Multimodal Technologies and Interaction

Review

How Architecture Builds Intelligence: Lessons from AI

Nikos A. Salingaros

Department of Mathematics, The University of Texas at San Antonio, One UTSA Circle,
San Antonio, TX 78249, USA; salingar@gmail.com

Abstract: The architecture in the title refers to physical buildings, spaces, and walls. Dominant architectural culture prefers minimalist environments that contradict the information setting needed for the infant brain to develop. Much of world architecture after World War II is therefore unsuitable for raising children. Data collected by technological tools, including those that use AI for processing signals, indicate a basic misfit between cognition and design. Results from the way AI software works in general, together with mobile robotics and neuroscience, back up this conclusion. There exists a critical research gap: the systematic investigation of how the geometry of the built environment influences cognitive development and human neurophysiology. While previous studies have explored environmental effects on health (other than from pathogens and pollutants), they largely focus on factors such as acoustics, color, and light, neglecting the fundamental role of spatial geometry. Geometrical features in the ancestral setting shaped neural circuits that determine human cognition and intelligence. However, the contemporary built environment consisting of raw concrete, plate glass, and exposed steel sharply contrasts with natural geometries. Traditional and vernacular architectures are appropriate for life, whereas new buildings and urban spaces adapt to human biology and are better for raising children only if they follow living geometry, which represents natural patterns such as fractals and nested symmetries. This study provides a novel, evidence-based framework for adaptive and empathetic architectural design.

Keywords: AI; architecture; design; development; empathetic design; empathy; geometry; infant cognition; intelligence; learning; visual environment

Academic Editor: Lars Erik Holmquist

Received: 14 November 2024
Revised: 18 December 2024
Accepted: 26 December 2024
Published: 27 December 2024

Citation: Salingaros, N.A. How Architecture Builds Intelligence: Lessons from AI. *Multimodal Technol. Interact.* **2025**, *9*, 2. https://doi.org/10.3390/mti9010002

1. Introduction

1.1. A Research Gap on How the Geometry of Buildings Affects the Body

Architecture is the art and craft of creating and shaping buildings for human habitation and use. Architectural design affects a spectrum of physical scales because a building's exterior influences people on the outside, while users experience the building details, its interior circulation, spaces, and surfaces from the inside. For close to one century, the practice of architecture has tended to concentrate on two contradictory ideas: creating "interesting" unusual forms, and applying industrial products such as concrete, glass, and steel for cost savings. Architectural theorists rely on ideological and sociopolitical arguments to justify this dual focus, yet the reasons for its continued adoption are the incentives of visual excitement and maximizing construction industry profits.

The results are favorable to the class promoting them but are not liked by many common people who find the buildings unfriendly to experience. This reaction has given rise to a debate for a preference between "modern" versus "traditional" architecture, without any definite resolution. In parallel, and somewhat belatedly, research on environmental effects of buildings on human health was initiated. So far, however, much of this work has focused on the multiple factors other than the buildings' geometry. And yet the geometry of the surroundings is known to strongly influence the human brain and its functions.

AI is already making significant strides in architectural practice through design software tools such as Architechtures, Finch, Leonardo, Qbiq, and others. These commercial programs generate realistic, functional designs that currently reflect mainstream industrial-modernist aesthetics. However, the same tools can be adapted to prioritize living geometry, cognitive ease, and salutogenic environments. By incorporating principles of living geometry into their training datasets, such programs could produce designs that resonate with human neurobiology and promote emotional well-being. Integrating biophilic patterns, fractal scaling, and nested symmetries into the generative algorithms would allow these programs to create spaces that satisfy adaptive and empathetic design, enhance cognitive performance, and reduce stress. AI holds immense potential to transform the design process, shifting it from purely visual innovation toward evidence-based, human-centered architecture. This study gathers information on how the geometry of the environment affects psycho-physiological states, and by extension, longitudinal effects on long-term human health. Geometry defines visual patterns in 2-D together with experienced space in 3-D. At the same time, the open question is raised on the possible changes environmental geometry could trigger in both infants and adults because of brain plasticity. While a few studies have addressed these topics, so far there is neither a concerted nor systematic approach to investigate the complex interactions between experienced geometry and neurophysiology. Hopefully, the present summary provides a blueprint and incentive for future investigations.

1.2. Using Interactive Technologies to Better Understand Adaptive Design

The connection between AI technologies and architecture is threefold: (*i*) AI can be used to generate novel designs based on verbal prompts; (*ii*) enhance architectural design by judging its components or choosing among alternative variants using criteria defined by the architect; and (*iii*) investigate the foundational notions of design by how it affects human health and life. This paper focuses on the third point, largely because architectural academia seems to show little interest in it. AI has the capability to analyze vast amounts of data related to how built environments interact with human biology.

Applying AI technologies—affective computing, empathetic AI, and machine learning—as a novel approach in architecture reintroduces emotion and engagement into design. Portable technologies like wearable electroencephalograms (EEGs), eye-tracking sensors, and facial expression analysis permit real-time feedback during both the design and post-occupancy phases of construction. These tools enable indirect emotional feedback by interpreting physiological responses, thus allowing designers to evaluate the psycho-physiological impact of architectural elements without subjective biases.

Learning by AI and infants requires complex, informationally rich environments to develop effectively. Large language models (LLMs) and developmental robotics learn from exposure to patterns and structures. Similarly, infants need exposure to complex, harmonious visual environments to develop neural pathways essential for cognitive functions like problem solving and spatial reasoning. By analyzing emotional responses and physiological reactions through AI, architects can create empathetic and adaptive environments that promote cognitive development and well-being. Integrating AI, developmental psychology, and neuroscience addresses architectural shortcomings.

The public reads about promising applications of new technologies to architecture, and especially those that involve AI. Such announcements are usually accompanied by flashy images of futuristic buildings with captions promising new levels of human achievement.

And yet, those efforts miss the point of adapting to human psycho-physiological needs. This is where AI should be applied to solve the century-old problem of privileging artistic form while neglecting biology in design. The human body needs to inhabit a very special geometry to maintain its health and well-being.

1.3. Intelligence Is Linked to Pattern Recognition

Intelligence represents the ability to process information and extract meaning from it, which can then be used to solve problems. Initially, this emergent neurological mechanism helped animals solve existential challenges; humans adapted it to more abstract applications such as art, mathematics, science, and technology. Conceptual thinking, learning, and problem-solving depend upon intelligence. Creativity is linked to but is not the same as intelligence, since the former stimulates the brain to create new situations whereas the latter uses cognition and logical reasoning to process known phenomena.

Pattern recognition comprises a large part of intelligence. The ability to judge settings and situations in terms of visual and other types of patterns establishes norms for the fight-or-flight response essential for survival. A familiar pattern is reassuring, but departures from the stored cache of known "safe" geometries trigger alarm in an unconscious reaction. Conscious intelligent reasoning then kicks in to evaluate the situation. Pattern processing as a basic part of intelligence also makes possible the creation and use of language.

A major component of the research gap identified in Section 1.1 is how the geometry of the environment shapes both the physiology of the brain and thinking processes. Investigations involving brain plasticity and infant learning show this to be occurring, even as the architecture profession ignores it. A novel contribution of the present paper is to raise this issue. Stress (which is a known effect of certain building geometries) leads to shrinking of brain tissue, in much the same way as Post-Traumatic Stress Disorder (PTSD) [1]. The control in those experiments is exposure to natural environments and plants (see the description of Biophilia in Section 1.4).

The argument outlined above implies that adults are expected to feel continuous anxiety and stress from inhabiting non-living geometries (defined in Sections 1.4 and 1.5 below). This controversial claim is serious enough, yet its consequences are nothing compared to the damage non-living geometries can do to children. Research reveals how the cognitive development of babies and young children is determined by the geometry of the environment in which they are raised. Accumulating data indicate that geometries favored by the architectural mainstream can inflict damage on our children. Interactive technologies are now used to verify this assertion.

1.4. A Specific Type of "Living Geometry" Shaped Human Evolution

This paper draws upon two main theories of how physiology reacts to environmental geometry: (*i*) biophilic design, and (*ii*) Christopher Alexander's living structure. Biophilia is the innate preference for living forms, an emotional/visceral connection achieved mostly visually by identifying geometrical elements common to living organisms and natural forms [2–4]. This theory is experimentally verified by medical measurements of improved healing when exposed to domestic animals, plants, and artificial structures that embody the specific type of geometry. Alexander's living structure (here narrowed to "living geometry") is a more abstract formulation that includes the geometrical part responsible for the biophilic effect, and singles out mathematical attributes of geometries that resonate with the body to produce a positive-valence effect [5–8]. The effects of living geometry are validated in part by experiments on emotional responses to fractal patterns, visual attention studies, and portable sensors measuring physiological states. There is an overlap between the two theoretical constructs (*i*) and (*ii*) given above.

The human body evolved to engage with its environment through a multi-channel information field (comprising the five senses: auditory, gustatory, olfactory, tactile, and visual). Increased sensitivity occurred through a selection process of physiological traits generated spontaneously among early ancestors. Our body is designed to be constantly connected to its immediate surroundings through information, and to respond mostly unconsciously. This paper focuses on the visual channel, which comprises the predominant type of data that we input and process. Development of the eye-brain system was driven by the necessity of constructing an interaction mechanism promoting survival.

Modern humans have not significantly changed from a biological perspective for the last 2–3 hundred millennia. The human neural system evolved to recognize what can be termed "living geometry" through processes of information processing, specifically defined by older ancestral eras. This group of visual qualities is characterized by both natural and biological forms representing animal and plant life. A comprehensive mathematical description would include the following properties:

(i) **fractal scaling** (structural details present at every magnification, and visually similar components occurring at different scales);
(ii) **nested symmetries** (multiple plane symmetries such as bilateral (mirror) reflectional symmetries combined with rotational and translational (linear repetition) symmetries supporting each other); and
(iii) **large-scale harmony** (achieved through alignment, visual harmony, similarity, ordering, and symmetry at a distance).

The concept of living geometry is described in greater detail elsewhere [9,10]. An abstract composition containing these features, such as a building or image, may be visually attractive but not positively engaging. Human neurophysiology is tuned to preferentially register—and respond to—special configurations that relate to natural geometries. Additional mathematical constraints act to trigger unconscious attention and engagement. Try to imagine the common geometrical qualities of plants, animals, traditional architecture from all around the world, historic places of worship, and favorite tourist spots. Despite the endless visual variety represented, all these share common features that make them viscerally attractive to humans.

The present work updates an earlier investigation on the relationship between architecture and the principal characteristics of organisms [11]. Seven properties define the mechanism of life: (1) organized-complexity, (2) metabolism, (3) replication, (4) adaptation, (5) intervention, (6) situatedness, and (7) connectivity. Living geometry corresponds to the first property; while the other six describe how an organism maintains its internal structure (2), perpetuates its structural template in time (3), and interacts with its environment dynamically (4, 5, 6, 7). The interaction mechanisms gave rise to intelligence, hence offer templates for analyzing parallels with AI.

During millennia, human beings have sought emotional nourishment from both nature and from their own creations. People link viscerally to the living geometry represented in organisms such as plants, domestic animals, and other persons. Biophilia provides a mechanism for healing. This positive-valence effect was initially associated with exposure to natural settings but was later found to encompass artificial structures that obey special configurations [12–15]. Visual connection occurs through the geometry, not some vitalistic force. And people use the same neural apparatus to respond to artificial living geometry. Architectural examples go back to times when builders worked from intuitive sensory feedback, adjusting forms and shapes to maximize the positive-valence emotional signal. It was unthinkable to design structures that made the user anxious; and if some built element or portion of a building was perceived to cause stress, then it was modified. Nevertheless, that knowledge was never documented, hence we now have to rediscover the specific geometrical characteristics that make people feel anxious or at ease, using experimental methods [16–21]. Results from those studies confirm that living geometry is best suited to human psycho-physiological responses.

The brain's natural pattern-recognition machinery is constantly seeking meaningful structures. Cognitive engagement is facilitated when the visual environment activates perception at an optimal level, with information that is neither too rudimentary nor too chaotic. Patterns that are neither monotonously uniform nor random align with the innate workings of neural architecture [22–24]. In a parallel direction of investigation, human-computer interaction research on how visual complexity in website layouts affects user experience reproduces essentially the same findings [25].

For example, viewing fractal structures is associated with minimal cognitive load—the phenomenon of "fractal fluency" [26]—as assessed by functional imaging of the brain [27,28], whereas the opposite is true for viewing parallel stripes [29]—a single-scale visual that causes headaches. (Fractal fluency refers to the improved ease by which the brain perceives fractal patterns because of their scaling similarity, as opposed to non-fractal patterns in which the scales are not distributed in a regular hierarchy, or there is no similarity among the different scales). Also, the easy visual registration of a face and its complex nested symmetries confers survival advantages already from birth. Infants are automatically attracted to faces—the mother's face being the first and most important—and, interestingly, no longer than a week after birth, they start to look longer at faces that adults deem attractive. By the age of 6 months, this effect generalizes across age, race, and sex [30,31].

This capability was essential in adapting humans to social interactions through interpreting subtle details of human faces and their expressions. In geometrical terms, we need to recognize bilateral facial symmetry about a vertical axis, and there exist specialized nerve cells in the brain for doing exactly this. We must also be able to decode extremely fine detail in facial features to "read" emotions and intentions. Survival depended upon the early emergence of perceptual refinement and sensitivity to specific geometrical features. Vertical mirror symmetry and fine detail connected to overall fractal scaling are part of living geometry.

A coherent, harmonious information field contains detail that is highly organized through multiple visual connections and symmetries. Our neural system evolved to constantly check for either attractive points of interest, or cues to possible threats. Note that the sensory apparatus prioritizes negative signals several times over positive signals, as potential dangers need to be acted upon immediately, whereas positive attractors can wait for further analysis (known as the negativity bias [32]). For this reason, one building that repels us will cancel out several nearby buildings that attract us [33,34].

1.5. Buildings and Cities That Violate Living Geometry

The above description of living geometry clashes with the dominant architecture of the 20th Century and its later developments, including today's favored styles. Non-adaptive architecture is distinguished by its lack of interaction with the user. Architects insist upon forms, spaces, and surfaces determined by ideology, but ignore human psycho-physiological needs [35]. For one century, building practice in the wealthy nations has adhered to a visual form language that opposes what our body craves in engaging with its environment. Structures are either disengaging, boring, or hostile and generate alarm in the observer [36–40]. This recent discovery relies upon data gathered by tools developed for the advertising and medical fields. Eye tracking, and eye-tracking simulation software, map where unconscious attention is drawn. Both appealing and threatening signals engage our body to act, which then applies conscious analysis to distinguish between the two cases.

Several studies have quantified the psychological effects of specific geometric patterns, such as fractals, on stress reduction and cognitive engagement. Hägerhäll et al. [41] measured electroencephalograms (EEG) showing that exposure to fractal images with a mid-range fractal dimension (D = 1.3–1.5) significantly reduces stress. A related study corroborated this effect by measuring Galvanic Skin Responses (GSR) [42]. Studies by Taylor et al. (2018) [43] showed that viewing fractal-based architectural patterns lowers cognitive load, enhancing visual fluency and promoting relaxation. Separate experiments have discovered the impact of varying architectural forms (curvature, enclosure, proportion) on physiological stress by means of clinical measurements such as electroencephalography (EEG), brain wave Alpha to Beta ratio, Functional Magnetic Resonance Imaging (fMRI), Heart Rate Variability (HRV), Galvanic Skin Response (GSR), Pupil Dilation, and salivary Cortisol [44]. These findings align with biophilic design principles, emphasizing that living geometry supports neurological health.

These new analytical tools can determine in large part how a person reacts emotionally to a building. Empirical studies such as experiments measuring stress levels in environments with and without living geometry validate the present arguments. Large faceless façades consisting of a blank wall, featureless concrete, or polished metal simply do not register unconsciously, as shown by eye-tracking studies (detailed in Section 6 below). A glass curtain-wall will usually not register, unless someone on the outside can see the people working behind the picture window; or there are reflections on the plate glass. Monotonous repetition has been shown to induce headaches (Section 6.4). All these cases generate alarm because the sensory system perceives a giant structure that cannot be categorized using built-in references on living geometry.

Opposing today’s prestigious buildings, millennia of human construction do in fact follow living geometry [45]. A survey of historical architectures, from all periods and from all over the world, reveals positive qualities linking them to natural and biological structures. This adaptive phenomenon continues in the major building activity taking place today, found in informal settlements and self-building uninfluenced by the dominant architectural narrative. The architectural establishment tries to erase informal buildings and substitute them with social housing schemes in the industrial-modernist style [46].

While urbanization sparks fierce debates, those do not usually question which artificial building geometries are themselves appropriate for human life. A discussion of aesthetics mixes opposite viewpoints from among experts, and that separate debate further complicates matters. New technologies such as AI and portable sensors help to disentangle the relevant factors, and finally answer important questions about healing environments.

2. Outline of This Paper

The present section serves as a roadmap to the detailed discussions in the rest of the paper. Section 3 presents experimental evidence demonstrating how environments rich in visual information improve cognitive development, particularly in infants. These findings support the central thesis of this paper, which is the positive impact of living geometry. Studies show that an informationally rich environment is needed for normal infant development (Section 3.1). This includes in large part direct visual signals from the baby’s immediate surroundings. The same principle holds true for mobile robots: the system learns from exposure to and interaction with the world (Section 3.2). When the training environment is informationally poor, then the trained robot is unable to function in a more complex setting.

Large language models such as ChatGPT are creating a revolution in how technology can mimic human thought and creativity. These programs work by learning a word’s semantic relationship to other words, moving up in an increasing hierarchy of linguistic structures. This process is analogous to discovering visual symmetries and connections among the components of a coherent visual composition (Section 3.3). Infant learning probably utilizes the same mechanism of building up relationships on different scales. The development of intelligence therefore depends upon complex and ordered informational input.

"Nature-deficit disorder" is postulated by Richard Louv to arise when children are insufficiently exposed to nature, and the analogous effect of a lack of nature-like symmetries in artificial environments is termed "symmetry-deficit disorder" (Section 3.4). Raising children in minimalist or random environments could be harming their development. Successfully training AI programs to beat people at board games applied insights from human learning to train the software; yet, this lesson has not been applied to improve children's environments. Spaces inhabited by children are not optimally designed for them because architects do not apply evidence-based principles (Section 3.5). Minimalistic environments cannot be good for children.

Section 3.6 presents speculative ideas on how an industrial-minimalist environment may even play a negative role in the whole process of conception and reproduction. The reason offered is that the unnatural information field of much of today's urban settings generates stress, which impacts the body negatively though unconsciously. There is a basic contradiction with living geometry.

Section 4 investigates the parallels between training AI programs through self-supervised learning and human brain development through the process of self-learning in infants. This analogy underlines the need for raising a child in a harmonious informational environment containing visually complex yet ordered components. These parallels work in real-world contexts where the intelligent entity learns from data that it itself organizes, not from following instructions. Both work on the concept of self-organization and self-supervised learning. AI programs use input data to detect regularities and create their own rules of organization; infants absorb environmental information that they organize internally to develop neural pathways.

Section 5 discusses the role of spatial fractality in promoting child development through active physical engagement. Subdividing the boundaries of larger spaces into smaller subspaces is known to adapt space to human use, especially to the needs of children. This process generates a fractal shape and is the opposite of insisting on smooth, abrupt walls. A child improves its learning potential for spatial processing and 3-D problem solving by exploring complex subdivided spaces visually and physically with its body.

Section 6 argues for implementing emotion and feedback in design. It introduces AI-driven tools capable of diagnosing emotional responses to architecture, validating the relationship between health and living geometry. Focusing on design that adapts to user emotions contrasts with applications of AI to design, which so far generate visually impressive artistic forms but do not test for their psycho-physiological impact (Section 6.1). Applying emotional engineering to architecture follows its highly successful applications in medicine and other disciplines (Section 6.2). Creating empathetic environments by applying AI would counteract a tradition in 20th Century architecture that disengaging spaces and surfaces are necessary for "modernity". New technologies enable measuring direct user feedback from physical mock-ups or designs in virtual reality to produce a new generation of empathetic buildings (Section 6.3).

Generative AI can now perform a 2-D Fourier transform of a visual online, which reveals the scale distribution of the design (i.e., the relative number of components of different sizes). This information creates an unconscious emotional reaction. Departures from a fractal type of scale distribution (known as "scale-free") cause visual distress and headaches (Section 6.4). Ancestral natural environments tend to be scale-free, as are traditional architectural and urban places. It turns out that much of industrial-modernist design deliberately violates a scale-free distribution, with negative consequences for the users and passers-by.

When asked to correlate high versus low intelligence with specific geometrical elements and properties, ChatGPT reproduced all the conclusions of this paper by correlating high intelligence with organized visual complexity (Section 6.5).

Finally, Section 7 concludes with recommendations for integrating these findings into architectural education and practice to foster adaptive, human-centered environments. Empirical results argue against the dominant practice of industrial-modernist architecture because it departs from biological and natural structure. Applying AI validates traditional architectures that achieved adaptation intuitively. Section 7 includes a useful list of points needing reform in architecture schools, which now prevent young architects from learning about healing environments and living geometry.

Anyone can easily transform the exterior and interior of their dwelling and workplace, up to legal restrictions, by applying inexpensive methods to implement living geometry (Section 7). If an architect is required, it is best to select one that has been trained in adaptive or traditional architecture. Children benefit the most from interior environments that embody coherent information: this especially applies to furnishings, with the ubiquitous glass coffee table coming in for severe condemnation.

3. Geometry Influences Reproduction and Child Development

3.1. Environmental Influences on an Infant's Developing Brain

Just as an AI program is trained by specific informational input relevant to the task, the baby's brain is trained by exposure to living geometry and other complex signals from smell, sound, touch, etc. Some parents intuitively sense this connection and try to expose their baby to a rich sensory experience. The complexity of perceived patterns in the environment contributes to shape cortical circuit structure and function [47–49]. In the aural domain, musical enrichment is believed to help children's cognitive, emotional, linguistic, and social development [50,51]. What is relevant to the present argument is the effect of passive listening (learning to play an instrument is beneficial later).

The opposite case in which babies suffer from sensory deprivation leads to catastrophic consequences of poor development [52–55]. This was made evident with groups of infants born during the COVID-19 lockdown, which restricted exposure to external visual information from nature, scenery, and other adults and babies. Homogeneous and minimalistic visual patterns lacking the richness of living geometry deprive the baby's brain of the complexity it needs to continue its natural growth trajectory [56,57]. In an environment with flattened informational stimulation, a baby loses access to the experiences that promote emotional bonding, environmental attachment, feelings of safety, and visuo-spatial reasoning.

The brain continues to produce new synapses up to the age of 2, when it starts a pruning process, whereby the synapses that mediate used (and useful) messaging are maintained and strengthened, whereas superfluous synapses are cut. This neurobiological process is known as synaptic pruning. Being the source of information, the environment plays a significant role in how the wiring of the brain develops [58].

The growth of an embryo into an adult exhibits some vestiges of the stepwise morphological transformations that a species went through as it evolved from its primitive ancestors. Animal embryos resemble other embryos of equivalent stages. This process is known as the "ontogeny recapitulates phylogeny" theory and applies to the human brain, but the final steps are also determined by the environment, not only genetics. Since human babies continue to develop their brain long after birth, their intelligence is influenced by the informational complexity of the immediate surroundings.

Practical implications can be presented sequentially. The optimal visual environment will start with bold black-and-white figures, then progress into more intricate detail as the baby grows. Exposure to detailed visuals from an early age helps to wire the brain for complex processing. This neural development is crucial for higher-order cognitive functions, such as analytical thinking and problem-solving. It is necessary to provide engaging and sufficiently complex static information for the baby to focus upon over time. Therefore, parents should abandon gray or white minimalist indoor environments and set up a complex yet harmonious visual setting.

3.2. Experimental Confirmation from Developmental Robotics

The purpose of this paper is to use interactive technology to discover unsuspected links between child development and the geometry of the environment. Insights from infant learning have been applied to help AI programs learn more efficiently [59–61]. The interaction of AI and neuroscience enabled breakthroughs such as training the program AlphaGo to play the board game of Go popular in East Asia, leading to a paradigm-shifting win over the world champion Lee Sedol in March 2016 [62].

In an analogous application, developmental (or epigenetic) robotics construct an embodied cognitive system that learns through interactions with the world, copying child development [63]. Developmental robots are programmed to acquire knowledge and skills gradually, building upon previous experiences. This incremental process builds up internal models of the world and mirrors the way children learn to recognize patterns, develop language, and acquire motor skills. Importantly, minimalist environments fail to provide the necessary complexity for these artificial systems to learn meaningful behaviors and patterns [64].

When the training environment is too restricted, it is possible to train a mobile robot to perform well in a specific setting, but it then becomes lost in a more complex situation with more varied visual information [65]. This effect of being unable to function with new data is known as “overfitting”. An overspecialization to limited training data results in a lack of robustness in performance, even in new environments with small changes. Increasing the training dataset by including geometrical transformations—that is, enriching the training environment by using symmetries—helps against overfitting [66].

3.3. Large Language Models (LLMs) Parallel Living Geometry

In both language and visual compositions, individual elements gain meaning through their relationships with other elements. A word’s significance is influenced by the words around it in a broader context, just as a visual element’s impact is shaped by its context within a harmonious composition. Large language models (LLMs) are therefore analogous to a geometrically coherent composition in which all elements work together through alignment, hierarchical scaling, and nested symmetries. Both are systems where the connections among all parts create cohesion and meaning.

Living geometry is defined through the harmonious linking of visual elements that achieves a cognitively unified whole. Associations among the pieces occur on all scales, and those cooperate to define larger and larger hierarchical groupings as the scale increases. A visual element’s impact is shaped by its context within the composition. In parallel with language, and with LLMs, individual words gain meaning through their relationships with other words. This process is repeated at higher scales to satisfy context and semantics. LLMs connect words into broader linguistic structures possessing narrative flow.

It is tempting to conjecture that a baby’s brain is trained using this same procedure (extracting hierarchical relationships) through observing living geometry in its environment. Aural and visual input that embodies coherent structure could form the mechanism for eventual language and thought. This discussion reinforces the conclusion reached in Section 3.1 above supporting a complex yet harmonious visual environment for infant development.

3.4. Preventing Symmetry-Deficit Disorder

Since the beginning of the last century, urban environments promote the aesthetics of design minimalism. At the same time, increasing built density has displaced much of plant life from cities. Being cut off from plants and natural forms leads to "nature-deficit disorder", as argued by Richard Louv [67,68]. Far from being only aesthetic, this deprivation seriously affects a child's development. An equally important concern is that children could now suffer from the analogous "symmetry-deficit disorder" because dominant architectural culture avoids living geometry [69]. Lacking living geometry in artificial structures proves to be an inadequate physical and visual stimulus for raising children.

Educators, parents, and pediatricians are becoming aware of the enormous health benefits of having children exposed to nature in a safe setting [70]. Knowledge of this effect used to be part of traditional wisdom in all societies. Connecting visually to natural forms shapes the child's conception of the world, whereas being raised in an industrial-minimalist environment leads to an opposite result of underdeveloped attachment to life. This mechanism of emotional nourishment is possible only from contact with nature and living geometry [71,72]. Yet, our society still has not acted upon the message coming from synthesizing all the evidence.

3.5. Disengaging Architecture Is Unfit for Children's Development

While "symmetry-deficit disorder" is not a formally recognized medical diagnosis, it highlights legitimate concerns about environments that do not support a child's physical and psychological health. Both nature-deficit disorder and symmetry-deficit disorder allude to the deprivation of essential environmental stimuli. Architects make choices without being cognizant of their effect on children. Objective, scientifically based criteria for design identify an environment that supports child development as follows: comfortable, emotionally warm, engaging, nurturing, perceptually stable, safe, and stimulating yet reassuring. Living geometry is not just one possible perspective among divergent discourses, if those other design directions fail to align with child psycho-physiology. Minimalist environments fail to achieve the above descriptors.

Architecture for many decades has been motivated to generate innovative "artistic" forms. Architects do this without investigating the consequences those built forms have on the users' psycho-physiology, and their training never prepares them to measure sensory feedback from what they build. The literature is full of architects' claims that they design for children, but they had no knowledge base to guide them, only untested assumptions. Modernist architects wrongly assumed that children would adapt to abstract and minimalist environments. Moreover, dominant practice claims fabricated positive neurological effects from favored buildings [73,74].

The practical implications are that child-friendly environments have special geometrical characteristics that embody biophilic properties and living geometry. This conclusion extends the reasoning of the previous sections that focused on infants, to apply to children of all ages. Affected architectural environments include the home, play spaces, and school. Real-world practice deviates from these conclusions, however, in implementing geometries that depart from the defining elements of biophilic and living geometries.

3.6. Conjecturing Living Geometry's Role Before Birth to Explain Dropping Natality Rates

While many factors contribute to declining populations in industrialized countries, the role of architecture and environmental design deserves special attention. The dominance of industrial-modernist geometry may be contributing to emotional disconnection from life and nature, indirectly discouraging the search for emotional bonding, and lowering birth rates. Visual symbols of efficiency, modernity, and progress are incompatible with the deeply rooted biological and psychological needs that living geometry fulfills. If the unnatural geometry of the environment is indeed contributing to declining birth rates, then society faces a profound dilemma: the very settings identified with advancement and sophistication may be undermining the population's long-term survival. Architecture is rarely questioned in terms of its impact on emotional well-being, family formation, and reproduction.

Even in the absence of direct data, it is tempting to conjecture whether the entire process of conception, fertility, and fetal development is affected by environment geometry. The life-supporting and stress-reducing qualities of living geometry may create conditions that are more conducive to the biological processes of reproductive health and childbearing. Stress levels are known to affect fertility, libido, pregnancy outcomes, and fetal development, while environmental factors influence hormone production and regulation crucial to those mechanisms.

An interesting historical detail is that already in 1933, Salvador Dalí criticized the industrial-modernist aesthetic as undermining the erotic and sensual dimensions of lived space [75]:

"The interior architecture of the modern home is absolutely depressing for making love; not a single detail predisposes one to the erotic instinct. This smooth universe, devoid of ornament, and ruled by the tyranny of the straight line evokes a sensation of antiseptic, surgical coldness and ultimately destroys in man any desire to give himself over to the senses." (Dalí [75], page 74).

It is in society's interest to ask what geometrical factors define an optimal setting for conception and childbearing [76]. Industrial-modernist interiors, devoid of biophilic patterns and living geometry, fail to stimulate the brain's reward centers, reducing the emotional warmth and sensuality essential for intimacy. Couples may feel less inclined to start families in environments that do not evoke a sense of emotional warmth, nurturing, and safety. The cultural conditioning that leads people to value modernist design over living geometry might also play a significant role in shaping family and reproductive choices. Are families living in emotionally engaging environments more likely to have children compared to those in minimalist-modernist environments? The decline in birth rates observed among the educated classes of industrialized countries underscores an unexplored connection between architecture and demographics.

The mother's emotional and psychological wellbeing during pregnancy affects fetal development, as environmental influence is arguably even more acute and decisive than usual. Living geometry could play a role in creating a supportive atmosphere for this state of mutual dependence on the linked child-mother environment. There is ample evidence that sensory experiences of the mother transfer to the developing fetus.

Does it matter that a baby's form is itself incompatible with the non-living geometry characteristic of "modernity"? A couple educated to privilege the cold industrial-modernist aesthetic is preconditioned to crave only objects and artifacts satisfying that specific crystalline geometry. How are such persons supposed to desire and create something rounded, softly curved, symmetrical, detailed, fractal, and harmoniously proportioned as their life goal? On the other hand, the urge to care for, love, and nurture a child aligns with the process of emotional engagement that living geometry naturally embodies. At the heart of this issue is a fundamental contradiction between the aesthetic ideology of modernist architecture and the biological needs of human life.

Here the conclusion is far-reaching even as it is highly controversial. A narrow set of visual images conditions future parents into a "preferred" geometry that is conjectured to go against the process of reproduction. A massive research effort is called for to validate this claim. Subsequently, society must reconsider its enthusiasm for the industrial-modernist aesthetic that is responsible for creating this geometrical antagonism with biological processes.

4. Applying AI Techniques of Learning to Understand Intelligence

Merging AI with neuroscience offers an important lesson supporting this paper's thesis: intelligence develops to handle complex information. In contradistinction, minimalist environments represent no visual intelligence. If the physical world lacks embedded structural information, then our own neural intelligence cannot interact with it, thus preventing cognitive engagement.

The AlphaGo software mentioned earlier (the original version known as the Fan Hui version), created with the AI program DeepMind, was trained on an enormous number of past games of Go. The software was not directly programmed with actual moves but learned the winning strategies from previous configurations. AlphaGo was programmed using a combination of supervised learning and reinforcement learning, including basic rules and heuristics of Go. The next step in AI development did away with programming the rules of the game and enabled the software to learn both rules and winning strategies from the data. The result was the program MuZero, which uses reinforcement learning algorithms to enable planning and learns entirely through self-play [77]. MuZero represents a major advancement over AlphaZero (the general software that was specialized to play Go as AlphaGo).

In self-supervised learning, AI models are designed to predict or reconstruct parts of the input data based on other parts, effectively learning the data's underlying structure without explicit direction [78]. This approach allows models to capture syntactic and semantic patterns inherent in information, and to develop rich internal representations on their own.

The parallel between self-supervised learning in AI models and infant brain development emphasizes the role of complex yet organized and symmetric visual patterns in the environment. Both self-supervised AI models and infants learn from data that they themselves organize. Infants absorb information from their surroundings, learning to recognize objects, patterns, and social cues through exposure. Infants utilize the organized patterns in visual stimuli to develop neural pathways. Experiments verified this mechanism in cats [79]. Subsequent studies on human infants revealed a distinct preference for visual organization, regularity, and symmetry, which guide the construction of neural circuitry in the visual cortex [80–82]. In both contexts (AI and human), coherence corresponds to the nervous system's inherent "tuning" and helps its circuit refinement at these critical stages. In AI, these patterns help models generalize from data, while in infants, they facilitate the recognition and processing of essential visual information.

Infants are learning a "foundation model" [83], developing the representation that will form the basis for every subsequent complex task. This process agrees with cognitive theories that base learning on a series of perceptual inputs that identify patterns. The baby builds a foundational mental representation and interpretive framework from a rich and continuous informational input from its environment. The process of self-supervised human learning from the environment is entirely analogous to self-supervised learning that develops foundational models in machine learning [84].

In practical situations, there is a lower complexity threshold for data, which refers to the level of intricacy in sensory input required to stimulate effective neural development. Organized patterns with connections and symmetries provide sufficient complexity to engage the brain's learning mechanisms without causing overload (such as occurs with random information). These patterns enable the detection of regularities and the formation of predictive models of the environment, which are foundational for higher cognitive processes such as problem-solving and reasoning.

5. Spatial Learning from Fractal Spaces

Children interact with their environment not just visually but physically. Traditional homes with bay windows, nooks, and furniture scaled to accommodate a child's size offer opportunities for spatial exploration and play [85]. Those play spaces are characterized as "cozy" seen from the child's perspective and may sometimes define a semi-enclosed child "sanctuary space" [86]. Such affordances enable children to develop spatial awareness and motor skills. A classic experiment with kittens showed that active physical interaction improved visual development, compared to only passive visual exposure to the environment [87]. Later studies in human infants identified active engagement with the environment as being crucial for the proper development of visual coordination and perception [88].

Complex interior spaces that combine a variety of connected spaces of different sizes represent a fractal subdivision [89]. Crenellated volumes offer more opportunities for hide-and-seek, cubby-building, and other spatial exploration activities that are crucial for cognitive development. The mechanism by which children learn through bodily movement has been studied in outdoor environments, and those findings are equally valid for indoors [90]. A variety of connected, complex spaces scaled to a child's size is essential for providing diverse play opportunities that support different developmental areas such as physical movement, 3-D problem solving, and spatial awareness.

Implementing design principles from the viewpoint of a child, such as accessible play areas and appropriately sized furniture, can significantly impact children's behavior and cognitive development. Research indicates that environments with complex, engaging spaces are more beneficial for children than stark, minimalist designs [91,92]. By acknowledging children's spatial experiences and preferences, architects can create environments that foster exploration, learning, and well-being. This child-centric approach leads to spaces that cater to the developmental needs of children: they are nurturing and stimulate active engagement, exploration, and play.

Affordances are the potential actions or interactions that an environment offers [93]. Traditional architectural elements such as baseboards, moldings, and varied textures provide natural "handholds" and reference points for children as they navigate spaces. Smooth walls and a lack of architectural details reduce the number of affordances available to children, however. Spaces that lack crannies, nooks, and varied geometries may provide fewer prompts for imaginative play and creative spatial thinking. Industrial geometries and minimalist environments do not challenge or stimulate a child to engage fully with its surroundings and develop spatial reasoning skills. This reduction in sensory input may impact the development of neural pathways related to spatial processing and pattern recognition.

It helps to assess both interior and exterior spatial fractality on opposite ends of a mathematical scale (characterized by the structure's fractal dimension). A subdivided volume containing many geometrical features—connected subspaces of different sizes—fits human affordances better, whereas a minimalist volume is simply a homogeneous space with abrupt, smooth boundaries. The situation is worsened when spatial boundaries are made from plate glass curtain walls or mirrored walls, because those are geometrically abrupt while pretending not to be there, thus causing cognitive dissonance.

The psychological warmth associated with traditional materials and designs can also influence emotional well-being. Traditional architectural designs often include ornamental features, textured materials, and varied color palettes that provide rich visual stimuli. Materials such as wood with visible grain and carved details offer tactile and visual complexity that engages a child's senses. Environments that feel welcoming and stimulating encourage social interaction and emotional security, which are essential for healthy development.

6. New AI Tools for Assessing Adaptive Environments

6.1. A Radically Different Application of AI to Design

The consensus in the technology sector is that generative AI will determine the future of emotional architecture [94]. Using continuous feedback during the design process could be called "cybernetic design". A design evolves stepwise, with generated design variants culled according to psycho-physiological fit. This is the only way to check for adaptation to human physiological and sensory requirements. Contrast this interactive approach with today's standard practice, which imposes an already-prepared but untested design on the users [95,96]. Such a design is not evaluated through evidence-based criteria.

Architectural publications are exploding with ideas applying AI tools to contemporary design. And yet, despite the enthusiasm, there appears to be little research directed into exploring healthy potentials. Promises to revolutionize the field of design remain on the superficial level of an image. Contemporary architects co-opt AI-assisted design to generate buildings as sculptural forms, prioritizing artistic expression above occupant needs [97,98]. Dominant architectural culture simply adopts AI to create visually compelling abstractions that align with established industrial-modernist aesthetics. Individuals harness the power of AI to promote what they already practice but do not allow AI to adapt a design to health [99].

There exists enormous potential in using generative AI for creative designs. Any ideological restriction stifles invention, however, since it allows only recombining and refining architectural elements within limited stylistic rules. An architectural form language that is perceived as cutting-edge, futuristic, and internationally recognizable results in a predictable—mostly negative or neutral—emotional response [100,101]. Instead of using AI to adapt and innovate, it becomes an exercise in aesthetic and intellectual conformity.

This paper combines several different tools and topics into an innovative approach to using AI in architectural design. The necessary condition for a clear formulation of adaptive design is the use of technology to predict emotional feedback. Inputs are a set of alternative designs—*partis* (organizing sketches) with variations—that satisfy the brief (the necessary budget, conditions, constraints, features, materials, needs, etc.) of a particular project. Each of those design alternatives is then tested virtually for the probable user response. The output is a much smaller set of design options that pass the criteria for positive-valence environments. A solution can then be chosen from among these and developed further by iteration using the same tools.

6.2. Getting Indirect Emotional Feedback

AI has achieved a breakthrough in utility by trying to incorporate emotion into its algorithms [102,103]. Starting from the basis that emotions are a consequence of our body's physiological responses to external stimuli, AI programmers are building emotion recognition models [104,105]. Human emotions can be inferred from physiological signals including electrocardiograms, electroencephalograms, eye tracking, galvanic skin responses, and skin temperature, plus emotional feedback from facial expressions and speech. Ironically, the way to re-introduce emotions into design is through interactive technologies and sensors, since an adult's conscious responses often get bogged down in learned prejudices and subjective arguments.

Commercial product design is profiting from advancements in emotional (or affective) engineering, which is beginning to be applied to architecture [106,107]. Empirical results come from analyzing how buildings and their environments evoke emotional changes in users. Studies so far focus on changing lighting conditions and color hue, and curves versus straight lines. Medical applications now use empathetic AI for verbal communication, helping to set up mechanisms for engagement and feedback [108,109]. Programs that engage with a user by employing compassionate responses represent a step towards truly embodied AI. Measured psycho-physiological reactions to the immediate environment reveal how physical structures influence human life (through visual information) negatively or positively. Data can be gathered either directly through sensors or indirectly through AI processing physiological signals from the autonomic nervous system [110–112].

By leveraging affective computing and machine learning algorithms, AI systems can infer emotional states without direct feedback from individuals. This capability is particularly valuable in assessing how environmental factors, such as the design of buildings and public spaces, influence people's moods and emotional well-being. AI systems can collect indirect emotional feedback by monitoring behavioral cues and physiological responses. Not only is this method much more accurate than personal surveys because it is unbiased by subjective factors, but it is now used to assess sensory feedback from infants.

Empathetic AI systems can simulate how different environmental designs influence sensory input and neural development in children. For example, AI can model the effects of varying textures, colors, and patterns on a child's attention and learning processes. Analyzing data from developmental psychology and neuroscience, AI can identify which environmental features are most conducive to promoting cognitive functions such as language acquisition, memory, and problem-solving.

The architects' technological but non-adaptive approach contrasts with information and communications technologies that find emotions extremely valuable. Architectural modernism introduced a disengaging design method that generates designs abstractly, which dominates today. Despite the intense feedback and visceral response of the user to the physicality of a building, architects do not acknowledge emotion as entering the process of design and subsequent use [113]. The building industry's successful business model therefore relies upon abstraction and emotional detachment.

6.3. Empathetic Design Uses AI-Empowered Tools

By re-introducing empathy into the design process, AI counteracts emotional numbing. Empathetic (or empathic) large language models (LLMs) are being successfully trained to show empathy when interacting verbally with people through written text [114–116]. Those AI programs prove very useful in education, medical diagnosis, psychotherapy, and related healthcare applications, where they mimic and support the task of human professionals. An analogous process—the visual equivalent for AI-enabled empathetic interaction—could train AI design software that responds to people's emotional expectations and needs.

The convergence of AI-driven emotional analysis with the ability to measure real-time user responses offers new ways to create empathetic environments [117]. Using emotion recognition, AI helps to envision architectural spaces and surfaces that support the users' emotional wellbeing. Large language models enable AI to grasp the nuances of human interactions and to base the design processes on empathy. Human-centered design implements a feedback loop of anticipating, responding to, and testing psycho-physiological effects. By analyzing large datasets from neuroscience and psychology, AI validates the role of living geometry in creating spaces that are attuned to human emotional needs.

New AI-based technology is able to measure people's emotional reaction to buildings both during the design phase (through virtual reality) and after completion (for post-occupancy evaluation). Combining eye-tracking sensors with facial expression analysis via AI gives an emotional map separately from the visual attention map [118,119]. These heatmaps reveal which aspects of a design establish positive-valence emotional engagement. Emotional heatmaps evaluate which portions of an image or physical setting trigger "joy" in the viewer [120], linking living geometry to measured "joy" [121]. Advertising and communication industries use this tool for evaluation, as well as to design computer-user interfaces and workspaces.

Pilot studies applying wearable neural and physiological measurement apparatus indicate how different spaces resonate emotionally with their occupants. Real-time responses to architectural configurations help to identify which spatial features elicit calm, comfort, excitement, or other affective states. Through electroencephalography (EEG), wearable biometric sensors, and eye-tracking technology, researchers and architects are starting to capture quantitative, emotionally relevant feedback that can guide design decisions [122–125]. These tools are laying the foundation of neuro-architecture.

Electroencephalograms (EEGs) can now be performed using a portable, wearable cap. Measurements processed using AI distinguish between the subject's negative and positive-valence reactions [126,127]. When used in combination with visual attention heat maps, these data identify regions of stronger engagement and also distinguish between negative and positive valence. Future architectural diagnosis must rely on a method of clarifying the interaction of arousal and emotion.

Several decades of medical knowledge and the development of artificial intelligence now help to recover previously disregarded design solutions that support health. Traditional design solutions were in large part selected for their emotion-enhancing qualities, but they fell out of favor as looking too "old-fashioned" for a society obsessed with modernity. Architects dropped many adaptive typologies for purely stylistic reasons. AI has broadened the spectrum of design possibilities to embrace style-free elements that nurture and protect future generations.

6.4. Generative AI Identifies Buildings That Cause Headaches

New online tools use generative AI in evaluating 2-D Fourier transforms, which reveal features of the spectral distribution of spatial scales. Like all fractals, living geometry follows a distributed scaling hierarchy that is "scale-free". No scale dominates because some substructure is evident at all magnifications, which in architecture means at all approaches, from far away up to touching the wall. But the monotonous repetition of a single simplistic unit (privileging a single scale) gives rise to headaches. Arnold Wilkins and his collaborators used 2-D Fourier transforms to analyze visual architectural patterns while surveying people's reactions including discomfort, headaches, malaise, and nausea [128–131]. They found that aversive symptoms correlate strongly with departures from scale invariance such as monotonous repetition and a missing range of scales.

Generative AI programs can now perform a 2-D Fourier transform of a building's image uploaded online to discover gaps or imbalances in the spatial frequency distribution. Using this novel and powerful analytical tool predicts the likelihood of visual discomfort. The magnitude spectrum of the image reveals either a power-law distribution characteristic of a fractal or its absence. Distinct periodic elements such as repetitive windows result in spikes at specific spatial frequencies, which show on the graph.

Iconic and even ordinary commercial buildings in 20th Century architecture and later, however, deliberately avoid scale-free design. Until recently, this ubiquitous geometrical feature was accepted as a stylistic choice justified as the privilege of an architect's artistic freedom; in fact, as a basic tenet of modernism. But now the negative-valence consequences of monotonous repetition on human health are exposed. Most important, any reader can easily perform the online Fourier transform analysis as indicated above to diagnose whether a building induces headaches in a user and passer-by.

6.5. ChatGPT as a Source of New Knowledge Relevant to Architecture: Linking Visual Intricacy to Sophisticated Cognitive Capabilities

Concept maps are graphical tools for organizing and representing knowledge through connecting lines and hierarchies. Commercial AI-powered Concept Map Generators point the way to hierarchical multi-scale nested structures that correlate with information processing capabilities [132]. A conceptual mapping of human intelligence onto visual patterns touches upon several fields, including cognitive science, information visualization, and network theory. More complex, denser interconnected networks are generally associated with higher intelligence in which complex cognitive structures establish intricate relationships among data and ideas.

ChatGPT and other equivalent large language models are being used increasingly as a source of easily accessible knowledge. Educational institutions face challenges on how to successfully incorporate ChatGPT in courses, since students are rapidly becoming reliant upon it for interactive learning outside the classroom. This could in fact be the key to architectural reform that would have been impossible even to contemplate previously. If students trust ChatGPT to solve their history and mathematics homework problems, then they should pay attention to the answers it gives to the questions raised by this paper.

The notion that visually complex geometric patterns signify higher "intelligence" is an intriguing conceptual hypothesis rather than a scientifically established fact. Humans do respond favorably to certain degrees of complexity, and hierarchical, well-organized patterns can facilitate cognitive processing. However, empirical research linking these attributes to "intelligence" is currently lacking. For this reason, the author performed a large language model experiment: asking ChatGPT to resolve how cognitive processes might reflect and be reflected in our perception of geometric complexity. When asked to list the geometrical characteristics of visual patterns that correspond by analogy to high versus low intelligence expressed in terms of relationships among components, ChatGPT provided two detailed lists as follows (here combined and edited):

A. ***High-intelligence*****:** Complex structures with nested symmetries, where smaller symmetrical components are hierarchically embedded within larger ones, enhance spatial reasoning and cognitive mapping. Continuous patterns with smooth transitions, enabling the eye to follow lines and shapes effortlessly, maintain attention and foster perceptual integration. Harmonious integration of aesthetically pleasing colors, forms, and textures promote positive emotional responses and engagement. Symmetry facilitates pattern recognition and predicts structure, thus stimulating cognitive processing;

B. ***Low-intelligence*****:** Asymmetrical designs lacking balance and proportion appear random and preclude cognitive engagement. Informationally flat structures without a hierarchical organization of patterns within patterns lead to severely reduced perceptual depth. At one extreme, simple, non-repetitive patterns do not exhibit self-similarity across scales; and at the other, disjointed and fragmented visuals have abrupt changes and discontinuities. Poorly organized elements scattered without meaningful relationships cause confusion and cognitive overload. Isolated elements and incoherent designs without a unifying theme offer little for the brain to recognize.

While this AI experiment does not establish anything, it is an unexpected revelation that resonates with intuitive logic. The above correlation, distilled from the aggregated responses produced by data-driven AI models, startles even those who are skeptical about the approach. Design as practiced in the last several decades would seem to correspond to low-intelligence geometry. The basis for this claim is the disconnect between the complexity of human cognitive needs and the visual environments created by mainstream architectural practice. Geometric simplicity fails to engage the brain's innate preference for complexity and organized patterns, thus paralleling a lower form of cognitive engagement or "intelligence". The intellectual effort required to perceive and mentally process such designs is minimal. Minimalist structures are mathematically trivial in the sense that they are trivially easy to describe.

Large language models had no compunction in establishing the above correlations. Extensive medical data on healing and learning environments are already embedded in the ChatGPT database. Even if architectural academia and practice ignore this corpus of consilient knowledge, it has been incorporated into the future learning mechanism made possible by large language models. Note that the prompt carefully avoided asking about architecture, because of the prevalent but untested opinions on this topic. Instead, the question was about geometry and intelligence.

The above correspondence presented by large language models agrees with imagery-based AI agents that discover the possible neurological mechanism of computation and intelligence [133]. Researchers hypothesize that visuospatial intelligence is learned from visuomotor experience of coherent complex patterns—living geometry—in the real world. Knowledge representation and reasoning mechanisms in AI systems therefore shed light upon cognitive processes, mental representations, and problem-solving ability in people.

7. Discussion: Why Architects Neglect Mechanisms for Intelligence

With rare exceptions, much of what is built today contradicts both biological precedent as well as inanimate natural structures [134]. Buildings, spaces, and surfaces that make up the dominant architectural paradigm—broken or minimalist shapes in raw concrete, plate glass, and exposed steel—depart significantly from living geometry. The far more numerous self-builders follow informal and vernacular construction arising from living geometry, which align more closely with natural informational patterns. Just as recent technology, especially AI, helps to uncover the problems with the geometry of the built environment, those same tools can be implemented to help fix them.

Looking towards institutional fixes for inadequate design, there is an inertia and formidable opposition from both the architectural and design professions and particular segments of society. After World War I, architecture as a discipline lost its epistemic humility. This is an understanding that beliefs, regardless of how strongly held, are susceptible to revision [135]. Therefore, reform must begin with restructuring the educational system, and there is already a worldwide movement to achieve this [136–139]. Classroom dynamics in architecture schools have six intended effects that work against adaptive change because they:

(1) Reinforce reductionistic industrial-minimalist images—labeled "sophisticated"—in the minds of impressionable students [5,6,137,138,140];
(2) Disseminate a made-up narrative whilst the curriculum excludes emotional (or affective) engineering for human–environment interactions [20,21,35,106,141];
(3) Suppress epistemic humility that encourages empathy towards the user and acts as a buffer against confirmation bias [15–17,45,142];
(4) Alienate students from outside learning by dismissing empirical knowledge as insignificant and a hindrance to design creativity [7,11,33,36,143];
(5) Never prepare interested students in scientific literacy to be able to read and comprehend the relevant research literature [144]; and
(6) Isolate students from architectural knowledge derived outside the siloed profession by keeping them busy with design studios [12,13,19,96,145].

It will take time to replace these established tenets of design education with new, adaptive tools because the system was never set up to question either its justification or its teaching method. After accepting inadequate environments from the mainstream profession since the 1920s, it is naïve to hope for spontaneous change. Society has an obligation to close the enormous chasm between what architects are trained to produce, versus what human beings actually need for their health and wellbeing. People must take architecture and design into their own hands, for the good of themselves and their families.

Neglecting the mechanisms for intelligence is a consequence of the dominant architectural system ignoring emotional and sensory feedback from what it produces. Psychophysiological interaction with the built environment is simply of no concern. This paper collected multimodal technologies for discovering and documenting this mechanism and suggested methods of improving human health. However, not only are such technological tools not part of architectural practice, but established training even dulls the body's own neurological responses. The desired goal is to detach people from their surroundings so that those can be evaluated using purely intellectual criteria—that the architectural establishment defines.

The ubiquitous industrial-modernist furniture is judged here to be emotionally hostile to children. Tubular steel and plate glass, exemplified in "design" chairs and tables, are not inviting materials to look at because of their reflective or transparent properties, nor are they attractive to touch. Families the world over unthinkingly buy such furniture without realizing the negative psychological consequences on toddlers navigating their living space. Running into a glass coffee table can result in very serious injuries [146]. Many traditional cultures have large stuffed floor cushions (poufs) and soft ottomans, which are far friendlier when a small child runs into them.

Caring parents should expose their children to exterior structures that embody living geometry and avoid those buildings and urban spaces that violate it (such as recent high-profile art galleries and museums, and "hard" contemporary plazas). Large-scale harmonious architecture is found principally in older, chiefly monumental buildings, which are no longer situated everywhere. A family may have to travel to locate a satisfying architectural experience. Families spend time in commercial spaces for shopping. The informational content is usually rich, with colors, curves, fractal shapes, and a limited number of symmetries. However, shop interiors displaying merchandise, from groceries to clothes to toys, do not show much visual coherence and harmony, which is an essential factor for brain development.

Children benefit from regular exposure to nature in a safe setting. Yet the global situation has changed for the worse during the past several decades. Whereas past generations assumed this right as natural, today's metropolitan regions have cut down vegetation to the point where children have little direct contact with bushes and trees. Because of its minimalistic informational content, a green lawn is no substitute for nature (despite being a favorite of image-based architects). A pocket park can be ruined by building industrial-minimalist benches, lamps, paved footpaths, planters, and sitting walls that negate any positive effect gained from the plants. The unnatural "design" aesthetic works against biophilia, even in the presence of nature.

In many situations, it is impractical and prohibitive to alter the architectural configuration of one's house or working environment; hence, other measures must be implemented. People should train themselves on the characteristics of healing environments and work hard to create those inside their homes using modest means. Significant benefits to children can be accomplished through interior decoration according to emotionally responsive principles, as well as an appropriate choice of furnishings. It is relatively easy to bring plant life indoors, thus introducing living geometry to living spaces.

A client in a position to require an architect should take great care to avoid hiring someone with built-in prejudices because of their education. Can society ask architects who practice a detached conception of the world to produce a more humane design? A much safer course of action is to employ only those professionals trained in traditional building and design techniques. In the USA, the Institute of Classical Architecture and Art (ICAA) is a hub for finding practitioners [147], while the various country chapters of the International Network of Traditional Building, Architecture and Urbanism (INTBAU) serve the same purpose globally [148].

8. Conclusions

This paper gathered the growing body of scientific evidence demonstrating how the geometry of the environment influences cognitive health and intelligence. Studies in environmental psychology and neuroscience confirm that geometrically enriched environments—incorporating fractal patterns, nested symmetries, and spatial hierarchies—enhance cognitive performance, reduce stress, and stimulate neural activity. Conversely, environments characterized by low visual complexity, minimalism, and monotony have been shown to inhibit mental engagement and cognitive development. The findings presented here uncover the need for living geometry in environments that support intelligence, particularly in developmental and educational contexts.

Having no intrinsic self-interest, AI can be focused on diagnosing and discovering optimal design solutions rather than pursuing the abstract forms preferred by mainstream practice. People should become active participants in shaping architecture, helped by AI. The results presented here aim to re-awaken a dulled sensitivity towards healing environments imbued with emotion and life. AI helps in the effort of recovering the natural capabilities of the human body to generate living geometry. Facts contradict one century during which people's natural capacity to judge the environment was numbed, forcing them to adopt disengaging buildings, interiors, and urban spaces.

The potential real-world impact of the research collected and synthesized in this paper is to shape the built environment with a very different "look" in the future. Architectural practice that respects living geometry, and utilizes tools such as AI, will generate buildings and urban spaces that feel more emotionally comfortable than those of today. Integrating AI-driven generative design tools with neuroscience can develop empathetic environments that are optimized for emotional well-being. The designs will recall, but not copy, more traditional ones. At the same time, new buildings that support this program are expected to enhance long-term human health.

Future research is needed to complete and reinforce existing evidence-based data on how the body responds to environmental geometry. Experiments should explore the neurophysiological effects of specific architectural elements, such as fractal scaling, nested symmetries, and tactile patterns, through long-term studies. Further empirical validation using portable technologies—like EEGs, eye-tracking, and heart rate monitors—can provide real-time awareness of user responses. Research into how living geometry influences not just cognitive development but also fertility, mental health, and stress recovery would reveal architecture's biological impacts. Lastly, future educational reforms should incorporate these findings into architectural curricula, training a new generation of evidence-based designers.

Nevertheless, it is difficult to communicate critical scientific knowledge about architecture when the profession itself does not wish to hear about it. People face a dilemma of choosing whom to believe: famous architects and architectural critics who praise today's fashionable buildings, or researchers outside architectural culture who claim that something is seriously wrong? The public usually trusts accepted authority and dismisses criticism seen to be situated on the system's margins. Yet a society that is concerned with its health needs to pay attention to science and not be misled by spectacle.

Funding: This research received no external funding.

Acknowledgments: ChatGPT-4o and ChatGPT-o1 were asked questions whose answers are quoted in the text. I thank Alexandros A. Lavdas for valuable comments and suggestions.

Conflicts of Interest: The author declares no conflicts of interest.

References

1. Hesham, M.K. Borderline in a linear city: Urban living is bringing borderline personality disorder into a crisis via neuroplasticity—An urgent call to action. *Front. Psychiatry* **2024**, *15*, 1524531. [CrossRef]
2. Kellert, S.R.; Heerwagen, J.; Mador, M. *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*; John Wiley: New York, NY, USA, 2008.
3. Joye, Y. Architectural lessons from environmental psychology: The case of biophilic architecture. *Rev. Gen. Psychol.* **2007**, *11*, 305–328. [CrossRef]
4. Salingaros, N.A. The biophilic healing index predicts effects of the built environment on our wellbeing. *J. Biourbanism* **2019**, *8*, 13–34. Available online: http://www.biourbanism.org/the-biophilic-healing-index-predicts-effects-of-the-built-environment-on-our-wellbeing/ (accessed on 26 October 2024).
5. Alexander, C. Lecture by Christopher Alexander at Harvard. Architexturez Imprints: New Delhi, India, 1982. Available online: https://patterns.architexturez.net/doc/az-cf-177389 (accessed on 28 October 2024).
6. Alexander, C. *The Nature of Order, 1: The Phenomenon of Life*; Center for Environmental Structure: Berkeley, CA, USA, 2001.
7. Salingaros, N.A. *A Theory of Architecture*, 2nd ed.; Sustasis Press: Portland, ON, USA, 2014.
8. Salingaros, N.A. How Mathematics Will Save the Built World! Common Edge, 28 January 2019. Available online: http://commonedge.org/how-mathematics-will-save-the-built-world/ (accessed on 28 October 2024).
9. Salingaros, N.A. Symmetry gives meaning to architecture. *Symmetry Cult. Sci.* **2020**, *31*, 231–260. [CrossRef]
10. Salingaros, N.A. Living geometry, AI tools, and Alexander's 15 fundamental properties. *Front. Archit. Res.* 2025, *submitted*.
11. Salingaros, N.A.; Masden, K.G. Architecture: Biological Form and Artificial Intelligence. *Structurist* **2006**, *45/46*, 54–61. Available online: https://patterns.architexturez.net/doc/az-cf-172793 (accessed on 28 October 2024).
12. Seresinhe, C.I.; Preis, T.; Moat, H.S. Using deep learning to quantify the beauty of outdoor places. *R. Soc. Open Sci.* **2017**, *4*, 170170. [CrossRef]
13. Ellard, C. Neuroscience, Wellbeing, and Urban Design: Our Universal Attraction to Vitality. *Psychol. Res. Urban Soc.* **2020**, *3*, 6–17. [CrossRef]
14. Gritzka, S.; MacIntyre, T.; Dörfel, D.; Baker-Blanc, J.; Calogiuri, G. The Effects of Workplace Nature-Based Interventions on the Mental Health and Well-Being of Employees: A Systematic Review. *Front. Psychiatry* **2020**, *11*, 323. [CrossRef]
15. Gaekwad, J.; Sal-Moslehian, A.; Roös, P.B.; Walker, A. A meta-analysis of emotional evidence for the biophilia hypothesis and implications for biophilic design. *Front. Psychol.* **2022**, *13*, 750245. [CrossRef] [PubMed]
16. Coburn, A.; Kardan, O.; Kotabe, H.; Steinberg, S.; Hout, M.; Robbins, A.; MacDonald, J.; Hayn-Leichsenring, G.; Berman, M. Psychological responses to natural patterns in architecture. *J. Environ. Psychol.* **2019**, *62*, 133–145. [CrossRef]
17. Coburn, A.; Weinberger, A.; Chatterjee, A. How architectural design influences emotions, physiology, and behavior. In *The Routledge International Handbook of Neuroaesthetics*; Skov, M., Nadal, M., Eds.; Routledge: Oxfordshire, UK, 2023; Chapter 10; pp. 194–217. [CrossRef]
18. Elbaiuomy, E.; Hegazy, I.; Sheta, S. The impact of architectural spaces' geometric forms and construction materials on the users' brainwaves and consciousness status. *Int. J. Low-Carbon Technol.* **2019**, *14*, 326–334. [CrossRef]
19. Karakas, T.; Yildiz, D. Exploring the influence of the built environment on human experience through a neuroscience approach: A systematic review. *Front. Archit. Res.* **2020**, *9*, 236–247. [CrossRef]
20. Bower, I.; Tucker, R.; Enticott, P.G. Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: A systematic review. *J. Environ. Psychol.* **2019**, *66*, 101344. [CrossRef]
21. St-Jean, P.; Clark, O.G.; Jemtrud, M. A review of the effects of architectural stimuli on human psychology and physiology. *Build. Environ.* **2022**, *219*, 109182. [CrossRef]
22. Biederman, I. Recognition-by-components: A theory of human image understanding. *Psychol. Rev.* **1987**, *94*, 115–147. [CrossRef] [PubMed]
23. Riesenhuber, M.; Poggio, T. Neural mechanisms of object recognition. *Curr. Opin. Neurobiol.* **2002**, *12*, 162–168. [CrossRef] [PubMed]
24. Van der Helm, P.A. *Simplicity in Vision: A Multidisciplinary Account of Perceptual Organization*; Cambridge University Press: Cambridge, UK, 2014.
25. Tuch, A.N.; Bargas-Avila, J.A.; Opwis, K.; Wilhelm, F.H. Visual complexity of websites: Effects on users' experience, physiology, performance, and memory. *Int. J. Hum.-Comput. Stud.* **2009**, *67*, 703–715. [CrossRef]

26. Taylor, R.P. The Potential of Biophilic Fractal Designs to Promote Health and Performance: A Review of Experiments and Applications. *Sustainability* **2021**, *13*, 823. [CrossRef]
27. Martins, M.J.; Fischmeister, F.P.; Puig-Waldmüller, E.; Oh, J.; Geissler, A.; Robinson, S.; Fitch, W.T.; Beisteiner, R. Fractal image perception provides novel insights into hierarchical cognition. *Neuroimage* **2014**, *96*, 300–308. [CrossRef]
28. Fischmeister, F.P.; Martins, M.J.D.; Beisteiner, R.; Fitch, W.T. Self-similarity and Recursion as Default Modes in Human Cognition. *Cortex* **2016**, *97*, 183–201. [CrossRef] [PubMed]
29. Penacchio, O.; Otazu, X.; Wilkins, A.J.; Haigh, S.M. A mechanistic account of visual discomfort. *Front. Neurosci.* **2023**, *17*, 1200661. [CrossRef] [PubMed]
30. Langlois, J.H.; Ritter, J.M.; Roggman, L.A.; Vaughn, L.S. Facial diversity and infant preferences for attractive faces. *Dev. Psychol.* **1991**, *27*, 79–84. [CrossRef]
31. Slater, A.; Von der Schulenburg, C.; Brown, E.; Badenoch, M.; Butterworth, G.; Parsons, S.; Samuels, C. Newborn infants prefer attractive faces. *Infant Behav. Dev.* **1998**, *21*, 345–354. [CrossRef]
32. Baumeister, R.F.; Bratslavsky, E.; Vohs, K.D. Bad is Stronger than Good. *Rev. Gen. Psychol.* **2001**, *5*, 323–370. [CrossRef]
33. Ruggles, D.H. *Beauty, Neuroscience and Architecture: Timeless Patterns and Their Impact on Our Well-Being*; Fibonacci Press: Denver, CO, USA, 2017.
34. Lavdas, A.A.; Salingaros, N.A. Architectural beauty: Developing a measurable and objective scale. *Challenges* **2022**, *13*, 56. [CrossRef]
35. Heatherwick, T. *Humanize: A Maker's Guide to Designing Our Cities*; Scribner Books: New York, NY, USA, 2023.
36. Sussman, A.; Hollander, J.B. *Cognitive Architecture: Designing for How We Respond to the Built Environment*, 2nd ed.; Routledge: Oxfordshire, UK, 2021.
37. Sussman, A.; Ward, J.M. Game-Changing Eye-Tracking Studies Reveal How We Actually See Architecture. Common Edge 2017. Available online: https://commonedge.org/game-changing-eye-tracking-studies-reveal-how-we-actually-see-architecture/ (accessed on 3 November 2024).
38. Salingaros, N.A.; Sussman, A. Biometric pilot-studies reveal the arrangement and shape of windows on a traditional façade to be implicitly "engaging", whereas contemporary façades are not. *Urban Sci.* **2020**, *4*, 26. [CrossRef]
39. Lavdas, A.A.; Salingaros, N.A.; Sussman, A. Visual attention software: A new tool for understanding the 'subliminal' experience of the built environment. *Appl. Sci.* **2021**, *11*, 6197. [CrossRef]
40. Valentine, C. Architectural allostatic overloading: Exploring a connection between architectural form and allostatic overloading. *Int. J. Environ. Res. Public Health* **2023**, *20*, 5637. [CrossRef] [PubMed]
41. Hägerhäll, C.M.; Laike, T.; Küller, M.; Marcheschi, E.; Boydston, C.; Taylor, R.P. Human physiological benefits of viewing nature: EEG responses to exact and statistical fractal patterns. *Nonlinear Dyn. Psychol. Life Sci.* **2015**, *19*, 1. [PubMed]
42. Taylor, R.P.; Spehar, B.; Wise, J.A.; Clifford, C.; Newell, B.R.; Martin, T.P. Perceptual and physiological responses to the visual complexity of Pollock's dripped fractal patterns. *Nonlinear Dyn. Psychol. Life Sci.* **2005**, *9*, 89–114. [PubMed]
43. Taylor, R.P.; Juliani, A.W.; Bies, A.J.; Spehar, B.; Sereno, M.E. The implications of fractal fluency for bioinspired architecture. *J. Biourban.* **2017**, *6*, 23–40. Available online: https://api.semanticscholar.org/CorpusID:85513025 (accessed on 28 October 2024).
44. Valentine, C. The impact of architectural form on physiological stress: A systematic review. *Front. Comput. Sci.* **2024**, *5*, 1237531. [CrossRef]
45. Alexander, C. *The Timeless Way of Building*; Oxford University Press: New York, NY, USA, 1979.
46. Galbraith, D. 15 Housing Projects from Hell. Oobject, 8 May 2009. Available online: https://www.oobject.com/category/15-housing-projects-from-hell/ (accessed on 28 October 2024).
47. Diamond, M.C. Response of the brain to enrichment. *An. Da Acad. Bras. De Ciências* **2001**, *73*, 211–220. [CrossRef] [PubMed]
48. Greenough, W.T.; Black, J.E. Induction of brain structure by experience: Substrates for cognitive development. In *Developmental Behavioral Neuroscience*; Gunnar, M.R., Nelson, C.A., Eds.; Lawrence Erlbaum Associates: Mahwah, NJ, USA, 1992; pp. 155–200.
49. Quartz, S.R.; Sejnowski, T.J. The neural basis of cognitive development: A constructivist manifesto. *Behav. Brain Sci.* **1997**, *20*, 537–556; discussion 556–596. [CrossRef] [PubMed]
50. Rauscher, F.; Hinton, S. The Mozart Effect: Music Listening is Not Music Instruction. *Educ. Psychol.* **2006**, *41*, 233–238. [CrossRef]
51. Saffran, J.R.; Loman, M.M.; Robertson, R.R. Infant memory for musical experiences. *Cognition* **2000**, *77*, B15–B23. [CrossRef] [PubMed]
52. Aresta, M.; Salingaros, N.A. The importance of domestic space in the times of COVID-19. *Challenges* **2021**, *12*, 27. [CrossRef]
53. Lavdas, A.A.; Salingaros, N.A. Can suboptimal visual environments negatively affect children's cognitive development? *Challenges* **2021**, *12*, 28. [CrossRef]
54. Mehaffy, M.; Salingaros, N.A. Intelligence and the Information Environment. Metropolis 2012. Available online: https://patterns.architexturez.net/doc/az-cf-172600 (accessed on 28 October 2024).

55. Salingaros, N.A. Modernist Architecture Melts Our Brains: Findings from Lockdown Suggest Environments Lacking the Complexity of Life May Pose a Threat to Humanity. The Critic (London), 4 September 2021. Available online: https://thecritic.co.uk/modernist-architecture-melts-our-brains/ (accessed on 28 October 2024).
56. Anderson, E.M.; Candy, T.R.; Gold, J.M.; Smith, L.B. An edge-simplicity bias in the visual input to young infants. *Science Advances* **2024**, *10*, eadj8571. [CrossRef]
57. Kiat, J.E.; Luck, S.J.; Beckner, A.G.; Hayes, T.R.; Pomaranski, K.I.; Henderson, J.M.; Oakes, L.M. Linking patterns of infant eye movements to a neural network model of the ventral stream using representational similarity analysis. *Dev. Sci.* **2022**, *25*, e13155. [CrossRef] [PubMed]
58. Sakai, J. How synaptic pruning shapes neural wiring during development and, possibly, in disease. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 28. [CrossRef]
59. Hassabis, D.; Kumaran, D.; Summerfield, C.; Botvinick, M. Neuroscience-Inspired Artificial Intelligence. *Neuron* **2017**, *95*, 245–258. [CrossRef] [PubMed]
60. Ullman, S. Using neuroscience to develop artificial intelligence. *Science* **2019**, *363*, 692–693. [CrossRef]
61. Ren, J.; Xia, F. Brain-inspired Artificial Intelligence: A Comprehensive Review. Arxiv Preprint, 27 August 2024. Available online: https://arxiv.org/html/2408.14811v1 (accessed on 28 October 2024).
62. Coppey, L. What Does AlphaGo vs Lee Sedol Tell Us About the Interaction Between Humans and Intelligent Systems? Medium, 15 March 2018. Available online: https://medium.com/point-nine-news/what-does-alphago-vs-8dadec65aaf (accessed on 28 October 2024).
63. Cangelosi, A.; Schlesinger, M. From Babies to Robots: The Contribution of Developmental Robotics to Developmental Psychology. *Child Dev. Perspect.* **2018**, *12*, 183–188. [CrossRef]
64. Lones, J.; Lewis, M.; Cañamero, L. From Sensorimotor Experiences to Cognitive Development: Investigating the Influence of Experiential Diversity on the Development of an Epigenetic Robot. *Front. Robot. AI* **2016**, *3*, 44. [CrossRef]
65. Zhao, W.; Queralta, J.P.; Westerlund, T. Sim-to-Real Transfer in Deep Reinforcement Learning for Robotics: A Survey. In Proceedings of the 2020 IEEE Symposium Series on Computational Intelligence (SSCI), Canberra, Australia, 1–4 December 2020; pp. 737–744. [CrossRef]
66. Al Rahman, A. Strategies to Mitigate Overfitting in Deep Learning. Linkedin, 20 August 2023. Available online: https://www.linkedin.com/pulse/strategies-mitigate-overfitting-deep-learning-abdullah-al-rahman (accessed on 28 October 2024).
67. Louv, R. *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*; Algonquin Books: Chapel Hill, NC, USA, 2008.
68. Frumkin, H.; Gregory, N.; Bratman, G.N.; Breslow, S.J.; Cochran, B.; Kahn, P.H., Jr.; Lawler, J.J.; Levin, P.S.; Tandon, P.S.; Varanasi, U.; et al. Nature Contact and Human Health: A Research Agenda. *Environ. Health Perspect.* **2019**, *125*, 075001. [CrossRef] [PubMed]
69. Mehaffy, M.; Salingaros, N.A. The Surprisingly Important Role of Symmetry in Healthy Places. Planetizen, 8 March 2021. Available online: https://www.planetizen.com/features/112503-surprisingly-important-role-symmetry-healthy-places (accessed on 28 October 2024).
70. Ernst, J.A. Early Childhood Nature Play: A Needs Assessment of Minnesota Licensed Childcare Providers. *J. Interpret. Res.* **2012**, *17*, 7–24. [CrossRef]
71. Gill, T. The Benefits of Children's Engagement with Nature: A Systematic Literature Review. *Child. Youth Environ.* **2014**, *24*, 10–34. [CrossRef]
72. Khaleghimoghaddam, N.; Bala, H.A.; Özmen, G.; Öztürk, S. Neuroscience and architecture: What does the brain tell to an emotional experience of architecture via a functional MR study? *Front. Archit. Res.* **2022**, *11*, 877–890. [CrossRef]
73. Overdijk, M. Richard Neutra's Therapeutic Architecture. Failed Architecture, 2 November 2015. Available online: https://failedarchitecture.com/richard-neutras-therapeutic-architecture/ (accessed on 3 November 2024).
74. Vivaudou, R. Richard Neutra's Health House: Was It Really Healthy? Issuu, 26 December 2010. Available online: https://issuu.com/dirthouse-photography/docs/neutra_health_house-was_it_really_healthy (accessed on 3 November 2024).
75. Dalí, S. De la beauté terrifiante et comestible de l'architecture Modern Style. *Minotaure* **1933**, *3/4*, 69–74.
76. Nepomnaschy, P.A.; Welch, K.B.; McConnell, D.S.; Low, B.S.; Strassmann, B.I.; England, B.G. Cortisol levels and very early pregnancy loss in humans. *Proc. Natl. Acad. Sci. USA* **2006**, *103*, 3938–3942. [CrossRef] [PubMed]
77. Schrittwieser, J.; Antonoglou, I.; Hubert, T.; Simonyan, K.; Sifre, L.; Schmitt, S.; Guez, A.; Lockhart, E.; Hassabis, D.; Graepel, T.; et al. Mastering Atari, Go, chess and shogi by planning with a learned model. *Nature* **2020**, *588*, 604–609. [CrossRef] [PubMed]
78. LeCun, Y.; Misra, I. Self-Supervised Learning: The Dark Matter of Intelligence. Facebook AI Research 2021. Available online: https://ai.facebook.com/blog/self-supervised-learning-the-dark-matter-of-intelligence/ (accessed on 3 November 2024).
79. Hubel, D.; Wiesel, T. Receptive Fields and Functional Architecture In Two Nonstriate Visual Areas (18 and 19) of The Cat. *J. Neurophysiol.* **1965**, *28*, 229–289. [CrossRef] [PubMed]
80. De Haan, M.; Pascalis, O.; Johnson, M.H. Specialization of neural mechanisms underlying face recognition in human infants. *J. Cogn. Neurosci.* **2002**, *14*, 199–209. [CrossRef] [PubMed]

81. Kouider, S.; Stahlhut, C.; Gelskov, S.V.; Barbosa, L.S.; Dutat, M.; de Gardelle, V.; Christophe, A.; Dehaene, S.; Dehaene-Lambertz, G. A neural marker of perceptual consciousness in infants. *Science* **2013**, *340*, 376–380. [CrossRef]
82. Bhatt, R.S.; Quinn, P.C. Different Approaches to the Study of Early Perceptual Learning. *Infancy* **2011**, *16*, 61–68. [CrossRef]
83. Bommasani, R.; Hudson, D.A.; Adeli, E.; Altman, R.; Arora, S.; von Arx, S.; Bernstein, M.S.; Bohg, J.; Bosselut, A.; Brunskill, E.; et al. On the Opportunities and Risks of Foundation Models. *arXiv* **2022**, arXiv:2108.07258. [CrossRef]
84. Cusack, R.; Ranzato, M.A.; Charvet, C.J. Helpless infants are learning a foundation model. *Trends Cogn. Sci.* **2024**, *28*, 726–738. [CrossRef]
85. Gibson, E.J.; Pick, A.D. *An Ecological Approach to Perceptual Learning and Development*; Oxford University Press: Oxford, UK, 2003.
86. Weinstein, C.S.; David, T.G. *Spaces for Children: The Built Environment and Child Development*; Plenum Press: New York, NY, USA, 1987.
87. Held, R.; Hein, A. Movement-produced stimulation in the development of visually guided behavior. *J. Comp. Physiol. Psychol.* **1963**, *56*, 872–876. [CrossRef] [PubMed]
88. Johnson, S.P. Development of the Visual System. In *Comprehensive Developmental Neuroscience: Neural Circuit Development and Function in the Brain*; Rubenstein, J.L.R., Rakic, P., Eds.; Academic Press: New York, NY, USA, 2013; Volume 3, Chapter 14; pp. 249–269. [CrossRef]
89. Crompton, A. The fractal nature of the everyday environment. *Environ. Plan. B Plan. Des.* **2001**, *28*, 243–254. [CrossRef]
90. Berkley, E.L.; Berkley, R.A. *The Importance of Outdoor Play and Its Impact on Brain Development in Children*; University of Missouri: Kansas City, MO, USA, 2016. Available online: https://seswps.umkc.edu/docs/berkley-items/the-importance-of-outdoor-play-and-its-impact-on-brain-development-in-children.pdf (accessed on 3 November 2024).
91. Day, C.; Midbjer, A. *Environment and Children: Passive Lessons from the Everyday Environment*; Routledge: Oxfordshire, UK, 2007.
92. Kelz, C.; Evans, G.W.; Röderer, K. The restorative effects of redesigning the schoolyard: A multi-methodological, quasi-experimental study in rural Austrian middle schools. *Environ. Behav.* **2015**, *47*, 119–139. [CrossRef]
93. Salingaros, N.A. Why we need to "grasp" our surroundings: Object affordance and prehension in architecture. *J. Archit. Urban.* **2017**, *41*, 163–169. [CrossRef]
94. Koehler, D. More than anything: Advocating for synthetic architectures within large-scale language-image models. *Int. J. Archit. Comput.* **2023**, *21*, 242–255. [CrossRef]
95. Silber, J. *Architecture of the Absurd: How Genius Disfigured a Practical Art*; Quantuck Lane Press: New York, NY, USA, 2007.
96. Curl, J.S. *Making Dystopia: The Strange Rise and Survival of Architectural Barbarism*; Oxford University Press: Oxford, UK, 2018.
97. Gorichanaz, T.; Lavdas, A.A.; Mehaffy, M.W.; Salingaros, N.A. The Impacts of Online Experience on Health and Well-Being: The Overlooked Aesthetic Dimension. *Virtual Worlds* **2023**, *2*, 243–266. [CrossRef]
98. Lavdas, A.A.; Mehaffy, M.; Salingaros, N.A. AI, the Beauty of Places, and the Metaverse: Beyond Geometrical Fundamentalism. *Archit. Intell.* **2023**, *2*, 8. [CrossRef]
99. Salingaros, N.A. Architecture's Abysmal Ignorance. Artificial Intelligence Reveals What Experts Deny. The Critic (London), 24 November 2022. Available online: https://thecritic.co.uk/architectures-abysmal-ignorance/ (accessed on 28 October 2024).
100. Rennix, A.; Robinson, N.J. Why You Hate Contemporary Architecture. Current Affairs, 31 October 2017. Available online: https://www.currentaffairs.org/2017/10/why-you-hate-contemporary-architecture (accessed on 3 November 2024).
101. Robinson, N.J. When Is the Revolution in Architecture Coming? Current Affairs, 15 April 2021. Available online: https://www.currentaffairs.org/2021/04/when-is-the-revolution-in-architecture-coming (accessed on 3 November 2024).
102. Perez, C.E. *Artificial Intuition*; Intuition Machine: Houston, TX, USA, 2018.
103. Perez, C.E. *Artificial Empathy*; Intuition Machine: Houston, TX, USA, 2023.
104. Khare, S.M.; Blanes-Vidal, V.; Nadimi, E.S.; Acharya, U.R. Emotion recognition and artificial intelligence: A systematic review (2014–2023) and research recommendations. *Inf. Fusion* **2024**, *102*, 102019. [CrossRef]
105. Li, Y.; Chan, J.; Peko, G.; Sundaram, D. An explanation framework and method for AI-based text emotion analysis and visualisation. *Decis. Support Syst.* **2024**, *178*, 114121. [CrossRef]
106. López, Ó.; Murillo, C.; González, A. Systematic Literature Reviews in Kansei Engineering for Product Design—A Comparative Study from 1995 to 2020. *Sensors* **2021**, *21*, 6532. [CrossRef] [PubMed]
107. Ren, H.; Shi, M.; Zhang, J. Research Contents, Methods and Prospects of Emotional Architecture Based on a Systematic Literature Review. *Buildings* **2024**, *14*, 997. [CrossRef]
108. Paolo, G.; Gonzalez-Billandon, J.; Kégl, B. Position: A Call for Embodied AI. In Proceedings of the 41st International Conference on Machine Learning, Vienna, Austria, 21–27 July 2024; Volume 235, pp. 1–16. Available online: https://openreview.net/pdf?id=e5admkWKgV (accessed on 3 November 2024).
109. Morrow, E.; Zidaru, T.; Ross, F.; Mason, C.; Patel, K.D.; Ream, M.; Stockley, R. Artificial intelligence technologies and compassion in healthcare: A systematic scoping review. *Front Psychol.* **2023**, *13*, 971044. [CrossRef] [PubMed]
110. Lisetti, C.L.; Nasoz, F. Using Noninvasive Wearable Computers to Recognize Human Emotions from Physiological Signals. *EURASIP J. Adv. Signal Process.* **2004**, *2004*, 929414. [CrossRef]

111. Gloor, P. *Happymeter*; Center for Collective Intelligence, MIT: Cambridge, MA, USA, 2022. Available online: https://www.happimeter.org (accessed on 28 October 2024).
112. Ramm, T.M.; Werwie, M.; Otto, T.; Gloor, P.A.; Salingaros, N.A. Artificial Intelligence Evaluates How Humans Connect to the Built Environment: A Pilot Study of Two Experiments in Biophilia. *Sustainability* **2024**, *16*, 868. [CrossRef]
113. Kaur, S.; Jain, B.; Kaur, G.; Malik, M.; Chaudhary, A.; Rewliya, V. Space and Emotion. *Int. J. Soc. Sci. Econ. Res.* **2021**, *6*, 1910–1922. [CrossRef]
114. Koranteng, E.; Rao, A.; Flores, E.; Lev, M.; Landman, A.; Dreyer, K.; Succi, M. Empathy and Equity: Key Considerations for Large Language Model Adoption in Health Care. *JMIR Med. Educ.* **2023**, *28*, e51199. [CrossRef]
115. Lee, Y.K.; Suh, J.; Zhan, H.; Li, J.J.; Ong, D.C. Large Language Models Produce Responses Perceived to be Empathic. *arXiv* **2024**, arXiv:2403.18148v1. [CrossRef]
116. Tu, T.; Palepu, A.; Schaekermann, M.; Saab, K.; Freyberg, J.; Tanno, R.; Wang, A.; Li, B.; Amin, M.; Tomasev, N.; et al. Towards Conversational Diagnostic AI. *arXiv* **2024**, arXiv:2401.05654. [CrossRef]
117. AI Front Desk, Empathy in Every Interaction: AI's Consistent Emotional Intelligence. AI Front Desk 2024. Available online: https://www.myaifrontdesk.com/blogs/empathy-in-every-interaction-ai-s-consistent-emotional-intelligence (accessed on 15 September 2024).
118. Lavdas, A.A. Eye-Tracking Applications in Architecture and Design. *Encyclopedia* **2024**, *4*, 1312–1323. [CrossRef]
119. Lavdas, A.A.; Sussman, A. Applications of Biometrics in Architectural and Environmental Design. In *Environmental Neuroscience*; Kühn, S., Ed.; Springer: Cham, Switzerland, 2024; pp. 227–254. [CrossRef]
120. Wang, R. Empathetic Gazes–Introduction to Emotional Heatmaps in iMotions. iMotions, 15 August 2023. Available online: https://imotions.com/blog/learning/product-news/empathetic-gazes-introduction-to-emotional-heatmaps-in-imotions/ (accessed on 28 October 2024).
121. Sussman, A.; Sekely, A.C. The Big Reveal: How Adding Art Changes the Office. Genetics of Design, 21 August 2024. Available online: https://geneticsofdesign.com/2024/08/21/the-big-reveal-how-adding-art-changes-the-office/ (accessed on 21 August 2024).
122. Iqbal, T.; Simpkin, A.J.; Roshan, D.; Glynn, N.; Killilea, J.; Walsh, J.; Molloy, G.; Ganly, S.; Ryman, H.; Coen, E.; et al. Stress Monitoring Using Wearable Sensors: A Pilot Study and Stress-Predict Dataset. *Sensors* **2022**, *22*, 8135. [CrossRef] [PubMed]
123. Coburn, A.; Vartanian, O.; Kenett, Y.N.; Nadal, M.; Hartung, F.; Hayn-Leichsenring, G.; Navarrete, G.; González-Mora, J.L.; Chatterjee, A. Psychological and neural responses to architectural interiors. *Cortex* **2020**, *126*, 217–241. [CrossRef]
124. Banaei, M.; Hatami, J.; Yazdanfar, A.; Gramann, K. Walking through Architectural Spaces: The Impact of Interior Forms on Human Brain Dynamics. *Front. Hum. Neurosci.* **2017**, *11*, 477. [CrossRef]
125. Higuera-Trujillo, J.L.; Llinares, C.; Macagno, E. The Cognitive-Emotional Design and Study of Architectural Space: A Scoping Review of Neuroarchitecture and Its Precursor Approaches. *Sensors* **2021**, *21*, 2193. [CrossRef] [PubMed]
126. Apicella, A.; Arpaia, P.; Mastrati, G.; Moccaldi, N. EEG-based detection of emotional valence towards a reproducible measurement of emotions. *Sci. Rep.* **2021**, *11*, 21615. [CrossRef]
127. Galvão, F.; Alarcão, S.M.; Fonseca, M.J. Predicting Exact Valence and Arousal Values from EEG. *Sensors* **2021**, *21*, 3414. [CrossRef]
128. Le, A.T.D.; Payne, J.; Clarke, C.; Kelly, M.A.; Prudenziati, F.; Armsby, E.; Penacchio, O.; Wilkins, A.J. Discomfort from urban scenes: Metabolic consequences. *Landsc. Urban Plan.* **2017**, *160*, 61–68. [CrossRef]
129. Penacchio, O.; Wilkins, A.J. Visual discomfort and the spatial distribution of Fourier energy. *Vis. Res.* **2015**, *108*, 1–7. [CrossRef]
130. Wilkins, A.J. Looking at Buildings Can Actually Give People Headaches. Conversation, 5 July 2018. Available online: https://www.cnn.com/style/article/why-looking-at-buildings-can-give-people-headaches/index.html (accessed on 13 August 2024).
131. Wilkins, A.J.; Penacchio, O.; Leonards, U. The built environment and its patterns: A view from the vision sciences. *J. Sustain. Des. Appl. Res. Innov. Eng. Built Environ.* **2018**, *6*, 42–48. [CrossRef]
132. Interaction Design Foundation. Concept Maps. Interaction Design Foundation, 16 June 2016. Available online: https://www.interaction-design.org/literature/topics/concept-maps (accessed on 28 October 2024).
133. Kunda, M. AI, visual imagery, and a case study on the challenges posed by human intelligence tests. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 29390–29397. [CrossRef]
134. Soules, M. *Icebergs, Zombies, and the Ultra Thin. Architecture and Capitalism in the Twenty-First Century*; Princeton Architectural Press: New York, NY, USA, 2021.
135. Singhal, D. Rethinking Business School Education: A Call for Epistemic Humility Through Reflexivity. Global Business School Network, 10 June 2024. Available online: https://gbsn.org/rethinking-business-school-education-a-call-for-epistemic-humility-through-reflexivity/ (accessed on 3 November 2024).
136. Bashier, F. Reflections on architectural design education: The return of rationalism in the studio. *Front. Archit. Res.* **2014**, *3*, 424–430. [CrossRef]
137. Tzonis, A. Architectural education at the crossroads. *Front. Archit. Res.* **2014**, *3*, 76–78. [CrossRef]

138. Buday, R. The Confused and Impoverished State of Architectural Research. Common Edge, 27 July 2017. Available online: https://commonedge.org/the-confused-and-impoverished-state-of-architectural-research/ (accessed on 28 October 2024).
139. Aumjaud, S.; Allam, Z. Decolonising the architectural education narrative will render more inclusive and culturally appropriate design solutions. *New Des. Ideas* **2020**, *4*, 58–60. Available online: http://jomardpublishing.com/UploadFiles/Files/journals/NDI/V4N1/Aumjaud%20and%20Allam.pdf (accessed on 28 October 2024).
140. Salingaros, N.A. What Architectural Education Does to Would-Be Architects, Common Edge, 8 June 2017. Available online: http://commonedge.org/what-architectural-education-does-to-would-be-architects/ (accessed on 28 October 2024).
141. Heatherwick, T.; Israel, M. Responding to the Built Environment: An Emotional Interaction. The Articulate Foundation, 2024. Available online: https://articulateshow.org/guides/responding-to-the-built-environment-an-emotional-interaction/ (accessed on 3 November 2024).
142. Nozzi, D. Modernist Architecture Is a Failed Paradigm Ruining Our World. Dom's Plan B Blog, 19April 2017. Available online: https://domz60.wordpress.com/2017/04/19/modernist-architecture-is-a-failed-paradigm-ruining-our-world/ (accessed on 3 November 2024).
143. Mitrović, B. *Architectural Principles in the Age of Fraud*; Oro Editions: Novato, CA, USA, 2022.
144. Pedersen, M.C.; Orfield, S.J. A Top Building Researcher Asks: Why Is Architecture Afraid of Science? Common Edge, 24 September 2017. Available online: https://commonedge.org/a-top-building-researcher-asks-why-is-architecture-afraid-of-science/ (accessed on 3 November 2024).
145. Salingaros, N.A. Architectural Knowledge: Lacking a Knowledge System, the Profession Rejects Healing Environments That Promote Health and Well-being. *New Des. Ideas* **2024**, *8*, 261–299. [CrossRef]
146. Tortorello, M. With Kids and Coffee Tables, It's Trip, Fall, Ouch. The New York Times, 29 December 2010. Available online: https://www.nytimes.com/2010/12/30/garden/30tables.html (accessed on 3 November 2024).
147. Institute of Classical Architecture and Art. Available online: https://www.classicist.org/about/ (accessed on 3 November 2024).
148. INTBAU Global Network, London, UK. Available online: https://www.intbau.org (accessed on 3 November 2024).