Dissanayake, W.M.S.S. and Amendra, S., 2026. Age-related variations in spatial cognition and spatial behaviour in botanic gardens: Evidence from the royal botanic gardens, Peradeniya. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Chandanie, H. and Tennakoon, G.A. (eds). *Proceedings of the 14th World Construction Symposium*, 10-11 July 2026, Sri Lanka. pp. 161-175. DOI: https://doi.org/10.31705/WCS.2026.13. Available from: https://ciobwcs.com/papers/

AGE-RELATED VARIATIONS IN SPATIAL COGNITION AND SPATIAL BEHAVIOUR IN BOTANIC GARDENS: EVIDENCE FROM THE ROYAL BOTANIC GARDENS, PERADENIYA

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ABSTRACT

Botanic gardens have evolved beyond plant conservation and research to serve as multifunctional landscapes. The study emphasises regeneration, sustainability, and resilient design, discovering user interactions and adaptations in these environments, an area that remains underexplored. Spatial cognition is reflected through spatial behaviour. This study examines the spatial behaviours of different age groups in the Royal Botanic Gardens, Peradeniya, Sri Lanka, to understand spatial cognition and its reflective behaviours. The study used the mixed-methods approach. The data collection was conducted based on four main methods to reduce bias and increase validity. A questionnaire survey, Onsite visitor interviews, three expert interviews, and onsite observation and mapping over three days of the peak visiting time. The study revealed that different age groups exhibit different spatial behaviours in the botanical gardens according to their cognitive abilities. The findings indicate that spatial behaviour varies across age groups. Young adults tend to explore more actively and navigate using landmarks, while older adults rely on signage, follow familiar routes, and prefer shaded resting areas. Children engage in educational exploration and can influence family movement patterns. These insights demonstrate the importance of age-responsive landscape design in enhancing navigation, spatial cognition, and overall user experience.

Keywords: *Botanic Gardens; Spatial behaviour; Spatial cognition.*

1. INTRODUCTION

Spatial cognition discusses the cognitive process by which humans can perceive, process, and navigate through their spatial world. It contains the basic components of wayfinding, mobility, and spatial behaviour, all of which change across the human life span and are differentially influenced across all life spans by age. These components do not change equally. It frames how one processes, remembers, and acts on spatial information throughout one's life. Modern neuroscience, particularly that involving single-unit recordings in freely moving animals, has elucidated how spatial information is encoded,

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integrated, and maintained over time. Such findings have significant implications for understanding human navigation within large-scale, complex, real-world environments and linking patterns of brain activity to equivalent spatial behaviour. This leads to a perspective of cognition as an embodied dynamic process rather than a static mental one.

International studies have investigated how age impacts spatial cognition and spatial behaviour in botanical gardens, however no studies have assessed the same qualities in Sri Lanka, specifically in the Royal Botanic Gardens, Peradeniya. Sri Lankan literature regarding botanical gardens is limited to botany, conservation, and ecological education, thus leaving the spatial experiences and behaviours of visitors wholly unexplored. Because of this, there is no database to inform the design of landscapes that adapt to the needs of multiple age groups in these types of environments. This research will resolve the gap of empirical knowledge regarding how spatial behaviour exhibits differences amongst visitors in relation to their age, and from this, the inability to design the gardens so that they adequately accommodate visitors of all ages.

2. LITERATURE REVIEW

2.1 HUMAN AGE

The World Health Organization (WHO) has long categorised individuals into different age groups (refer Table 1).

Table 1: Human age as a global standard

Life stage	Age range	Source
Children	Under 18	UNICEF, 2019
Youth	15–24	WHO, 2019
Adults	25–64	Havighurst, 1972

As cognitive development differs across these age groups, variations in spatial cognition and related behaviours can also be expected (refer Table 2).

Table 2: Human age and cognitive development

Life Stage	Age Range	Key Cognitive / Executive Function Developments	Key References
Children	0–12 years	Emergence of executive functions; development of attention control, cognitive flexibility, goal setting, and information processing. Near-comparative maturity of EF by ~12 years, forming the foundation for later self-regulation and goal-directed behaviours.	Anderson (2002)
Adolescence	12–20 years	Transition to formal operational thinking (12–15 years). Continued diversification of abilities and refinement of cognitive structures (15–20 years). Cognitive development is gradual and not strictly age bound.	Piaget (1972)
Adults & Older Adults	Young adulthood onward	Peak cognitive performance is reached in early adulthood. From mid-adulthood onward, processing speed gradually declines, which	Salthouse (1996)

Life Stage	Age Range	Key Cognitive / Executive Function Developments	Key References
		underlies broader reductions in working memory, reasoning, and spatial ability. Cognitive development in adulthood is therefore characterised by a progressive slowing of information processing rather than continued structural growth.	

The illustration in Figure 1 delineates the progression of cognitive development throughout the human lifespan.

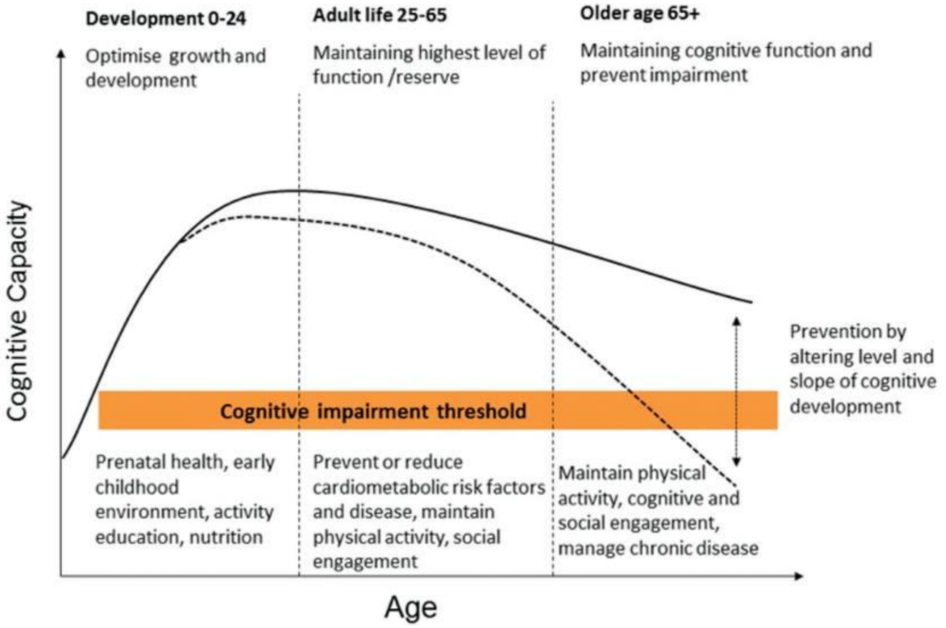

Figure 1:Schematic representation of the trajectory of cognitive development over the life-course capacity may vary according to lifestyle, environment, education and health

2.2 SPATIAL COGNITION

Environmental perception can be defined as the interpretation of sensory information from the environment, which varies with age. Spatial cognition, according to APA (2018), can be described as the mental process for obtaining and processing information concerning the spatial environment, which includes needs that go beyond the primary needs for survival, decision, orientation, and adaptability in navigating the environment. Research has been conducted on spatial cognition, including the use of environments such as botanical gardens, which provide a mix of both natural and artificial features, providing a better understanding of the relationship between humans and the environment. An example of this can be found in the study by Nori et al. (2009), which found the relationship between visuospatial working memory and the ability to navigate the botanical garden.

2.3 SPATIAL BEHAVIOUR

Spatial behaviour across environments varies significantly by age groups, with differences in cognitive abilities, sensory perception, and prior experience. The process of spatial exploration during childhood exhibits an egocentric nature and is cantered on oneself, with younger children relying more heavily on egocentric strategies than older children or adults, who are increasingly able to shift toward more effective landmark and metric strategies as they age (Yang et al., 2019).The development of spatial skills continues until late adolescence and early adulthood, where one becomes more mobile and exposed to the environment, resulting in an enhanced allocentric approach and improved navigational capacity compared to older people (Hegarty et al., 2024). There is a slight decrease during mid-life years characterised by a switch from allocentric to egocentric approach and reduced environmental exploration (Yu et al., 2021). In old age, significant problems with navigation arise, especially in creating cognitive maps and adopting different perspectives, mostly because of the shrinkage of the hippocampus and decreased activity of the retro splenial cortex (Wiener et al., 2013; Moffat, 2009).

2.4 ANALYSIS AND APPLICATION OF THEORIES

Understanding spatial cognition requires examining the theories that explain wayfinding, mobility, and specifically, spatial behaviour. Although Attention Restoration Theory, Spatial Cognition, Place Attachment Theory, and Space Syntax Theory are discussed separately, they overlap through their shared focus on human-environment interaction. Together, these theories explain how spatial form, perception, cognition, and emotional attachment collectively influence human behaviour, movement, and experience within a space, highlighting the multidimensional nature of spatial experience.

2.4.1 Attention Restoration Theory (ART)

Exposure to natural environments has shown that it can help restore a limited cognitive resource, which in turn enhances advanced cognitive performance. According to a formal review by Stevenson, Schilhab, and Bentsen (2018), exposure to natural systems, although attention-grabbing, focuses attention on process-related effects that change with low to moderate intensity. According to Neilson et al. (2019), preferred traits for a scene include coherence and legibility. Coherence refers to the way information is organised to be easily understood, while legibility refers to what is next, which allows for better navigation and orientation. These traits contribute to understanding a scene and a sense of safety, which reduces unexpected and threatening events. On the other hand, complexity and mystery traits involve exploration, with complexity being the number of elements, with highly varied environments that are difficult to categorise. Mystery, however, refers to undiscovered elements beyond what is seen. These traits have a link with restorative environments in the ART model, with a preference for natural environments, which has a historical survival advantage. According to Kaplan and Kaplan (1989), spaces that provide a mental map that is easily understood provide a survival and aesthetic advantage, and humans tend to explore and be drawn to it. Four aesthetic variables i.e. (i) Coherence, (ii) Legibility, (iii) Complexity, and (iv) Mystery have been identified for understanding and exploration, which include immediate and inferred information.

2.4.2 Space Syntax Theory

Space syntax is a theoretical and methodological framework developed by Hillier and Hanson that analyses spatial configurations and their influence on social and behavioural patterns within urban environments. The core components of space syntax include indicators such as connectivity, integration, intelligibility, and choice, which collectively assess the accessibility, coherence, and navigability of spatial networks (An et al., 2024).

2.4.3 Place Attachment Theory

Emotional and symbolic attachments are formed by people due to common interpretations and common experiences in relation to any location; this process is termed place attachment or space attachment. Emotional attachment is linked to how people see and interact with their physical world. According to Altman and Low (1992), symbolic attachment occurs through common symbols and meanings attached to any given place. Additionally, Stedman (2003) argues that some qualities of the place enhance positive emotional attachment to the place (Hashemnezhad, Heidari, & Hoseini, 2013) (refer Figure 2).

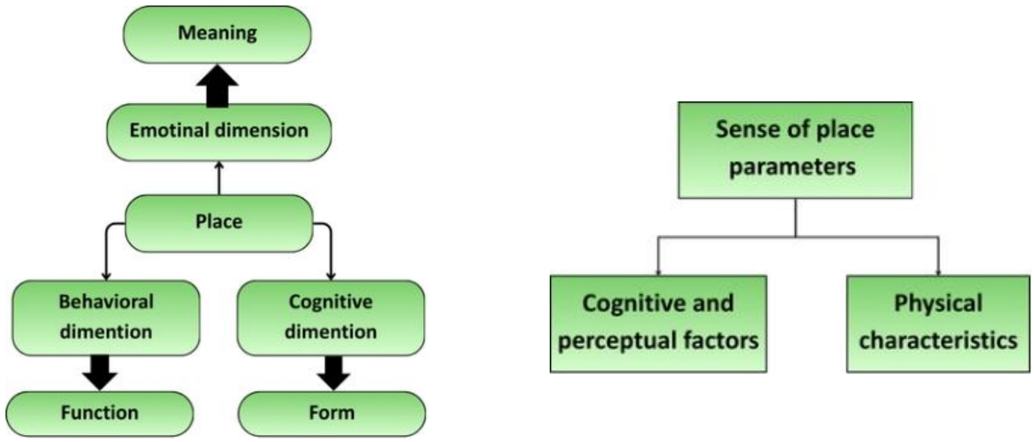

Figure 2: Sense of place factors and dimensions of creating places- Hashemnezhad, Heidari and Mohammad Hoseini (2013).

While ART, Spatial Cognition Theory, Place Attachment Theory, and Space Syntax Theory have their basis in distinct disciplines, all four theories are interrelated in their analysis of human behaviour. The configuration of spaces affects the way humans interact with the environment in terms of navigation, spatial cognition, and experience, leading to their emotional attachment and psychological restoration within spaces. It is thus important to note that human behaviour is determined by the interplay between the physical space itself and its psychological effects on the individual at various developmental stages.

2.5 Parameters of the Study

The theoretical framework was developed based on previous studies and theories, highlighting how these theories are interconnected with each other. According to that, developed parameters are defined and detailed further to study in the selected site, as explained in the table below (refer Table 3).

Table 3: Selected parameters and the definitions

Parameter	Definition
Visitor Preferences and Interests for key locations of the garden.	Patterns of choices and motivations that influence how visitors engage with environments (Falk & Dierking, 2016).
Seating and Rest Areas Usage	Patterns of how people use seating and rest areas as part of their spatial experience (Whyte, 1980).
Social Interaction Patterns	Observable behaviours in how individuals and groups communicate and gather within spaces (Gehl, 2011).
Engagement Opportunities	The extent to which spaces facilitate active participation, learning, and emotional connection (Packer & Ballantyne, 2002).

3. RESEARCH METHODOLOGY

The study uses a convergent parallel mixed-methods design, gathering and analysing quantitative and qualitative data simultaneously for a comprehensive understanding. The Royal Botanic Gardens at Peradeniya were selected for their extensive land area (refer Table 4) and visitor numbers (refer Figure 3) compared to other botanic gardens in Sri Lanka.

Table 4: Land area analysis of botanic gardens

Botanic Garden	Approximate Land Area (Acres)
Royal Botanic Gardens, Peradeniya	147
Mirijjawila Botanical Garden	300
Hakgala Botanical Garden	68
Seethawaka Botanical Garden	105
Henarathgoda Botanical Garden	44
Ganewaththa Medicinal Plant Garden	52

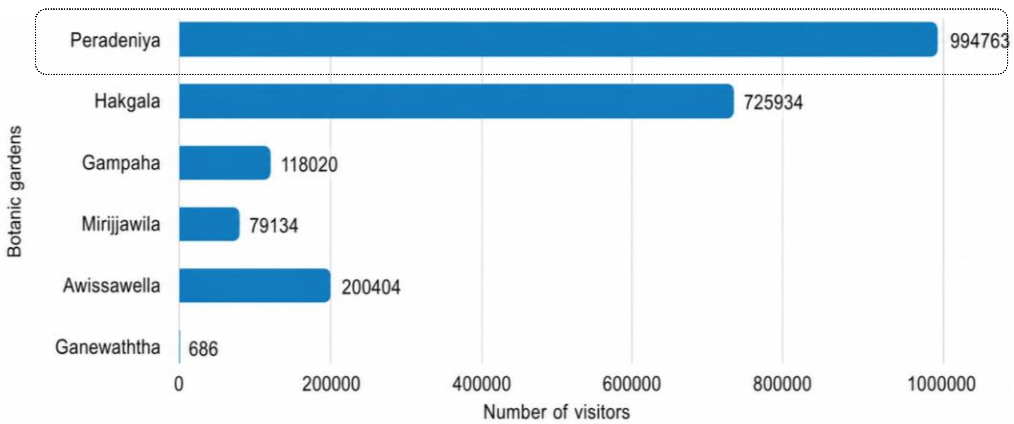

Figure 3: Annual visitors count for botanic gardens

The study was conducted in August, a peak arrival month, to understand how patterns of variation arise. The study employed a simple random sampling method to select participants for onsite interviews, thereby minimising bias and ensuring equal opportunity of selection within the defined target population (Etikan & Bala, 2017). The sample was limited to individuals ranging from youth to pre-seniors, as children and older adults were excluded for methodological reasons. Children's mobility, wayfinding, and spatial experiences are often mediated by caregiver behaviour, which could confound the findings (Cushing & Miller, 2019; van Vliet, 1983). Likewise, older adults may face mobility and accessibility constraints; only residents were included in the study to Prior research indicates that cultural background significantly shapes how individuals perceive, navigate, and interpret spatial environments (Low, 2017; Rapoport, 1982), and familiarity with an environment plays a crucial role in shaping spatial cognition and sense of direction (Piccardi et al., 2011). By focusing exclusively on locals who, by definition, have greater environmental familiarity, the study sought to maintain cultural and cognitive homogeneity, thereby, reducing variability in spatial responses. This approach increases the internal validity of the study, although it may limit the generalisability of findings to non-local populations.

3.1 DATA COLLECTION METHODS

Data were collected through four main methods, and the analysis process is summarised in Table 5.

Table 5: Data collection methods in detail

Method	Method in detail
Questionnaire Survey	The questionnaire includes both qualitative and quantitative questions about spatial behaviour, covering landscape preferences, user activities, and engagement. It also addresses pathway characteristics, signage, seating areas, and different locations. Data analysis was performed using MS Excel and Jamovi.
Site Observation &Photographic Documentation	The site visits were conducted over two weekdays and one weekend day to capture a broader range of visitor behaviours and activity patterns. Systematic observations were conducted of different areas to document spatial behaviours, movement patterns, and visitor preferences. In most areas, people were counted and documented. Highly crowded areas were photographed and documented using head counter software. The data collection was conducted by dividing the site into seven zones and selecting locations for photographic observation.
On-site visitor interview	The data collection was conducted outside the premises of the Botanic Garden due to the legal restrictions imposed by the Botanic Garden Ordinance of Sri Lanka. The data was gathered from visitors who had recently exited the garden. The sample comprised 70 participants. In the onsite interview, children's behaviour was analysed based on the caregivers' explanations, but their explanations showed the significant influence of the children on the overall behaviour of the group.
Expert's Interview	The questionnaire consists of both qualitative and quantitative questions. Interview conducted as a semi-structured interview with three experts who work in the industry and are engaged with the design aspects of Royal Botanic Gardens, Peradeniya. Two people are landscape architects, and one person is a Senior Agriculture and Landscape Instructor, School of Floriculture and Landscape Gardening, Royal Botanic Garden, Peradeniya, Sri Lanka.

The methodological framework has been established to provide a comprehensive overview of the study's overall work process (refer Figure 4).

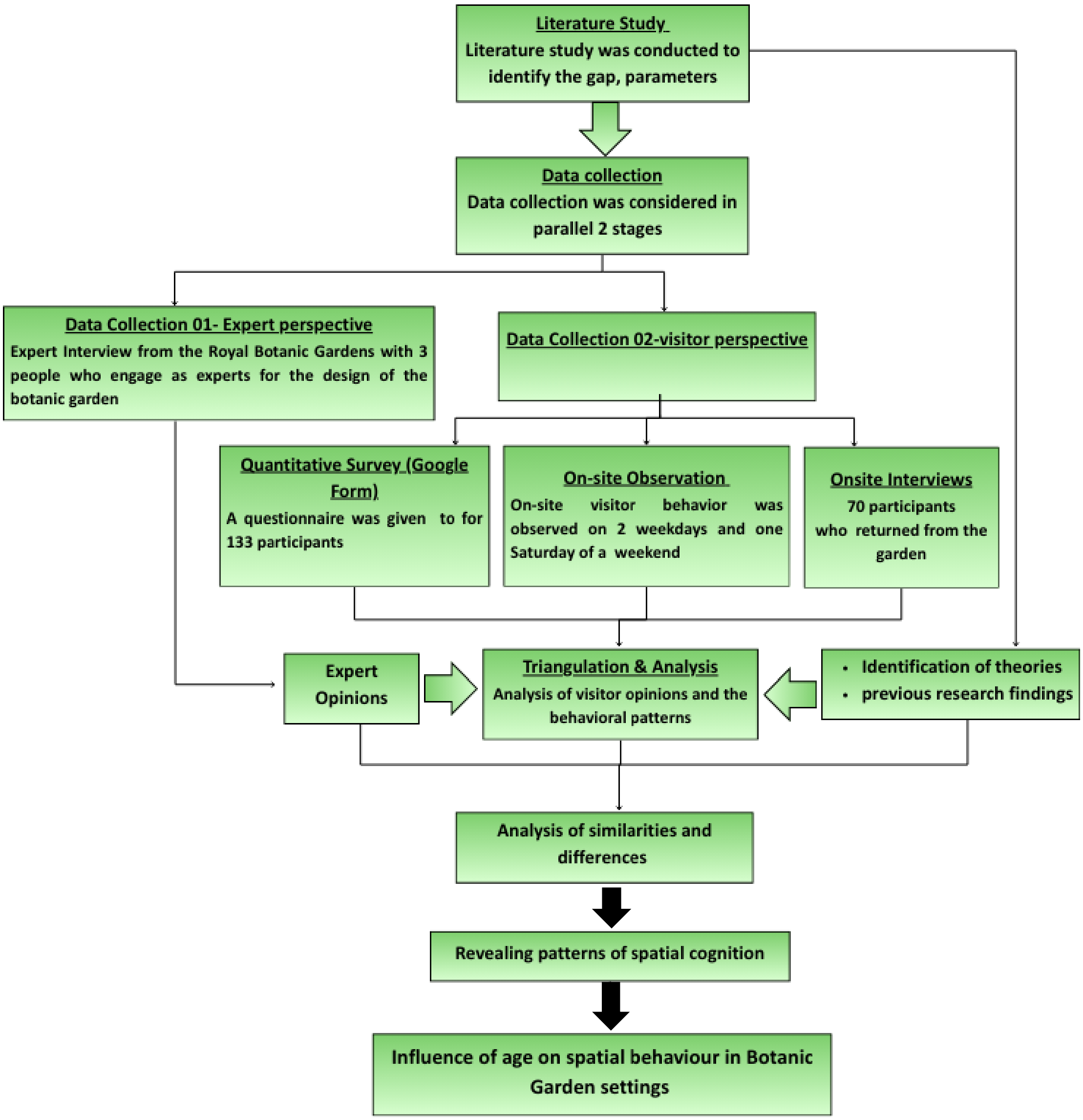

Figure 4: Methodological framework

4. DATA ANALYSIS

Under the spatial behaviour parameter, there are four sub-parameters considered for the study. According to expert opinions, the selected parameter analysis is given in Table 6. All experts emphasised the need for balanced primary and secondary circulation systems. Visitor movement patterns reveal selective spatial integration shaped by accessibility, visual prominence, and cognitive mapping processes.

Table 6: Expert opinions analysis of spatial behaviour

Parameter	Analysis
Visitor Preferences and Interests	Expert responses consistently indicate that spatial preference is structured by group composition, social intention, and environmental recognition. Prominent landscape elements function as cognitive anchors, while exploratory movement patterns reflect higher spatial confidence and adaptive engagement.
Seating and Rest Area Usage	Rest-area occupation varied according to desired levels of interaction, enclosure, and psychological comfort. Spatial use demonstrates restorative behaviour patterns influenced by privacy gradients and collective versus passive occupation.
Social Interaction Patterns	Social activity concentrated around visually dominant and accessible nodes, whereas peripheral routes supported lower-intensity and semi-private interaction. This reflects the influence of spatial visibility and territorial behaviour on social clustering.
Engagement Opportunities	Experts identified differences in navigational behaviour and interpretive engagement across visitor groups. Underutilised zones indicate that spatial legibility and landmark hierarchy strongly influence circulation and experiential depth.

The onsite observations were systematically collected from pre-selected viewpoints in each zone (refer Figure 5). All gathered data were analysed using Jamovi software. A set of one-way ANOVAS was run, focusing on differences between a group of eight varying age groups, ranging from children to seniors, for all activities measured.

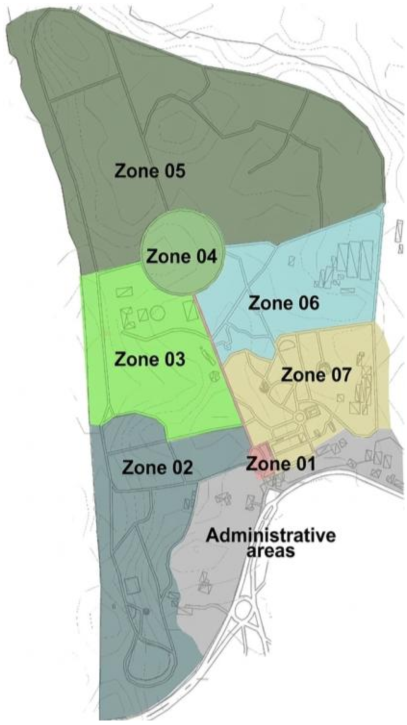

Figure 5: Zones of the study

Table 7: Analysis of observed behaviours

Activity	F-Statistic	df_1, df_2	p-Value	N (people)	Significance
Walking	1.128	7, 392	0.345	570	
Observing Nature	**2.611**	**6, 119**	**0.021**	**209**	✓
Sitting on the Floor	0.536	6, 70	0.779	170	
Sitting	0.420	5, 12	0.826	36	
Getting Food (Cafeteria)	0.552	5, 6	0.734	35	
Photography	0.495	3, 16	0.691	24	
Playing	**6.593**	**2, 21**	**0.006**	**24**	✓
Standing/Leisure	0.308	5, 12	0.899	23	
Sitting on a Bench	2.248	2, 15	0.140	13	
Reading the Map	1.500	2, 6	0.296	9	
Standing	0.400	1, 2	0.592	8	
Lying on the Floor	2.000	1, 2	0.293	4	

$p < 0.05$. Significant. Two walking observations with missing age breakdowns (N = 220 people) were imputed using proportional distribution based on observed walking patterns. Total sample: N = 1,125 people across 113 observation records. Highlighted rows indicate statistically significant results.

Significant differences between all age groups were found when comparing how each respective age category engaged in two activities (observing nature: F [6, 119] = 2.611; p = .021; playing: F [2, 21] = 6.593; p = .006). Conversely, the overall pattern of participation was similar for each respective age group in the remaining activities (walking: F [7, 392] = 1.128; p = .345; sitting on the floor: F [6, 70] = 0.536; p = .779; sitting on a bench: F[2, 15] = 2.248; p = .140; all other activities). Activities that had low sample sizes (i.e., < 10 participants) should be considered in their respective context when compared to the rest of the observations (i.e., lying on the floor: N = 4; standing: N = 8).

Figure 6: Provided seating arrangement references for the questionnaire survey

Seating and Rest Areas Seating preferences vary across age groups, as analysed using the collected data from the questionnaire survey (refer Figure 6). Adolescents received higher ratings, particularly for Seating 2, 3, and 5 (means = 5.00). Among larger groups, Youth (18–24) and Young Adults (25–34) tended to rate seats moderately, with means mostly around 3.3– 4.2 and showed relatively low variability (SD ≈ 0.8–1.2). Middle-aged Adults (35–44) and Older Adults (45–54) generally expressed stronger preferences for Seating 1 and 5 (means ≈ 4.0–4.5), with moderate variability (SD ≈ 0.7–1.3). Pre-seniors (55–64) were more inconsistent, showing lower averages (≈ 3.2–3.7) yet higher variability (SD ≈ 1.7), suggesting diverse opinions within this group. Seniors (65+) gave extreme values (means = 2.0–5.0), yet with only one respondent, these results are not reliable. Overall, Seating 1 and 5 received the highest mean ratings across most groups with lower variability, while Seating 3 had the lowest overall ratings with higher variability, indicating less consistent preference (refer Figure 7).

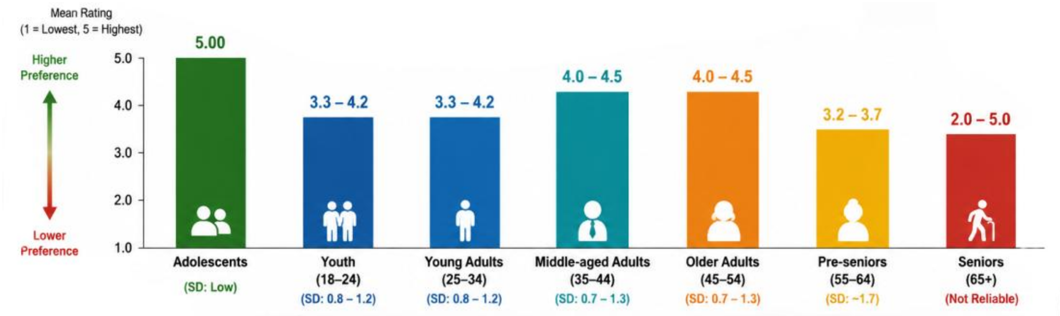

Figure 7: Mean ratings of seating preferences across different age groups

Activities and the emotional connections are analysed using the questionnaire survey according to the age groups to gain a deeper understanding of spatial cognition among different age groups. The analysis reveals calmness is the most prominent emotional response across all age categories, particularly among youth (18–24) and young adults (25–34). This highlights a strong confirmation of comfort and relaxation among younger groups. Blends involving calmness, excitement, and nostalgia are more typical among young and middle-aged adult groups, reflecting that in these environments, seating triggers a multi-tiered experience involving balance between tranquillity, excitement, and introspection. Nostalgia by itself or involving calmness runs more among young and older adult groups, signifying introspective experience with space. Seating elicits largely comfort-related feelings, with younger groups displaying wider diversity and older adult groups underlining calmness and introspective states (refer Figure 8).

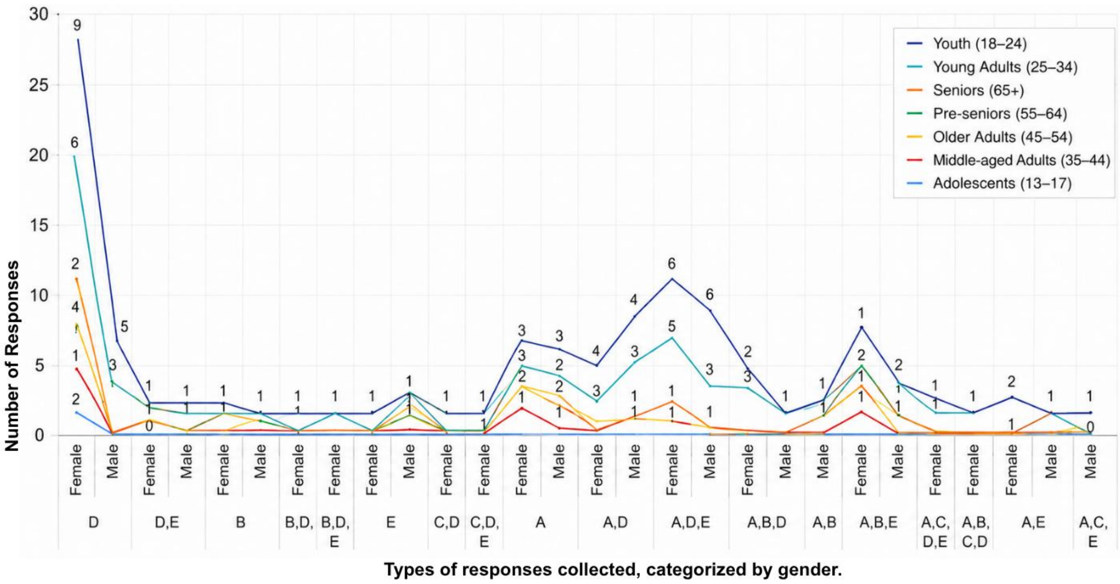

Figure 8: Age-related patterns of environmental preferences

The data collected presents an examination of environmental preferences across six age groups i.e. Adolescents, Youth, Young Adults, Middle-aged Adults, Older Adults, Pre-seniors, and Seniors) and gender categories. The environments were classified into five categories: A - Lush vegetation B - Sparse greenery, C - high level of manmade objects D - Natural elements (trees, rocks, streams), and E - Structured landscapes (flowerbeds, lawns).

Among all age and gender groups, the landscapes with natural elements (D) present the highest overall mean preference scores, with adolescents (13–17) and youth (18–24) reaching the highest values. Globally, the distribution of means corroborates a marked and coherent preference for vegetation-rich, nature-dominant environments with minimal artificial components across demographic groups.

4.1 DISCUSSION

This study shows that age significantly affects spatial behaviour, landscape use, and emotional responses in the Royal Botanic Gardens, Peradeniya. The findings indicate distinct differences in navigation patterns, activity preferences, and emotional experiences, emphasising the need for age-sensitive botanic gardens.

4.1.1 Age and Spatial Navigation

Navigation behaviours vary by age; older people often follow established routes using well-supported signage, compared to younger people who are more likely to explore various routes and areas around the site. There was a tendency for older people to avoid more complex spatial areas, such as peripheral regions; however, younger adults were willing to take more exploratory routes than their older counterparts. This creates support from previous studies that indicate that older adults rely more on following routes for navigation than younger adults and that younger adults exhibit greater flexibility in navigating through an environment while older adults exhibit lower degrees of flexibility in navigating an environment (Moffat, 2009; Wiener et al., 2013; Hegarty et al., 2024). A notable finding was the role of children as “spatial catalysts” within family groups. Children frequently influenced movement decisions by drawing attention to botanical displays, interpretive signage, and less-visited areas. This suggests that educational and heritage landscapes can encourage exploration through child-driven curiosity, extending previous observations of caregiver-child wayfinding dynamics.

4.1.2 Age and Landscape Use

There were age differences regarding the different types of landscaping being used. For example, it was found that older and middle-aged individuals tended to congregate more near the entrances, walkways, and activity points within the landscape, whereas younger people were usually found in low-traffic, shaded areas that provided them with privacy and a more natural view of their surroundings. This pattern corresponds to both Whyte’s (1980) social visibility preferences in landscape usage and to the fact that there were age-related differences in the types of landscaping used. Activity type was based on the individual’s age; therefore, age likely influenced the behaviour of an individual in relation to the landscape rather than total mobility. The time spent playing, viewing nature, resting, and reading a map was very different between the three groups; however, there was no significant difference in the amount of time spent walking or standing between the groups. As such, discretionary activities are influenced more (age-discretionary behaviours) by the individual's age than by their basic movement behaviours (walking/standing).

4.1.3 Emotional Reactions and Restoration

Individuals from all age cohorts felt at peace the most frequently, providing evidence that ART, which states that being in a natural environment produces emotional restoration (Kaplan & Kaplan, 1989), holds true. Older individuals felt nostalgic and reflective to a greater extent than younger individuals, indicating that older individuals had a greater emotional connection to the landscape.

4.1.4 Spatial Configuration and Movement

Visitor patterns closely corresponded with the garden's spatial structure. Highly integrated and visible areas, particularly those containing prominent landmarks, attracted greater numbers of visitors. These results support the conclusion that spatial configuration plays a significant role in shaping movement patterns and space use within the garden. In comparison to the main pathways dominating the garden, the peripheral zones of the garden, which are ecologically valuable areas outside the major pathways, were grossly underutilised (based upon the landscape quality), even though they are ecologically valuable. This indicates that spatial legibility and landmark visibility contribute to the degree of exploration, and for older visitors. Across all age groups, there were clear preferences for areas with dense vegetation and natural features. This consistency supports the theories of the positive relationship between natural environments and restful behaviours, and positive experiences of natural landscapes. Additionally, these results indicate that the Heritage and Cultural Value of the Royal Botanic Gardens contribute to the enjoyment of nature by visitors irrespective of age.

4.2 LIMITATIONS

Uncontrolled variables likely confounded age-related findings. For example, visitors' familiarity with the gardens, spatial layout, or social group (family vs peers), education/occupation, and botanical interest were not examined. Prior work shows that higher education predicts better wayfinding, and obesity (high BMI) is linked to restricted mobility and a smaller life-space, suggesting such factors could influence path choices and resting behaviour.

5. CONCLUSIONS

This research supports previous evidence that age plays a role in how people think spatially and act during an activity at Royal Botanic Gardens Peradeniya, shows a lack of studies on the influence of age on emotional responses to nature in Sri Lanka; and provides information about how age can affect the discretionary use of land (i.e., where people choose to go) at the botanical gardens, particularly for nature observation and play; while basic behaviours related to movement are similar across all age groups (e.g., walking). Younger visitors tended to prefer environments that were natural and contained a lot of vegetation with an exploratory route to reach their destination, while older adults tended to use well-connected, accessible spaces with places to sit that were enclosed. Children can act as spatial catalysts for family members in creating travel patterns. Calmness was the most frequent emotional reaction across all ages, providing evidence of the restorative nature of the botanical gardens. Nostalgia was more frequently reported among older adults than among younger adults. There was a lack of use of peripheral areas by all age groups, indicating a need for improved spatial legibility and visibility of landmarks. These results suggest that designers should create age-responsive landscapes using improved signage and seating that is accessible to all and enhanced wayfinding to better serve the diverse visitor population.

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