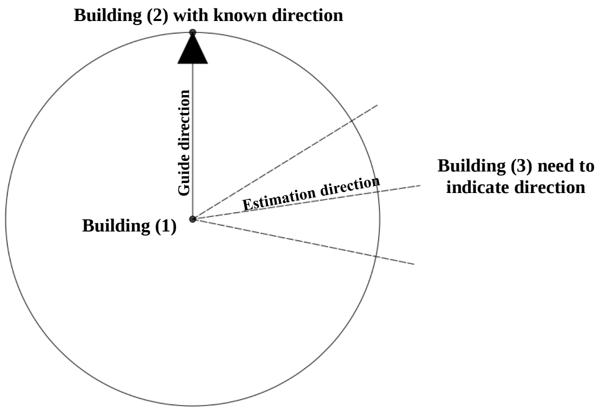


Figure 7. A simulated protractor that used to estimate direction in Pointing task (Authors based on Karkasina et al. (2021)).

2.1.3.2. Estimation of distance

In this task, participants are required to estimate the distance between two urban objects or landmarks. This estimation can be either free or cued. In free estimation, participants provide their own estimates without constraints, such as estimating the distance between Building A and Building B. In cued estimation, participants are given a cue, such as the distance between Building A and Building C, and then asked to estimate the distance from Building A to Building B. An example of such cues, where the researcher assisted the participants in estimating distance by providing the route distance between Building 5 and Building 1 in the study area and then asked the participants to estimate the distance between Building 5 and Building 2 (Ishikawa & Montello, 2006; Willis et al., 2009; Karkasina et al., 2021; Vaez et al., 2021; Kapaj et al., 2023).

Generally, there are two methods of distance estimation: straight-line distance, where participants estimate the direct distance to the destination along a specific direction, and route distance, where participants estimate the total distance by summing the route segments from the starting point to the destination. To evaluate distance estimation, the differences between the estimated and actual distances are calculated. Higher score values indicate poorer estimations, while lower score values indicate more accurate estimations (Ishikawa & Montello, 2006; Karkasina et al., 2021).

2.2 The recent approach:

Recently, new technologies and digital tools have been developed to assess visual-spatial cognition. One important tool for measuring visual attention during real-world navigation is mobile eye-tracking glasses like Tobii glasses. This device features a front-facing camera that captures video of the surroundings in front of the user, along with two rear-facing cameras positioned under each eye to record videos of the user's pupils.

The data from these videos is analysed to create a final video output showing the front-facing video with the gaze location overlaid on top. This visualization helps to indicate the duration of fixations on relevant elements such as facades and furniture in the environment, which aids in assessing spatial knowledge acquisition (see Figure 8) (Dong, et al., 2020).

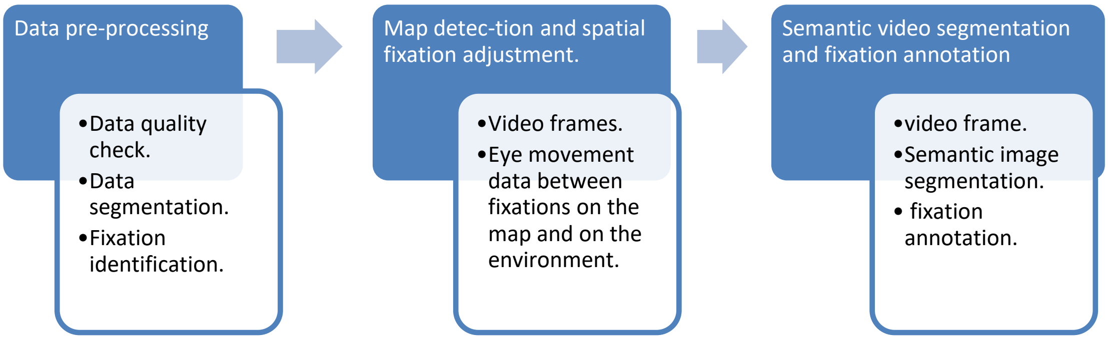


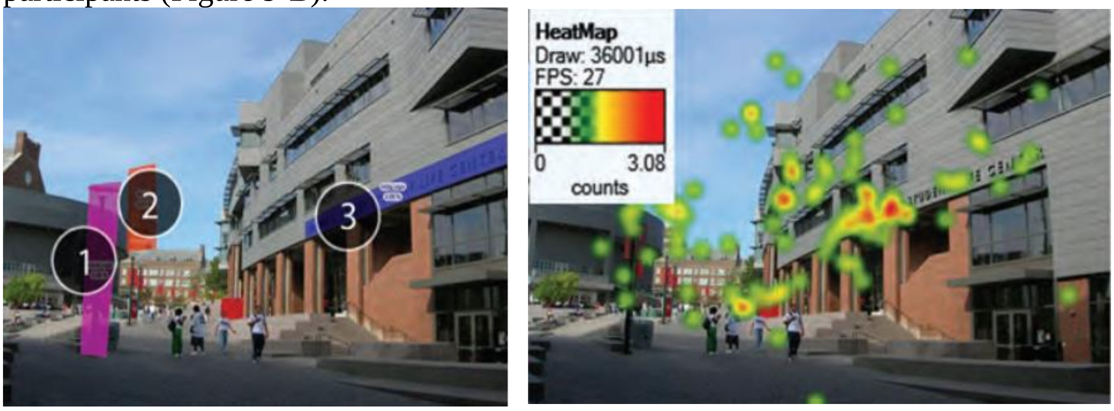
Figure 8. The three stages of data processing in the eye-tracking method (Adapted from Dong, et al., 2020)

2.2.1. Eye-tracking metrics and terms

Mobile eye tracking technology accurately measures human gaze behaviour during navigation in real-world environments, offering valuable insights into the information acquisition process. In eye tracking studies, the main measurements are based on gaze points, saccades and fixations. Gaze points refer to the specific locations in the visual field where a person directs their gaze. Saccades are rapid eye movements that occur when the gaze shifts quickly from one point to another. Fixations occur when a gaze point is maintained for a certain duration, indicating focused attention on a specific object. This reflects cognitive function and visual complexity (Dong et al., 2021; Tang, 2020; Xu et al., 2022; Wenczel et al., 2017).

The effectiveness of visual search is determined by saccade frequency, calculated by dividing the number of saccades by the duration of wayfinding. The average saccade duration (in milliseconds) is the mean of all saccade durations, while the average saccade amplitude (in degrees) reflects the extent of the visual search. On the other hand, information processing efficiency is studied based on fixation frequency, obtained by dividing the number of fixations by the wayfinding duration. A higher fixation frequency may indicate semantic significance. The average fixation duration (in milliseconds) represents the mean of all fixation durations. A higher value indicates more time spent decoding and higher cognitive processing levels. Fixation sequences provide insight into the order and direction of fixations, revealing what initially attracts a participant's attention and how the stimulus is perceived. Eye movement-based video classification fixation using labels such as Building, Wall, Person, Road, Terrain, Sidewalk, Moving objects (Bicycle, Car, or Truck), and Static objects (Vegetation, Fence, Pole, Sky, or Traffic sign) (Xu et al., 2022).

The analysis of saccades and fixations can be conducted using two methods: Areas of Interest (AOIs) and Heatmaps. AOIs are specific regions of stimuli that are of particular interest for study and can be compared against each other if needed (Figure 9-A). Heatmaps, on the other hand, visually represent fixation positions over time overlaid on stimuli, allowing for aggregation and comparison across groups or participants (Figure 9-B).



A B

Figure 9. (A): AOI analysis, (B): Heatmap analysis,
(Tang, 2020, available under CC BY-NC 4.0 license).

3. Discussion

The review of the previous studies has shown that wayfinding is a complex process involving multiple cognitive processes and behaviours. Researchers have employed various methods to investigate visual cognition in urban environments, which differ in the types of questions posed to participants, the nature of responses elicited, and the methods used for implementation and analysis. For example, the free recall method involves asking questions without any prompts or stimuli, allowing participants to freely provide answers through writing, drawing, interviews, or verbal descriptions. In contrast, the cued recall method provides questions with prompts, such as verbal words, visual pictures, or blank maps with a designated starting point, requiring participants to choose the words and photos they remember or draw the navigation route on the blank maps. The estimation method involves determining directions, angles, or distances between buildings.

Participants' knowledge is typically assessed at two levels: a basic level, which involves recalling elements only, and an advanced level, which involves recalling the relationships between elements. Lynch's basic techniques, such as free map sketching and photographic cues, are still relevant today, with slight adjustments to adapt to technological advancements. Technology has streamlined data storage and analysis, especially with software that can capture and evaluate the sequence of map drawings. Photographic cue tasks have evolved from printed images to photos displayed on digital screens.

The impact of navigational aids on spatial knowledge acquisition is the main focus of the majority of reviewed papers. The key findings suggest that while advanced tools like GPS and AR systems can be time-saving, interactive and facilitate navigation, they may have a negative effect on users' spatial cognition compared to traditional tools such as paper maps and local signage. For example, Ishikawa et al. (2008) found that GPS users had a higher mean absolute error in direction estimation and lower accuracy in map sketching. Similarly, Wang and Worboys (2016) observed that Google Maps users paid less attention to their surroundings, while Schwering et al.

(2017) Ben-Elia (2021) reported poor performance by Google Maps users in pointing accuracy, route recall, and landmark recognition.
Furthermore, studies by Huang et al. (2012, 2013) and Dong et al. (2021) indicated that AR navigation could also lead to lower spatial memory performance. The studies by Ahmadpoor and Heath (2018) and Ahmadpour et al. (2020) supported these findings, showing that non-GPS users had significantly better recognition memory and higher recall accuracy. Vaez et al. (2021) found that paper map group outperformed other groups in route accuracy and map quality, while the local-signage group performed better in relative object positioning compared to GPS group.
Additionally, studies by Huynh and Doherty (2007), Huang et al. (2012, 2013), Schwering et al. (2017), Abou El-Ela (2018), and Vaez et al. (2021) have emphasized the significance of landmarks and paths in shaping spatial memory. They observed that landmarks and paths were the most commonly depicted elements in map sketches and the most frequently mentioned features in verbal descriptions. Wenczel et al. (2017) noted that landmarks with higher visual salience attracted more attention. These findings offer valuable insights that should be taken into account in future urban design and planning endeavours.

4. Conclusion

Based on a review of previous research, this article has explored different methods for studying spatial cognition that urban planners and designers can use to enhance urban environments. The findings reveal two primary approaches: the conventional approach and the recent approach. The conventional approach includes free recall, cued recall, and estimation methods. Free recall involves tasks like answering questions, sketching maps, conducting interviews, and describing routes verbally. Cued recall uses word cues, photographic cues and marking up maps for scene recognition, scene order, and route recognition. The estimation method includes tasks for estimating direction and distance. The recent approach utilizes eye-tracking technology to analyse saccade and fixation durations to identify elements that attract people's gaze. To gain a deeper understanding of spatial cognition, it is recommended to use a combination of traditional and recent methods.
The reviewed studies indicate that while advanced navigational aids like GPS and AR systems can aid in navigation, they may impair spatial knowledge acquisition and weaken spatial memory compared to traditional tools such as paper maps and local signage. This highlights the need for further research to understand the reasons behind the lower performance of GPS and AR users and to explore potential solutions for this issue. The studies also emphasize the importance of landmarks and paths in enhancing spatial memory. This result suggests the need for further research to compare spatial memory across different urban environments, such as crowded cities, gated communities, heritage districts, and rural areas to identify the most effective elements in each setting. It is also required to investigate spatial memory among individuals with disabilities to determine effective elements for each type of disability.
Ultimately, this review has several limitations. First, only three online databases were searched, potentially excluding other relevant studies. Second, the scope of the search was limited to the terms "wayfinding," "navigation," and "perception," so incorporating additional keywords could have revealed further pertinent articles. Third, only English-language papers were considered, which may have led to the omission of significant research published in other languages. Moreover, as with any literature review, studies published after the search period were not included, leaving

the most recent research unreviewed. Therefore, future reviews should aim to expand the search criteria to explore additional dimensions of spatial-visual cognition.

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