Neurourbanism and Neuroarchitecture
How can Cognitive Sciences Inform Design?

Efrosini Charalambous[1]

Abstract: Research on the relationship between the built environment and human perception, behaviour and experience is by no means new to the fields of architectural and urban studies. Relevant traditional methods used to address these issues include post-occupancy surveys, ethnographic and phenomenological approaches as well as observations of behaviours and movements in spatial settings (e.g. space syntax). However, a fresh perspective into the embodied experience of the built environment has come to complement these attempts. Neuroacrhitecture and neurourbanism are two emerging research fields that take advantage of advancements in neuroscientific knowledge, and cutting-edge technology to gain a deeper understanding of the brain-body-environment relationship. These fields are rapidly gaining traction, and the translation of research findings into evidence-based design parameters is vital for creating spaces that fit our situated emotional and cognitive needs. The paper adopts a theoretical stance inviting the reader to re-imagine how neuroscientific knowledge on the brain-body-environment interaction can be generated and translated in formats that can inform architectural and urban design. The paper offers a brief review of the neural turn in architectural and urban studies, followed by a detailed discussion of the main challenges (and potential remedies) related to the translation of such biological evidence into design research and practice. The paper aims to draw attention to the potential valuable contribution of neuroarchitecture and neurourbanism to evidence-based design practices and the development of urban policies that can positively shape our everyday experience.
Keywords: Neuroarchitecture, Neurourbanism, Evidence-based Design, Neurophenomenology, Environment-behaviour.

1. Background

Since the "design methods movement" in the 60s, design practitioners have started exploring ways to intertwine scientific and research-based knowledge with design practice. Around the same period, the growing dissatisfaction with the lack of knowledge regarding human-environment interaction gave birth to the field of 'Environment-Behaviour' (E-B) studies. According to Amos Rapoport (2008), one of the founders of the field, it began as an attempt to advance relevant scientific knowledge essential for improving the design of the built environment through criteria-based evaluations of outcomes and to develop a body of knowledge for evidence-based design. Starting with Ulrich's (1984) pioneering work, revealing that having a window with a view to nature is beneficial for surgery patients' health, evidence-based practices in healthcare design often focus on how improvements in health are linked to environmental features, such as patient recovery in relation to building layout

1. University of Cyprus, Frederick University.

DOI: 10.36158/979125669182116

(Hamilton, 2003, 2017; Ulrich *et al.*, 2008). In general, the aim is to fit the particular needs of different users through design, and potentially improve cognitive performances such as learning and memory, productivity and teamwork, or even the quality of life.

Theoretical and empirical work from the field of neuroscience has great potential to expand the E-B field and its objectives. Zeisel (2006: 356) considers the possible contributions of such a neuroscientific lens and recommends that "[i]f a new paradigm is to further the discipline of environment-behaviour studies, it must shed new light on old concepts and introduce new concepts, methods, theories and models". Introducing neuroscientific insights into the design process allows us to move beyond post-occupancy evaluations, shedding light on non-conscious perceptual and affective dimensions of our architectural and urban experience. Even if traditional tools can capture important behavioural patterns, we may now start exploring why an observed behaviour might be occurring (Farling, 2015). This can lead to diverse and innovative ways of implementing new insights on environmental behaviour in evidence-based design: integrating aspects of human and non-human behaviour (Atelier Bow-Wow), quantifying patterns of movement and co-presence (Spacelab), emphasising on the relational agent-environment field of action (RAAAF). This fresh outlook into the embodied and psychological realms of the built environment is also facilitated by the latest technological developments (e.g. biosensors), complementing the traditional methods used in the E-B field (e.g. surveys, interviews, observations, analysis of archival plans). The integration of neuroscience into E-B studies opens up new possibilities for developing data-driven approaches to human experience and behaviour.

Besides neuroscience, knowledge linked to network theory and social physics, guiding most space syntax work (Hillier, 1996, 2005), is also relevant to E-B studies, extending further the traditional disciplinary boundaries of the field (Rapoport, 2008). Evidence-based design approaches in space syntax have focused, for example, on the relationship between spatial configuration and human behaviour in the context of workplace design (Sailer *et al.*, 2008), hospital ward design (Pachilova & Sailer, 2020) as well as in urban design and pedestrian flows (Karimi, 2012). Although space syntax is positivist conceptually, its definition of space is phenomenological according to David Seamon (1994, 2007). It is studied in terms of how it appears to humans in terms of everyday experiences, behaviours and events (Hillier, 2005).

Such phenomenological traditions in architectural and urban studies may complement current efforts for neurophenomenological approaches to cognition. This offers a great opportunity for developing overlapping research agendas, leading to more phenomenologically-driven approaches and experimental setups (e.g. Charalambous *et al.*, 2021; Charalambous & Djebbara, 2023) and, perhaps, to evidence that is more relevant to architecture and urban discourses. Nevertheless, the interdisciplinary dialogue between architectural and urban design, on the one hand, and cognitive sciences, on the other, is not trivial. Neither is the 'marriage' of scientific research and design practice. To understand how cognitive science can inform design the paper discusses two main challenges i.e. the disciplinary knowledge gap and the research-practice gap. The paper sketches out briefly the state and tendencies of current research on neuroarchitecture and neurourbanism. Then it explores in detail the demands related to a) the inherently interdisciplinary nature that requires reciprocal engagement and flexible, creative thinking and b) the translation of biological, physiological and experiential evidence into design practice. The paper discusses potential remedies to overcome such obstacles in an attempt to find pathways for advancing the contribution of neuroarchitecture and neurourbanism in evidence-based design, urban planning and policies that can positively shape our everyday experience.

2. The Neural Turn in Architectural and Urban Studies

The neural turn in E-B studies led to the emergence of research agendas that focus on gathering empirical neuroscientific data and on evaluating intuitive understandings of architects regarding the brain-body-environment interaction (Eberhard, 2007, 2009; Mallgrave, 2011). Recent reviews illustrate well how relevant neuroscientific findings can advance the knowledge regarding the cognitive, emotional and experiential dimensions of the built environment (Bower *et al.*, 2019; Higuera-Trujillo *et al.*, 2021; Karakas & Yildiz, 2020; Rad *et al.*, 2021). Phenomenological accounts have gained momentum with the neural turn (Holl *et al.*, 2006) leading to the exploration of concepts such as mood and atmospheres (Canepa *et al.*, 2019; Griffero, 2016) multisensory integration (Pallasmaa, 2012; Spence, 2020) and attunement (Perez-Gomez, 2016). Furthermore, exploring concepts related to relevant theoretical frameworks such as affordances (Djebbara, 2022; Jelić, 2022; Rietveld & Kiverstein, 2014) contributes to understanding dimensions of architecture that go beyond its visual form. A large body of research in the field demonstrates how architectural and environmental features influencing perception, emotion, cognition and behaviour can have an impact, for example, on way-finding and orientation (Ghamari & Sharifi, 2021), on stress reduction in healthcare environments (e.g. Higuera-Trujillo *et al.*, 2020), on students' cognitive performance (e.g. AL-Ayash *et al.*, 2016) or the everyday experience of special populations such as those living with dementia (Barrett *et al.*, 2019; e.g. Zuanon & Cardoso de Faria, 2018). Such neuroarchitectural explorations offer the possibility to become sufficiently knowledgeable of brain-body-environment interactions, as well as of the diversity of behavioural patterns and needs among different populations.

Similarly, the emergence of neurourbanism (and neurogeography) responds to the increasing need to better understand the interdependencies between urbanisation and mental wellbeing (Adli *et al.*, 2017; Ancora *et al.*, 2022; Buttazzoni *et al.*, 2021; Fett *et al.*, 2019; Reichert *et al.*, 2020). Urban living and urban upbringing are considered risk factors for poor mental health (Lederbogen *et al.*, 2011; Peen *et al.*, 2010). Factors such as living in a harsh and unpredictable environment, social isolation and commuting stress (Pykett *et al.*, 2020) are associated with a higher risk for chronic social stress, which in combination with other social, psychological and genetic factors can have a severe negative impact on mental health. Crowding, noise, pollution and fragmented social networks also contribute to such outcomes (Mavros, J Wälti, *et al.*, 2022; Tost *et al.*, 2015). On the other hand exposure to nature, urban green space, and biodiversity in contrast to urban density, appear to be a key resilience factor for mental health – inducing relaxation restoration, stress reduction and resilience (Lin *et al.*, 2020; e.g. Olszewska-Guizzo *et al.*, 2020; Tost *et al.*, 2019). Furthermore, being able to navigate and orient oneself easily in a city is another key factor affecting urban life (Jeffery, 2019). Neurourbanism can complement ongoing social research on urban stressors and determinants of urban wellbeing. The integration of biological and social perspectives (Pykett *et al.*, 2020) on urban emotions can provide rich evidence for policy-making and the design of healthier city environments for individuals and communities.

3. The Knowledge Gap and Interdisciplinary Reciprocity

Integrating the distinct modes of disciplinary thought associated with cognitive science, on the one hand, and architectural and urban design, on the other, essentially involves the juxtaposition of two very different forms of knowledge. That is factual and tacit knowledge (the form of knowledge gained through experience and reflection). Arguably, this suggests a number of challenges for design researchers of neuroarchitecture and neurourbanism: a) the 'translation', integration and transferability of accumulated information; b) balancing the tension between scientific claims of universality and the particularities of different 'contexts' shaping situated cognition; and c) establishing effective interdisciplinary reciprocity and reflexivity.

3.1. *Mapping the Evidence*

Empirical studies on the brain-body-environment relationship coming from different disciplines are often heterogeneous and produce highly specialised knowledge with no obvious linkages or 'bridges' between the existing literature (Rapoport, 2008). Connecting the scattered findings remains a difficult task since what is required is relevant 'maps' illustrating how the linkages between these 'islands' are conceptually structured or which areas need further development. An essential component for advancing evidence-based design thinking in neuroarchitecture and neurourbanism is mapping the evidence e.g. meta-analysis reports (Higuera-Trujillo *et al.*, 2021; e.g. Karakas & Yildiz, 2020; Reichert *et al.*, 2020). Innovative interdisciplinary thinking can be also impeded by difficulties in intellectual communication (e.g. conceptual terms used, disciplinary jargon, multiplicity of writing styles and publication journals). Translating scientific findings into terms that are more closely linked to architectural discourse can facilitate transcending disciplinary boundaries and even lead to new design hypotheses (Edelstein, 2008).

However, without a theoretical framework or a critical attitude this may result in over-generalisation, oversimplification, misinterpretation or in literal, prescriptive, universal guidelines that lack contextualisation to the particularities of each design problem (Hamilton, 2003). In other words, it is essential to synthesise the fragmented findings into conceptual frameworks or explanatory theories at a higher level of abstraction, which can facilitate the navigation, transferability and communication of the different findings (Rapoport, 2008). Otherwise, their meaning might not always be clear. Two significant theoretical approaches currently predominant in neuroarchitectural inquiries have great potential in facilitating a genuine interdisciplinary dialogue since they highlight the link between the environment (the physical and the socio-cultural) and cognition (Jelić *et al.*, 2016; Rietveld & Brouwers, 2017; Wang *et al.*, 2022). Enactive-embodied perspectives (the 4EA model) emphasise the embodied, enactive, extended, embedded and affective nature of cognition and perceptual experience (Rowlands, 2010; Varela *et al.*, 1992) and focus on the role of recurrent sensorimotor patterns of perception-action cycles that are shaped and shape our engagement with the built environment. Ecological psychologists (Gibson, 1966; Heft, 2001) argue that it is through direct perception that we can pick up relevant environmental information in the ambient energy arrays (e.g. detecting affordances). These rich accounts of agent-environment dynamics and co-determination highlight the importance of the specific situation, context and environment of the agent.

3.2. *Contextualisation vs. Universality*

Research findings regarding human experience require a great degree of reflection before they can form a credible evidence-based terrain. It is often debatable to what degree and under what conditions empirical results (and their interpretation) on how we perceive, experience and behave in architectural and urban settings can be generalised as universal laws applicable to other situations, populations and cultures. Narrow forms of evidence may be naively considered adequate for providing prescriptive universal neuro-design guidelines. However, we cannot assume that architecture is simply and solely driven by material or hedonistic factors because human beings are inherently bio-culturally complex (Mallgrave, 2015; Ritchie, 2020).

As Pykett (2015) argues, such assumptions may only offer a 'blinkered view' of the specific phenomenon with little consideration of the 'context' and its influence. Even if the context is formally acknowledged, the conceptualisation of what a 'context' is can be vague, narrow or can vary substantially. Especially regarding urban experiences and city life, reducing the concept of context to immediate surroundings can be quite problematic. To be able to inform urban interventions with neuro-evidence we need to be able to consider the dynamics between the intra-personal (e.g. individual brain dynamics) and intersubjective scales e.g. how social production of space shapes human subjectivity. Understanding the brain *in situ* requires more expansive ways of understanding the quality of urban experience and what drives behaviour, decisions and shapes subjectivities (Pykett, 2015)[2]. This suggests a need for neurourbanism and neuroarchitecture that move beyond the reductionistic tendencies, driven instead by phenomenological insights about embodied, enactive, and situated cognition. As Gallagher (2011: 86) claims "A phenomenologically-informed neuroscience can also be a critical neuroscience". Studies in cognitive neuroscience exploring, for example, questions of social cognition, agency and intention formation, phenomena not reducible to physio-biological processes, may reveal aspects of human relations that involve "larger pragmatic and social interactions in the lifeworld". Reflecting on the research methods, findings and contextual particularities of urban life expands the potential of integrating neuron-based knowledge in evidence-based practices for urban policy.

3.3. *Designerly Modes of (Neuro)scientific Inquiry*

The problem of 'disciplinary imperialism' may be another factor impeding the attempt to transcend disciplinary boundaries. This is not a rare phenomenon in academia, especially when the involved disciplines attract funding at different rates. This can result in one-sided research agendas, often led mainly by cognitive scientists. Consequently, designers are not the driving forces of such agendas and "[t]hey are thus not usually seen by governments and sophisticated clients as at the forefront of the field. These problems could be seen to exist at what we might call the policy level" (Lawson, 2013: 34). The prevalence of scientific rigour over the seemingly 'messy' designerly ways of knowing might easily give a mistaken impression that architectural and urban thinking is subservient to (neuro)scientific approaches. However, designers have learned different ways to deal with the ambiguous multifaceted factors and complex interdependencies of "wicked problems" (Rittel & Webber, 1973), which are not amenable to conventional approaches such as linear, incremental problem-solving. Designers tend to "reflectively redesign their design process" to fit the particularities of the situation they come across each time (Sweeting, 2017). Through this process, a single solution or idea can suddenly solve several problems at once. Consequently, a new interdisciplinary research framework needs to be established in order to embrace a greater degree of reflexivity and a more designerly mode of doing (neuro) science, embracing the values inherent in the designerly ways of knowing (Cross, 1982). Glanville (1999, 2014) argues that research is not a set of procedures and rules, but a way of acting; it is essentially a "design act". It is a self-reflective activity. It is about researching research and redesigning designs.

These views support a groundbreaking avenue of applying design research in the science field, rather than vice versa (Sweeting, 2017). During design thinking, designers are often actively engaged in self-reflectivity regarding the embodied experience of future imaginary architectural scenes and urban landscapes (Mallgrave, 2011). Expertise in such a skilful reflec-

2. As Pykett (2015) comments "If the materialism of our urban experience is to be understood geographically and historically, there is a need to address the specificity of that urban experience in terms of the political, economic, social and cultural driving forces that influence our behaviours, shape our subjectivities and direct our attentions in particular ways within particular spaces".

tive practice along with the phenomenological tradition in architectural and urban studies offers a wealth of knowledge that can significantly contribute to renewed attempts to incorporate first-person accounts into empirical neuroscience (Gallagher, 2004). Neurophenomenology, as proposed by Valera (1996), is a disciplined approach to the subjective experience as part of scientific inquiries and appears to be a very promising ground for ecological research inquiries on the experience of the built environment (Jelić, 2015). Restructuring the path(s) of the interdisciplinary dialogue between cognitive sciences and architectural and urban studies can lead towards a more transformative and creative design of neuroscientific research; an ecological and phenomenologically-driven, experimental science of neuroarchitecture.

4. Bridging the Research-Practice Gap

Being familiar with the state-of-the-art of existing literature is essential to use the available evidence in the design process. However, design practitioners often have limited access to academic research and often lack the necessary sophisticated skills to search and critically evaluate the literature[3] (Lawson, 2013). The skills and habits of design practitioners can certainly be enriched through a relevant reform of the existing curriculum of architectural education. However, integrating evidence-based thinking into design practices requires not only reflecting on the role of design practitioners but also on the design process. Cognitively-relevant design heuristics (Emo, 2019) can be used as tools giving the designers more immediately accessible knowledge during the design process, facilitating in turn the emergence of hybrid practices combining tacit knowledge with academic knowledge.

4.1. *Cognitively-Relevant Design Heuristics*

Finding adequate ways to represent the knowledge derived from academic research can greatly facilitate its successful integration in the design process. Different methodological and analytical tools that capture aspects or phenomena related to cognition and perceptual experience can be employed as design heuristics. Design heuristics can be used iteratively as tools that facilitate design thinking (Gray *et al.*, 2016). Introducing knowledge from cognitive sciences in the form of perspective-taking, using narrative tools or storytelling formats, not only places the human perspective at the centre of the design process, but enhances at the same time designers' reflexivity and ability to immerse themselves in the life of future inhabitants, but also facilitates discussions and familiarity with relevant scientific knowledge[4].

A powerful tool for evaluating the strength of available scientific evidence in relation to the particularities of the design problem is a simulation model. Agent-based modelling, for instance, is often used to simulate complex situations and study emergent phenomena. By assigning different cognitively-relevant attributes (e.g. internal states, rules of behaviour) to individual agents we can observe and evaluate aggregated results such as occupant behaviour in certain buildings, or differences in cognitive agents' wayfinding performance associated with different architectural scenarios e.g. various 3D multilevel configurations (Gath-Morad *et al.*, 2020).

Furthermore, spatial analysis tools such as space syntax and isovist analysis have been often used to interlink neuroscience, cognition and environmental psychology with config-

3. A survey of evidence-based practice in architecture and urban planning found that although 80% of responders acknowledge the need for evidence in the design process 68% reported that they never or very rarely reviewed literature (EBD Journal, 2014).

4. According to recent study the use of spatial cognition and architectural strategies cards during design thinking processes improved user-centred perspectives and facilitated the introduction and communication of scientific concepts (Mavros, Conroy Dalton *et al.*, 2022).

urational and visibility features of spatial layouts. Space syntax appears to capture successfully in the same formal model both the physical structure and human behaviour such as movement flows in urban spaces across different cities and cultures (Hillier, 1996). This is most likely due to the types of analyses used, able to pick up on components that are naturally processed during cognition (Hillier, 2012; Penn, 2003). The capacity of these modelling techniques to quantitatively capture properties linked to cognition has been demonstrated in empirical studies focusing on spatial behaviour and experience (Dalton *et al.*, 2012; Emo, 2014; Hölscher *et al.*, 2006; Wiener *et al.*, 2007) as well as brain dynamics (Sakellaridi *et al.*, 2015; Charalambous *et al.*, 2021; Javadi *et al.*, 2017) and has been also explored theoretically (Marcus *et al.*, 2016; Marcus, 2018). Linking behavioural and neural data to quantitative descriptions of spatial properties can perhaps facilitate more immediate access to neuro-based knowledge for design practice.

4.2. *Designerly Modes of Doing Science in Architectural Education*

One way to equip future design practitioners with the set of knowledge and skills to critically read the relevant literature is to reform the curriculum of architectural education (Tvedebrink & Jelić, 2021). This can be done by introducing material that familiarises students with scientific approaches while giving room for them to imagine more designerly modes of doing science[5]. However, currently, there is little emphasis on evidence-based practices as well as on approaches that involve the collection and analyses of data (both qualitative and quantitative) on human behaviour, perception and experience. Becoming familiar with evidence-based design practices can enhance students' skills to acquire, assess and apply research-based knowledge. Pallasmaa (2012) further observes that there has been a disregard for architecture as embodied experience[6] due to the dominance of vision over other senses. He highlights the need to re-emphasise the nature of the experience of architecture as a "multi-sensory sensing of atmospheres, feelings, and moods" (Pallasmaa, 2013: 13). Introducing (neuro) phenomenological design inquiries into architectural education may be a fruitful way of sharing scientific insights and shaping students' design thinking process. Increasing their awareness of the embodied, multimodal and affective dimensions of architectural experience and elevating their sensibility towards user needs and experiences can lead to more inclusive human-centred approaches that embrace a diversity of bodies and user experiences (Chrysikou, 2018). As a result, this can strengthen the students' sense of the multifaceted responsibility regarding not only environmental but social sustainability, which might soon be a crucial part of building assessment (Stender & Walter, 2019).

4.3. *Hybrid Practices*

The practice of architecture and urban design is undoubtedly a multifaceted form of engagement, often intersecting with the world of academia through the use of theoretical frameworks, historical accounts and research findings as well as through teaching and publishing. Recently, the notion of the 'hybrid practitioner'[7] has been proposed to capture this mul-

5. There are several cases of such advanced curriculums in architectural education starting in 2017 with the "Certificate in Neuroscience for Architecture" from the New School of Architecture in San Diego and the "Master of Science Neuroscience Applied to the Architectural Design" by the University of Architecture Iuav in Venice, the "Architecture, Health, and Well-being" at the Department of Architecture, Design, and Media Technology, Aalborg University, Denmark and the "Evidence-based design. Methods and Tools for Evaluating Architectural Design" at ETH.

6. In Pallasmaa's words, "an architectural work is not experienced as a collection of isolated visual pictures, but in its fully embodied, material and spiritual presence" (Pallasmaa, 2012: 44).

7. The threefold role of the hybrid practitioner involves: a) an operative attitude when using academic expertise to inform, develop and innovate practices b) an embodied understanding of the practice of design and empirical understanding of how things are made in their specific spatial and geographical context, which can be used to inform academic research;

tidimensional figure that "simultaneously practices architecture, carries out research, and educates the next generation" (Schreurs *et al.*, 2022: 24). Hybrid practitioners may enrich and even challenge academic epistemology "thanks to their accurate instinct for contemporaneity and their independent and entrepreneurial attitude" (Schreurs *et al.*, 2022: 23).

There are some interesting examples of hybrid practices, influenced in different ways by theories and knowledge from cognitive sciences that explore in diverse ways how individuals' behaviour and movement are shaped in relation to the built environment. For instance, the concept of "architectural behaviorology" forms the basis of an architectural design theory and methodology, guiding the majority of the work of the Tokyo-based atelier Bow-Wow (Tsukamoto & Kaijima, 2010). They design ecosystems of behaviour by synthesising aspects of human behaviour and experience (architectural ethnography) with the behaviour of environmental elements such as light, air etc. and the building's behaviour in its surroundings. Their design practice is about activating behaviours of human and non-human agents to create community livelihoods[8]. Another design practice influenced by cognitive sciences and ecological psychology is Rietveld Architecture-Art-Affordances (RAAAF). Their design projects and published work explore the idea of affordances as a relational field, as a set of possibilities for action for a certain individual that experientially "stands out" among the rest of the landscape of affordances (van Dijk & Rietveld, 2016). On the other hand, London-based practice Spacelab adopts a more quantitatively inclined approach to explore how actions are shaped and how they shape our sense of the environment embracing the idea of data-driven design. Combining data on human behaviour (observational studies), human experience (VR) and spatial configuration (space syntax) enables the practice to evaluate, for example, the performance of a spatial layout and how it integrates or segregates people and thus its potential to facilitate communication and collaboration in workplaces.

Concluding Remarks

Neuroscientific inquiries into the experience of the built environment (including its cognitive, perceptual and affective dimensions) can certainly provide a rich base of evidence for design thinking. Nevertheless, it is essential to acknowledge the many challenges involved. Neuro-based evidence on architectural and urban experiences involves aspects related to both the physical brain and subjective human experience. Incorporating such evidence in the design involves working within a 'third culture' of knowledge, the 'designerly ways of knowing'. Consequently, integrating neuro-based knowledge in design thinking requires transcending boundaries across fundamentally distinct areas of knowledge: a) a body of theoretical knowledge based upon observation, measurements and hypothesis testing focusing on the natural world with a primary concern for 'truth'; b) a body of interpretive knowledge based on criticism, evaluation and discourse focusing on human experience with a concern for 'justice'; and c) a body of practical knowledge based upon sensibility, invention and implementation with a primary concern for 'appropriateness' (Cross, 1982; Archer, 2005).

Implementing neuroscientific evidence in design research and practice requires a creative approach that explicitly acknowledges the complex interdependencies of the design process.

and c) communicating the design knowledge through teaching, lecturing, writing and publishing (Schreurs *et al.*, 2022: 24). Although the notion of the hybrid practitioner has been initially introduced to capture the conjunction of design practice with histories and theories derived from academic work, the term may also encompass the integration of explanatory theories and the interpretation of empirical findings.

8. "Behaviorology brings about an immediate shift in subjectivity, inviting many different elements together and calling into question who or what may be the main protagonist of a space. Through this ecological approach our imagination follows the principles of nature and experiences space from a variety of perspectives. When one is surrounded by and synchronized to the liveable rhythms embedded in different behaviors – there is no experience quite so delightful" (Tsukamoto & Kaijima, 2010: 15).

In contrast to evidence related to technical details, which can be easily implemented later in the design process, evidence regarding the impact of the designed built environment on cognition, perception and the formation of habitual patterns, has a much higher degree of complexity (Lawson, 2013). It cannot be simply implemented in the form of optimisation strategies or prescriptive guidelines because understanding the experiences and needs of the potential occupants lies at the generative core of the design. This form of evidence-based design thinking implies a change in the design process, where evidence informs decisions at different key moments throughout the workflow. In this way, scientific knowledge and objective criteria can be interwoven with reflective practice reinforcing the intuitive and creative processes underlying design dexterity.

A genuine reciprocal interdisciplinary dialogue can generate mutually inventive ways of moving towards the acquisition of new knowledge. Insights gained from phenomenological inquiries into the architectural experience can drive experimental design and the formation of situated embodied hypotheses. Furthermore, the re-conceptualisation of the triad brain-body-environment as a complex dynamic system calls for a reconsideration of the conventional scientific research agenda as well (Gallagher, 2017). Shifting the boundaries of disciplinary thought on cognition, from computational explanations to enactivist accounts, opens up new possibilities for more creative experimental setups that respond more directly to inquiries relevant to architectural design, urban planning and urban policy.

References

Adli, M., Berger, M., Brakemeier, E.-L., Engel, L., Fingerhut, J., Gomez-Carrillo, A., Hehl, R., Heinz, A., H, J.M., Mehran, N., Tolaas, S., Walter, H., Weiland, U., Stollmann, J. (2017), "Neurourbanism: towards a new discipline", *The Lancet. Psychiatry*, 4(3): 183-185.

AL-Ayash, A., Kane, R.T., Smith, D., Green-Armytage, P. (2016), "The influence of color on student emotion, heart rate, and performance in learning environments", *Color Research and Application*, 41(2): 196-205.

Ancora, L.A., Blanco-Mora, D.A., Alves, I., Bonifácio, A., Morgado, P., Miranda, B. (2022), "Cities and neuroscience research: A systematic literature review", *Frontiers in Psychiatry / Frontiers Research Foundation*, 13, 983352.

Barrett, P., Sharma, M., Zeisel, J. (2019), Optimal spaces for those living with dementia: principles and evidence. *Building Research and Information*, 47(6): 734-746.

Bower, I., Tucker, R., Enticott, P.G. (2019), "Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: A systematic review", *Journal of Environmental Psychology*, 66, 101344.

Buttazzoni, A., Parker, A., Minaker, L. (2021), "Investigating the mental health implications of urban environments with neuroscientific methods and mobile technologies: A systematic literature review", *Health & Place*, 70, 102597.

Canepa, E., Scelsi, V., Fassio, A., Avanzino, L., Lagravinese, G., Chiorri, C. (2019), "Atmospheres: Feeling architecture by emotions", *Ambiances*, 5, https://doi.org/10.4000/ambiances.2907.

Charalambous, E., Djebbara, Z. (2023), "On Natural Attunement: Shared Rhythms Between the Brain and the Environment", *Neuroscience and Biobehavioral Reviews*, 105438.

Charalambous, E., Hanna, S., Penn, A. (2021), "Aha! I know where I am: the contribution of visuospatial cues to reorientation in urban environments", *Spatial Cognition and Computation*, 21(3): 197-234.

Chrysikou, E. (2018), "Why we need new architectural and design paradigms to meet the needs of vulnerable people", *Palgrave Communications*, 4(1): 1-6.

Cross, N. (1982), "Designerly ways of knowing", *Design Studies*, 3(4): 221-227.

Dalton, R.C., Hölscher, C., Turner, A. (2012), "Understanding Space: The Nascent Synthesis of Cognition and the Syntax of Spatial Morphologies", *Environment and Planning. B, Planning & Design*, 39(1): 7-11.

Djebbara, Z. (2022), *Affordances in Everyday Life: A Multidisciplinary Collection of Essays*, Springer Nature.

Eberhard, J.P. (2007), *Architecture and the brain: A new knowledge base from neuroscience*, Greenway Communications/Östberg.

Eberhard, J.P. (2009), *Brain Landscape The Coexistence of Neuroscience and Architecture*, New York: Oxford University Press.

Edelstein, E.A. (2008), "Searching for Evidence", *HERD*, 1(4): 95-110.

Emo, B. (2014), "Seeing the axial line: evidence from wayfinding experiments", *Behavioral Sciences*, 4(3): 167-180.

Emo, B. (2019), "Why Evidence-Based Methods Are Useful for Architectural and Urban Design", in *Research Culture in Architecture*, Basel: Birkhäuser: 173-182.

Farling, M. (2015), "From intuition to immersion: architecture and neuroscience", in R.S. Pallasmaa J. (ed.), *Mind in Architecture: Neuroscience, Embodiment, and the Future of Design*, Cambridge, Mass.: The MIT Press.

Fett, A.-K.J., Lemmers-Jansen, I.L.J., Krabbendam, L. (2019), "Psychosis and urbanicity: a review of the recent literature from epidemiology to neurourbanism", *Current Opinion in Psychiatry*, 32(3): 232-241.

Gallagher, S. (2004), "Hermeneutics and the Cognitive Sciences", *Journal of Consciousness Studies*, 11(10-11): 162-174.

Gallagher, S. (2011), "Scanning the lifeworld: Toward a critical neuroscience of action and interaction", in Chowdery, S., Slaby, J. (eds.), *Critical Neuroscience: A Handbook of the Social and Cultural Contexts of Neuroscience*, Oxford: Blackwell: 85-110.

Gath-Morad, M., Aguilar, L., Dalton, R.C., Hölscher, C. (2020), *cogARCH: simulating wayfinding by architecture in multilevel buildings*, Proceedings of the 11th Annual Symposium on Simulation for Architecture and Urban Design, Article 8.

Ghamari, H., Sharifi, A. (2021), "Mapping the Evolutions and Trends of Literature on Wayfinding in Indoor Environments", *European Journal of Investigation in Health, Psychology and Education*, 11(2): 585-606.

Gibson, J.J. (1966), *The senses considered as perceptual systems*, https://psycnet.apa.org/fulltext/1966-35026-000.pdf.

Glanville, R. (1999), "Researching Design and Designing Research", *Design Issues*, 15(2): 80-91.

Glanville, R. (2014), "The sometimes uncomfortable marriages of design and research", in Rodgers, P.A., Yee, J., *The Routledge companion to design research*, London: Routledge: 9-22.

Gray, C.M., Seifert, C., Yilmaz, S., Daly, S., Gonzalez, R. (2016), "What is the Content of "Design Thinking"? Design Heuristics as Conceptual Repertoire", *International Journal of Engineering Education*, 32(3B): 1349-1355.

Griffero, T. (2016), *Atmospheres: Aesthetics of Emotional Spaces*, London: Routledge.

Hamilton, D.K. (2003), "The four levels of evidence-based practice", *Healthcare Design*, 3(4): 18-26.

Hamilton, D.K. (2017), "Evidence, Best Practice, and Intuition", *HERD*, 10(4): 87-90.

Heft, H. (2001), *Ecological Psychology in Context: James Gibson, Roger Barker, and the Legacy of William James's Radical Empiricism*, London: Routledge.

Higuera-Trujillo, J.L., Llinares, C., Macagno, E. (2021), "The Cognitive-Emotional Design and Study of Architectural Space: A Scoping Review of Neuroarchitecture and Its Precursor Approaches", *Sensors*, 21(6), https://doi.org/10.3390/s21062193.

Higuera-Trujillo, J.L., Llinares Millán, C., Montañana i Aviñó, A., Rojas, J.-C. (2020), Multisensory stress reduction: a neuro-architecture study of paediatric waiting rooms, *Building Research and Information*, 48(3): 269-285.

Hillier, B. (1996), *Space is the machine: a configurational theory of architecture*, Cambridge: Cambridge University Press.

Hillier, B. (2005), "Between Social Physics and Phenomenology: Explorations towards an urban synthesis?", in van Nes, A. (ed.), *5th International Space Syntax Symposium Proceedings*, TUDelft: 3-23.

Hillier, B. (2012), "Studying Cities to Learn about Minds: Some Possible Implications of Space Syntax for Spatial Cognition", *Environment and Planning. B, Planning & Design*, 39(1): 12-32.

Holl, S., Pallasmaa, J., Gómez, A.P. (2006), *Questions of Perception: Phenomenology of Architecture*, San Francisco: William Stout.

Hölscher, C., Meilinger, T., Vrachliotis, G., Brösamle, M., Knauff, M. (2006), "Up the down staircase: Wayfinding strategies in multi-level buildings", *Journal of Environmental Psychology*, 26(4): 284-299.

Jeffery, K. (2019), "Urban Architecture: A Cognitive Neuroscience Perspective", *The Design Journal*, 22(6): 853-872.

Jelić, A. (2015), "Designing 'pre-reflective' architecture: Implications of neurophenomenology for architectural design and thinking", *Ambiances*, *1*, https://doi.org/10.4000/ambiances.628.

Jelić, A. (2022), "What is architecture for? designing as enriching the landscape of affordances", *Adaptive Behavior*, 30(6): 585-587.

Jelić, A., Tieri, G., De Matteis, F., Babiloni, F., Vecchiato, G. (2016), "The Enactive Approach to Architectural Experience: A Neurophysiological Perspective on Embodiment, Motivation, and Affordances", *Frontiers in Psychology*, 7: 481.

Karakas, T., Yildiz, D. (2020), "Exploring the influence of the built environment on human experience through a neuroscience approach: A systematic review", *Frontiers of Architectural Research*, 9(1): 236-247.

Karimi, K. (2012), "Special issue: Evidence-informed and analytical methods in urban design", *Urban Design International*, 17(4), 253-256.

Lawson, B. (2013), "Design and the Evidence", *Procedia – Social and Behavioral Sciences*, 105: 30-37.

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., Wüst, S., Pruessner, J.C., Rietschel, M., Deuschle, M., Meyer-Lindenberg, A. (2011), "City living and urban upbringing affect neural social stress processing in humans", *Nature*, 474(7352): 498-501.

Lin, W., Chen, Q., Jiang, M., Tao, J., Liu, Z., Zhang, X., Wu, L., Xu, S., Kang, Y., Zeng, Q. (2020), "Sitting or Walking? Analyzing the Neural Emotional Indicators of Urban Green Space Behavior with Mobile EEG", *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 97(2): 191-203.

Mallgrave, H.F. (2011), *The Architect's Brain: Neuroscience, Creativity, and Architecture*, New York: John Wiley & Sons.

Mallgrave, H.F. (2015), "Embodiment and enculturation: the future of architectural design", *Frontiers in Psychology*, 6: 1398.

Marcus, L. (2018), "Overcoming the subject-object dichotomy in urban modeling: Axial maps as geometric representations of affordances in the built environment", *Frontiers in Psychology*, 9: 449.

Marcus, L., Giusti, M., Barthel, S. (2016), "Cognitive affordances in sustainable urbanism: contributions of space syntax and spatial cognition", *Journal of Urban Design*, 21(4): 439-452.

Mavros, P., Conroy Dalton, R., Kuliga, S., Gath Morad, M., Robson, S., Hölscher, C. (2022), "Architectural cognition cards: a card-based method for introducing spatial cognition research and user-centred thinking into the design process", *Architectural Science Review*, 65(2): 120-137.

Mavros, P., J Wälti, M., Nazemi, M., Ong, C.H., Hölscher, C. (2022), "A mobile EEG study on the psychophysiological effects of walking and crowding in indoor and outdoor urban environments", *Scientific Reports*, 12(1): 18476.

Olszewska-Guizzo, A., Sia, A., Fogel, A., Ho, R. (2020), "Can Exposure to Certain Urban Green Spaces Trigger Frontal Alpha Asymmetry in the Brain? – Preliminary Findings from a Passive Task EEG Study", *International Journal of Environmental Research and Public Health*, 17(2): 394.

Pachilova, R., Sailer, K. (2020), "Providing care quality by design: a new measure to assess hospital ward layouts", *Journal of Architecture*, 25(2): 186-202.

Pallasmaa, J. (2012), *The Eyes of the Skin: Architecture and the Senses*, New York: John Wiley & Sons.

Pallasmaa, J. (2013), "Towards a neuroscience of architecture", in Tidwell, P. (ed.), *Architecture and Neuroscience*, Tapio Wirkkala-Rut Bryk Foundation.

Peen, J., Schoevers, R.A., Beekman, A.T., Dekker, J. (2010), "The current status of urban-rural differences in psychiatric disorders", *Acta Psychiatrica Scandinavica*, 121(2): 84-93.

Penn, A. (2003), "Space Syntax And Spatial Cognition: Or Why the Axial Line?", *Environment and Behavior*, 35(1): 30-65.

Perez-Gomez, A. (2016), *Attunement: Architectural Meaning after the Crisis of Modern Science*, Cambridge, Mass: MIT Press.

Pykett, J. (2015), *Brain Culture: Shaping Policy Through Neuroscience*, Bristol: Policy Press.

Pykett, J., Osborne, T., Resch, B. (2020), "From Urban Stress to Neurourbanism: How Should We Research City Well-Being?", *Annals of the Association of American Geographers. Association of American Geographers*, 110(6): 1936-1951.

Rad, P.N., Behzadi, F., Yazdanfar, A., Ghamari, H., Zabeh, E., Lashgari, R. (2021), *Cognitive and perceptual influences of architectural and urban environments with an emphasis on the experimental procedures and techniques*, https://psyarxiv.com/d2h4m/download?format=pdf.

Rapoport, A. (2008), "Environment-behavior studies: Past, present, and future", *Journal of Architectural and Planning Research*, 25(4): 276-281.

Reichert, M., Braun, U., Lautenbach, S., Zipf, A., Ebner-Priemer, U., Tost, H., Meyer-Lindenberg, A. (2020), "Studying the impact of built environments on human mental health in everyday life: methodological developments, state-of-the-art and technological frontiers", *Current Opinion in Psychology*, 32: 158-164.

Rietveld, E., Brouwers, A.A. (2017), "Optimal grip on affordances in architectural design practices: an ethnography", *Phenomenology and the Cognitive Sciences*, 16(3): 545-564.

Rietveld, E., Kiverstein, J. (2014), "A Rich Landscape of Affordances", *Ecological Psychology: A Publication of the International Society for Ecological Psychology*, 26(4): 325-352.

Ritchie, I. (2020), "Mind in life in architecture: A conversation with architectural historian Alberto Pérez-Gómez", *Architectural Design*, 90(6): 14-21.

Rittel, H.W.J., Webber, M.M. (1973), "Dilemmas in a general theory of planning", *Policy Sciences*, 4(2): 155-169.

Rowlands, M.J. (2010), *The New Science of the Mind: From Extended Mind to Embodied Phenomenology*, Cambridge, Mass.: MIT Press.

Sailer, K., Budgen, A., Lonsdale, N., Turner, A., Penn, A. (2008), "Evidence-Based Design: Theoretical and Practical Reflections of an Emerging Approach in Office Architecture", *DRS Biennial Conference Series*, https://dl.designresearchsociety.org/drs-conference-papers/drs2008/researchpapers/44/.

Sakellaridi, S., Christova, P., Christopoulos, V.N., Vialard, A., Peponis, J., Georgopoulos, A.P. (2015), "Cognitive mechanisms underlying instructed choice exploration of small city maps", *Frontiers in Neuroscience*, 9: 60.

Schreurs, E., Storgaard, E., Michels, M. (2022), "Roles and challenges of the hybrid practitioner", in Voet, C., Schreurs, E., Thomas, H. (eds.), *The Hybrid Practitioner: Building, Teaching, Researching Architecture*, Leuven: Leuven University Press: 19-25.

Seamon, D. (1994), "The life of the place: A phenomenological commentary on Bill Hillier's theory of space syntax", *NA*, 7(1): 35-48.

Seamon, D. (2007), "A lived hermetic of people and place: Phenomenology and space syntax", *Proceedings, 6th International Space Syntax*, http://krex.k-state.edu/dspace/bitstream/handle/2097/1689/SeamonISSS6.pdf?sequence=1.

Spence, C. (2020), "Senses of place: architectural design for the multisensory mind", *Cognitive Research: Principles and Implications*, 5(1): 46.

Stender, M., Walter, A. (2019), "The role of social sustainability in building assessment", *Building Research and Information*, 47(5): 598-610.

Sweeting, B. (2017), "Design research as a variety of second-order cybernetic practice", in Riegler, A., Müller, K.H., Umpleby, S.A. (eds.), *New Horizons for Second-Order Cybernetics*, Singapore: World Scientific, 227-238.

Tost, H., Champagne, F.A., Meyer-Lindenberg, A. (2015), "Environmental influence in the brain, human welfare and mental health", *Nature Neuroscience*, 18(10): 1421-1431.

Tost, H., Reichert, M., Braun, U., Reinhard, I., Peters, R., Lautenbach, S., Hoell, A., Schwarz, E., Ebner-Priemer, U., Zipf, A., Meyer-Lindenberg, A. (2019), "Neural correlates of individual differences in affective benefit of real-life urban green space exposure", *Nature Neuroscience*, 22(9): 1389-1393.

Tvedebrink, T.D.O., Jelić, A. (2021), "From Research to Practice: Is Rethinking Architectural Education the Remedy?", *HERD*, 14(1): 71-86.

Ulrich, R.S. (1984), "View through a window may influence recovery from surgery", *Science*, 224(4647): 420-421.

Ulrich, R.S., Zimring, C., Zhu, X., DuBose, J., Seo, H.-B., Choi, Y.-S., Quan, X., Joseph, A. (2008), "A review of the research literature on evidence-based healthcare design", *HERD*, 1(3): 61-125.

Varela, F.J. (1996), “Neurophenomenology: A Methodological Remedy for the Hard Problem”, *Journal of Consciousness Studies*, 3(4): 330-349.

Varela, F.J., Rosch, E., Thompson, E. (1992), *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, Mass: MIT Press.

Wang, S., Sanches de Oliveira, G., Djebbara, Z., Gramann, K. (2022), “The Embodiment of Architectural Experience: A Methodological Perspective on Neuro-Architecture”, *Frontiers in Human Neuroscience*, 16: 833528.

Wiener, J.M., Franz, G., Rossmanith, N., Reichelt, A., Mallot, H.A., Bülthoff, H.H. (2007), “Isovist analysis captures properties of space relevant for locomotion and experience”, *Perception*, 36(7): 1066-1083.

Zeisel, J. (2006), *Inquiry by Design: Environment/behavior/neuroscience in Architecture, Interiors, Landscape, and Planning*, Foreword by Eberhard, J., New York: W.W. Norton.

Zuanon, R., Cardoso de Faria, B.A. (2018), “Landscape design and neuroscience cooperation: Contributions to the non-pharmacological treatment of Alzheimer’s disease”, in *Lecture Notes in Computer Science*, Berlin: Springer International Publishing: 353-374.