ENVIRONMENTAL DESIGN

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BIONOVA

Journal of Eco+urbanism & Neuroarchitecture

WHERE RESEARCH INSIGHTS MEET PUBLIC ENGAGEMENT

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EDITORIAL DIRECTOR'S NOTE

We are delighted to present the debut issue of the Journal of Eco+urbanism & Neuroarchitecture (JEN), a novel initiative by BIONOVA aimed at transcending the traditional boundaries of scientific research dissemination.

JEN seamlessly integrates the rigor expected of a scholarly journal with the accessibility and appeal of a magazine to bridge the gap between scientific knowledge and public engagement.

Our commitment to democratising scientific knowledge stems from the understanding that bringing about transformative change within our society requires an inclusive approach. The inherent jargon and exclusivity of scientific literature often pose challenges for those whose lives it could profoundly impact. JEN's commitment to accessibility is a dedication to fostering an informed society.

As we embark on this exciting journey with our debut issue, we extend our deepest gratitude to our team at JEN and our guest contributors. We welcome you to join us in this initiative as we navigate the intriguing intersection of architecture, the environment, and neuroscience.

ANN ROCHYNE THOMAS
Editorial Director
Journal of Eco+urbanism & Neuroarchitecture (JEN)

Spatial Planner, Neurodesign Consultant and Science Journalist
Founder, Centre for Climate Resilience
Founder, BIONOVA
Kerala, India

EDITORIAL PREFACE

We take immense pride in unveiling a meticulously curated compilation of articles within the debut issue of the Journal of Eco+urbanism & Neuroarchitecture (JEN). These contributions aim to deepen our comprehension of the dynamic interplay between the built and natural environments and human perception, targeting both the scientific community and the public.

"Multimodal Taste Perception: Bridging Neuroscience and Gastronomy" delves into the complex interactions between environmental stimuli and food perception. Veronica Giannini's multidisciplinary approach enables informed discussions on improving the overall quality of our gastronomic experiences.

In "Healthcare Spaces: The Intersection of Design, Health, and Well-Being", Clarissa Machado makes a compelling case for reimagining healthcare environments by emphasising architectural design's transformative impact on healthcare spaces. The article incorporates insights from multiple studies for the creation of healthcare environments that prioritise human well-being and the translation of environmental factors into viable user advantages.

In the study "Insights from a Study on Multimodal Experiences in a Plaza", Yohany Albornoz and Gladys Maestre explore the role of architectural design in shaping perceptions of protection in urban spaces. Their findings can guide planners and designers in creating urban spaces that foster a sense of safety.

In "Biophilic Design in Educational Environments: Fostering Learning and Wellbeing", Vanina Salinas examines the advantages of integrating biophilic design elements into educational infrastructure to foster improved cognitive function and emotional well-being among students. The article can help advance the discourse on the relationship between architecture and teaching and learning by offering insights into educational space design.

In "Perceiving Architecture Through Peripheral Vision: A Proposed Model for Metamorphic Spaces in Classroom Design", Veronica Giannini and Giulia Mastrocinque discuss the roles of central and peripheral vision in the perception of architecture. They introduce the concept of Metamorphic Spaces (MS) and highlight the potential for environments to transcend static interiors and transform dynamically to align with evolving human needs.

In "Unlocking the Evaluation of NbS Benefits", Chloé Mecqinion and Sebastien Kidushi Mboma present an innovative methodology developed within the framework of a World Bank project by Groupe Huit in collaboration with Arter. This methodology evaluates the benefits of nature-based solutions (NbS) and assists in selecting the most appropriate NbS based on local characteristics. The methodology has universal applicability, as it links NbS categories with the plant species comprising them.

In "Transitioning Towards Socio-Ecological Resilience in the Ganga River Basin", Jahnavi Bhatt proposes an adaptive spatial planning model that offers a holistic approach to addressing the challenges posed by climate change and urbanisation, bridging the gap between national policies and localised adaptation efforts in the Ganga River Basin in India.

These articles cover a wide range of scholarly work that will both inform and inspire our readers. I express my deepest appreciation to both the team at JEN and our guest contributors for their commitment to bringing this unique compendium of articles to existence.

LORÍ CRÍZEL
Managing Editor
Journal of Eco+urbanism & Neuroarchitecture (JEN)

Architect, Urban Planner and Author
Professor of Neuroarchitecture,
Instituto Politecnico di Milano, Italy and IPOG, Brazil
ANFA Brazil Chapter Chair
(Academy of Neuroscience for Architecture)
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Interior Neuro-designer,
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Italy.

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Co-Founder of Studio Synsēa
Italy

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JAHNAVI BHATT
Urban Designer,
Strategic Planner, and Architect
U.K.

EDITORIAL COMMENTARY

We are delighted to present "Multimodal Taste Perception: Bridging Neuroscience and Gastronomy", a review article authored by Veronica Giannini, a neuroscientist with a focus on human perception in the built environment, and "Healthcare Spaces: The Intersection of Design, Health, and Well-Being", by Clarissa Machado, a seasoned architect with a well-rounded expertise in neuroarchitecture and a deep interest in understanding human behavior.

Giannini takes us on an exciting exploration into the world of taste perception. It goes beyond the simple notion of how food tastes, offering us a comprehensive understanding of how our senses collectively shape our culinary experiences. She highlights intriguing factors, including the ambiance of a dining space and the design of cutlery, which play a part in how we perceive taste.

Machado delves into the realm of healthcare spaces and explores how architectural choices can serve as crucial determinants in shaping the health outcomes and overall experiences of individuals within healthcare environments. She uncovers how elements such as natural light, acoustic considerations, and adaptable layouts can significantly affect the physical and psychological well-being of patients during their hospital stays.

These two articles, despite their distinct subject matters, share a common thread—the vital role of built environments in shaping human perception. The hospitality industry is dedicated to crafting unforgettable guest experiences, while healthcare centres its efforts on optimising patient outcomes and alleviating stress. Be it the inviting ambiance of a restaurant or the layout of a hospital room, the design choices within these spaces wield the power to shape our sensory perceptions and overall well-being.

Giannini's and Machado's contributions can guide us to consciously design our spaces, whether for healthcare, dining, or leisure, with a primary goal of enriching human experiences. They beckon us towards a future where architecture transcends mere functionality and becomes a medium for inspiring transformation, elevating our surroundings into instruments for the enhancement of public well-being.

NEUROGASTRONOMY

MULTIMODAL TASTE PERCEPTION: BRIDGING NEUROSCIENCE AND GASTRONOMY

VERONICA GIANNINI
Neuroscientist, Researcher, and Consultant
Co-Founder of Studio Synsēa
Italy

ABSTRACT

Perceptual features of the environment, ranging from all different scales, constantly influence human behavioural output on various levels. It is by means of our nervous system that the sensorial qualities of both tangible and intangible stimuli partially contribute to the continous characterisation of our neurophysiological, cognitive, and emotional states.

This intricate dialogue between exogenous stimuli and endogenous responses generates information that contributes to the overall perceived quality of our experiences, specifically if the activity is as complex and multimodal as food perception. Literature has shed light on the challenging interference of small- to large-scale ambient and physical variables on human perceptions of gastronomic experiences, with potential implications that range from the intensity of dish flavour to the memorability of a meal. This article aims to discuss these mechanisms and their implications for gastronomic experiences from a multidisciplinary perspective.

INTRODUCTION

In the daily life of every human, exposure to any environment at any moment immediately generates a set of useful information that is bound to contribute to our endogenous and exogenous responses[1].

Tangible features such as architecture, small-scale design components, etc., as well as intangible features such as lighting, acoustics, etc., of the surroundings play an immeasurable yet decisive role in shaping our experiences.

Our sensory receptors and channels, the most well-known of which are visual, auditory, olfactory,

[1]Hudspeth, A. J., & Logothetis, N. K. (2000). Sensory systems. *Current Opinion in Neurobiology,* 10(5), 631-641.

tactile, and gustative, carefully select and transmit useful data in the form of above-threshold stimuli into our higher processing circuitry, where semantic meanings are attributed and involuntary physiological responses are generated[2,3].

Our senses never cease to provide input. By means of the never-ending dialogue between outer stimuli and our nervous system, we are able to act upon, react to, and interact with the space around us in the form of motor actions, emotions, physiological effects, and cognitive states[4].

FOOD PERCEPTION

A very common misconception is that the experience of food is the result of the taste we perceive when savouring a dish. In reality, the experience of food is the product of a combination of endogenous and exogenous factors that extend beyond taste[5].

In this perspective, the configuration of environmental variables collectively contributes pieces to a puzzle, shaping our responses through complex multimodal sensory integrations. This constitutes the foundational system for the fascinating mechanisms governing food and taste perception[6].

The set of chemical reactions that occur between our tongue and palate when chewing is only one piece of this puzzle; much is dependent on our brain's interpretation of all sensory inputs derived from other sources, such as past experiences etched in memory and the resulting emotions[7]. Only at this point can we talk about food perception, and only at this level of sensory integration are we finally in the midst of a gastronomic experience.

The knowledge about specific networks and circuitry that come into play when eating is a relatively recent result of advances in neuroimaging techniques. For example, Functional Magnetic Resonance Imaging (fMRI) has been employed to gather quantitative data on how impressively overwhelming food can be for the human nervous system. Studies using fMRI have shown that the simple anticipation of food assumes greater neural activation than the consumption of the food itself[8], and that the sight of a desirable dish can interfere with our metabolic cerebral homeostasis, increasing it by 24%[9].

The act of eating is one of the most holistic experiences for our nervous system. It is a complex task of combining information from the environment, such as colours, smells, textures, sounds, shapes, lighting, temperature, materials, etc., with all the semantic information we have stored in memory, in addition to the chemical and sensorial information derived from the food itself.

[2]Thierry, G. (2016). Neurolinguistic relativity: How language flexes human perception and cognition. *Language Learning,* 66(3), 690-713.

[3] Gibbons, C. H. (2019). Basics of autonomic nervous system function. *Handbook of Clinical Neurology,* 160, 407-418.

[4]Pleger, B., & Villringer, A. (2013). The human somatosensory system: From perception to decision making. *Progress in Neurobiology,* 103, 76-97.

[5]Spence, C., & Piqueras-Fiszman, B. (2014). *The perfect meal: The multisensory science of food and dining*. John Wiley & Sons.

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Contemporary insights into the substantial impact of secondary factors on determining the excellence of our gastronomic experiences lay the groundwork for a wide spectrum of considerations.

- Does the type of lighting influence the intensity of specific tastes?
- Do the materials and weight of the cutlery used contribute to a person's enjoyment of the food?
- Does the interior design partially determine the amount of time clients are willing to spend in a restaurant?

By deciphering the effects that tangible and intangible stimuli from the environment can have on our taste and overall perception, we could potentially unlock new avenues for enhancing the gastronomic experience to its maximum.

BRIDGING NEUROSCIENCE AND FOOD-RELATED EXPERIENCES

The Provencal Rose Paradox, coined by Charles Spence[10], elucidates the typical phenomenon where individuals perceive the taste and quality of a food or beverage differently in different contexts, such as while enjoying a fine wine on a Mediterranean vacation and experiencing it differently while consuming the same wine at home. The product remains consistent, yet our perception of it changes drastically, frequently leading us to believe that it might have tasted significantly superior on the initial occasion as opposed to the subsequent one. This paradox highlights the fundamental importance of the surrounding environment in which food is enjoyed.

Prior studies have indicated that the utilisation of black utensils, encompassing cutlery and tableware, may exert an influence on the perception of sweet flavours, potentially diminishing their perceived sweetness and overall enjoyment[11,12]. The weight of the container where food is served highly influences our perception of its value, flavour, and density[13]. Lighting also plays a substantial role in shaping patrons' perceptions within restaurant settings. For instance, the presence of green lighting has been associated with the perception of shorter service waiting times[14]. A similar phenomenon is observed concerning background noise and tempo, where specific tempos have the potential to dictate the duration of patrons' visits and the amount of their investment in a gastronomic experience[15].

Various environmental factors, spanning from small to large scales, significantly influence how we perceive a dish. This highlights potential opportunities for further exploration in this realm. It is important to note that individual outcomes can exhibit considerable variation depending on the specific context, and this should be regarded as a potential limitation. This interplay between environmental cues and gastronomic experiences suggests exciting possibilities, particularly in the restaurant industry, where a neuroscientific approach can optimize sensory environments.

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[15]Wilson, S. (2003). The effect of music on perceived atmosphere and purchase intentions in a restaurant. *Psychology of Music*, 31(1), 93-112.

CONCLUSION

Neurogastronomy serves as a novel approach to conscious dining and an inclusive and accessible translational approach from theory to practice.

Additional research is required to evaluate how exogenous variables can be altered and combined to subliminally contribute to achieving optimal results, as well as to better understand their interplay in relation to taste and the perception of the dining experience. Exploration in this domain represents a promising step towards incorporating the insights from neurograstronomy into restaurant management and design.

KEY RESEARCH OUTCOMES

The multidisciplinary approach used in this study not only deepens our understanding of taste perception but also highlights the vital role of design in shaping our sensory encounters.

It underscores the need for intentional and thoughtful design strategies in culinary contexts, revolutionising how we approach what is acknowledged as the most overwhelming stimulus known to humankind: food.

HEALTHCARE DESIGN

HEALTHCARE SPACES: THE INTERSECTION OF DESIGN, HEALTH, AND WELL-BEING

CLARISSA MACHADO
Architect, Urbanist and
Specialist in Neuroscience
Applied to Design
Italy.

ABSTRACT

Architectural design is decisive in creating spaces that positively affect users' psychological and physical health. This article delves into a few key environmental factors identified in existing research that are associated with their effects on human behaviour and overall well-being within healthcare spaces. Significant design strategies, such as exposure to natural light, acoustic control, incorporation of biophilic elements, and the use of flexible layouts, are highlighted as approaches to mitigate commonly observed adverse outcomes associated with hospitalization. These outcomes encompass issues such as social isolation, stress, depression, sleep disturbances, and medical errors.

Drawing insights from multiple studies, this article compiles supportive evidence that can inform the creation of improved healthcare spaces by transforming the environmental factors that impact users into potential benefits. This will enhance patient outcomes while also elevating the experiences of a broader range of stakeholders, including healthcare staff and the families of patients. This article does not propose a completely new theory or model but aims to advance the conversation around the transformative power of design in healthcare settings.

INTRODUCTION

Whether beneficial or adverse, environmental impacts on people are a manifestation of the intricate symbiosis between people and their environment. This understanding of the dynamic interplay between architecture and human experience has deepened in recent decades.

A combination of scientific research with rigorous social and cultural observation provides greater analytic confidence in incorporating findings based on physical, physiological, psychological, and social measures along the design process. Embracing an interdisciplinary approach and applying scientific knowledge, the "neuro-architectural" approach can guide the design process by correlating stimuli from the built environment with quantified measures of the brain and body's responses, along with sociological, behavioural, and economic outcomes[1].

This article explores the intersection of architectural design and healthcare by analysing the strategies that can mitigate the adverse effects and enhance the positive impacts on users' health in hospital environments. Utilising an extensive literature review, a comprehensive synthesis of information within the field is presented.

The primary objectives of this study are:

- to identify and understand the adverse outcomes of patients associated with healthcare environments, based on existing literature;
- to highlight design strategies that have proven effective in improving health outcomes; and
- to examine the role of architectural design within these contexts, taking into account the multifaceted perspectives of the various stakeholders, including patients, their families, visitors, and healthcare personnel. This endeavour aims to provide a holistic view to inform the design of healthcare spaces.

Architectural design holds significant potential to contribute to an individual's overall health, performance, and well-being within healthcare spaces. However, the traditional methodology in architectural delivery tends to follow a predominantly linear trajectory, characterised by limited participant interaction and frequently neglecting post-construction analysis and post-occupancy evaluations.

This issue is addressed by a scientific approach known as Evidence-Based Design (EBD), which fundamentally includes collaboration with stakeholders such as patients, carers, and frontline staff to incorporate their experiences into the design process rather than relying solely on default systems and processes[2]. EBD connects design elements with healing results, applying the most effective strategies observed[3]. This can lead to improvements in clinical outcomes, economic performance, productivity, customer satisfaction, and cultural measures[4]. The incorporation of thoughtful design principles can alleviate the sensory challenges experienced within healthcare environments, a consequence of patients contending with the dual pressures of medical treatments and uninspiring standardized design[5].

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OUTCOMES

Ulrich[6] defines "outcomes" as a broad indicator or measure of healthcare quality, including observable signs and symptoms relating to patients' conditions, satisfaction, safety concerns (such as infection, error rates, risk of falls, etc.), and economic factors such as cost of care and turnover. A range of physical, psychological, and environment-related factors greatly impact patient well-being, recovery rates, and the overall effectiveness of care[6,7]. However, this discussion focuses on social isolation, depression, stress, sleep issues, and medical errors.

SOCIAL ISOLATION

Isolation remains a significant issue for patients, especially those enduring prolonged hospital stays. It can engender feelings of disconnection from family and friends, leading to loneliness and depression. These feelings can demotivate patients from participating in self-care activities, potentially resulting in delayed recovery. Prolonged social isolation can result in detrimental health outcomes, such as cognitive decline and increased mortality rates[8].

STRESS

Patient stress, arising from illness-related challenges such as reduced capabilities and uncertainties and potentially painful medical procedures, is compounded by unfavourable physical-social healthcare environments, often characterised by noise, limited privacy, and inadequate social support[9]. Stressful experiences, according to Segerstrom and Miller[10], alter immune response features and increase vulnerability to adverse medical outcomes, which are either mediated by or resisted by the immune system. Noise can be considered a pervasive stressor that elevates psychological and physiological stress in patients and worsens other reactions[6]. Beyond patients, stress is also prevalent among the families of patients, visitors, and healthcare staff[6]. When healthcare facility staff experience high stress levels, it can compromise the quality of healthcare delivery, leading to adverse effects on patient wellness.

DEPRESSION

Depression is a prevalent issue in the healthcare environment. For patients, the lack of natural light, restricted access to views of nature, and limited privacy can exacerbate depressive symptoms[6]. Healthcare professionals are not immune to these effects. Highly stressful environments, long working hours, and emotional demands can make healthcare professionals more susceptible to depression[11]. A notable instance of the impact of depression is demonstrated in a study of paediatric residents, which found that those suffering from depression were over six times more likely to make medication errors than their non-depressed colleagues[12].

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SLEEP PROBLEMS

Sleep, a fundamental component of the healing process, can be significantly compromised in hospital settings due to excessive noise, light, and frequent night-time interruptions for medical procedures. This can hamper patient recovery[13].

Disturbances in the sleep-wake cycle not only lead to poor sleep quality and consequent fatigue but also changes in the body's circadian rhythms. This can have further health implications[14]. Insufficient sleep is associated with an increased risk of chronic diseases, including high blood pressure, diabetes, depression, bipolar disorder, and seasonal affective disorders[15].

Ironically, hospital environments often seem designed specifically to disrupt sleep. Several studies describe equipment noises, loud personnel, unpleasant lighting, uncomfortable bedding, inadequate room temperature, and procedure time as the primary sleep-disrupting factors[5].

MEDICAL ERRORS

The design and layout of healthcare environments have significant implications for patient safety. Factors such as distractions during critical tasks, poor lighting, space organisation, and equipment position can heighten the likelihood of errors[16,17]. Communication among healthcare workers can also be impacted by environmental factors[1]. Research has shown that implementing specific design strategies can aid in minimising these risks. For instance, sound-absorbing materials to decrease noise and increase bright lighting at workstations can help minimise distractions, reduce medical errors, and improve work efficiency[6].

DESIGN STRATEGIES FOR IMPROVED OUTCOMES

This section of the paper explores four key designs: incorporation of natural light, acoustic control, the inclusion of biophilic elements, and the use of individual control and flexible layouts. It also discusses how they can be harnessed to address the adverse outcomes associated with hospitalization discussed in the previous section.

To enhance health outcomes and overall quality of care in healthcare settings, it is crucial to apply design strategies that optimize environments for healthcare professionals and patients.

Each strategy is backed by evidence from literature review showing its effectiveness in enhancing patient, family, and staff experiences in healthcare settings, thereby underscoring the role of architecture as a silent partner in healthcare provision.

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[17]Malone, E. B., & Dellinger, B. A. (2011). *Furniture design features and healthcare outcomes*. The Center for Health Design, 73. https://www.healthdesign.org/sites/default/files/FurnitureOutcomes_2011

NATURAL LIGHT

The incorporation of natural light into healthcare settings has tangible implications for health and performance. Natural light has been associated with several health benefits, such as reduced pain and depressive symptoms among patients and increased staff satisfaction levels. These benefits are likely due to its role in regulating circadian rhythms and promoting a sense of connection with the external environment[6]. Besides contributing to energy conservation, access to natural light has been demonstrated to enhance patients' sleep quality and even speed up recovery[18]. For healthcare staff, exposure to natural light can play a role in reducing errors and managing stress levels, thus promoting a healthier and more productive work environment[19].

Edelstein[14] points out certain factors which should be accounted for in the design process, such as ageing or cognitive decline, that can make the discernment and comprehension of visual stimuli more challenging. Aspects such as glare and thermal discomfort may negatively impact mood and task performance.

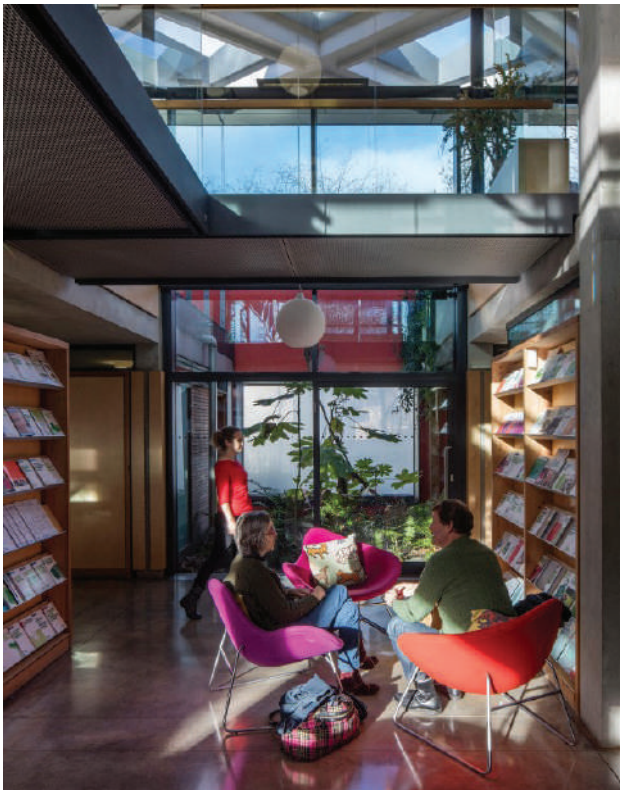

Figure 1. Natural light flows into the main spaces of Maggie's West London, at Charring Cross Hospital[20].

Providing access to natural light and allowing patients and staff to control glare and lighting levels is of utmost importance for a human-centric hospital design, as it directly influences the physical and psychological well-being of hospital occupants[15]. In the context of individuals undergoing extended hospitalisation or prolonged stays, it becomes imperative to offer illumination that surpasses mere utilitarian purposes. Implementing personalised or localised lighting solutions capable of dynamically adjusting their colour temperature over the course of the day serves to create a perceptible transition from daytime to night-time. This, in turn, fosters positive mental health among such individuals[5].

ACOUSTIC CONTROL

High noise levels in hospitals contribute to stress, anxiety, and sleep disturbances, compromising patient recovery and staff performance. It can create communication barriers between healthcare staff and patients, adversely affecting the quality of the care provided[6,20,21]. It raises the risk of medical errors due to miscommunication, misinterpretation, interference, and increasing stress among the hospital staff[1,16].

Effective acoustic strategies may include using sound-absorbing materials, changing the position of noisy equipment, establishing 'quiet zones', and creating buffer spaces between the areas prone to noise generation.

[18]Boyce, P., Hunter, C., & Howlett, O. (2003, September). *The benefits of daylight through windows*. Lighting Research Center, Rensselaer Polytechnic Institute.
[19]Leather, P., Pyrgas, M., Beale, D., & Lawrence, C. (1998). Windows in the workplace: Sunlight, view, and occupational stress. *Environment and Behavior,* 30(6), 739-762. https://doi.org/10.1177/001391659803000601
[20]RSHP. (n.d.). Maggie's West London Centre. https://rshp.com/projects/health-and-science/maggies-west-london-centre/
[21]Busch-Vishniac, I. J., We st, J. E., Barnhill, C., Hunter, T., Orellana D., & Chivukula R. (2005, December). Noise levels in Johns Hopkins Hospital. *The Journal of the Acoustical Society of America,* 118(6): 3629-45. https://doi.org/10.1121/1.2118327

Design interventions, such as strategically placing care stations away from patient rooms and using sound masking technologies, can also help moderate noise levels and create a more favourable healing environment[17]. Furthermore, the option for patients to stay in single-bed rooms can contribute to quieter and more restful environments[6,16,22].

Excessive noise is one of the most prevalent complaints in healthcare environments, linked to slower recovery rates and elevated psychophysiological stress due to anxiety and annoyance. Implementing design solutions that significantly reduce noise levels may provide a more peaceful and conducive environment for both healing and work[6].

BIOPHILIC DESIGN ELEMENTS

Biophilic design is an approach that involves many strategies that incorporate elements of nature into architectural design. They can take many forms, including, but not limited to, providing views of nature, incorporating outdoor and indoor plants and gardens, utilising water features, integrating sounds of nature, and using natural materials in the built environment.

Figure 2. Khoo Teck Puat Hospital, Singapore[23,24]

Research indicates that access to biophilic elements promotes positivity, reduces stress, and aids in managing depression[6,16]. The benefits of biophilic design on patient health and recovery were elucidated by a study conducted in 1984 by Roger Ulrich. The study found that patients in rooms with a view of nature experienced shorter post-operative hospital stays, required fewer analgesics, and encountered fewer postoperative complications than their counterparts in rooms with windows facing a brick wall[25].

Figure 3.: Queen Elizabeth University Hospital, Glasgow, Horatio's Garden[24,25]

Green outdoor areas can serve as venues for therapeutic and rehabilitative activities. Their presence can also foster social support and provide a distraction, thus reducing stress among families and carers[6,26]. Additional research has supported these findings. Marcus and Barnes[22] reported that exposure to hospital gardens and outdoor spaces led to positive outcomes for different stakeholders. Employees felt more productive, patients reported feeling better and exhibiting more tolerance towards their medical procedures, and visitors experienced relief from the stress related to hospital visits. Incorporating well-designed gardens, courtyards, or roof terraces brings fresh air and nature closer to people. It also provides quality spaces for relaxation and an escape from stressful clinical settings.

[22]Ulrich, R. S. (2006). Essay: Evidence-based health-care architecture. *Lancet,* 368, 538-539. https://doi.org/10.1016/S0140-6736(06)69921-2
[23]RMJM. (n.d.). Khoo Teck Puat Hospital. https://rmjm.com/portfolio/khoo-teck-puat-hospital-singapore/
[24]Ghadiri, N. (2017). *Seven of the UK's healing hospital gardens – in pictures.* https://www.theguardian.com/healthcare-network/gallery/2017/sep/12/seven-uks-healing-hospital-gardens-pictures
[25]Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, 224(4647), 420-421. https://doi.org/10.1126/science.6143402
[26]Ulrich, R. S. (1999). Effects of gardens on health outcomes: Theory and research. In M. Cooper & M. Barnes (Eds.), *Healing gardens: Therapeutic benefits and design recommendations*, New York, John Wiley, 27-86.

CONTROL AND FLEXIBLE LAYOUTS

One of the principles of "Universal Design" pertains to flexibility, with an emphasis on accommodating a diverse spectrum of individual preferences and capabilities[27]. This can be effectively applied to healthcare settings, fostering a sense of control and facilitating social support for patients while also enabling efficiency for staff. These adaptable social spaces can be tailored to accommodate individual and group needs, enhancing the hospital experience for all[5,6].

Flexibility safeguards against long-term waste by curtailing the waste of materials, time, and energy. Beyond resource conservation, flexible layouts exhibit adaptability to accommodate individual requirements and foster beneficial social interaction through the provision of versatile spaces equipped with comfortable, movable furniture.

Control also plays a critical role in reducing stress and anxiety, which are common feelings in hospital settings[9]. Design features that enable patients to adjust various environmental elements, such as bed position, temperature controls, lighting levels, sound settings, and access to natural light[29] grant them greater autonomy and comfort, ultimately nurturing a therapeutic milieu.

Figure 4. Perspective of Living Systems Health Centre by Ab Rogers Design. The design has a flexible nature to enable the repurposing of the layout[28].

CONCLUSION

By incorporating well-considered design strategies, it is possible to not only enhance the physical health but also the psychological wellbeing of occupants in healthcare institutions.

Furthermore, these design paradigms not only impact patients but also their families, who provide invaluable emotional support, and the dedicated healthcare professionals who administer care. This holistic approach represents a promising step towards a more sustainable healthcare system that promotes healing, well-being, and satisfaction among all stakeholders.

KEY RESEARCH OUTCOMES

The exploration of evidence-based design strategies, including the integration of natural light, implementation of acoustic control measures, incorporation of biophilic elements, and adoption of flexible layouts, offers a comprehensive roadmap to creating healthcare environments that ameliorate the myriad challenges associated with hospitalization. These strategies hold the potential to revolutionise the healthcare industry.

[27]The Center for Universal Design. (1997). *The Principles of Universal Design,* Version 2.0. Raleigh, NC: North Carolina State University. https://design.ncsu.edu/wp-content/uploads/2022/11/principles-of-universal-design
[28]Young, E. (2022, September). With the right architecture, the hospital building can be a 'third carer' for patients. *RIBAJ.* https://www.ribaj.com/intelligence/opportunities-health-design-research-wolfson-living-systems-ab-rogers
[29]Huisman, E., Morales, E., van Hoof, J., Kort, H. (2012) Healing environment: A review of the impact of physical environmental factors on users. *Building and Environment,* 58, 70-80. https://doi.org/10.1016/j.buildenv.2012.06.016

EDITORIAL COMMENTARY

We are delighted to present three articles that explore how environmental factors, both indoors and outdoors, impact human experiences. Each study delves into a specific aspect of this relationship, whether it is the perception of protection in urban spaces, the use of biophilic design in educational settings, or the creation of adaptable learning environments indoors.

A prospective empirical study titled "Insights from a Study on Multimodal Experiences in a Plaza" is presented by Gladys Maestre, an award-winning neuroscientist, and Yohany Albornoz, an architect and independent researcher with a focus on neuroarchitecture and who is specialising in commercial built environments. Albornoz and Maestre explore the perception of protection in urban space through user reactions to their environment in cities, particularly in open urban spaces. The authors highlight the significance of a contemporary constraint: diminishing urban space. The research outputs provide crucial insights for the audience that is interested in reshaping cities to accommodate the diversity of human activities.

The contribution by Vanina Salinas, titled "Biophilic Design in Educational Environments: Fostering Learning and Well-Being" explores the impact of nature on the learning process and its potential to revolutionise educational practices while fostering well-being. As an architect and specialist in neuroscience applied to architecture, Salinas delves into the concept of biophilia and its application as a tool to enhance learning experiences. The author explores how the incorporation of biophilic elements, such as natural light, nature views, indoor plants, and safe spaces, can profoundly impact students' attention, cognitive abilities, and overall well-being. The article offers practical design strategies that hold promise for revolutionising classroom settings.

Grounding their work in the evolving discourse on neuroarchitecture, Veronica Giannini, a pioneering neuroscientist specialising in human perception in the built environment, and Giulia Mastrocinque, an innovative interior designer with a keen focus on enhancing user well-being through design, collaboratively present their contribution, "Perceiving Architecture through Peripheral Vision: A Proposed Model for Metamorphic Spaces in Classroom Design". Giannini and Mastrocinque unveil the Metamorphic Spaces (MS) theory, an approach for exploring peripheral architectural variables to cultivate dynamic classroom environments. They delve into how judicious manipulation of design elements can give rise to diverse atmospheres, thereby facilitating neurophysiological, cognitive, and emotional alignment with the varied learning activities of students. They offer practical design strategies through ceiling-related modifications that have significant implications for students' behavioural outcomes and academic performance.

These articles collectively advocate for the meticulous design of indoor spaces to prioritise the well-being of all, especially in the context of the expanding "indoor generation".

URBAN PHENOMENOLOGY

INSIGHTS FROM A STUDY ON MULTIMODAL EXPERIENCES IN A PLAZA

YOHANY ALBORNOZ
Architect, Researcher and Consultant in Neuroscience Applied to Architectural Design
Founder and Creative Director,
The Marketer Architect
U.S.A

GLADYS MAESTRE
Neuroscientist and Director, Alzheimer's Disease Resource Centre for Minority Ageing Research
Professor of Neurosciences and Human Genetics, School of Medicine, University of Texas (RGV)
U.S.A.

ABSTRACT

In the emerging field of neuroarchitecture, understanding the neurophysiological responses elicited by urban spaces is crucial for enhancing the quality of life. This study investigates the modulation of neurophysiological responses in relation to the perception of protection in urban environments. By exploring the impact of immediate, previously visited, or contiguous spaces on the sensory experiences of individuals, we aim to uncover insights into the interplay between architectural design, multisensorial experiences, and the modulation of perceived protection.

Using a holistic phenomenological approach, we designed an experiment involving 100 participants to examine how the atmosphere of preceding spaces influences the perception of protection in subsequent spaces. The results and conclusions of this study contribute to the development of methodologies for understanding the neurophysiological responses associated with different levels of perceived protection in urban areas. Ultimately, this research provides valuable insights for architects, urban designers and planners, seeking to create urban spaces that enhance well-being and foster a sense of protection. It provides a new approach to the design of architectural transitions and a smoother change of scale from the exterior to the interior of a building.

INTRODUCTION

In our modern world, characterised by unprecedented urbanisation, preserving human well-being within urban spaces is paramount. Researchers such as Fred Gage, John Paul Eberhard, and Eve Edelstein advocate for neuroarchitecture, a discipline that aligns design with human neurophysiology.

Neuroarchitecture offers the potential to cultivate healthier urban ecosystems by crafting environments that nurture our well-being, foster a connection with nature, and elevate urban living. It holds great promise for creating designs that enhance the quality of life in urban areas[1].

One important aspect of the study of the multimodal sensory experience through architecture is to better understand how the various sensory inputs of a building or a public space influence our emotions, perceptions, and behaviour. Understanding the neurophysiological responses to these aspects is crucial for designing spaces that promote well-being, health, and sustainability[1].

We designed a study on multimodal sensory experiences in a plaza that attempts to provide valuable insights into how architectural design can promote well-being. The central question of our study was whether the neurophysiological responses in a space could be modulated or changed by the responses generated in the immediately preceding space. We wanted to understand if the perception of protection in a plaza could be modulated by the atmosphere of the preceding space.

This concept is closely related to the phenomenon known as priming. Priming refers to the process by which exposure to a stimulus influences an individual's subsequent perception, behaviour, or response to a related stimulus. Research in cognitive psychology has demonstrated the powerful influence of priming on various aspects of human perception and behaviour[2,3]. Research has shown that prior experiences or stimuli can activate related mental constructs or expectations[2], leading to biased perceptions and responses in subsequent situations.

[1]Liu, Z.; Yang, Z.; Osmani, M. (2021). The relationship between sustainable built environment, art therapy, and therapeutic design in promoting health and well-being. *Int. J. Environ. Res. Public Health,* 18, 10906. https://doi.org/10.3390/ijerph182010906
[2]Bargh, J. A., Chen, M., & Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal of personality and social psychology,* 71(2), 230–244. https://doi.org/10.1037/0022-3514.71.2.230
[3]Higgins, E. T. (1996). Knowledge activation: Accessibility, applicability, and salience. In E. T. Higgins & A. W. Kruglanski (Eds.), *Social psychology: Handbook of basic principles* (pp. 133-168). Guilford Press.

In our study, we hypothesised that the atmosphere and sensory inputs of the preceding space would prime individuals to perceive and evaluate the subsequent plaza space differently in terms of "Perception of Protection". The scope of our work was to design a space and an experiment that would allow us to respond to and validate the question. The actual run of the experiment would be the next step in future research. To accomplish our intention, we concentrated our efforts on understanding the neurophysiological responses in a plaza where a strong feeling of exposition was detected in the external area (Space #1) and a highly contrasting perception of protection in the subsequent internal arcade (Space #2).

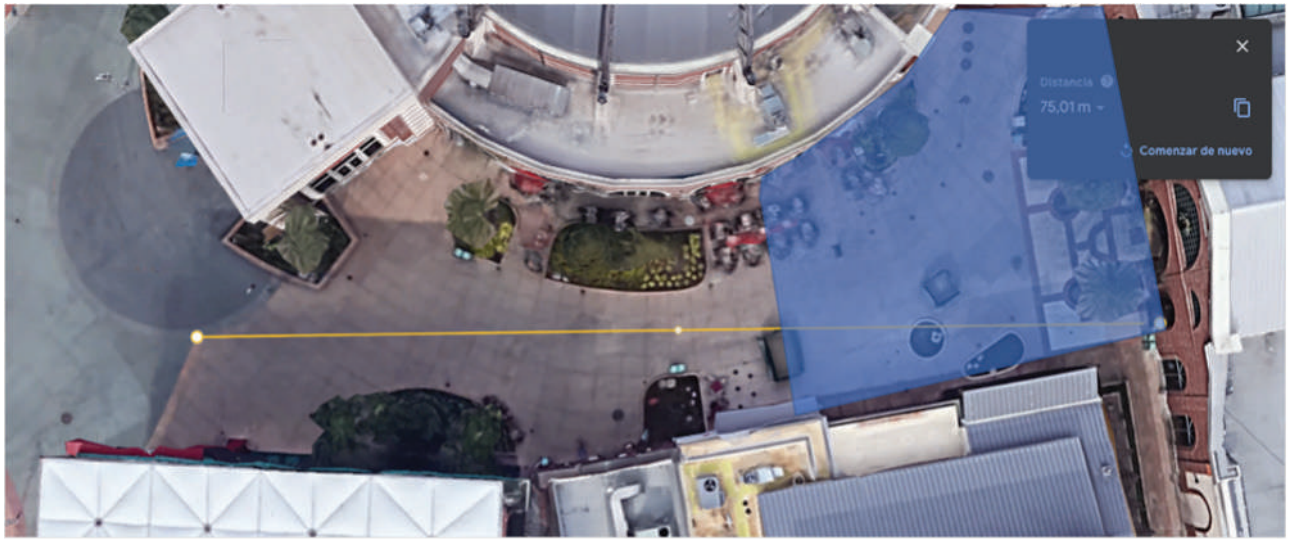

Figure 1. View of the Plaza on Google Earth

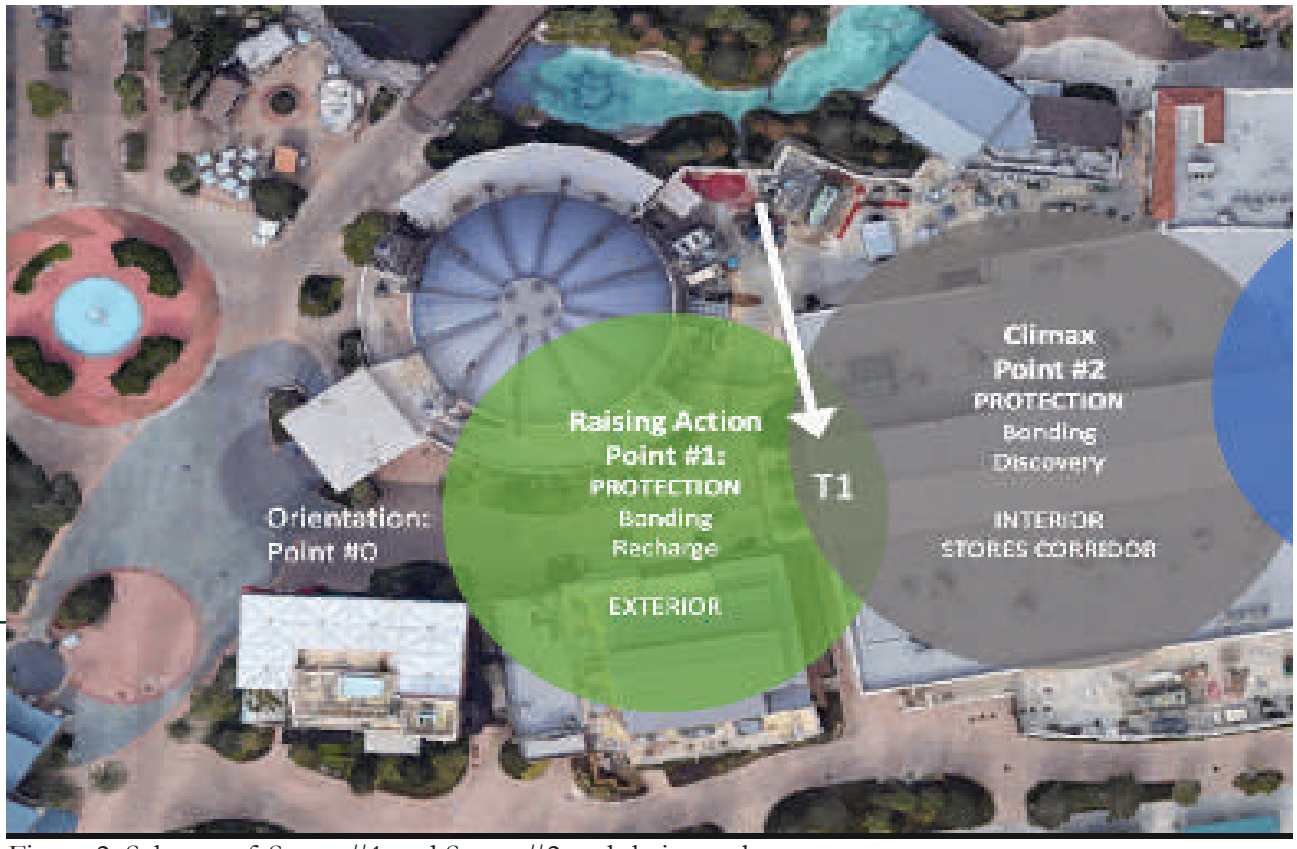

Figure 2. Scheme of Space #1 and Space #2 and their overlap.

The current situation provides a perceived major Perception of Protection inside the Arcade.

THE EXPERIMENT

We designed an experiment with 100 participants using virtual reality models of the plaza and surrounding spaces, in which we will include an "informed consent form", and provide an explanation of the potential effects that may arise in participants with specific vulnerabilities. The same group of participants will experiment with both conditions. This research will not examine gender differences, and both males and females will be involved. Subjects will be 50% men and 50% women between 50 and 65 years old. Half of them will start with a control condition, and half of them will start with an experimental condition.

The participants will be staff or faculty of the University of Texas at Rio Grande Valley who volunteer to take part in our research. IRB approval from the university will be obtained, and all subjects will sign an appropriate informed consent. The data will be stored and encrypted by Base64 on a password-protected computer and accessed only by the research team and for approved scholarly purposes. To ensure confidentiality, participation will be kept anonymous. Participants will follow a protocol throughout the experiments, and they will be stationary and seated.

We will first describe the procedure and technology that will be used.

- Participants will be seated and individually rigged up with the Oculus Rift head-mounted device for virtual reality, a portable EMOTIV EPOC EEG, earphones, and will be instructed to attach the IntelliSense Patch to the chest. Individuals with chest hair will be advised to depilate the area prior to affixing the patch.
- All participants will undergo prior exposure to a commercial VR demo environment to acquaint them with VR technology and the first-person navigation experience.
- The technical settings of the Oculus will be calibrated for each individual.
- All subjects will be exposed to two successive spaces (S1-first space and S2-second space). They will be randomly assigned to begin the experiment either in Control or Experimental S1.
- In the second set of experiments, they will be presented with exactly the same successive spaces but will be exposed to the other condition (Control or Experimental S1) that they did not experience in the first set.
- The space will be presented following a natural navigation approach to S1 and then continuing to S2. The speed of navigation will be predetermined and the same for all subjects.

We hypothesised that people's feelings and physiological responses to the perception of protection in one space can be manipulated by changing the previous space's atmosphere in terms of size, enclosedness, field of view, etc. The changes would be related to lower stress levels and higher relaxation levels on the transition from Space #1 to Space #2, and a different rate of perception of protection in Space #2. Participants in the experimental condition would report lower stress and higher relaxation levels during the transition from the prior space to the plaza.

The Control Condition will be a model created in virtual reality emulating the real-time conditions of the space. The Experimental Condition will also be a virtual reality model in which Space #1 has been modified to have a more protective atmosphere than in the Control Condition, with the expectation of altering the perception of Space #2, which is not being modified at all. The methods that will be used in this work have been developed for a better understanding of cognitive neuroscience[4].

[4]Ward, J. (2020). *The student's guide to cognitive neuroscience.* New York, NY: Psychology Press.

Hartig, Kaiser, and Bowler conducted research that sheds light on the aspects of perceived protection and restorative potential of various environments. They developed a measure called the Perceived Restorativeness Scale (PRS) that assesses people's perceptions of the restorative qualities of their environment[5]. Their work has served as a reference for our study.

Figure 3. External Plaza, identified as Space #1

Our study suggests that the perception of protection in a plaza can be enhanced by modifying the atmosphere of the preceding space. By incorporating architectural elements associated with protection, such as enclosing walls, natural vegetation, outdoor benches, or water features, architects and urban planners can create a sensory transition that promotes a sense of safety and relaxation[6]. This, in turn, can encourage people to spend more time in public spaces and engage with the natural environment[7].

This study also highlights the importance of a holistic, phenomenological approach to architectural design[8]. Although it is necessary to narrow down the question and work only with one variable to get outcomes from science, it is hard to isolate architectural elements and understand their influence without a specific context. Designers would rather create atmospheres and experiences where many variables interplay. The main essence is "Protection of the Pack". The major interventions were done through protective features, sub-essences and restorative features. By setting the main essence and sub-essences and running a risk and protective factor analysis, we could identify flaws in the architectural experience. This helped us determine what elements we could include to improve it in the direction of the intended essences[9].

Figure 4. Internal Arcade, identified as Space #2

By understanding the multimodal sensory experience through architecture and how it could affect our neurophysiological responses, architects and urban planners could create designs that promote well-being, health, and sustainability. By running this experiment, our findings could suggest that the perception of protection in a plaza can be enhanced by incorporating architectural elements that promote relaxation and safety and by adopting a holistic phenomenological approach to design[10]. The results of this experiment could provide specific insights into the neurophysiological responses of a space that provides different levels of perception of protection, and on how this can be influenced by immediate, previously visited, or contiguous spaces.

[5]Hartig, T., Kaiser, F. G., & Bowler, P. A. (2001). *Further development of a measure of perceived environmental restorativeness. Working paper,* Institute for Housing and Urban Research, Uppsala University.
[6]Martínez-Soto, J., de la Fuente Suárez, L. A., & Ruiz-Correa, S. (2021). Exploring the links between biophilic and restorative qualities of exterior and interior spaces in Leon, Guanajuato, Mexico. *Frontiers in Psychology*, 12, 717116.
[7]Koohsari, M. J., Kaczynski, A. T., Mcormack, G. R., & Sugiyama, T. (2014). Using Space Syntax to assess the built environment for physical activity: Applications to research on parks and public open spaces. *Leisure Sciences*, 36(2), 206-216. DOI: 10.1080/01490400.2013.856722
[8]Merleau-Ponty, M. (1995). *Phenomenology of perception*. London, UK: Routledge.
[9]Ruzzon, D. (2021). *Neuroscience applied to architectural design*. Tuned Publication.
[10]Seamon, D. (2000). Phenomenology, place, environment, and architecture: A review of the literature. *Phenomenology Online*, 36, 1-29.

The design of our experiment, its theoretical basis, and the architectural design process proposed could serve as a methodology for upcoming researchers and designers to create spaces that are more aligned with the needs and preferences of the people who will use them, promoting a sense of ownership and belonging to the public spaces.

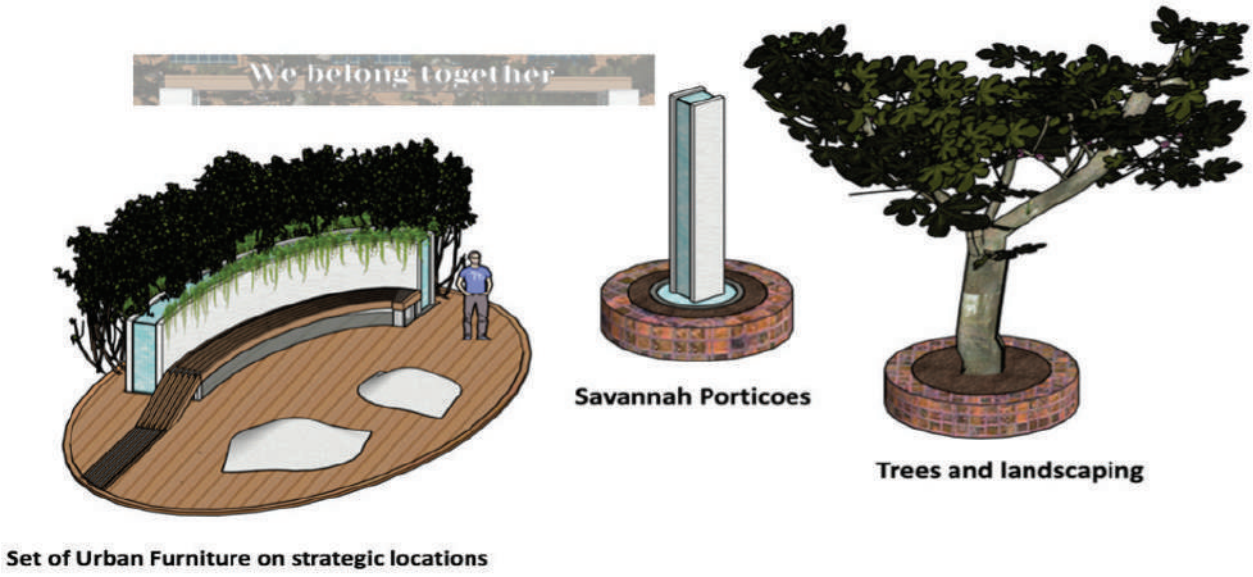

Figure 5. Representation of the three main elements of the architectural intervention.

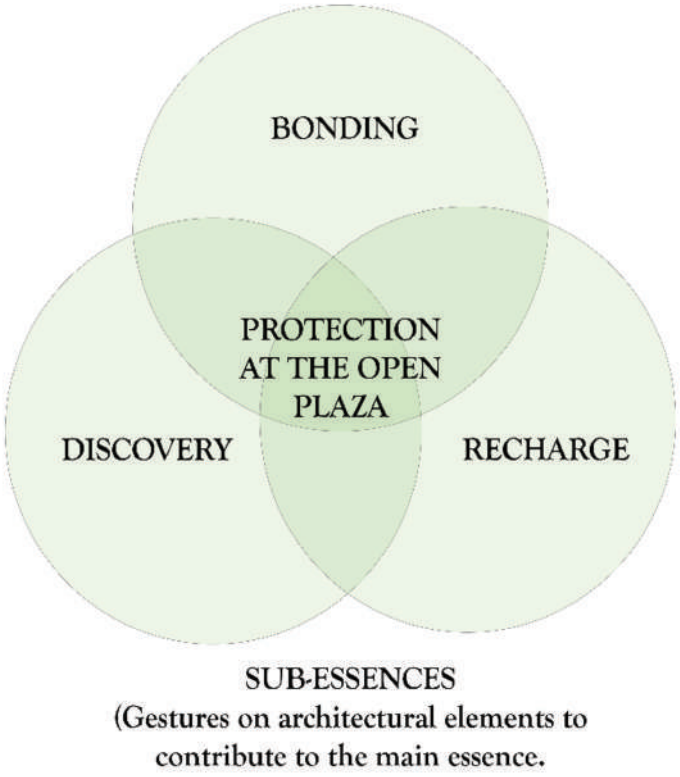

Figure 6. Essence and Sub-Essence of the Project

Figure 7. Experimental Condition (Architectural Proposal for Space #1)

Figure 8. Control Condition (Original Architecture on Space #1)

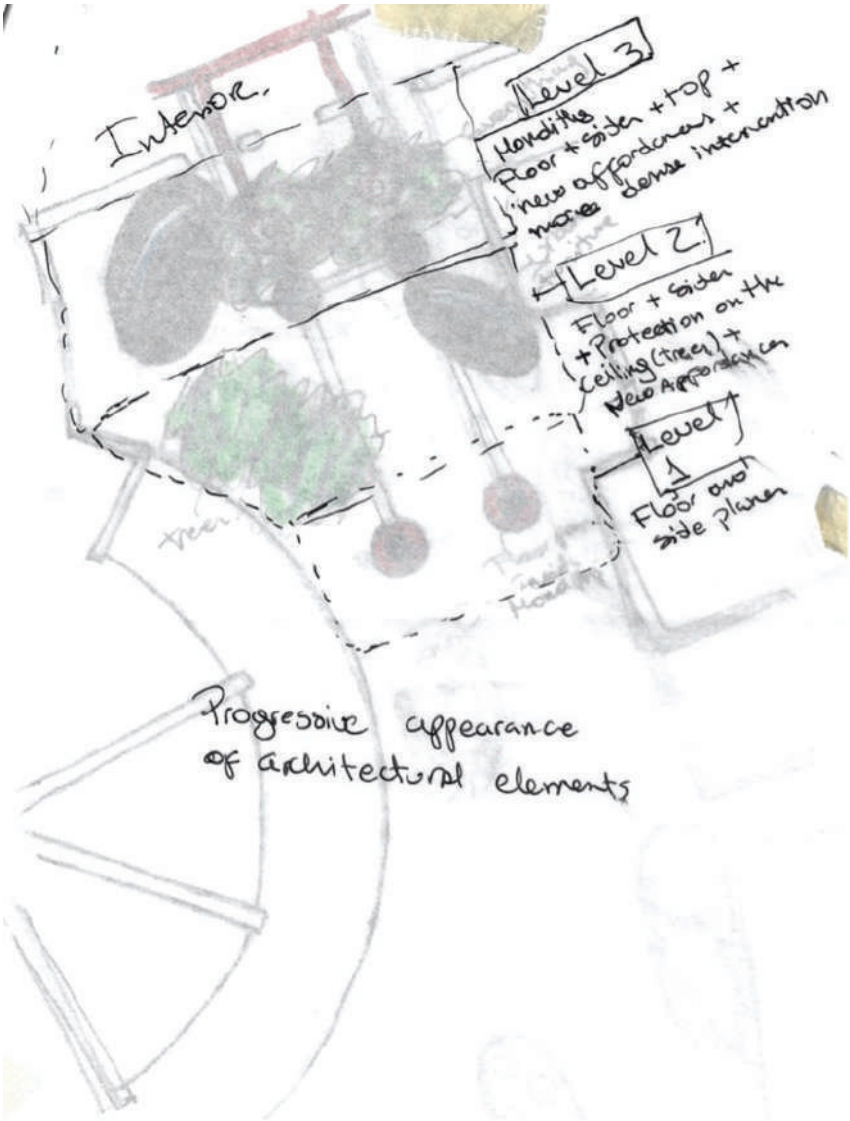

Figure 9. The sequence of progressive appearances of architectural elements.

Elements applied to the space (Experimental Condition): Intervention on the horizontal floor and the vertical lateral plane with the introduction of Savannah Porticoes. Predominant surfaces: bricks, white textured stucco, and water[11].

Figure 10. View #1: Visualisation of Level 1

Elements applied to the space (Experimental Condition): Intervention on the horizontal floor and the vertical and lateral planes, with the introduction of a set of urban furniture. Predominant surfaces: wood, metal, vegetation, textured stucco, and water[11].

Figure 11. View #2: Visualisation of Level 2

Elements applied to the space (Experimental Condition): Intervention on the horizontal floor, the vertical lateral and the horizontal top plane with the repetition of Savannah Porticoes, reinforcing their presence with a message, a set of urban furniture, and trees[11].

Figure 12. View #3: Visualisation of Levels 2 to 3

Elements applied to the space (Experimental Condition): Increased density of the architectural elements of the proposal — an extension of the internal floor on the exterior[11].

Figure 13. View #4: Visualisation of Level 3

Elements applied to the space (Experimental Condition): Closing of the passage shortens the distance between architectural elements on the three planes: floor, lateral, and top[11].

Figure 14. View #5: Visualization of Level 3

[11]Albornoz, Y., & Maestre, G. (2021). *Neurophysiological Responses to Multisensorial Experiences in a Transition in a Plaza.* (Trabajo de grado de posgrado). Università Iuav di Venezia, Annual Postgraduate Specialisation Programme of First Level in "Neuroscience Applied to Architectural Design".

CONCLUSION

The meticulously crafted experimental process developed in this study can reveal how individuals respond to the spatial arrangements within urban environments. The forthcoming results of this experiment are poised to yield profound insights into the neurophysiological reactions that unfold within spaces, evoking varying degrees of perceived protection.

These findings will uncover the multifaceted factors that influence such sensory perceptions, encompassing inputs from immediate, previously visited, or contiguous spaces. The actionable insights derived from this investigation have the potential to usher in a paradigm shift in our approach to urban planning and city design.

KEY RESEARCH OUTCOMES

By highlighting the neurobiological basis of people's perception of urban spaces, this study provides a solid foundation for evidence-based design decisions. It presents a roadmap for crafting urban environments that not only accommodate the physical and social needs of people but also nurture their psychological well-being.

EDUCATIONAL INFRASTRUCTURE DESIGN

BIOPHILIC DESIGN IN EDUCATIONAL ENVIRONMENTS: FOSTERING LEARNING AND WELL-BEING

VANINA SALINAS
Architect, Urban Planner, and
Specialist in Neuroarchitecture
Co-Founder, Neuroarquitectura en Red
Argentina

ABSTRACT

Built environment professionals are increasingly recognising the profound impact of our surroundings on human cognition, emotions, and behaviour, with a particular focus on overall wellbeing. The environmental context in which individuals are situated also exerts a significant influence on the process of learning. Within this context, educational environments have emerged as critical spaces for shaping learning experiences. This growing emphasis on educational space design revolves around the need to create settings that can effectively accommodate a wide range of learning activities. This article highlights the positive impact of integrating nature-inspired elements into educational settings, including natural light, nature views, indoor plants, and safe spaces. Furthermore, it provides practical design strategies aimed at revolutionizing classroom environments to optimize effective teaching and learning.

INTRODUCTION

Human beings engage with their environment through their senses, utilising the information gathered from past experiences to construct a subjective perception of their surroundings. Effective assimilation of information hinges on the prior, accurate perception and processing of that information. The cognitive process serves as our means of interpreting the environment, relying on stimuli captured through our sensory organs. The urban environment overloads us with stimuli, affecting our attention and causing overexertion and mental fatigue. Nature, on the contrary, exerts restorative work by concentrating the stimuli to a minimum, reducing, in turn, the load of attention, and increasing mental acuity[1,2].

Our perception is susceptible to influences such as attentional factors, emotions, and memories[3]. "The brain only learns if there is emotion", says Francisco Mora Terue[4]. Emotions play a vital role in facilitating learning by stimulating neural network activity and strengthening synaptic connections. In essence, when positive emotions are involved, the process of learning becomes more effectively consolidated within our brains[5].

Neuroplasticity[6] is the nervous system's remarkable capacity to adapt and reorganise itself in response to various environmental stimuli throughout an individual's life. It underscores the brain's ability to adjust and learn from the new experiences and challenges presented by its surroundings. The environment emerges as a potent catalyst capable of influencing human attitudes and cognitive processes. Therefore, the creation of healthy, nurturing, and positive environments becomes paramount in promoting optimal brain development and fostering sound mental health among individuals. The physical and psychological elements within the spaces where students are situated play a pivotal role in shaping their learning and development[3].

The objectives of this paper are as follows:

- To conduct a comprehensive review to ascertain whether the principles of neuroarchitecture have the potential to enhance the academic efficacy of educational institutions.
- To explore the role of biophilic design as a pedagogical tool, exploring its capacity to positively impact learning processes and overall well-being within the educational domain.

The literature review shows an increasing scholarly interest in investigating the interconnected dynamics of architecture, education, and the natural environment. Empirical studies affirm the influence of design on the pedagogical process. Insights drawn from neuroscience further advocate the necessity of crafting more affective spaces that foster deeper connections with the natural world[5]. Recent technological advancements, including the integration of educational technology such as Augmented Reality (AR), Virtual Reality (VR), adaptive learning, and gamification into the classroom, often lack alignment with prevailing pedagogical models and educational contexts.

[1]Mokhtar Noriega, F., Jimenez Rodriguez, M. A., Heppell, S., & Segovia Bonet, N. (2016). Creating learning spaces with students for the third millennium. *Bordón: Pedagogy Magazine,* 68(1), 61-82. http://hdl.handle.net/11162/125986

[2]Berman, M. G., Jonides, J., & Kaplan, S. (2008). The Cognitive Benefits of Interacting with Nature. *Psychological Science,* 19(12), 1207-1212. http://doi.org/10.1111/j.1467-9280.2008.02225.x

[3]Portero Tresserra, M., & Campos Calvo-Sotelo, P. (2018). Architecture, neuroscience and education: strategies and didactic spaces for innovative learning in the university. *RELAPAE,* 9, 149-165. https://doi.org/10.22201/iisue.24486167e.2019.165.59403

[4]Benavidez, V., & Flores, R. F. (2019). *The importance of emotions for neurodidactics.* Wimb Lu, 14(1), 25-53. https://doi.org/10.15517/wl.v14i1.35935

[5]Mora Teruel, F. (2014). *Neuroeducation*. http://hdl.handle.net/10630/10881

[6]Mora F. (2013). *Keys to Practical Reason, Educate from the Brain.* ISSN 1130-3689, Nº 230, pp. 118-123

This misalignment occasionally manifests as a stagnation in the design of educational facilities, where some school environments appear to have remained unchanged and disconnected from these technological innovations (Figures 1 and 2).

THE DESIGN OF LEARNING ENVIRONMENTS

Neuroeducation[9], which studies the brain's functioning during the teaching-learning process, evidences the need for more affective construction. It calls for the conversion of school spaces into pleasant and inspiring environments that favour learning and are capable of driving the change that teaching needs in the 21st century. Beyond academic achievement, ensuring students' optimal emotional states is equally important for educational institutions.

Figure 1. Spatial organisation of a classroom in a school from the year 1871[7]

Mora's research demonstrates that cognitive performance experiences degradation when individuals perceive discomfort within their surroundings and encounter environmental stimuli that serve as distractions or confront suboptimal conditions for engaging in specific mental tasks[10].

It is important to stop considering educational spaces as mere containers and start treating them as true educational instruments[11]. The space is the "third teacher", as Loris Malaguzzi, creator of the Reggio Emilia Schools, points out. The space environment is thus a fundamental element that seeks the connection between architecture and educational endeavour.

Figure 2. Spatial organisation of a contemporary school classroom in 2021[8]

It is imperative to scrutinise the influence exerted by the environment on the processes of teaching and learning[12]. In the design of educational settings, due consideration must also be given to the interplay between cultural and emotional factors alongside physical characteristics. Assessments conducted within educational contexts necessitate a holistic evaluation that encompasses various dimensions.

[7]Rena Upitis. (2004). *School Architecture and Complexity.* https://doi.org/10.29173/cmplct8713
[8]Tanner, C. K. (2000). The influence of school architecture on academic achievement. *Journal of Educational Administration,* 38(4), 309–330. https://doi.org/10.1108/09578230010373598
[9]Sternberg, E. M., & Wilson, M. A. (2006). Neuroscience and architecture: seeking common ground. *Cell,* 127(2), 239-242. doi: 10.1016/j.cell.2006.10.012
[10]Eberhard, J. P. (2009). Applying Neuroscience to Architecture. *Neuron,* 62(6), 753-756. http://doi.org/http://dx.doi.org/10.1016/j.neuron.2009.06.001
[11]Wilson, E. O. (Year). Title. *Iberoamerican Journal of Social and Human Sciences,* ISSN: 2395-7972.
[12]Salingaros, N. A. (2015). Biophilia and healing environments: healthy principles for designing the built world. New York: Terrapin Bright Green, LLC. *Frontiers of Architectural Research,* 11(1), 114-141. https://doi.org/10.1016/j.foar.2021.07.006

The integration of neuroscience provides valuable insights into the mechanisms underlying human perception, spatial orientation, navigation, and the potential impacts of the physical environment on cognitive processes, problem-solving skills, and mood[12]. Leveraging insights from neuroscience, including the emerging field of neuroarchitecture, as well as drawing upon principles from biophilia[11]—an innate human inclination to connect with nature and other living entities—and behavioural sciences such as psychology offers a promising avenue for designers and architects.

This approach enables them to craft more immersive and enriching learning experiences where the spatial configuration, individual components, and broader physical environment assume a pivotal role in enhancing the educational context.

Negative physiological, cognitive, and emotional factors, such as stress, lack of interest, and attention in students, might be addressed more effectively with a foundational understanding of neuroscience principles[13]. Psychologists Rachel and Stephen Kaplan formulated the theory of "The Restoration of Attention" in 1989. This theory postulates that the overload of stimuli in our urban environment affects our attention and causes overexertion and mental fatigue. In contrast to constructed environments, nature exerts restorative work by concentrating stimuli to a minimum, reducing, in turn, the burden of attention and thereby increasing mental acuity[14].

Biophilia[11], as proposed by Wilson (1984), presents a hypothesis asserting that our sensory systems have evolved with a distinct predisposition for heightened perception and responsiveness to stimuli associated with the natural environment. This theory states that humans have a deep-rooted affinity for nature due to our evolutionary history, and our senses are finely tuned to respond to natural elements.

According to Salingaros[12], eight biophilic elements within architectural spaces contribute to our well-being.

- Light: This element holds substantial significance in our visual perception, metabolism, and circadian rhythms;
- Colour: It has direct associations with our emotional responses;
- Gravity: Our preference for objects that are in gravitational equilibrium and exhibit stability is influenced by this factor, as we are accustomed to such arrangements in nature;
- Fractals: Human beings tend to respond positively to certain geometric patterns that contain hierarchical subdivisions of the same structure itself;
- Curved Shapes: These shapes are abundant in nature and tend to have a calming effect;
- Detail: It is our inherent expectation to encounter a degree of detail within artificial spaces that closely mirrors the level of detail commonly observed in natural settings.
- Water: Given our biological need for this element, its presence in architectural spaces offers us a sense of tranquillity; and
- Life: There exists an inclination among individuals to seek contact with other living beings.

A common misconception lies in the indiscriminate incorporation of biophilia, involving the introduction of an abundance of plants into every available space. It is important to recognise that diverse strategies exist for the effective integration of biophilia within design principles.

[13]Keniger, L. E., Gaston, K. J., Irvine, K. N., & Fuller, R. A. (2013). What are the Benefits of Interacting with Nature? *International Journal of Environmental Research and Public Health,* 10(3), 913-935

[14]Tanner, C. K. (2014). The Interface Among Educational Outcomes and School Environment. *Natural Science*, 4(1), 4.

Some of these strategies include[15]:

- Increasing natural light: Maximising the utilisation of skylights, windows, and reflective surfaces to enhance the presence of natural light.
- Creating nature views: Ensuring that nature views are positioned at an appropriate height for students and staff to engage with.
- Introducing indoor plants: The strategic placement of indoor plants, including the use of green walls, can greatly enhance the aesthetics and functionality of a learning space and can also contribute to better air quality and acoustic comfort.
- Incorporating natural elements: Utilising natural materials, such as tactile wood furniture, exposed beams, and stonework, to stimulate the sense of touch wherever possible.
- Including references to nature: Incorporating natural textures, patterns, colours, and images into floor and wall coverings serves as an effective alternative in places where direct exposure to natural elements is limited.
- Creating safe spaces: Designating zones for various activities, including areas for focused productivity and those intended for relaxation and restoration, characterised by muted colours, soft furnishings, and subdued lighting, can act as retreats from the bustling daytime activities to rejuvenate both staff and students.

Designers responsible for shaping school environments are increasingly recognising that the integration of natural elements enhances all three dimensions—physical, cultural, and emotional—in educational communities[16].

The act of gazing out of classroom windows was conventionally viewed as a source of distraction[17] within educational settings. However, the act of directing one's gaze towards an external view, particularly one that encompasses natural elements positioned approximately 15 metres away, positively impacts the human brain. Contemplating a real natural landscape or a photograph of a natural landscape for 40 seconds temporarily alters the focal length of vision, thereby inducing a state of relaxation within the visual faculties. This helps the brain recover and maintain an optimal state of concentration[18].

A study conducted by Tanner across 71 American schools situated in the state of Georgia revealed that students who had the opportunity to observe their natural surroundings through their windows achieved higher grades in subjects encompassing language comprehension, the arts, and mathematics compared to their peers who lacked such exposure[19].

Wells' research demonstrated that viewing natural environments through windows had a positive impact on the concentration levels of children aged between 7 and 12 years. When the vista included more greenery, these children performed better in standardised attention tests[19].

[15]Zhong, W., Schröder, T., & Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. *Frontiers of Architectural Research,* 11(1), 114-141. https://doi.org/10.1016/j.foar.2021.07.006
[16]Keniger, L. E., Gaston, K. J., Irvine, K. N., & Fuller, R. A. (2013). What are the benefits of interacting with nature? *International Journal of Environmental Research and Public Health*, 10(3), 913-935.
[17]Tanner, C. K. (2014). The interface among educational outcomes and school environment. *Natural Science,* 4(1), 4.
[18]Lee, K. E., Williams, K. J. H., Sargent, L. D., Williams, N. S. G., & Johnson, K. A. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. *Journal of Environmental Psychology,* 42, 182–189. https://doi.org/10.1016/j.jenvp.2015.04.003
[19]Wells, N. M. (2014). The role of nature in children's resilience: Cognitive and social processes. *In Greening in the Red Zone* (pp. 95-109). Springer.

Additionally, ongoing research endeavours are exploring the influence of outdoor environments, such as school playgrounds, on academic performance[20]. Kaplan (2008)[2] found the attentional overload posed by urban environments was higher compared to natural ones. Taylor[21] stated that students with attention deficit hyperactivity disorder (ADHD) showed a decrease in their symptoms after being exposed to or staying in a green space.

In accordance with the Attention Restoration Theory (ART), urban environments impose substantial demands on the cognitive faculties responsible for voluntary attentional control. These demands necessitate efficient discrimination between relevant and irrelevant stimuli within the surrounding milieu. The cognitive resource associated with focused and directed attention[22] is susceptible to depletion due to the demands imposed by the urban environment. Consequently, this depletion can lead to a deterioration in performance on tasks reliant on such attentional capacities. This highlights the significance of embracing a holistic approach that integrates the entire individual, along with all their sensory faculties, as an increasingly effective methodology for facilitating the learning process. Another decisive factor in the design and construction of an educational facility pertains to its spatial orientation, a factor that exerts direct control over the extent of natural illumination that permeates the building's interior spaces. Additionally, the acoustic environment plays a substantial role in shaping the overall learning environment.

Light stands out as a pivotal biophilic element significantly impacting human well-being, particularly in its role of synchronising our circadian rhythm, which regulates our sleep-wake cycle[23]. This assertion is substantiated by the findings of Edwards and Torcellini in 2002[3], who affirm that exposure to natural light correlates with enhanced performance in academic tasks. Furthermore, it is important to acknowledge that the modulation of light intensity can exert a discernible influence on students' cognitive functions and relaxation, as elucidated by relevant research[23]. Several issues stem from the disruption of this circadian rhythm, including cognitive impairments and increased drowsiness[23]. When extrapolated to the educational domain, reduced access to natural light can exert adverse effects on students, influencing

Figure 3.

Figure 4.

In figures 3 and 4, the integration of expansive windows or positioning at an elevation affords both educators and learners panoramic vistas of the outdoors and natural environments[24,25].

[20]Schutte, A. R., Torquati, J. C., & Beattie, H. L. (2015). Impact of urban nature on executive functioning in early and middle childhood. *Environment and Behavior.* http://doi.org/10.1177/0013916515603095

[21]Taylor, A., & Kuo, M. (2011). Could exposure to everyday green spaces help treat ADHD? Evidence from children's play settings. *Applied Psychology: Health and Well-Being,* 3, 281-303. https://doi.org/10.1111/j.1758-0854.2011.01052.x

[22]Bratman, G. N., Hamilton, J. P., Hahn, K. S., Daily, G. C., & Gross, J. J. (2015). Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proceedings of the National Academy of Sciences of the United States of America,* 112(28), 8567-8572. https://doi.org/10.1073/pnas.1510459112

[23]Anthes, G. (2013). Nature experience reduces rumination and subgenual prefrontal cortex activation. *Communications of the ACM,* 56(6), 13-15. https://doi.org/10.1145/2461256.2461262

[24]Thurston Elementary School. Mahlum Architects Inc. Springfield, Oregon, United States. Credit: Lincoln Barbour. Retrieved from www.lincolnbarbour.com

[25]Scholem Aleichem school, In Villa Crespo. CLAIMA20160313_0081.

their well-being and academic performance.

Figure 5.

In figure 5, we observe allusions to elements found in nature within the design of the furniture. The incorporation of curved contours evokes a sense of organic forms, while the colour palette employed mirrors the hues commonly found in the natural world[26,27].

In figures 6 and 7, it is evident how natural vegetation has been thoughtfully integrated into the environment, seamlessly becoming an integral component of both the spatial arrangement and the design of the furniture[28].

Figure 6.

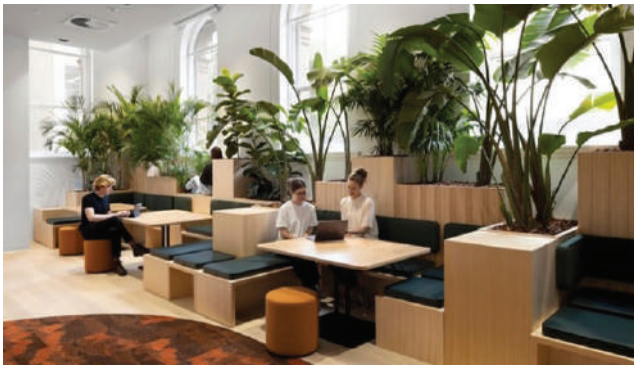

Figure 7.

CONCLUSION

Research consistently demonstrates that students immersed in biophilic settings exhibit remarkable improvements in learning efficiency, stemming from reduced stress levels, heightened attention, and accelerated cognitive recuperation.

This underscores the profound influence of biophilic elements on concentration and cognitive stimulation during the learning process. Embracing this holistic approach holds the potential to revolutionise educational spaces, fostering an environment where both knowledge acquisition and well-being flourish harmoniously.

KEY RESEARCH OUTCOMES

The fusion of neuroscience and biophilic principles not only redefine the contours of learning environments, but also heralds a paradigm shift in the pursuit of optimal learning and well-being.

[26] Los beneficios de la biofilia en los espacios educativos. Retrieved from https://aeispaces.com/2023/01/06/los-beneficios-de-la-biofilia-en-los-espacios-educativos/

[27] Mobiliario en el aula. Retrieved from https://www.educaciontrespuntocero.com/noticias/mobiliario-en-el-aula/

[28] Victorian Academy of Teaching and Leadership. Retrieved from https://arquitecturayempresa.es/noticia/academia-de-ensenanza-y-liderazgo-designinc

METAMORPHIC ARCHITECTURE

PERCEIVING ARCHITECTURE THROUGH PERIPHERAL VISION: A PROPOSED MODEL FOR METAMORPHIC SPACES IN CLASSROOM DESIGN

GIULIA MASTROCINQUE
Interior Neuro-designer,
Co-Founder of Studio Synsēa
Italy.

VERONICA GIANNINI
Neuroscientist, Researcher, and Consultant
Co-Founder of Studio Synsēa
Italy

ABSTRACT

Central and peripheral vision play distinctive yet parallel roles in the perceptions of architecture. As peripheral vision seems to be prevalent and decisive in the perception of atmospheres rather than focal and distinct design features, we hypothesise peripheral architectural variables to be a key feature in a novel approach to interior design. Following awareness and necessity of providing atmospheres that, in a short period of time, change, and evolve according to the types of experiences that are expected for these environments, we propose the Metamorphic Spaces (MS) theory.

Using a theoretical framework applied to classroom design, we assess fundamental elements pertinent to the perception of peripheral architecture and explore possible modifications aimed at creating environments that align with the requirements of students. The aim is to provide a basic yet applicable tool that facilitates people's neurophysiological, cognitive, and emotional requirements when experiencing built spaces and that allows a dual nature of environments rather than limiting interiors to a conventional static character.

INTRODUCTION

In recent years, there has been an increased focus on the intersection of neuroscience and architectural design. This heightened interest stems from a growing recognition of the profound influence that the built environment wields over people.

The dynamic adaptation of our nervous system is necessitated by the continual processing of sensory inputs received from the external environment. These inputs, facilitated through our sensory channels, including sight, hearing, touch, and numerous others (such as thermoception and proprioception), enable humans to interact with a diverse range of exogenous stimuli, thereby acquiring a multitude of sensory information in various forms[1].

When we interact, both passively and actively with an environment, every single piece of information somehow contributes to a complex output that manifests itself on various levels, ranging from neurophysiological measures to cognitive, behavioural, and emotional patterns. Awareness of this intricate mechanism sets the basis for detailed considerations of the multitude of possible effects that any kind of architecture can exert on our being. Our topic of interest refers specifically to interior spaces and the way design features greatly contribute to the mood and physiological status of users.

ADAPTING ENVIRONMENTS: A METAMORPHIC SPACES THEORY

When considering conventional modern interior architecture, a limiting quality that comes to mind is its unchanging nature. Regardless of their architectural or structural characteristics, indoor environments, including workplaces, residential and educational spaces, typically exhibit a static nature, irrespective of the diverse activities that may transpire within them.

The main feature that is conventionally accepted to change during the day and seasons is lighting, either natural or artificial. Lighting can greatly contribute to satisfying the requirements for a space to be utilised, and its variations can accompany and favour circadian rhythms[2]. However, when contemplating additional design elements that play a pivotal role in establishing an appropriate ambiance for various activities, effecting changes tailored to specific requirements often prove to be challenging to implement.

One straightforward and intuitive way of defining an environment's nature can be explained by means of dualism: "activating" or "de-activating". With specific reference to Henry Mallgrave's theory[3], environments potentially have the means of informing our autonomic nervous system, soliciting either our sympathetic or parasympathetic activity. Information from the built environment in the form of

[1]Moller, A. R. (2003). *Sensory systems: Anatomy, physiology and pathophysiology.* Gulf Professional Publishing.
[2]Sholanke, A., Fadesere, O., &Elendu, D. (2021, March). The Role of Artificial Lighting in Architectural Design: A Literature Review. *In IOP Conference Series: Earth and Environmental Science* (Vol. 665, No. 1, p. 012008). IOP Publishing.
[3]Francis, M. H. (2015). *L'empatiadeglispazi. Architettura e neuroscienze,* Raffaello Cortina Editore, Milano.

sensory inputs thus contributes to a normal physiological adjustment in either direction. Although every space is different, and users' needs vary accordingly, we can broadly attempt to define the features that characterise the two types of spaces. For activating environments, these can be synthesised into higher visual complexities to stimulate our visual attention, such as brighter colours, more intense lighting, and higher ceilings. For de-activating environments, organic shapes, reduced visual complexity, neutral colours, and lower ceilings are preferred. Our Metamorphic Spaces (MS) theory raises considerations for the adaptability of design elements within indoor architecture to promptly accommodate a wide range of activities. Consequently, we are inquiring into the mechanisms through which environmental characteristics can be dynamically altered via design interventions, with a particular focus on peripheral architectural elements.

A PERIPHERAL VIEW AND PERCEPTION OF ARCHITECTURE

"Paradoxically, we grasp the atmosphere before we identify its details or understand it intellectually"[4]. Physiologically speaking, the peripheral visual system is highly sensitive to motion and changes in the environment. It provides us with a wide-angle view of the surroundings, allowing for the detection of potential threats, navigation, and situational awareness[5]. While central vision provides clarity and precise details, peripheral vision contributes to a broader awareness of the visual environment.

Rooney and colleagues[6] hypothesise that humans experience architecture in two fundamental ways: by consciously evaluating it intellectually through focal object processing and by evaluating it in terms of atmosphere through pre-conscious ambient spatial processing. In line with Elisabetta Canepa's interpretation of atmosphere, described as a perceptive experience and a condition of sensory-motor, emotional, and cognitive resonance between a person and their constructed environment[7], we embrace this construct in relation to a potential application of metamorphic peripheral design features that contribute to defining a space as either physiologically activating or de-activating.

SCHOOL CLASSROOMS: FROM STATIC TO METAMORPHIC

It is advisable that classrooms encompass both modalities, namely activation and deactivation, to cater to varying needs at different times of the day. For instance, during lectures or study sessions, it is essential that the environment promotes a sense of tranquillity and concentration conducive to enhanced focus and productivity. Conversely, there are instances when the classroom should transform into a dynamic and stimulating space, fostering creativity, and facilitating social interactions among students.

Traditionally, students are expected to adapt to these shifting modalities in their learning environments. However, peripheral architectural features typically remain unaltered. Addressing this limitation by modulating peripheral architectural aspects, such as ceiling height and spatial configurations, can significantly enhance the adaptability and effectiveness of educational spaces to meet the diverse requirements of learners. This nuanced approach aligns with the Metamorphic Spaces (MS) theory,

[4]Pallasmaa, J. (2014). Space, place and atmosphere. Emotion and peripheral perception in architectural experience. *Lebenswelt: Aesthetics and Philosophy of Experience,* 4(1), 230-245.
[5]Srikantharajah, J., & Ellard, C. (2022). How central and peripheral vision influence focal and ambient processing during scene viewing. *Journal of Vision*, 22(12), 4-4.
[6]Rooney, K. K., Condia, R. J., &Loschky, L. C. (2017). Focal and ambient processing of built environments: Intellectual and atmospheric experiences of architecture. *Frontiers in Psychology,* 8, 326.
[7]Canepa, E., Scelsi, V., Fassio, A., Avanzino, L., Lagravinese, G., &Chiorri, C. (2019). Atmospheres: Feeling architecture by emotions. Preliminary neuroscientific insights on atmospheric perception in architecture. Ambiances. *Environment sensible, architecture et espaceurbain,* (5).

offering a valuable means for optimising classroom design in accordance with varying learning contexts and goals.

Literature has investigated how features of space can highly impact students' behavioural outcomes and well-being, with a general consensus towards flexible layouts, balanced visual complexities, novelty elements, and well-defined spatial features to correlate with positive behaviour, academic performance, and social interactions[8,9]. Within the realm of peripheral architecture, one illustrative case study pertains to the manipulation of ceiling height. In 1979, Moore and colleagues[10] differentiated between the effects of lower and higher ceilings in spaces for children, attributing lower ceilings to quieter activities and higher ceilings to more active playing. The same is supported by Read and colleagues[11], who investigated ceiling height variations in relation to children's cooperative behaviour and found a positive correlation. In a similar paradigm, Meyers-Levy and Zhu[12] suggest that higher ceilings tend to prime individuals for more creative and abstract thinking, whereas the opposite is true for lower ceilings, suggesting these to support detailed-oriented thinking.

PROPOSAL FOR A PRACTICAL SOLUTION

While we shall refrain from an exhaustive exploration of mechanical solutions for realizing a metamorphic space, we propose an approach that can facilitate swift and efficient transitions in atmosphere. These transitions would be perceptible through our peripheral vision and ideally aligned with the dynamic requirements of students in classrooms. Our proposed model envisions the feasibility of implementing a dynamic 3D ceiling structure, operable through the deployment of baffles that can either close and descend in a horizontal orientation, or open and ascend to a vertical full-height position. This mechanism serves as a tangible embodiment of the concept of metamorphic spaces within our framework. By integrating this single proposed variable with additional potential environmental modifications, including spatial layouts and visual complexities, future classrooms could manifest a complete metamorphic nature, aligning with the evolving needs of students. This would provide suitable stimuli that cater to the varying phases encountered throughout the school schedule, allowing classrooms to seamlessly transition between activating and deactivating states as required.

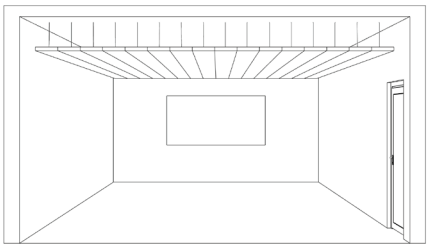

Fig. 1. Mode A

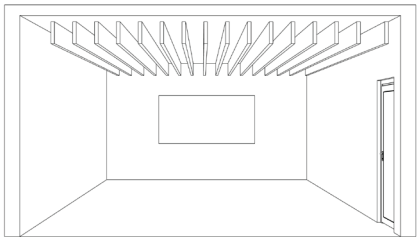

Fig. 2. Mode B

[8]Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2015). The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. *Building and Environment*, 89, 118-133.

[9]Abbas, M. Y., & Othman, M. (2010). Social behavior of preschool children in relation to physical spatial definition. *Procedia-Social and Behavioral Sciences,* 5, 935-941.

[10]Moore, G. T., Lane, C. G., Hill, A. B., Cohen, U., & McGinty, T. (1979). *Recommendations for child care centers.* Milwaukee, WI: Center for Architecture and Urban Planning Research.

[11]Read, M. A.; Sugawara, A. I.; Brandt, J. A. (1999). Impact of Space and Colour in the Physical Environment on Preschool Children's Cooperative Behaviour. *Environment and Behaviour,* 31(3), 413– 428. doi:10.1177/00139169921972173

[12]Meyers-Levy, J., & Zhu, R. (2007). The influence of ceiling height: The effect of priming on the type of processing people use. *Journal of Consumer Research,* 34(2), 174-186.

CONCLUSION

Our Metamorphic Spaces (MS model) exemplifies how a single feature, such as ceiling height, could significantly enhance and align with students' needs in school classrooms. Nonetheless, extensive research is warranted to substantiate and gather quantifiable data regarding the advantages of such modifications, both in terms of individual features and when combining various alterations in classroom design. This evolution in the design of classrooms highlights the potential for adaptability and responsiveness of educational spaces according to the dynamic nature of learning and pedagogical activities.

KEY RESEARCH OUTCOMES

Our exploration into the potential of peripheral architecture heralds a promising transformation in classroom design. Recognising the profound influence of architectural and design elements on our cognitive and neurophysiological functions, we have unveiled a rudimentary yet compelling model.

EDITORIAL COMMENTARY

In an age where urbanisation and climate change cast formidable shadows over our environment, the following studies offer a ray of hope in our endeavour to protect our invaluable natural capital. "Unlocking the Evaluation of NbS Benefits," authored by Chloé Mecqinion and Sébastien Kidushi Mboma, and "Transitioning towards Socio-Ecological Resilience in the Ganga River Basin" by Jahnavi Bhatt, shed light on the vital importance of preserving ecosystems and bolstering socio-ecological resilience. The authors emphasise the critical importance of engaging local actors in conservation and sustainable development efforts.

Chloé Mecqinion, an NbS and climate change consultant, and Sébastien Kidushi Mboma, a biodiversity management expert, shine a spotlight on the vital role of nature-based solutions (NbS) in urban contexts. They offer a comprehensive tool for decision-makers and experts to prioritise NbS projects. By meticulously evaluating the attributes of plant species in terms of climate change mitigation, disaster risk reduction, and socio-economic contributions, their methodology equips experts to make well-informed decisions in the face of urban expansion. The case study in Kinshasa serves as an inspiring example of its potential. Mecqinion and Kidushi reiterate that the health and resilience of urban centres are inextricably linked to the conservation of nature. Their approach to NbS demonstrates its versatility and global applicability as a valuable tool for sustainable and resilient urban landscapes.

In the conceptual article titled "Transitioning towards Socio-Ecological Resilience in the Ganga River Basin", Jahnavi Bhatt, an urban designer and strategic planner, examines the challenges to the Ganga (Ganges) River basin in India that are being caused by urbanisation and climate change. Bhatt proposes the creation of an "Adaptive Spatial Planning Framework". This approach recognises the interdependence of social, economic, and ecological factors, enabling a more comprehensive understanding of the basin's dynamics to mitigate vulnerabilities heightened by climate change and urbanisation. She asserts that a framework that bridges the gap between national climate policies and localised adaptation strategies will enable cohesive and coordinated actions to facilitate a transformative path towards a more resilient future for the Ganga River Basin.

Mecqinion and Kidushi's "Methodology for Assessing NbS Benefits" and Bhatt's "Adaptive Spatial Planning Framework" are both relevant in the broader context of preserving natural capital and building sustainable socities. These frameworks emphasise context-specificity and the interdependence of ecological and urban health, offering valuable guidance for regions worldwide facing similar challenges.

ENVIRONMENTAL MANAGEMENT

UNLOCKING THE EVALUATION OF NBS (NATURE-BASED SOLUTIONS) BENEFITS

CHLOÉ MECQINION
NbS and Climate Change Consultant
France

SEBASTIEN KIDUSHI MBOMA
Biodiversity Management Expert
Congo

ABSTRACT

In Kinshasa, there is a complex relationship between nature and urbanization. The rapid influx of nearly two thousand new residents daily necessitates the continuous conversion of approximately five hectares of land for urban development, often at the expense of precious natural areas. However, when natural forces reclaim urban spaces, the consequences are substantial, resulting in destructive events such as flooding, erosion, and deadly heatwaves.

In the absence of methodologies to quantify the services rendered by nature and, in particular, its contribution to the mitigation of climate risks, nature remains seen as a short-term, exploitable resource. This perception leads to its systematic destruction in times of vulnerability. To transform it into a shared asset essential for urban survival, we need to quantify and recognise its value.

Within the framework of a World Bank project, Groupe Huit, in partnership with Arter, has developed a methodology to evaluate the benefits of nature-based solutions (NbS) and to help select the best NbS according to the ground characteristics and the challenges at stake.

Beyond the project's objective, which was to propose a NbS strategy for the entire urban perimeter of Kinshasa, this article proposes to examine the importance of a better knowledge of local biodiversity for the evaluation of NbS impacts. In this article, we provide a comprehensive overview of the methodology used for the evaluation of NbS benefits while attempting to highlight its limitations.

INTRODUCTION

Nature-based solutions (NbS) have received substantial backing from international donors and are recognised as an effective strategy for climate adaptation[1]. Many authors argue that they bring co-benefits, such as improving the attractiveness of places, improving health and quality of life, and creating green jobs[2,3,4]. However, their implementation in developing countries has been hindered by a lack of public resources and land management tools, economic pressures on the population, standard engineering methods, etc. This has resulted in NbS projects that are unambitious and/or with severely compromised sustainability[4].

For instance, to meet the needs of its populace, the government of the Democratic Republic of the Congo established Presidential Valleys and Green Belts in Kinshasa in 1972, primarily for agricultural production[5]. The former green belts are now densely populated areas in the centre of the sprawling city as a result of the exponential demographic growth[6], which has taken over all intra-urban and peripheral spaces.

[1] *Secretariat of the Convention on Biological Diversity.* (2009). The Convention on Biological Diversity Plant Conservation Report: A Review of Progress in Implementing the Global Strategy for Plant Conservation (GSPC). Montreal.

[2] Gómez Martín, E., Giordano, R., Pagano, A., van der Keur, P., & Máñez Costa, M. (2020). Using a system thinking approach to assess the contribution of nature-based solutions to sustainable development goals. *Science of The Total Environment*, 738, 139693. https://doi.org/10.1016/j.scitotenv.2020.139693

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[4] Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S., & Turner, B. (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology,* 27(8), 1518–1546. https://doi.org/10.1111/gcb.15513

[5] Nzuzi, F.L. (2011). *Kinshasa Planification & Aménagement.* Editions L'Harmattan. ISBN 978-2-296-46875-7.

[6] According to the SOSAK (Strategic Orientation Plan for the Kinshasa urban area), Kinshasa currently hosts an additional 2,000 people per day.

The methodology presented here was developed to meet the study's specific objectives and is based on an atlas of local vegetation prepared for Kinshasa. Nevertheless, its universality is rooted in its approach, which establishes an intrinsic link between NbS and the constituent plant species. Also, the tools proposed, such as the indicators and scoring values, have potential applicability across diverse projects.

In this framework, the World Bank mandated Groupe Huit[7] to propose a NbS strategy over the urban territory of Kinshasa based on

- the physical suitability for NbS implementation; and
- the expected benefits of NbS, which is the subject of this article.

METHODOLOGY TO EVALUATE NBS BENEFITS

The 2021 World Bank NbS catalogue[8] defines NbS as 'approaches that use nature and natural processes for delivering infrastructure, services, and integrative solutions to meet the rising challenge of urban resilience'. The World Bank has compiled a list of 14 categories of NbS adapted to various scales and field conditions, such as urban forests, terraces, and slopes, or sandy shores. Groupe Huit[7] developed the methodology outlined in Table 1 based on an evaluation of benefits of different NbS for the purpose of determining the best solution when multiple NbS could be implemented at a single location.

Table 1. Groupe Huit's methodology for assessing NbS benefits[9,10]

LIST OF SPECIES
• Preparation of a list of available indigenous plant species in Kinshasa
• Description of their main characteristics such as size, roots, canopy, etc.
IMPACTS ON CLIMATE CHANGE
• Selection of benefit categories and indicators
• Scoring the contribution of each plant to the above indicators based on their main characteristics and including the weightage of the indicators
AGGREGATION INTO NBS
• Evaluation of the compatibility of plant species with NbS categories
• Determination of a typical mix of plants per NbS family
• Calculation of average scores per NbS for each of the project indicators
COMPARISON OF NBS BENEFITS
• Comparison of NbS benefits (target diagram)
• Prioritisation of the NbS that provides the most benefits

[7]Groupe Huit is a French consulting firm specialized in urban development and engineering studies, which was, for this specific study, in consortium with ARTER (a Belgian consulting firm), and worked with VSI Afrique (a Congolese consulting firm) as local partners.

[8]World Bank. (2021). *A Catalogue of Nature-based Solutions for Urban Resilience.* Washington, D.C.: World Bank Group. Link to Document

[9]Groupe Huit, ARTER. (2014). *Schéma D'orientation Stratégique de l'Agglomeration de Kinshasa (SOSAK).* [Study report].

[10]Groupe Huit, ARTER. (2022). *Unlocking the Full Potential for Low-Carbon Emissions and Urban Resilience in the City of Kinshasa - Specifications of implemented NbS EXCEL tool.* [Study report].

I SELECTION OF SPECIES

The first step of the methodology consists in establishing a list of plants that could be mobilised in NBS projects as per Table 2 .

Table 2. Extract from the prepared list of plants that can be mobilized in Kinshasa

SCIENTIFIC NAME	VERNACULAR NAME	MORPHOLOGICAL TYPE	SIZE CATEGORY
Acacia auriculiformis	Acacia	tree	second size (between 15 and 30m)
Acacia mangium	Acacia	tree	second size (between 15 and 30m)
Albizia saman	Arbre à pluie	tree	first size (> 30m)
Aleurites mollucana	n/a	tree	first size (> 30m)
Artocarpus altilis	Arbre à pain	tree	second size (between 15 and 30m)
Artocarpus heterophyllus	Jacquier	tree	second size (between 15 and 30m)
Bambusa vulgaris	Bambou de Chine	tree	second size (between 15 and 30m)
Cananga odorata	Ylan-ylan	tree	second size (between 15 and 30m)
Canarium schweinfurthii	Arbre à ancens	tree	first size (> 30m)
Ceiba pentandra	Kapokier	tree	first size (> 30m)
Chrysopogon zizanoides	Vétiver	grass	third size (<15m)
Cinnamomum verum	Laurier	shrub	second size (between 15 and 30m)
Cupressus lusitanica	Cyprès du Mexique	tree	second size (between 15 and 30m)
Dacryodes edulis	Safoutier	tree	second size (between 15 and 30m)
Delonix regia	Flamboyant	tree	third size (<15m)
Eucalyptus camaldulensis	n/a	tree	first size (> 30m)
Eucalyptus citriodora	Eucalptus citronné	tree	first size (> 30m)
Garcinia mangostana	Mangoustanier	tree	second size (between 15 and 30m)
Gmelina arborea	Gmelina	tree	second size (between 15 and 30m)
Khaya ivorensis	n/a	tree	second size (between 15 and 30m)
Lagerstroemia speciosa	Lilas des Indes	tree	third size (<15m)
Lannea antiscorbutica	Mukumbi	tree	second size (between 15 and 30m)
Lannea welwitschii	Mukumbi	tree	second size (between 15 and 30m)
Leucaena leucocephala	Faux mimosa	tree	third size (<15m)
Maesopsis eminii	Arbre parapluie	tree	second size (between 15 and 30m)
Mangifera indica	Manguier	tree	first size (> 30m)

The local knowledge of Ibi Village[11] was crucial in the selection of both indigenous and exotic species. The biodiversity expert selected species that were available in the local plant nurseries, described their adaptation abilities, and evaluated their potential contributions to the project objectives.

Figure 1. The agro-forestry project in Ibi village[12].

[11]Ibi Village is a large ecological project of 22, 000 hectares on the highland of Bateke in the southeast of Kinshasa in the Democratic Republic of the Congo.
[12]Agro-forestry initiative in the Bateke plateau

II SELECTION OF INDICATORS TO MEASURE THE IMPACT ON CLIMATE ADAPTATION AND MITIGATION

The second step of our study involved the identification of relevant indicators to assess the benefits of nature-based solutions (NbS) in alignment with our project's objectives. In our research, we conducted an analysis of climate-related risks faced by Kinshasa, including threats such as landslides, floods, and urban heat islands. This analysis emphasized the primary objective of evaluating NbS for their effectiveness in reducing disaster risk. Additionally, as our project received funding from the City Climate Finance Gap Fund, we recognized the importance of carbon sequestration as a key objective within the NbS strategy. Furthermore, considering the context of extreme poverty in Kinshasa and the necessity for sustainability, our teams proposed a third objective: the provision of socio-economic services through NbS. This objective was not only a measure of project performance but also a vital component for ensuring the continued effectiveness of NbS interventions in the region. For each of the three benefit categories (risk reduction, carbon sequestration, and socio-economic co-benefits), several indicators were identified, and the corresponding data was entered at the level of each plant species constituting the NbS, as detailed in Table 3.

Table 3. Indicators and Scoring Methodology

Benefit category	Indicators from plant species' properties	Scoring
Carbon sequestration	• Morphological type: trees sequester more carbon than herbaceous plants and shrubs • Growth rate: sequestration is high in fast-growing species because the plant has high requirements to ensure the proper functioning of its metabolism • Size of the leaves: the larger the leaves, the higher the photosynthetic capacity	Based on Djaouga et al., Groupe Huit[9,10] used allometric equations to calculate above-ground biomass from height, diameter, and density. The conversion factor was used to convert above-ground biomass into below-ground biomass. Finally, we used the conversion factor of 0.487 to estimate the tonnes of carbon sequestered per ha per year. These calculations allowed our team to classify each species per average sequestration/ha/year: 3: More than 30t CO2 eq/ha/year; 2: between 10 and 30t CO2 eq/ha/year; and 1: less than 10t CO2 eq/ha/year.
Socio-economic co-benefits	• Possible exploitation of the wood; • Food or medicinal production: whether the species can be marketed or used for self-consumption as a food or medicinal product; • Biodiversity hosting capacity: the contribution of plant species to the repopulation of wildlife is important because these species can generate new socio-economic benefits such as honey production, edible caterpillars, etc.; • Potential ornamental use; • Cultural value: Social cohesion was duly considered with primary focus directed towards large trees that served as communal gathering sites, landmarks, etc.	• Possible exploitation of the wood: 3: yes; 0: no potential exploitation of wood. • Food or medicinal production: 3: yes; 0: no potential food or medicinal production. • Biodiversity hosting capacity: 3 yes; 0: no biodiversity hosting capacity. • Potential ornamental use: 3: yes; 0: no potential ornamental use. • Cultural value: 3: yes; 0: no cultural value. The consultant assigned different weightings to these criteria, acknowledging their differing levels of importance. Notably, the potential for wood, food, or medicinal production was deemed twice as significant as the other indicators.

Risk reduction	• Reduces the urban heat island risk and the ability of plant species to create humus, which contributes to soil nourishment and improves soil stabilisation, effectively reducing erosion and flood risks. In addition, the leaves protect the soil from the direct impact of rain and consequently reduce the phenomenon of landslides. • The size of the canopy determines the extent of shade, which can minimise urban heat island risk.	Limited humus production and evapotranspiration; 1: small leaves and/or low foliage density imply limited humus production and evapotranspiration. • Shading: 3: high shading; 2: medium shading; 1: low shading. Given their substantial significance, these three ratings were combined to calculate an average rating indicative of the risk reduction potential associated with each plant species.

Depending on the objectives of the projects planning to use this methodology, the above could be improved by increasing the number of indicators and making the description of the input data in the plant atlas more detailed and objective.

III AGGREGATION OF PLANT IN TYPICAL NBS

In order to associate the list of plant species with the NbS categories outlined by the World Bank, our team conducted an evaluation based on the hydrophilic characteristics exhibited by each plant species. While this approach offers a level of accuracy, it is important to note that enhancing precision could involve considering additional criteria, such as suitability for slope stabilisation or compatibility with densely urban environments. Groupe Huit identified a typical blend of trees, shrubs, grasses, lianas, and crops for each NbS category. This comprehensive mix was designed to account for the likely proportion of their presence within the NbS, thus influencing the calculation of the impact score. This specific composition of plants, tailored to each NbS category, is climate-specific and readily adaptable for future applications of the methodology in different geographical contexts.

The final scores for each NbS category were calculated by weighting the plant-based scores with the proportion of each morphological type for the NbS category under consideration, as shown in Table 4.

Table 4. NbS Categories

NBS CATEGORY	TREES	SHRUBS	GRASSES	LIANAS	CROPS	Total
OPEN GREEN SPACE	10	20	70	0	0	
Carbon sequestration score	2.6	1.1	1.0	1.0		1.2
Risk reduction score	2.4	1.6	1.0	1.0		1.3
Socio-economic score	1.3	1.2	1.0	0.9		1.0
URBAN FOREST	70	10	10	10	0	
Carbon sequestration score	2.6	1.1	1.0	1.0		2.1
Risk reduction score	2.4	1.6	1.0	1.0		2.0
Socio-economic score	1.3	1.2	1.0	0.9		1.2
GREEN CORRIDORS	60	20	20	0	0	
Carbon sequestration score	2.6	1.1	1.0	1.0		2.0
Risk reduction score	2.4	1.6	1.0	1.0		1.9
Socio-economic score	1.3	1.2	1.0	0.9		1.2
RIVER RENATURATION	30	30	40	0	0	
Carbon sequestration score	2.6	1.0	1.0	1.0		1.5
Risk reduction score	2.6	1.0	1.0	1.0		1.5
Socio-economic score	1.6	1.0	1.0	1.0		1.2

RIVER FLOODPLAIN	30	30	40	0	0	
Carbon sequestration score	2.6	1.0	1.0	1.0		1.5
Risk reduction score	2.6	1.0	1.0	1.0		1.5
Socio-economic score	1.6	1.0	1.0	1.0		1.2
URBAN AGRICULTURE	10	0	0	0	90	
Carbon sequestration score	2.8	1.1	1.0	1.0	1	1.2
Risk reduction score	2.7	1.8	1.3	1.0	1.0	1.2
Socio-economic score	2.0	1.9	1.8	1.0	2.7	2.6
BIORETENTION AREA	30	30	40	0	0	
Carbon sequestration score	2.6	1.0	1.0	1.0		1.5
Risk reduction score	2.6	1.0	1.0	1.0		1.5
Socio-economic score	1.6	1.0	1.0	1.0		1.2
WETLAND	30	30	40		0	
Carbon sequestration score	2.6	1.0	1.0	1.0		1.5
Risk reduction score	2.6	1.0	1.0	1.0		1.5
Socio-economic score	1.6	1.0	1.0	1.0		1.2
TERRACES AND SLOPES	30	30	40		0	
Carbon sequestration score	2.9	1.0	1.0	1.0		1.6
Risk reduction score	2.6	1.6	1.7	1.0		1.9
Socio-economic score	1.4	1.5	0.9	1.0		1.2
GREEN ROOF			100		0	
Carbon sequestration score	1.0	1.1	1.0	1.0		1.0
Risk reduction score	1.0	1.6	1.0	1.0		1.0
Socio-economic score	1.0	1.2	1.0	0.9		1.0

IV COMPARISON OF NBS BENEFITS

The above steps culminated in the form of impact scores per NbS as presented in Figure 2 along with the possibility of comparing the NbS categories against various project objectives. In cases where several NbS were appropriate for a specific location, these performance scores were used to enable selection of the best NbS (with the most benefits) to form part of the city's NbS strategy.

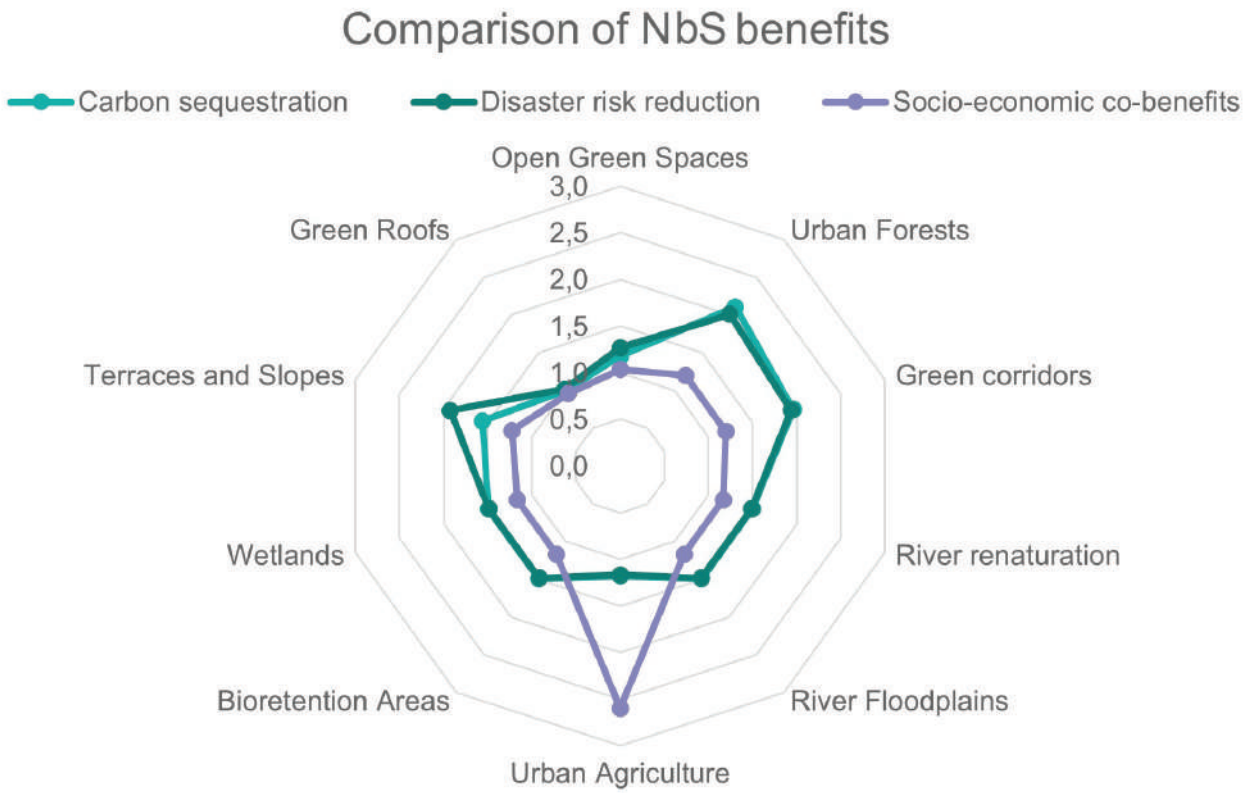

Figure 2. Comparison of NbS benefits[9,10]

CONCLUSION

In a world where urbanization and environmental challenges continue to intensify, this case study illuminates a path forward—one that integrates nature-based solutions into the heart of urban planning.

The methodology developed in this study introduces a comparative assessment approach for gauging the advantages of nature-based solutions, predicated upon the criteria established by the World Bank. The ongoing research conducted by Groupe Huit aims to quantifying supplementary dimensions of impact, encompassing but not limited to reductions in flood occurrences, quantifiable economic savings, and reduced negative health-related outcomes. These endeavours hold the potential to enhance and diversify the toolkit available for the comprehensive evaluation of nature-based solutions, promising a more nuanced understanding of their multifaceted benefits, and contributing to more informed decision-making in NbS project design.

KEY RESEARCH OUTCOMES

This study not only underscores the intrinsic link between nature and society but also provides a practical roadmap for nurturing these connections. As we look to build sustainable and resilient landscapes for future generations, we must bear in mind that nature is not merely a part of the solution; it is the solution.

ADAPTIVE SPATIAL PLANNING

TRANSITIONING TOWARDS SOCIO-ECOLOGICAL RESILIENCE IN THE GANGA RIVER BASIN

JAHNAVI BHATT
Urban designer, Strategic Planner and Architect,
U.K.

ABSTRACT

The capitalistic and economy-driven approach towards urbanisation in India has led to a great disparity between different socio-cultural groups as well as put a huge pressure on ecological systems. Further, with the changing climate, these groups are increasingly vulnerable to hazards. This can be observed even in the Ganga (Ganges) River Basin, where unplanned urbanisation has led to a fragmented river system that puts several local settlements at increasing risk. The approach to planning water-centric projects has not been holistic in the past, and with the uncertainties of changing times, the planning approach needs to be more adaptive to the future challenges of climate change and urbanisation. The objective of the article is to review the current development trend within the existing planning system and develop a possible adaptive spatial planning model for design that would include local communities and governing bodies in the planning process.

INTRODUCTION

The Ganga River has held high ecological, social, and environmental significance for the country and its people. With the rapid growth and development of urban centres along the river, the pressure on the river basin, as well as water demands are constantly increasing. The unregulated development of various sectors along the river bank has led to extreme degradation of the river.

The Ganga basin covers an area of 1,016,124 km^2 and is the most populated river basin in the world, with a density of about 400 people per square kilometer[1]. More than half of the population in the region directly relies on the agriculture sector or secondary occupations such as fishing, boating, and animal husbandry for employment. The ongoing rapid urbanisation and industrialisation along the riverbanks pose a serious threat to the environment, impacting food production and employment in the river basin.

The delta region in the eastern part of the basin faces constant erosion hazards due to the morphological changes of the river, while the plains in the western part suffer from water scarcity and fluctuating rainfall. Over the years, there has been a major shift in its hydrology due to several human activities. The river is also challenged by the lack of an integrated water management strategy, becoming a highly fragmented river system due to the construction of huge barrages and dams for hydroelectricity and irrigation, unmonitored industrial use of water, and intensive, unplanned development of the cities and towns along its banks. The design and development of infrastructure within the river basin at one point can cause challenges at other points in the system.

The Adaptive Spatial Planning Framework builds on an understanding of socio-ecological systems (SES) and the concept of resilience. It is a methodology to guide the planning and development of spatial areas in a flexible and adaptive manner. Intensive research has been carried out to understand the workings of SES[2], but very little has been translated into practical design solutions. Dynamic planning pathways within an adaptive spatial planning model for the river basin can help achieve coherent development across the river basin. With interventions and actions that have consequences at different scales, it is necessary to utilise the potential of adaptive planning that has the capacity to evolve with changing times.

This article seeks to explore how resilience, SES, and adaptive spatial planning frameworks can be applied to foster coherent development across the river basin, considering the need for interventions and actions that have implications at various scales.

CHALLENGES

CLIMATE HAZARDS AND IMPACTS

The Ganga River basin has experienced a rise in the mean temperature. The glacier origins of the Ganga have been melting rapidly, impacting the microclimate of the region[3]. Due to the reduction in forest cover, the region is experiencing impacts from flooding and unregulated river flow[3]. With increasing temperatures, the precipitation in certain regions has increased tremendously and are experiencing short periods of heavy rainfall.

[1]Acciavatti, A., Bierig, A., Corrigall, D., & Mehrotra, R. (2015). *Ganges water machine* (1st ed.). Hong Kong: Color Separations and Printing: ORO Group Ltd.

[2](Côte, Muriel & Nightingale, Andrea. (2011). Resilience Thinking Meets Social Theory Situating Social Change in Socio-ecological Systems (SES) Research. *Progress in Human Geography*. 36. 10.1177/0309132511425708.

[3]Kattel, G.R. Climate warming in the Himalayas threatens biodiversity, ecosystem functioning and ecosystem services in the 21st century: is there a better solution? *Biodiversity Conservation* 31, 2017–2044 (2022). https://doi.org/10.1007/s10531-022-02417-6

SOCIO-ECONOMIC VULNERABILITIES

The basin is a complex society, with most of the population still living in rural areas with low standards of living. As most poor people reside in eco-sensitive, and high-risk zones, their vulnerability to ecological conditions is also high. While the impact of climate change will be felt by all, the poor will suffer the most. This loss varies across the basin depending on the coping capacity of the communities and their access to resources[4].

IMPACTS OF INFRASTRUCTURE PROJECTS

Large-scale infrastructure projects are developed and constructed along the river to achieve economic gains. Twenty-four dams have already been constructed on the northern tributaries that form the Ganga to achieve hydropower energy[1]. In the central belt of the river, an elaborate network of canals has been constructed since 1853 for irrigation and water supply purposes. The infrastructure has led to a fragmented river system that compromises the ecology and hydrology of the river. Moreover, the capitalist development approach in India is creating a spatially unjust society[5].

BUILDING RESILIENCE

UNDERSTANDING VULNERABILITY AND HAZARDS

Vulnerability to environmental hazards increases the potential loss of ecosystem services and the economy. The loss is specific to the geographical location of the hazard and is described in the Hazard-of-Place Model of Vulnerability developed by Cutter (2003)[6]. The model portrays how the hazard potential is either moderated or enhanced by the geographic location and social fabric of the place.

EVOLUTION OF THE CONCEPT OF RESILIENCE

Older models of ecosystem dynamics were centred on the notion that ecosystem and population attributes undergo temporal fluctuations. These models were primarily oriented toward the concept of the 'balance of nature,' wherein the biophysical system was presumed to gravitate towards a stable equilibrium following a single climate aftershock[7]. Consequently, resilience was construed as the system's ability to attain this singular stable equilibrium state. In the later part of the 1990s, the notion of resilience became closely intertwined with the principles of the 'new ecology[8].' This paradigm recognised ecosystem dynamics as a system characterised by multiple equilibria. Subsequently, extensive studies and research endeavours were undertaken to comprehend the interactive dynamics existing between social and ecological systems. Drawing inspiration from the theories highlighting the co-evolutionary relationship between humans and biophysical elements, the concept of a 'social-ecological system' (SES) emerged.

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[4]Adger, W. & Agrawala, Shardul & Mirza, M.M.Q. & Conde, Cecilia & O'Brien, Karen & Pulhin, Juan & Pulwarty, R. & Smit, B. & Takahashi, Kiyoshi. (2007). *Assessment of adaptation practices, options, constraints and capacity. Climate change 2007: impacts, adaptation and vulnerability.* Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. 717-743.

[5]Soja, E.W. (2009). Regional Planning and Development Theories. *International Encyclopedia of Human Geography.* 259-270. 10.1016/B978-008044910-4.00877-47

[6]Cutter, S. L. (2003). The vulnerability of science and the science of vulnerability. *Annals of the Association of American Geographers,* 93(1):1-12.

[7]Clements, F. (1936). Nature and Structure of the Climax. *The Journal of Ecology,* 24(1), 252. doi: 10.2307/2256278

[8]Botkin, D. (1990). Discordant harmonies: a new ecology for the twenty-first century. *Choice Reviews Online,* 28(04), 28-2102-28-2102. doi: 10.5860/choice.28-2102

This innovative framework of evolutionary resilience assumed a crucial role in redirecting the emphasis from the quantitative availability of resources to the breadth of feasible response options[2]. SES is a forward-looking approach to human and environmental change. It focuses on how human actions, aspects of culture, social bonding, and indigenous knowledge play an important role within the system to achieve resilience. Hence, SES can help in analysing feedback and determining which forms of environmental governance is most appropriate for a location. Thus, this model can be critical for future-proofing the planning of cities in eco-sensitive zones.

PLANNING PROCESS IN INDIA

Post-independence, in 1950, the Planning Commission was established by the Government of India to develop Five Year Plans that guide development at state and local district levels. As per the Indian Constitution, urban improvement is a state subject[9]. The local government does not have the power to pass enactments on urban projects. While the National Planning Commission laid out detailed guidelines for development, funds were allocated state-wise to implement projects without the possibility for local governments to propose approaches that were more aligned with the local context. With the 74th Amendment bill in 1992, there was a shift in the planning process. Governing bodies were formed at town and city levels to carry out development[9]. Though the decisions were still made at the Centre, the implementation process was made simpler with smaller governing bodies working at local scales, such as municipalities and gram panchayats, a basic governing institution acting as the cabinet in Indian villages.

With the changing economic patterns and development of neo-liberal policies, a new planning commission called the Niti Aayog, was established in January 2015. The power is now attributed to state-governing bodies to develop plans to achieve sustainable development. The local bodies and, most importantly, the stakeholders, the people, are still excluded from the planning process. With the new development strategies, there are steps in the planning process where public meetings are conducted and public opinions are heard to achieve the actual demands of people. Unfortunately, these meetings are often held with limited stakeholders. Amongst the most vulnerable segments of the population, there exists a notable lack of awareness regarding these gatherings, effectively alienating them from the participatory process.

The climate change adaptation policy for India is being developed with eight sub-missions that are yet to be integrated into the overall national planning framework. The missions aim to focus on the reduction of GHG (greenhouse gases) emissions and energy conservation, among others. These missions often have spatial implications at local scales and need integration with urban development missions. Moreover, policies lack the cooperation of decentralised governance and local planning processes.

There is an absence in the framework and mechanisms that facilitate a mix of top-down and bottom-up approaches by including community-based adaptation[10]. Further, the top-down engineered approach with visible quick-fix solutions such as pollution reduction, green energy use, and climate control in diverse communities and that have their own cultural and religious understandings has not delivered positive outcomes[11]. Spatial planning has become a bureaucratic process, leading to a single-minded approach to land-use regulations to deal with a multi-actor and multi-scaling network of society[12].

[9]*Landmarks and Development of the Town Planning Process in India*, 2019

[10]Mehta, L., Srivastava, S., Adam, H., Alankar, Bose, S., Ghosh, U., & Kumar, V. (2019). Climate change and uncertainty from 'above' and 'below': perspectives from India. *Regional Environmental Change,* 19(6), 1533-1547. doi: 10.1007/s10113-019-01479-7

[11]Das, P. and Tamminga, K. (2012). *The Ganges and the GAP: An Assessment of Efforts to Clean a Sacred River. Sustainability*, 4(8), pp.1647-1668.

[12]Boelens, L. (2010). Theorizing Practice and Practising Theory: Outlines for an Actor-Relational-Approach in Planning. *Planning Theory,* 9(1), 28-62. Doi: 10.1177/1473095209346499

ACTOR-RELATIONAL APPROACH IN PLANNING

For the successful execution of planning processes, there is a need for a strong institutional framework for national, provincial, and local planning bodies. Unfortunately, in recent times, the planning system has started experiencing failure in promoting the human-environment perspective in planning. This is because the current and past planning frameworks have always been developed from within the bureaucratic system or from a ruling government perspective.

With the evolution of Actor-Network Theory (ANT) in planning, this single-minded approach can be changed. ANT is based on the idea that the world is made up of multiple, heterogeneous networks of actors. Considering the theory of ANT in planning, governance, and spatial planning, it can become a more collaborative process with informal partnerships between public, private, and civic actors[12]. The process allows several actors to come to a common table and discuss the aspirations and challenges of the system.

With an established actor network system, the connections between actions and their responsibilities and outcomes for individual actors can be well understood. The planning process under such a framework is likely to become a long process involving bilateral talks and roundtable discussions, yet it seems to be able to achieve a fruitful outcome for most stakeholders. For a robust outcome, it is important to understand the role of social capital in the collective actions of the planning process. Networking social capital linkages with a "well-functioning" state can help achieve co-management of resources[13]. Along with strong networks within social capital, this can help communities cope with the stress brought about by climate change.

ADAPTIVE PLANNING DESIGN STRATEGIES ACROSS THE SCALE

Adaptive planning policies are necessary to mitigate the threats from climate change impacts. They can help increase society's capacity to adapt to both anticipated and unanticipated risks. Important adaptive policy (re)design and implementation tools include decentralised decision-making, multi-stakeholder engagement and integration of different governments and private institutions, and the continuous learning process for city planning. The effects of anthropogenic interventions at one location are noticed at different locations and scales within the system. Beginning at the regional scale, development strategies derived could be aimed at addressing the challenges witnessed across the basin. These strategies could form a strong framework for interventions at different scales, focusing on holistic development and a vision for the basin. The process of adaptive planning could also help in transferring the rights of the river Ganga to the local communities, making resource distribution just[14].

While most strategies will be applicable directly at local scales, some might require negotiations and exceptions based on local culture, practices, and context. For this purpose, a set of metropolitan-scale strategies can be developed. These strategies are location-specific. They are formulated under the overall vision and framework of regional strategies for socio-ecological resilience. The involvement of local actors and participants becomes more prominent and necessary for strategy development and execution at this scale. Furthermore, local adaptation tests establish how the combination of different climate

[13]Adger, W., Huq, S., Brown, K., Conway, D., & Hulme, M. (2003). Adaptation to climate change in the developing world. *Progress In Development Studies,* 3(3), 179-195. Doi: 10.1191/1464993403ps060oa
[14]Davoudi, S. (2018). Just Resilience. *City & Community,* 17(1), 3–7. https://doi.org/10.1111/cico.12281

adaptation strategies at regional scales works to achieve adaptation to climate change at the local scale. A detailed framework of dynamic adaptive pathways can be prepared based on the strategies derived from different challenges at different scales.

DYNAMIC ADAPTIVE PATHWAYS

Interventions within ecosystems, particularly those concerning water management, are intrinsically linked to long-term perspectives and have enduring consequences. These demand meticulous planning, as the decisions made today must grapple with the uncertainties of the future, necessitating a high degree of adaptability and foresight.

The dynamic nature of complex systems introduces a critical dimension characterised by pivotal junctures commonly referred to as tipping points. These junctures are frequently associated with factors such as heightened climate-related risks or the onset of crises, where the efficacy of existing actions may become obsolete. Consequently, such junctures necessitate the implementation of supplementary actions. It is at these tipping points that the potential for the emergence of new adaptive pathways becomes apparent, often entailing a transformation in stakeholder involvement and corresponding actions.

The dynamic adaptive pathways framework offers a unique opportunity for the systematic exploration of potential courses of action through the sequential arrangement of feasible strategies. This approach also takes into account the diverse range of external factors and their evolution over time[15]. This makes the formulation of a long-term strategic vision for the future, coupled with a resolute commitment to immediate, short-term actions crucial to sustainable spatial planning.

[15]Haasnoot, M. & Kwakkel, Jan & Walker, Warren & Maat, Judith. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*. 23. 10.1016/j.gloenvcha.2012.12.006

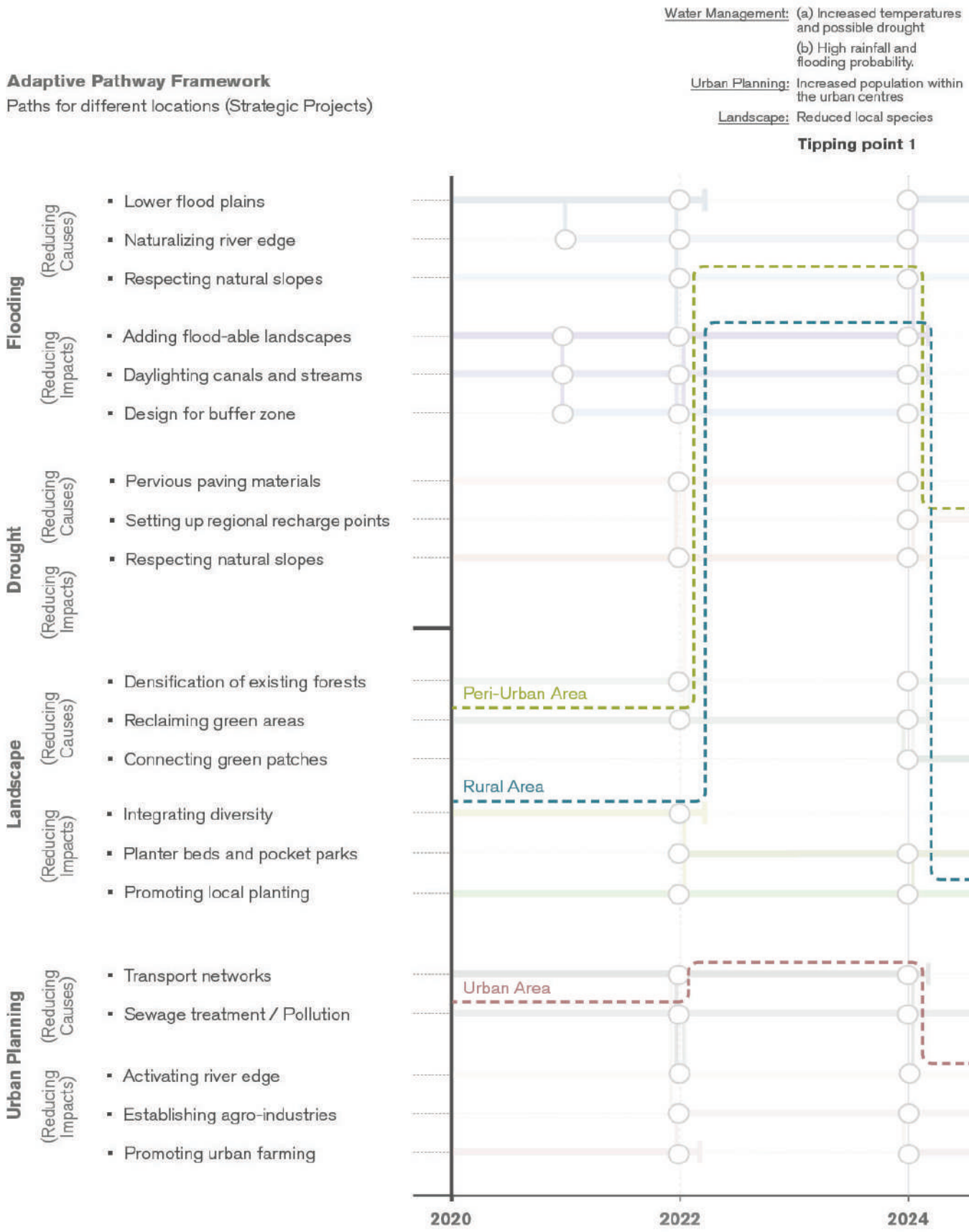
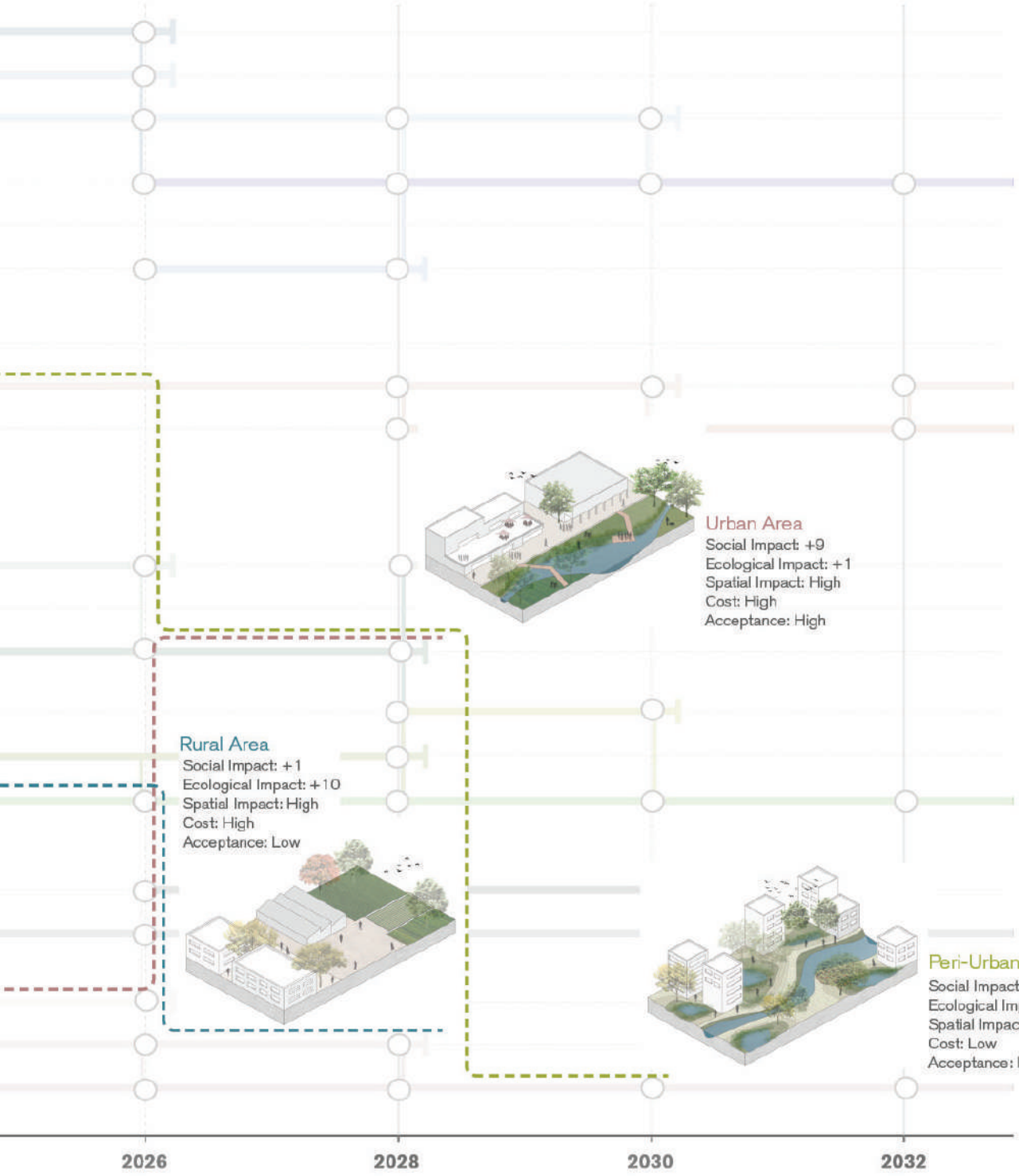


Figure 1. Adaptive pathways for strategic project selection. Multiple dynamic adaptive pathways can be developed within a single framework for different context locations, namely urban, peri-urban, and rural areas within the Ganga River basin, to achieve holistic development within the larger ecosystem.

Water Management: (a) Higher temperature and droughts
(b) Increased flooding frequency
Urban Planning: Land crisis within urban centres
Landscape: Loss of local species

Tipping point 2



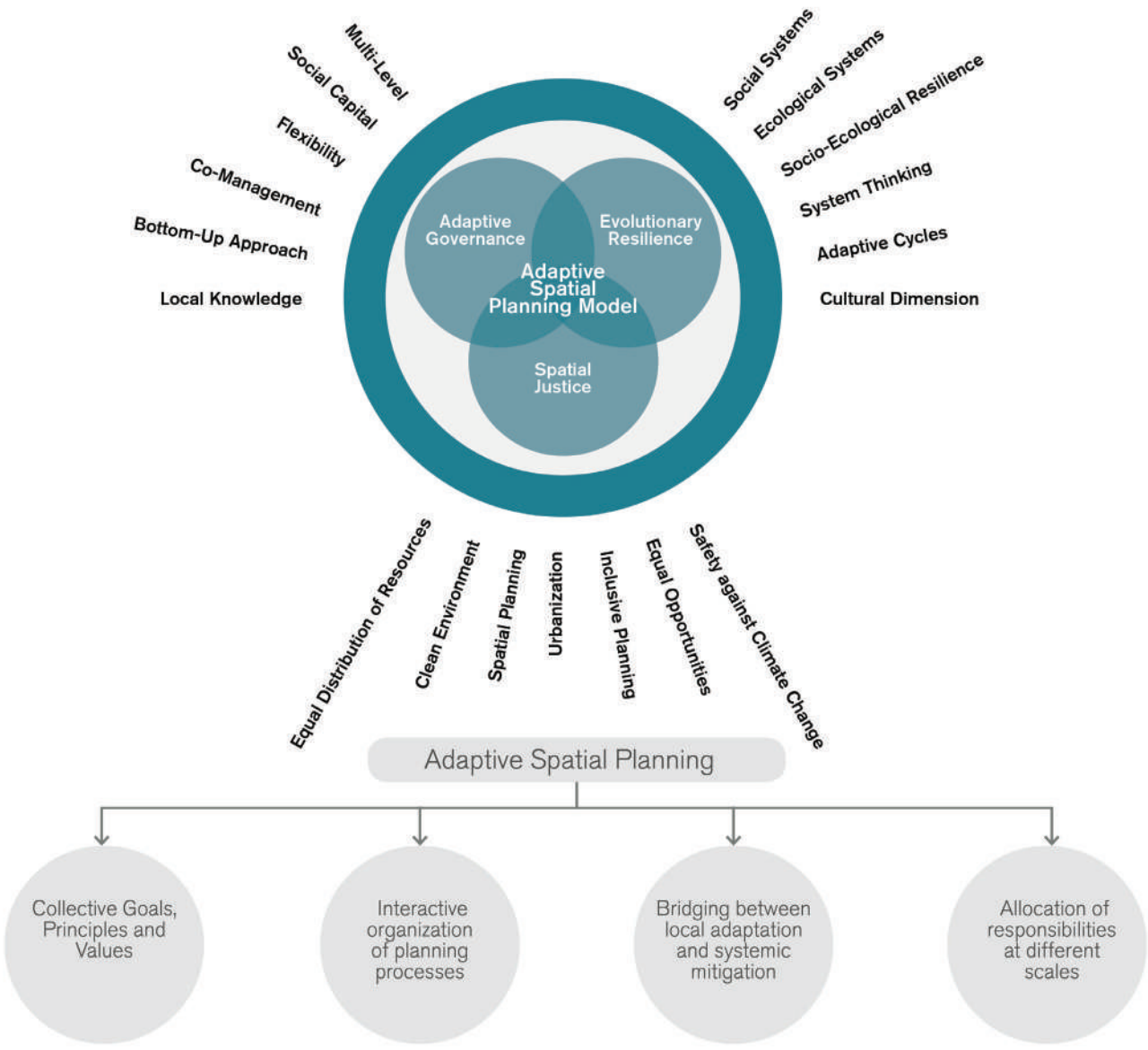


Figure 2. Adaptive Spatial Planning Model

CONCLUSION

The adaptability of society plays a crucial role in determining its resilience. To enhance our capacity to navigate the challenges posed by climate change and its repercussions, it becomes vital to contextualise national policies at the local level, giving due regard to regional conditions and cultural ethos. Establishing effective feedback mechanisms for the refinement of national policies further fortify our preparedness. This can enable local designs to evolve into invaluable instruments for exploration, strategy validation, and policy enhancement.

While the approach of adaptive spatial planning and integration looks theoretically feasible and beneficial, achieving it requires more data and site-specific analysis to modify institutional characteristics and achieve optimum benefits. Hence, the adaptive spatial planning model represents an approach to planning that warrants in-depth exploration and implementation in the context of climate change adaptation. This iterative process stands poised to drive forward future policies and enhance project efficacy.

KEY RESEARCH OUTCOMES

The seamless incorporation of local, self-organised entities into our adaptive planning framework can serve as the vital bridge connecting national-level policy formulation within formal institutions to the execution of strategies and design interventions at the grassroots level.

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