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Analyzing Children's Mental Maps through Lynch's Imageability and Matthews' Typology: A Mixed-Methods Study of Urban Neighborhoods in Algeria

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Abstract

This study investigates how children perceive and cognitively represent their urban neighborhoods through the analysis of mental maps. The research was conducted with 100 children aged 9–11 years from two different types of neighborhoods in Batna, Algeria. The study adopts an integrated mixed-methods framework combining Lynch's (1960) theory of urban imageability and Matthews' (1992) representational typology to analyze both the spatial content and representational forms of children's drawings. Quantitative analysis based on Lynch's framework revealed that landmarks and paths dominate children's spatial representations, appearing in 91% and 83% of the drawings respectively. MANOVA results demonstrated a significant effect of neighborhood morphology on children's spatial representations (Pillai's Trace = 0.211, $F(5,84) = 4.489$, $p = 0.001$, $\eta^2 = 0.211$). In contrast, age and gender showed limited overall effects. Qualitative analysis revealed that the progression toward schematic representations was not solely associated with age-related cognitive development but was also linked to neighborhood morphology, indicating that the configuration of the built environment plays an important role in shaping how children organize and internalize spatial information. To deepen the interpretation of representational patterns, the study employed a complementary coding framework based on ten analytical axes addressing dimensions such as spatial organization, detail, perspective, labeling, and social interaction. The findings reveal that both developmental progression and neighborhood form jointly contribute to the way children construct and express spatial representations. The study contributes empirical evidence from the Algerian context and highlights the importance of legible and child-sensitive urban environments in supporting children's spatial cognition and environmental engagement.

1.0 INTRODUCTION

Children's daily interactions with urban environments play a crucial role in developing their spatial understanding and environmental knowledge. Examining the ways in which children mentally represent their surroundings offers valuable insights into the links between urban morphology and spatial cognition (Chawla, 1992).

The concept of spatial cognition has long been central to research on environmental psychology. Since Tolman’s (1948) seminal work on cognitive maps, scholars have emphasized that spatial knowledge is not a simple reflection of physical space but rather a mental construction shaped by perception, experience, and memory (Downs & Stea, 1973, 1977; Tuan, 1975; Gould & White, 1986). Neighborhoods therefore function as lived environments shaped by sensory, social, and emotional experience (Anderson, 2010; Merleau-Ponty, 2012). These environments function as developmental arenas where cognitive, emotional, and social competences are developed (Halseth & Doddridge, 2000; Veitch et al*.,* 2008).

Developmental psychology has important insights into how spatial understanding evolves during childhood. According to Piaget and Inhelder (1956, 1960), children's understanding of space evolves through successive developmental stages, progressing from egocentric representations toward increasingly organized and abstract spatial reasoning. In early stages, children tend to represent space through recognizable objects and personal experiences, while more advanced stages involve the ability to organize spatial relationships from an allocentric perspective (Newcombe, 1989). This developmental perspective has provided the theoretical basis for numerous studies examining children's drawings and cognitive maps.

A substantial body of research indicates that children’s spatial representations evolve progressively from pictorial and experience-based depictions toward more schematic and organized forms (Matthews, 1980, 1992). Beyond developmental factors, characteristics of the built environment also influence how children perceive, organize, and understand spatial settings. Within this perspective, Lynch's (1960) imageability framework identifies five fundamental spatial elements: paths, edges, districts, nodes, and landmarks, which organize cognitive representations of urban space. These elements have also been identified in children’s mental maps, although often in simplified or symbolic forms (Golledge & Stimson, 1997; Wood & Beck, 1989; Halseth & Doddridge, 2000).

Recent studies suggest that urban morphology and neighborhood structure can significantly influence how children perceive and represent space. Environmental affordances, accessibility, and spatial complexity shape children’s opportunities for exploration and interaction with their surroundings (Çanakçıoğlu, 2015; Özgece et al., 2015; Van Heel et al., 2023). Consequently, spatial cognition should be understood not only as a developmental process but also as an experiential one that emerges through everyday engagement with the physical environment. From an urban design perspective, opportunities for environmental exploration and everyday movement within neighborhoods can influence how children acquire spatial knowledge and construct cognitive representations of space (Han et al., 2022; Zhao et al., 2023). Understanding how children perceive and structure neighbourhood space is therefore important, as cognitive representations are associated with navigation, place attachment, perceived safety, and children’s experiences of local environments.

Despite the extensive international literature on cognitive mapping, empirical studies examining children’s spatial representations remain limited in many regions, particularly in North Africa. In Algeria, research addressing the relationship between urban morphology and children’s spatial cognition is notably under-explored. Rapid urbanization and large-scale housing developments have significantly transformed the urban landscape of Algerian cities, often prioritizing housing quantity over the spatial quality of neighborhoods. These changes raise important questions about how children experience and interpret contemporary urban environments.

Within this context, Batna was selected as a representative case study due to its rapid urban growth and the coexistence of contrasting residential typologies. As one of Algeria’s major urban centers and the regional metropolis of the Aurès (ONS, 2008; Fekkous et al., 2023), the city reflects the tensions between rapid urbanization and mass housing production. In particular, the expansion of high-density housing developments has often prioritized quantitative objectives over children's socio-spatial needs, contributing to what Beddiaf and Dib (2022) describe as "dead images" of urban space. Batna provides a particularly relevant case because the coexistence of collective housing estates and low-density individual housing neighborhoods creates distinct spatial conditions within the same urban and cultural context. This allows the influence of neighborhood morphology to be examined while minimizing broader socio-cultural variation.

Beyond the geographical context, there is also a critical need to refine the variables analyzed within such environments. Although developmental stages have been well documented, fewer studies systematically integrate individual variables (such as age and gender) with environmental variables (such as housing typology and urban morphology). Addressing these gaps requires analytical frameworks that combine quantitative attention to spatial elements with qualitative sensitivity to representational styles (Darbyshire et al., 2005). While previous studies have generally examined either developmental factors or environmental characteristics, relatively few have investigated how these dimensions interact in shaping children's spatial representations. Consequently, the mechanisms through which urban morphology may reinforce, constrain, or modify developmental patterns of spatial cognition remain insufficiently understood. This limitation is particularly evident in rapidly urbanizing contexts where children experience markedly different residential environments within the same city.

This study addresses these gaps by examining children's spatial representations in two contrasting neighborhoods in Batna, Algeria, characterized by different residential morphologies (collective and individual housing). By comparing these urban configurations, the study investigates how environmental and demographic factors shape children's cognitive representations of neighborhood space.

The concepts of spatial cognition, mental maps, and spatial representations are closely related but represent distinct dimensions of spatial understanding. Spatial cognition encompasses the mental processes involved in perceiving, organizing, interpreting, and using spatial information to understand and navigate the surrounding environment (Golledge, 1999). Within this framework, mental maps are internal cognitive representations of the environment, reflecting how spatial knowledge is structured in memory (Lynch, 1960; Downs & Stea, 1973). In this study, spatial representations refer specifically to the externalized expression of these mental maps through children's drawings, which constitute the primary empirical data. While analytically distinct, these concepts are used in a complementary manner to link cognitive processes with their graphical expression.

Despite growing interest in children's cognitive mapping, most studies have examined developmental processes and environmental characteristics separately. As a result, limited attention has been paid to how urban morphology interacts with children's developmental capacities to shape both the content and structure of spatial representations. This limitation is particularly evident in rapidly urbanizing contexts, where children experience contrasting residential environments within the same city. Addressing this issue requires analytical approaches capable of examining not only what children represent in their mental maps, but also how these representations are organized and expressed. In light of these research gaps, the present study is guided by the following two research questions:

1. How do children construct mental representations of their neighborhoods?
2. To what extent are these representations influenced by individual factors (age and gender) and environmental factors (housing typology and neighborhood morphology)?

To investigate these research questions, the study employs a convergent mixed-methods design that integrates quantitative analysis of spatial elements, based on Lynch's framework, with qualitative interpretation of representational styles using Matthews' typology. This integrated analytical approach enables a more nuanced examination of how children construct and express their cognitive representations of urban neighborhoods.

By integrating developmental and urban perspectives, the study contributes to the literature in three complementary ways:

1. Theoretical contribution: It integrates Lynch's urban imageability framework with Matthews' developmental typology, offering a multi-dimensional understanding of children's spatial cognition.
2. Methodological contribution: It develops an integrated analytical framework that combines Lynch's imageability elements, Matthews' representational typology, and a complementary ten-axis coding system, enabling the simultaneous analysis of both the content and structural organization of children's mental maps.
3. Contextual contribution: It provides empirical evidence from Algerian urban contexts, which remain underrepresented in studies of children's spatial perception.

The study is grounded in the hypothesis that children progressively construct multidimensional spatial representations of their residential environments, evolving from sensory and pictorial perceptions toward more structured cognitive maps. These representations are shaped by both developmental factors (age and gender) and environmental factors related to neighborhood morphology.

2.0 THEORITICAL FRAMEWORK

2.1 Kevin Lynch's Theory of Urban Imageability

Lynch's (1960) theory of urban imageability posits that the physical organization of the urban environment influences the formation of clear and coherent mental representations, allowing individuals to perceive, organize, and navigate space more effectively. Lynch identified five key elements that structure spatial representations: (1) Paths, habitual routes such as streets or alleys, which for children may include the way to school or play areas. (2) Edges, boundaries or discontinuities (e.g., walls, rivers, railways) that help organize spatial cognition. (3) Districts, coherent urban areas with distinctive identity, often central in children's perceptions of their neighborhoods. (4) Nodes, focal points such as squares, intersections, or community centers, where social interactions and transitions occur. (5) Landmarks, distinctive features like mosques, towers, trees, or playgrounds, used as reference points in navigation.

While Kevin Lynch's imageability elements were originally formulated at a macro-urban scale, they are conceptually downscaled in this study to the micro-environment of the residential neighborhood. Here, broad urban 'districts' manifest as localized residential zones differentiated by their specific housing typologies and architectural patterns, while grand 'landmarks' or 'nodes' translate into community-scale visual anchors and everyday social gathering spaces familiar to children (Burkut & Köseoğlu, 2022).

Children, according to subsequent studies (Golledge & Stimson, 1997), make use of these elements in simpler and more sensory-motor forms compared to adults. Research by Çanakcioğlu (2015) further demonstrated that variables such as gender and socio-economic background significantly affect the complexity of children's mental maps, highlighting the relevance of Lynch's framework for analyzing children's spatial representations. In the current study, Lynch's theory provides a methodological foundation for quantitatively assessing the presence or absence of these five elements in children's drawings.

2.2 Matthews' Classification Approach to Children's Mental Maps

Matthews (1992) offered a complementary perspective by focusing not only on what children represent but also on how they represent space. His typology categorizes children's drawings into six representational styles (ranging from pictorial to schematic and verbal forms) each reflecting different developmental stages. (1) Pictorial, visually descriptive, emphasizing familiar objects without accurate spatial relations. (2) Pictorial/Verbal, similar but includes written labels to clarify meaning. (3) Pictorial Schematic, transitional, combining visual realism with initial spatial organization. (4) Pictorial Schematic/Verbal, adds linguistic cues to structured spatial representation. (5) Schematic abstract, map-like representations with logical spatial relations. (6) Schematic/Verbal combines abstract mapping with written references for accuracy.

This typology enables researchers to interpret children's representational styles and examine how they reflect developmental characteristics alongside environmental and social influences. Unlike Lynch's framework, which emphasizes the spatial content of mental maps, Matthews' approach focuses on the form and organization of representation, offering additional insight into how children express their understanding of space.

2.3 Integrating Lynch's and Matthews' Frameworks

Lynch's and Matthews' frameworks provide complementary perspectives for analyzing children's spatial representations. While Lynch's theory focuses on the structural elements of urban space, Matthews' typology emphasizes the developmental forms through which children represent these elements. By integrating both approaches, the present study adopts a mixed-methods framework that examines both the content and the form of children's drawings. In this framework, neighborhood morphology, age, and gender are treated as independent variables, whereas children's spatial representations constitute the dependent variable.

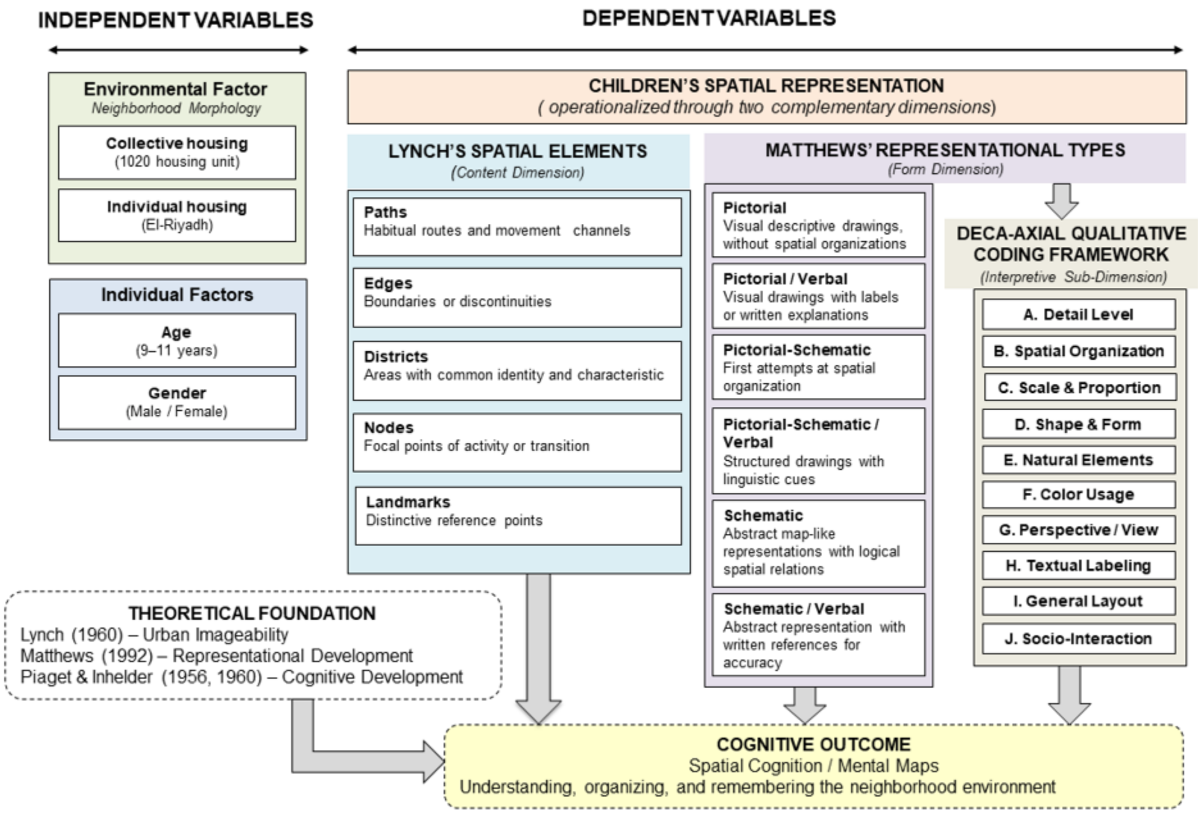

Figure 1. Conceptual framework of the study showing the relationships between environmental and demographic variables and children's spatial representations. (Source: Authors, 2026)

3.0 METHODOLOGY

3.1 Research Design

A convergent mixed-methods design was employed to examine children's spatial representations in different urban contexts. This approach combines quantitative analysis of spatial elements with qualitative analysis of children's drawings, providing a comprehensive examination of both the content and organization of children's spatial representations.

The quantitative component examines the distribution and variation of spatial elements using statistical methods (MANOVA), while the qualitative component focuses on the representational characteristics of drawings through Matthews' (1992) typology and a structured coding framework. The integration of these approaches enables triangulation, enhancing the validity and interpretative depth of the findings (Creswell & Plano Clark, 2008).

This synthesis is achieved at the interpretation level, where quantitative results are compared against qualitative complexity to examine how neighborhood morphology affects the organization and spatial content of children's mental representations.

3.2 Study Area and Sample

Data were collected in Batna, Algeria, from two residential neighborhoods characterized by contrasting urban morphologies. The first site, El-Riyadh, represents a low-density individual housing neighborhood characterized by a relatively regular and legible urban layout. The second site, 1020 Logements, represents a high-density collective housing estate with a more complex spatial organization.

The sample comprised 100 children aged 9–11 years, with 50 participants recruited from each neighborhood. The sample was balanced by gender to facilitate comparative analysis of demographic and environmental influences on children's spatial representations.

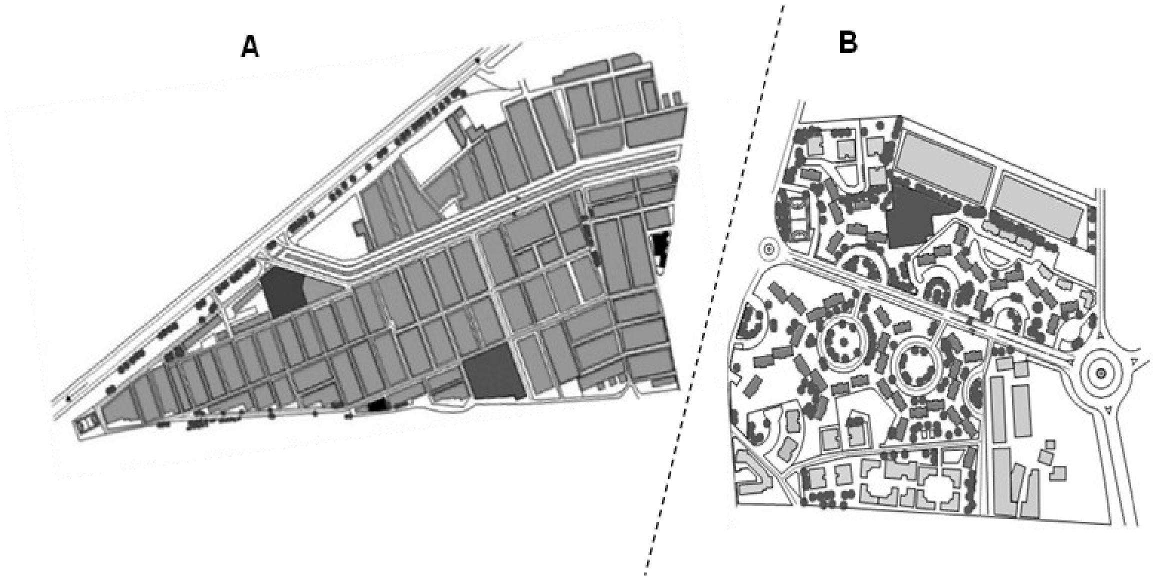

Figure 2. Map of the neighborhood's distribution: (A) El-Riyadh neighborhood and (B) 1020 Units Housing. (Source: Authors, 2026)

3.3 Data collection

The drawing sessions were conducted in classrooms with teachers assisting in explaining the task and clarifying the instructions. Each child was asked to produce a memory-based drawing of his or her neighborhood, which constituted the primary source of data for the analysis. This method is widely used in studies of spatial cognition as it captures both perceived spatial elements and cognitive organization of space context (Downs & Stea, 1973; Matthews, 1984; Halseth & Doddridge, 2000).

3.4 Variables and Operationalization

The study examines children's spatial representations as the main dependent variable. This construct was operationalized through two main analytical dimensions: (1) the spatial elements represented in children's drawings based on Lynch's (1960) framework; and (2) the representational forms analyzed using Matthews' (1992) typology. To deepen the qualitative interpretation of representational forms, a complementary set of ten analytical sub-dimensions (Axes A–J) was employed.

The Independent Variables include neighborhood morphology, gender, and age (9–11 years). Table 1 summarizes the operationalization of these variables and their corresponding indicators.

Table 1. Variables and Operationalization.

Variable Type	Variable Name	Operationalization
Independent (IV)	Neighborhood type	Individual Housing, and Collective Housing
Independent (IV)	Child's Age	9, 10, 11 years old
Independent (IV)	Child's Gender	Male or Female
Dependent (DV)	Lynch's Spatial Elements	Count and frequency of: Paths, Edges, Districts, Nodes, .and Landmarks
Dependent (DV)	Matthews' Typology	Qualitative classification into: (1) Pictorial, (2) Pictorial-.Schematic, or (3) Schematic
Qualitative sub-dimensions	Analytical axes (A–J)	Internal organization analysed through 10 axes(A-J)

(Source: Authors, 2026)

3.5 Data analysis

Data analysis combined complementary quantitative and qualitative approaches. Quantitative coding followed Lynch's (1960) imageability framework by recording the occurrence of five spatial elements: paths, edges, districts, nodes, and landmarks. The coded dataset was analyzed in SPSS 22. Descriptive statistics (frequencies and percentages) were first used to summarize the distribution of variables, followed by MANOVA to examine the effects of neighborhood morphology, age, and gender on the spatial elements. Model assumptions were evaluated using Levene's test for homogeneity of variance and the Shapiro-Wilk test for normality. Statistical significance was assessed alongside Effect Sizes (Partial η^2) to determine the practical significance of the findings, as recommended for complex urban datasets.

Qualitative analysis drew on Matthews' (1992) representational typology, through which each drawing was assigned to one of six categories: pictorial, pictorial/verbal, pictorial-schematic, pictorial-schematic/verbal, schematic, and schematic/verbal. MAXQDA 24 supported the qualitative coding process, facilitating the interpretation of developmental patterns, symbolic features, and variations in spatial reasoning.

To examine variations in children's spatial representations beyond Matthews' (1992) general stages, an additional deca-axial coding framework (Axes A–J) was developed in MAXQDA 24. This framework operationalizes established theories from environmental psychology into observable graphic indicators. As detailed in Table 2, each axis tracks the transition from primitive-pictorial views to advanced-abstract mapping.

Table 2. Detailed Qualitative Coding Framework (Axes A–J)

Axis	Dimension	Codes & Levels	Description of Indicators	Theoretical Basis
A	Detail Level	A1: Low A2: Med A3: High	From simplified elements to precise architectural and urban details.	Appleyard (1970); Golledge (1992)
B	Spatial Relations	B0: None B1: Partial B3: Coherent	Evaluation of the logical and topological organization between elements.	Piaget & Inhelder (1967); Matthews (1992)
C	Scale & Proportion	C0: Off C1: Mixed C2: Near-real	Accuracy of relative sizes and distances between urban features.	Matthews (1992); Golledge (1992)
D	Shape & Form	D1: Iconic D2: Geometric D3: Mixed	Transition from freehand iconic symbols to structured geometric forms.	Golledge (1992)
E	Natural Elements	E0: Present E1: Absent	Presence or absence of natural features (trees, greenery…)	Golledge (1992); Kose (1985)
F	Color Usage	F0: Mono F1: Limited F2: Rich	From monochromatic to rich (≥4 colors) with semantic/symbolic value.	Kose (1985); Lewis (1987)

G	Perspective / View	G1: Front/Side G2: Oblique G3: Top-down	Shift from egocentric frontal views to allocentric map-like perspectives.	Piaget & Inhelder (1967); Matthews (1992)
H	Textual Labeling	H0: None H1: General H2: Specific	Use of labels (e.g., "house" vs. "Street Name") as cognitive compensation.	Meehan (2018)
I	General Layout	I0: Clutter I1: Moderate I2: Clear	Overall visual organization, clarity, and lack of overlapping elements.	Matthews (1992)
J	Socio-Interaction	J1: Individual J2: Interaction J3: Symbolic	Presence of people, social activities, or symbolic icons of interaction.	Kose (1985); Lewis (1987)

(Source: Authors, 2026)

To ensure the internal consistency of the visual analysis, the researcher employed an intra-rater reliability procedure using MAXQDA 24. A random subsample of 100 drawings (n=20) was re-coded after a time interval. The Intercoder Agreement function was utilized, applying a minimum overlap rate of 80% at the segment level. The analysis yielded a high percentage of agreement (91.4%), with a Cohen's Kappa coefficient of 0.89, indicating almost perfect agreement according to Landis and Koch's criteria. This confirms that the coding process was stable and the identified themes were consistently applied across the dataset.

Based on this analytical framework, the results are presented in two integrated stages. First, the quantitative findings examine the distribution of Lynch's spatial elements and the statistical significance of differences across neighborhoods and demographics, utilizing MANOVA to assess effect sizes. Second, the qualitative analysis explores representational typologies and developmental patterns using Matthews' classification and the detailed coding axes. Together, these analyses reveal how environmental structure and developmental processes interact in shaping children's mental representations of urban space.

3.6 Ethical Considerations

The research adhered to ethical principles for studies involving children. Participation was voluntary, and official authorization was obtained from the Directorate of Education of Batna before data collection. To protect participants' privacy, all drawings were anonymized and treated confidentially throughout the research process.

4.0 RESULTS AND DISCUSSIONS

4.1 Spatial Elements in Children's Mental Maps: A Structural Analysis

The structural composition of children's mental maps was analyzed using Lynch's (1960) framework. Table 3 presents the distribution of spatial elements and their subcategories identified in children's drawings.

The results indicate that landmarks (91%) and paths (55%) are the most frequently represented elements, suggesting that these components form the primary structure of children's spatial representations.

Among landmarks, residential buildings (91%) and schools (83%) are the most frequently depicted, followed by shops and green spaces. This predominance reflects the importance of everyday environments and routine activity spaces in shaping children's spatial knowledge.

Similarly, paths (particularly those connecting home and school (55%)) play a central role, highlighting the significance of daily movement patterns in the organization of mental maps.

In contrast, elements such as edges (≤4%) and nodes (8%) are only marginally represented, indicating a limited emphasis on broader spatial structure and connectivity. Rather than reflecting a deficit, this pattern suggests that children's representations are primarily organized around meaningful places and functional routes.

This interpretation is consistent with the concept of environmental affordances (Gibson, 1979), which emphasizes how spatial knowledge emerges through interaction with frequently used environments. It also aligns with the action-based stage of spatial development described by Hart and Moore (1973), where spatial understanding is closely linked to everyday activities and destination-based experiences.

Overall, these findings indicate that children's mental maps are structured around familiar locations and habitual routes, rather than abstract spatial configurations requiring higher levels of spatial integration. This pattern is consistent with previous research emphasizing the role of environmental familiarity in shaping spatial cognition, place attachment, and well-being (Kyttä et al., 2016; Golledge, 1999; Hart & Moore, 1973).

Table 3. Distribution of spatial elements with subcategories identified in children's drawings according to Lynch's (1960) framework

Element	Subcategory	%	Element	Subcategory	%
Landmarks	Residential buildings	91	**Paths**	Home-school	55
	Schools	83		Isolated paths	28
	Shops / stores	72		Home–other	24
	Green spaces	55	**Districts**	Collective housing	56
	Mosques	37		Individual housing	50
	Football fields	23	**Nodes**	Roundabouts	8
Edges	Railway / Valley	2 / 4		Central squares	8

(Source: Authors, 2024)

4.1.1 Statistical Comparison of Spatial Elements by Neighborhood Morphology and Demographic Variables

To examine the combined effects of environmental and demographic factors on children's spatial representations, a Multivariate Analysis of Variance (MANOVA) was performed.

The MANOVA results revealed a significant multivariate effect of neighborhood morphology, Pillai's Trace = 0.211, $F(5, 84) = 4.48$, $p = 0.001$, $\eta^2 = 0.211$, indicating that the physical structure of the residential environment plays a substantial role in shaping children's spatial representations. In contrast, the main effects of gender ($p = 0.694$) and age ($p = 0.635$) were not statistically significant at the multivariate level.

Table 4 presents the significant univariate effects. Differences between neighborhoods were observed for districts ($F = 9.058$, $p = 0.003$, $\eta^2 = 0.093$), nodes ($F = 5.720$, $p = 0.019$, $\eta^2 = 0.061$), as well as for paths and landmarks, although with smaller effect sizes.

Table 4. Summary of significant multivariate and univariate effects of neighborhood morphology, age, and gender on spatial elements based on MANOVA results.

Source	Spatial Elements	F	p	η2
Neighborhood	**Districts**	9.058	.003*	.093
	Nodes	5.720	.019*	.061
	Paths	5.032	.027*	.054
	Landmarks	5.092	.027*	.055
Age * Neighborhood	**Landmarks**	4.227	.018*	.088
	Edges	3.499	.035*	.074
Gender * Neighborhood	**Landmarks**	4.825	.031*	.052

Significant at p < .05 Note: For brevity, non-significant main effects for Age and Gender are omitted from the table but were accounted for in the model. (Source: Authors, 2024)

These results suggest that neighborhood morphology selectively influences specific spatial elements rather than the overall quantity of elements represented. Children living in El-Riyadh (individual housing) depicted districts more frequently, which may be related to the clearer spatial organization and more legible boundaries of the low-density layout (Lynch, 1960; Appleyard, 1970). Conversely, the higher representation of nodes in the collective housing environment (1020 Logements) likely reflects the functional importance of shared spaces such as courtyards and playgrounds, which act as focal points for social interaction (Kyttä et al., 2016; Gehl, 2011).

In addition to these main effects, several interaction effects were identified. A significant interaction between age and neighborhood morphology was found for landmarks ($p = 0.018$, $\eta^2 = 0.088$) and edges ($p = 0.035$, $\eta^2 = 0.074$). This suggests that the development of certain spatial elements varies depending on the characteristics of the built environment.

More specifically, older children in El-Riyadh showed an increased tendency to represent edges and peripheral landmarks, indicating a more differentiated understanding of spatial boundaries. This pattern may reflect a progression toward more structured spatial knowledge, consistent with developmental models of spatial cognition (Hart & Moore, 1973; Matthews, 1992). In contrast, this progression appears less pronounced in the collective housing environment, where the representation of these elements remains relatively stable across age groups.

This finding can be interpreted through the lens of environmental affordances (Gibson, 1979), suggesting that certain urban forms may provide more opportunities for the exploration and integration of spatial features. Rather than indicating a limitation, this pattern highlights how different environments can support distinct pathways in the development of spatial understanding.

The significant interaction between gender and neighborhood morphology regarding landmark representation ($p = 0.031$) suggests that spatial cognition is shaped not only by developmental processes but also by the socio-spatial contexts in which children experience their environments. One possible explanation relates to differences in children's opportunities for environmental exploration and everyday mobility. Previous studies have shown that socio-cultural norms can influence the degree of spatial autonomy granted to boys and girls, thereby affecting their interactions with neighborhood environments and the spatial knowledge they acquire (Abu-Ghazzeh, 1998; Malone, 2007; Zeiher, 2003). Within such contexts, girls may rely more heavily on familiar and functionally significant landmarks, such as schools, mosques, or other frequently visited destinations, which serve as stable reference points within their everyday activity spaces. Recent research further suggests that children's opportunities for independent mobility are influenced by neighborhood characteristics, parental permissions, and socio-economic conditions, all of which may affect environmental exploration and spatial learning (Huang et al., 2024; Tyagi & Raheja, 2024).

Furthermore, recent studies suggest that neighborhood characteristics may influence children's opportunities for exploration through factors such as perceived safety, parental supervision, and access to outdoor spaces (Zhao et al., 2023; Lopes et al., 2021). In high-density residential environments, these factors may affect the extent to which children engage with their surroundings and develop spatial familiarity. Conversely, the more legible street layout of El-Riyadh may facilitate orientation and the identification of environmental reference points. Such interpretations are consistent with research highlighting how urban form can either support or constrain children's spatial experiences depending on prevailing social and cultural norms (Porter, 2020).

4.2 Qualitative Analysis: Representational Typologies (Matthews' Framework)

Figure 3 presents the distribution of children's drawings according to Matthews' (1992) typology of representational styles, grouped into three developmental levels: pictorial, pictorial-schematic, and schematic.

The results show that pictorial and pictorial-verbal representations are the most prevalent, accounting for the majority of the drawings. In these drawings, children primarily depict recognizable objects such as houses, streets, and schools, often accompanied by written labels. A second group of drawings corresponds to pictorial-schematic representations, reflecting a transitional stage in which spatial elements are more systematically organized. In contrast, fully schematic representations remain relatively limited, indicating that only a smaller proportion of children employ more abstract spatial structures.

These findings suggest a progressive shift from object-based and visually descriptive representations toward more structured spatial organization, consistent with developmental models proposed by Piaget and Inhelder (1960) and Matthews (1992).

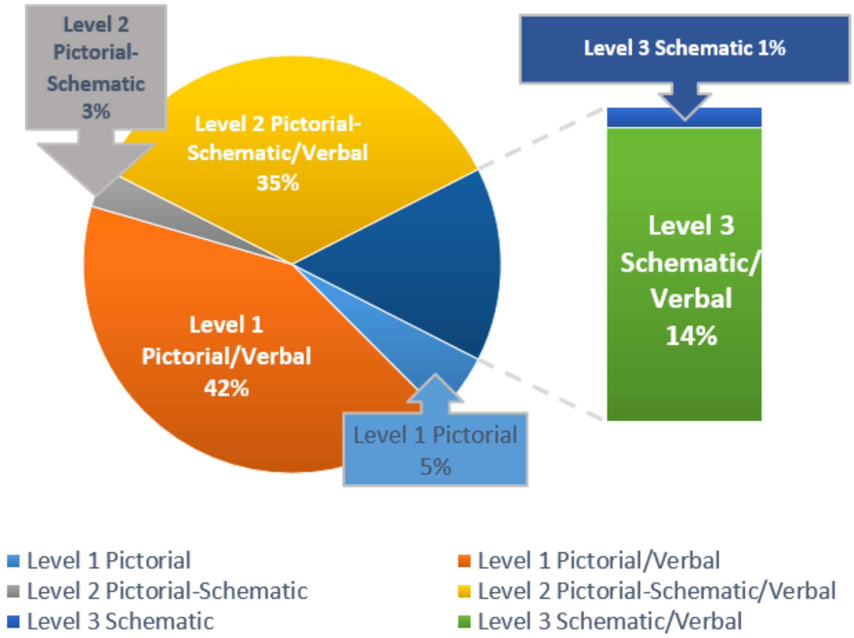

Figure 1. The distribution of drawings according to Matthews' (1992) typology of representational styles. (Source: Authors, 2025)

4.2.1 Representational Differences by Neighborhood, Gender, and Age

Table 5 presents the distribution of representational types according to neighborhood, gender, and age.

The results indicate that children from the 1020 collective housing neighborhood tend to produce a relatively higher proportion of schematic and schematic-verbal drawings compared to those from El-Riyadh. This pattern may reflect differences in spatial complexity and environmental structure, which could encourage more systematic encoding of spatial relationships.

This difference may be associated with the greater spatial complexity and diversity of affordances in the collective housing context, which can encourage children to encode spatial relationships in a more systematic manner. Kyttä et al. (2018), who found that organized urban environments could support the development of more advanced spatial representations by offering varied opportunities for interaction and exploration, have reported similar observations.

Gender-based differences were also observed in the distribution of representational styles. Boys showed a higher proportion of schematic and schematic-verbal maps (22% vs. 6%), whereas girls more frequently produced pictorial and pictorial-verbal representations. These maps often emphasized identifiable objects and, in some cases, included richer visual detail. However, as with previous analyses, these differences should be interpreted cautiously, as they remain descriptive and not statistically significant. Similar gender-related tendencies have been noted in earlier studies, although findings remain inconsistent and context-dependent (Matthews, 1987; Heth et al., 1997; Burkut & Köseoğlu, 2020).

Age-related differences are more consistent. Younger children (9 years) are predominantly represented in pictorial categories, while older children (11 years) show a higher presence of schematic forms. This progression is consistent with Piaget and Inhelder's (1960) theory of spatial development, which describes a gradual transition from perceptually grounded to more structured spatial representations. Similar developmental transitions have also been documented in studies of children's cognitive mapping (Matthews, 1992; Hart & Moore, 1973).

Table 5. Distribution of Matthews' categories by neighborhood typology, gender, and age.

Level	Subtype	1020 Neighborhood	El-Riyadh Neighborhood	Male	Female	9 years	10 years	11 years
L1	Pictorial	3	2	2	3	3	2	0
	Pictorial/Verbal	21	21	17	25	13	24	5
L2	Pictorial-Schematic	2	1	2	1	3	0	0
	Pictorial-Schematic/Verbal	15	20	17	18	6	24	5
L3	Schematic	1	0	1	0	0	1	0
	Schematic/Verbal	8	6	11	3	4	6	4
Total	—	50	50	50	50	29	57	14

(Source: Authors, 2025)

Three representative drawings are presented in Figure 4 to illustrate this progression. Figure 4(a) illustrates pictorial or pictorial-verbal representations (Level 1), characterized by the use of recognizable objects, iconic symbols, and limited spatial organization. These drawings typically emphasize emotionally or functionally significant places, such as the home or school. Figure 4(b) illustrates a transitional (pictorial-schematic) representation (Level 2), in which spatial elements begin to be arranged more systematically, indicating an emerging understanding of spatial relationships. Finally, Figure 4(c) presents a schematic or schematic-verbal representation (Level 3), characterized by clearer spatial structure, simplified forms, and more coherent organization. These drawings are more frequently observed among older children and those living in the collective housing environment.

Together, these examples highlight the gradual shift from object-based representations toward more abstract and spatially organized cognitive maps, reflecting both developmental progression and the influence of environmental experience.

Note: Alphanumeric indicators are superimposed onto the raw, Corresponding English translations are as follows: Sketch (a): [a1] House (مسكن); [a2] Mosque (مسجد); [a3] Primary School (مدرسة).
Sketch (b): [b1] School Zerouni Brothers (مدرسة الإخوة زروني); [b2] Shops/ Store (كشك/مكتبة); [b3] Home (البيت).
Sketch (c): [c1] Primary School (المدرسة); [c2] House (سكن); [c3] football field (ملعب); [c4] Mosque (مسجد); [c5] Residential Units (سكنات); [c6] Apartment Blocks (عمارات); [c7] Commercial Shops (محلات); [c8] Dentist clinic (طبيب أسنان); [c9] Military Housing (سكن عسكري).

Figure 4. Examples of children's drawings illustrate the progression of representational styles according to Matthews' (1992) typology: (a) pictorial/pictorial-verbal, (b) pictorial-schematic, and (c) schematic/schematic-verbal representations. (Source: Authors, Fieldwork Data)

4.2.2 Structural Characteristics of Drawings

The analysis of the 10 analytical axes (A–J) provides a more detailed understanding of children's representational strategies. Table 5 summarizes the main structural characteristics of children's drawings based on the coding framework (axes A–J).

The results indicate that a majority of the drawings exhibit moderate detail (57%) and partial spatial organization (53%), reflecting an intermediate stage of cognitive control. This incomplete organization highlights challenges in clearly encoding urban structural elements (Lynch, 1960), suggesting that urban legibility varies significantly across the studied environments. A predominant reliance on front-view perspectives (72%) was observed, a hallmark of egocentric or iconic representation (Matthews, 1992). Conversely, the emergence of top-view and schematic perspectives in more advanced drawings marks a developmental shift toward abstract spatial reasoning. This transition from pictorial memory to allocentric representation is a demanding cognitive task (Downs & Stea, 1973), requiring substantial mental effort to synthesize complex urban morphology into a coherent structure.

Furthermore, the widespread use of labels (91%) underscores the compensatory role of language in clarifying meaning when spatial precision is lacking. In this context, language acts as a cognitive scaffold, bridging the gaps in unified spatial schemas through socially agreed-upon naming conventions. In contrast, the scarcity of social interaction symbols (<10%) suggests that children conceptualize their neighborhoods primarily in physical and functional terms. This finding diverges from Chawla's (1992) emphasis on the social dimensions of place attachment, implying that in this specific urban context, functional utility and physical safety are prioritized; thus, the environment's affordances (Gibson, 1979) are perceived mainly through movement and use.

Table 5. Frequency distribution across analytical axes. (Source: Authors, 2025)

Axis	Code	%
Detail	A1-LOW	29
	A2-MED	57
	A3-HIGH	14
Spatial Organization	B0-NONE	25
	B1-PARTIAL	53
	B3-COHERENT	22
Scale	C0-OFF	38
	C1-MIXED	56
	C2-NEAR	6
Shape	D1-ICONIC	43
	D2-GEOM	11
	D3-MIX	46
Nature	E0-ABSENT	43
	E1-PRESENT	57
Color	F0-MONO	36
	F1-LIMITED	34
	F2-RICH	30
View	G1-FRONT	72
	G2-OBL	7
	G3-TOP	42
Labeling	H0-NONE	9
	H1-GEN	54
	H2-SPEC	37
Layout	I0-CLUTTER	17
	I1-MOD	44
	I2-CLEAR	39
Social	J1-IND	3
	J2-INTERACT	3
	J3-SYMB	9

To explore the relationships among coded variables (Axes A–J), a co-occurrence analysis was conducted via MAXQDA's Code Relations Browser. This identified how specific features (e.g., schematic layouts and top-view perspectives) align with Matthews' representational levels. The resulting patterns, mapped in Figure 5, reveal a three-tiered developmental progression from iconic encoding to abstract organization:

At **Level 1 (Early Stage)**, Characterized by pictorial and egocentric features. The analysis showed a reliance on visual details, front-view perspectives, and functional landmarks, confirming that early spatial perception is rooted in personal utility.

Level 2 (Transitional Stage) A critical integration point where iconic details coexist with nascent structural features. The systematic encoding of paths and mixed perspectives indicates a growing attempt to reconcile personal experience with objective structural schemas.

Finally, **Level 3 (Advanced Schematic Stage)** Marked by full abstraction and allocentricity. These maps feature top-view perspectives, clear layouts, and precise metric relations, with a noticeable decline in emotional or pictorial elements. This coherence was most prominent among older children and those from denser urban settings.

These patterns suggest that cognitive development is influenced not only by age-related maturation but also by the spatial structure and legibility of the built environment.

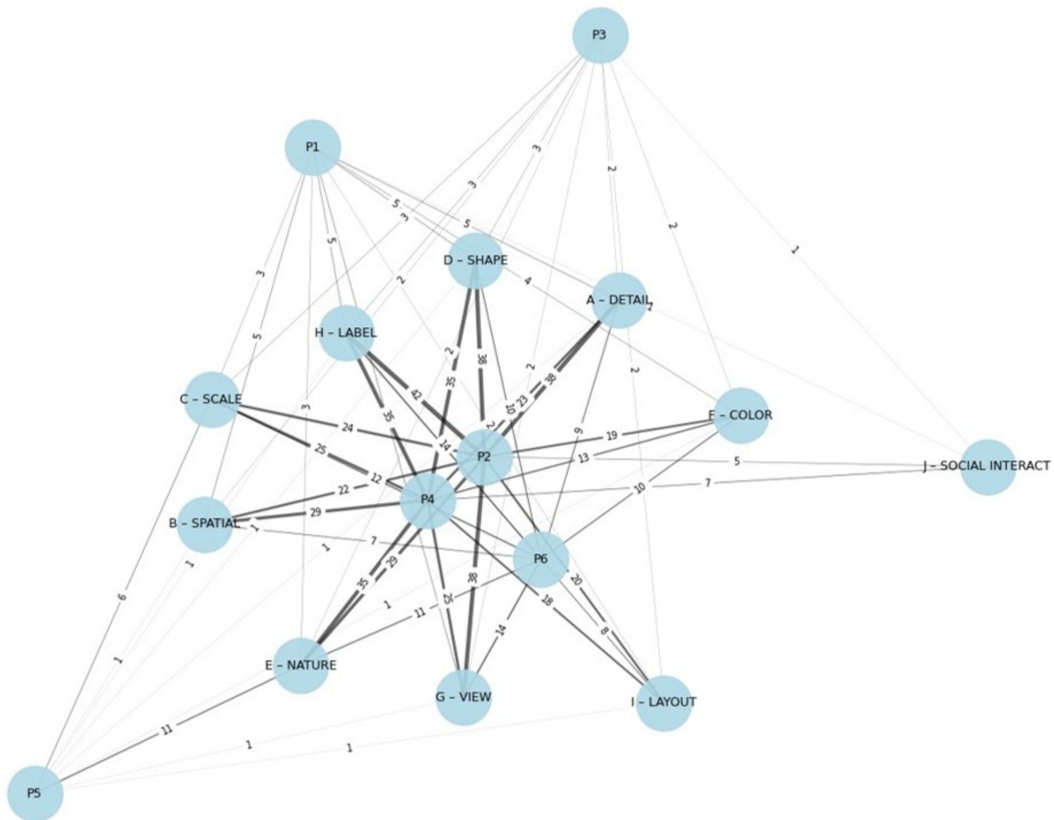

Figure 5. Code relations network between Matthews' levels and the Analytical Axes.
(Source: Authors, 2025)

Together, these findings validate a progressive shift from perceptual realism to conceptual organization, illustrating how spatial cognition matures through the integration of sensory, symbolic, and environmental experience. Children's drawings are not merely depictions of physical form but expressions of how lived environments shape their mental organization of space. Stokas et al. (2021) reported similar patterns in their study of Greek primary school children, whose drawings revealed a gradual transition from colorful, pictorial depictions of familiar places toward more structured and plan-like representations as cognitive and spatial understanding developed.

However, it is important to address the demographic variables where MANOVA tests did not yield statistically significant differences. The researcher acknowledges that the limited size of specific sub-groups, notably the 11-year-old group (n=14), may have constrained the statistical power of the analysis, potentially increasing the probability of a Type II error. This approach aligns with the findings of Meehan (2018), who argued that children's free-recall maps often reflect a 'wayfinding logic' and functional environmental knowledge that may not be fully captured by traditional geometric or purely quantitative metrics. By prioritizing the subjective experience of routes and landmarks over abstract spatial accuracy, Meehan (2018) suggests that children's cognitive mapping is a dynamic process, a perspective that supports this study's reliance on qualitative depth to explain patterns where statistical power was limited.

4.3 Synthesis: Integrating Quantitative and Qualitative Insights

The integrated analysis confirms that children's spatial cognition is a product of the interaction between developmental maturation and environmental morphology. While quantitative data highlights the dominance of landmarks and paths as primary structural elements, qualitative insights via Matthews' typology reveal a reliance on pictorial-verbal styles, reflecting a transition toward spatial abstraction. Statistical differences across neighborhoods, such as the prevalence of districts in El-Riyadh versus nodes in 1020 Units, underscore how neighborhood typology dictates the content of mental maps.

The coding analysis across the analytical axes further highlights this developmental transition. While many drawings display moderate detail and partial spatial organization, the presence of clearer layouts and top-view perspectives in some cases indicates the emergence of more structured spatial reasoning. The frequent use of textual labels suggests that language often functions as a complementary tool that helps children clarify spatial relationships when visual representation alone is insufficient.

Taken together, these findings indicate that children's mental maps are shaped through the interaction between cognitive development and environmental experience. Spatial understanding does not develop solely through internal maturation; it is also influenced by the opportunities for exploration, movement, and social interaction provided by the built environment. In this sense, urban morphology can be understood as a contextual framework that supports or constrains the development of spatial knowledge.

From a broader perspective, the results highlight the importance of designing residential environments that are legible, accessible, and rich in recognizable spatial cues. Urban layouts that provide clear pathways, identifiable landmarks, and safe communal spaces may facilitate children's orientation and spatial learning while strengthening their sense of place.

5.0 LIMITATIONS OF THE STUDY

The findings should be interpreted in light of several limitations.

First, the sample size (N = 100), while sufficient for identifying overall trends, resulted in relatively small subgroups when disaggregated by age, gender, and housing typology, particularly for the 11-year-old cohort. This limitation may have reduced the statistical power of some comparative analyses and should be considered when interpreting age-related differences.

Although children's spatial representations varied according to neighborhood morphology, the study did not directly assess independent mobility or socio-economic conditions. Previous research has shown that parental licence for independent mobility varies according to neighborhood characteristics and socio-economic context, influencing children's opportunities for environmental exploration and spatial learning (Huang et al., 2024; Tyagi & Raheja, 2024). Consequently, these factors may have acted as unmeasured influences on children's cognitive maps and should be incorporated into future investigations.

Finally, reliance on sketch maps may underestimate the spatial knowledge of children with limited drawing abilities or lower fine motor skills. Future research could complement cognitive mapping with GPS tracking, participatory GIS approaches, walk-along interviews, or other child-centered methods to better capture children's environmental experiences and spatial behavior.

6.0 CONCLUSIONS

This study investigated the intricate relationship between urban morphology and children's spatial cognition by integrating Lynch's (1960) urban imageability framework with Matthews' (1992) representational typology. Analyzing 100 mental maps from two contrasting neighborhoods in Batna, Algeria, the research underscores that children's spatial knowledge is a dynamic construct shaped by both developmental maturation and environmental affordances.

The findings reveal that children's mental representations are primarily structured around functional landmarks and paths, reflecting a spatial logic rooted in everyday navigation and familiar focal points. However, the comparative analysis highlights the decisive role of neighborhood typology: while the low-density irregular layout of El-Riyadh fosters a stronger sense of district identity, the high-density collective environment of the 1020 Units emphasizes nodes as vital social and orientation anchors. Qualitatively, the transition from pictorial to schematic styles confirms a developmental shift toward spatial abstraction, often supported by textual labeling as a cognitive compensatory tool.

From a planning perspective, these results advocate for child-sensitive urban design that prioritizes legibility and accessibility. Creating neighborhoods with clear pathways, recognizable landmarks, and safe communal spaces is essential not only for orientation but for strengthening children's sense of place and environmental autonomy. While limited by sample size and socio-economic variables, this research demonstrates that sketch maps are powerful diagnostic tools for urban planners. Future studies should complement these visual narratives with mobile methods, such as GPS tracking, to further capture the lived complexities of children's urban experiences.

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7.0 REFERENCES

Abu-Ghazzeh, T. M. (1998). Children's use of the street as a playground in Abu-Nuseir, Jordan. Environment and Behavior, 30(6), 799–831.

Anderson, J. R. (2010). Cognitive Psychology and Its Implications. Worth Publishers.

Appleyard, D. (1973). Notes on urban perception and knowledge. *Image and environment. Cognitive mapping and spatial behavior*, 109-114.

Beddiaf, W., & Dib, B. (2022). Informal urban development in urban cities. Spatial assessment in the city of Batna, Algeria. *Technium Soc. Sci. J.*, 37, 658. https://doi.org/10.47577/tssj.v37i1.7708

Blades, M., Blaut, J. M., Darvizeh, Z., Elguea, S., Sowden, S., Soni, D., & Uttal, D. (1998). A cross-cultural study of young children's mapping abilities. *Transactions of the Institute of British Geographers,* 23(2), 269-277. https://doi.org/10.1111/j.0020-2754.1998.00269.x

Brunet, R., Ferras, R., & Théry, H. (1992). Les mots de la géographie, dictionnaire critique, Paris. Reclus/La Documentation Française.

Burkut, E. B., & Köseoğlu, E. (2020). An investigation into the home environments of 10-14 age group children in the cognitive maps. Journal of Design Strategy and Art, 2(1), 15–30.

Çanakçıoğlu, N. G. (2015). Can cognitive maps of children be analysed by space syntax?. *A| Z ITU Journal of the Faculty of Architecture,* 12(3), 127-140.

Chawla, L. (1992). Childhood place attachments. *In Place attachment* (pp. 63-86). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4684-8753-4_4

Clark, V. L. P., & Creswell, J. W. (2008). *The mixed methods reader*. Sage.

Dalton, R., & Bafna, S. (2003, June). The syntactical image of the city: A reciprocal definition of spatial elements and spatial syntaxes. In *4th international space syntax symposium*. https://discovery.ucl.ac.uk/id/eprint/1104/

Darbyshire, P., MacDougall, C., & Schiller, W. (2005). Multiple methods in qualitative research with children: more insight or just more? *Qualitative research*, 5(4), 417-436. https://doi.org/10.1177/1468794105056921

Downs, R. M., & Stea, D. (1973). *Image and Environment: Cognitive Mapping and Spatial Behavior*. Aldine Publishing.

Downs, R. M., & Stea, D. (1977). *Maps in Minds: Reflections on Cognitive Mapping*. Harper & Row.

Downs, R. M., & Stea, D. (2011). Cognitive maps and spatial behaviour: Process and products. *The map reader: Theories of mapping practice and cartographic representation*, 312-317.

Elnesr, M., & Said, N. G. (2023). Sketch, Photo, Sound: Lived and Represented Space of the Child Experience in the Green Built Environments. Studying the Eco-districts in France. *Ain Shams Engineering Journal*, 14(6), 102113. https://doi.org/10.1016/j.asej.2023.102113

Farokhi, M., & Hashemi, M. (2011). The analysis of children's drawings: social, emotional, physical, and psychological aspects. *Procedia-Social and Behavioral Sciences*, 30, 2219-2224. https://doi.org/10.1016/j.sbspro.2011.10.433

Fekkous, N., Alkama, D., & Fekkous, K. (2023). Cartography and analysis of the urban growth, case study: Inter-communal grouping of Batna, Algeria. *Quaestiones Geographicae*, 42(1), 123-138. https://doi.org/10.14746/quageo-2023-0009

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Golledge, R. G. (1992). Place recognition and wayfinding: Making sense of space. *Geoforum*, 23(2), 199-214. https://doi.org/10.1016/0016-7185(92)90017-X

Golledge, R. G. (Ed.). (1999). *Wayfinding behavior: Cognitive mapping and other spatial processes*. JHU press.

Golledge, R. G., & Stimson, R. J. (1997). *Spatial behavior: a geographical perspective*, New York [etc.].

Golledge, R. G., Gale, N., Pellegrino, J. W., & Doherty, S. (1992). Spatial knowledge acquisition by children: Route learning and relational distances. *Annals of the Association of American Geographers*, 82(2), 223-244. https://doi.org/10.1111/j.1467-8306.1992.tb01906.x

Gould, P., & White, R. (1986). *Mental Maps*. Routledge.

Halseth, G., & Doddridge, J. (2000). Children's cognitive mapping: a potential tool for neighborhood planning. *Environment and Planning B: Planning and Design*, 27(4), 565-582. https://doi.org/10.1068/b2666

Han, L., Wang, Y., Ao, Y., Ding, X., Li, M., & Wang, T. (2022). The built environment impacts on route choice from home to school for rural students: A stated preference experiment. *Frontiers in public health*, 10, 1087467. https://doi.org/10.3389/fpubh.2022.1087467

Huang, W. Y., Feng, J., & Wong, S. H. (2024). Independent mobility and physical activity among children residing in an ultra-dense metropolis. *Translational Exercise Biomedicine*, *1*(3-4), 236-243. https://doi.org/10.1515/teb-2024-0006

Hart, R. (1979). *Children's Experience of Place*. New York: Irvington Publishers.

Hart, R. A., & Moore, G. T. (1973). The development of spatial cognition: *A review* (pp. 246-288).

Heth, C. D., Cornell, E. H., & Alberts, D. M. (1997). Differential use of landmarks by 8-and 12-year-old children during route reversal navigation. *Journal of Environmental Psychology*, 17(3), 199-213. https://doi.org/10.1006/jevp.1997.0057

Hume, C., Salmon, J., & Ball, K. (2005). Children's perceptions of their home and neighborhood environments, and their association with objectively measured physical activity: a qualitative and quantitative study. *Health education research*, 20(1), 1-13. https://doi.org/10.1093/her/cyg095

Kose, M. (1985). The effect of color on the perception of the built environment. *Environmental Design Research Association (EDRA) Proceedings*, 16, 125-135.

Kyttä, M., Broberg, A., Haybatollahi, M., & Schmidt-Thomé, K. (2016). Urban happiness: context-sensitive study of the social sustainability of urban settings. *Environment and Planning B: Planning and Design*, 43(1), 34-57. https://doi.org/10.1177/0265813515600121

Kyttä, M., Oliver, M., Ikeda, E., Ahmadi, E., Omiya, I., & Laatikainen, T. (2018). Children as urbanites: mapping the affordances and behavior settings of urban environments for Finnish and Japanese children. *Children's Geographies*, 16(3), 319-332. https://doi.org/10.1080/14733285.2018.1453923

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 159-174.

Lynch, K. (1960). *The Image of the City*. Massachusetts: The MIT Press.

Malone, K. (2013). “The future lies in our hands”: Children as researchers and environmental change agents in designing a child-friendly neighborhood. *Local environment*, 18(3), 372-395. https://doi.org/10.1080/13549839.2012.719020

Matthews, M. H. (1980). Children represent their environment: Mental maps of Coventry city centre. *Geoforum*, 11(4), 385-397. https://doi.org/10.1016/0016-7185(80)90025-1

Matthews, M. H. (1984). Environmental cognition of young children: Images of journey to school and home area. *Transactions of the Institute of British Geographers*, 9(1), 89–105. https://doi.org/10.2307/621869

Matthews, M. H. (1992). *Making Sense of Place: Children’s Understanding of Large-Scale Environments*. Hemel Hempstead: Harvester Wheatsheaf.

Meehan, P. J. (2018). “*Draw me a map of your town”: An investigation of the construction of a free-recall hand-drawn map of a known physical environment by young children* (Doctoral dissertation). Canterbury Christ Church University, United Kingdom.

Merleau-Ponty, M. (2012). *Phenomenology of perception* (DA Landes, Trans.).

Moran, M. R., Eizenberg, E., & Plaut, P. (2017). Getting to know a place: Built environment walkability and children’s spatial representation of their home-school (h–s) route. *International journal of environmental research and public health*, 14(6), 607. https://doi.org/10.3390/ijerph14060607

Newcombe, N. (1989). The development of spatial perspective taking. *Advances in Child Development and Behavior*, 22, 203–247. https://doi.org/10.1016/S0065-2407(08)60415-2

Office National des Statistiques (ONS). (2008). Recensement Général de la Population et de l'Habitat 2008. Résultats Principaux. Algiers, Algeria: ONS.

Özgece, N., Edgü, E., & Taluğ, M. (2015, January). Exploring children’s perceptions and experiences of outdoor spaces. In *10th International Space Syntax Symposium* (Vol. 125, pp. 1-15).

Piaget, J., & Inhelder, B. (1956). *The Child’s Conception of Space*. Routledge & Kegan Paul.

Piaget, J., Inhelder, B., & Szeminska, A. (1960). *The Child’s Conception of Geometry*. Basic Books.

Stokas, D., Strezou, E., Malandrakis, G., & Papadopoulou, P. (2017). Greek primary school children’s representations of the urban environment as seen through their drawings. *Environmental Education Research*, 23(8), 1088-1114. https://doi.org/10.1080/13504622.2016.1219316

Tolman, E. C. (1948). "Cognitive Maps in Rats and Men." *Psychological Review*, 55(4), 189–208.

Tuan, Y. F. (1975). Images and mental maps. *Annals of the Association of American Geographers*, 65(2), 205–213.

Tyagi, M., & Raheja, G. (2021). Children's independent mobility licence and its association with the built and social environment: A study across neighbourhood typologies in Kolkata. *Children's Geographies*, *19*(6), 717-734. https://doi.org/10.1080/14733285.2021.1891526

Van Heel, B. F., Van den Born, R. J. G., & Aarts, M. N. C. (2023). Everyday childhood nature experiences in an era of urbanisation: An analysis of Dutch children's drawings of their favourite place to play outdoors. *Children's Geographies*, 21(3), 378-393. https://doi.org/10.1080/14733285.2022.2071600

Veitch, J., Salmon, J., & Ball, K. (2008). Children's active free play in local neighborhoods: a behavioral mapping study. *Health education research*, 23(5), 870-879. https://doi.org/10.1093/her/cym074

Wood, D., & Beck, R. (1989). *Mental Maps. In Rethinking Cartography*. University of Chicago Press.

Zhao, X., Hussain, N., Shukor, S. F. A., & Ning, J. (2023). Neighbourhood physical environment influences on children's outdoor play: A systematic review. *Frontiers in Built Environment*, 9, 1193309. https://doi.org/10.3389/fbuil.2023.1193309