Review

Not peer-reviewed version

How Architecture Builds Intelligence: Lessons From AI

Nikos A Salingaros *

Posted Date: 19 November 2024

doi: 10.20944/preprints202411.1342.v1

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

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 a minimalist environment that contradicts 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. Results from the way AI software works, together with mobile robotics and neuroscience back up this conclusion. Human intelligence arose as a response to information from the natural environment consisting of bushes, rocks, trees, and animals including other humans. Geometrical features in the ancestral setting shaped neural circuits that determine cognition. Human neurophysiology has worked well in abstract thinking to develop mathematics, science, and technology. However, the contemporary built environment consisting of raw concrete, plate glass, and exposed steel sharply contrasts with natural geometries. It appears that traditional and vernacular architectures are appropriate for life, while new buildings and urban spaces will adapt to human biology and be better for raising children only if they follow living geometry.

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

1. Introduction

1.1. Using Interactive Technologies to Better Understand Adaptive Design

Applying AI technologies — affective computing, empathetic AI, and machine learning — as a novel approach in architecture re-introduces emotion and engagement into design. Portable technologies like wearable electroencep halograms (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, 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 the shortcomings of modern architectural practices.

The public reads about promising applications of new technologies, and especially those that involve AI, to architecture. 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

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 November 2024 doi:10.20944/preprints202411.1342.v1

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.

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

The human body evolved to engage with its environment through a multi-channel information field. This 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 all the following properties together:

(i) **fractal scaling** (structural details present at every magnification, and similar components at different scales);

(ii) **nested symmetries** (multiple plane symmetries such as bilateral reflectional symmetries combined with rotational and translational symmetries supporting each other); and

(iii) **large-scale harmony** (achieved through alignment, similarity, ordering, and symmetry at a distance).

The concept of living geometry is described in detail elsewhere [1–6]. An abstract composition containing these features 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.

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. Biophilia denotes the instinctive human attraction to living forms, which also provides a mechanism for healing [7–12]. Visual connection occurs through 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 signal [13–18].

For example, viewing fractal structures is associated with minimal cognitive load (the phenomenon of "fractal fluency" [19]), as assessed by functional imaging of the brain [20,21], whereas the opposite is true for viewing parallel stripes [22] (a single-scale visual that causes headaches). 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 [23,24].

This capability was essential in adapting humans to social interactions through interpretating 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

 doi:10.20944/preprints202411.1342.v1

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 [25]). For this reason, one building that repels us will cancel out several nearby buildings that attract us [26,27].

1.3. Buildings and cities that violate living geometry

The present work updates an earlier investigation on the relationship between architecture and the principal characteristics of organisms [[28]]. 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, and (3) interacts with its environment dynamically (4, 5, 6, 7). The interaction mechanisms gave rise to intelligence, hence offer templates for analyzing parallels with AI.

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, and ignore human psycho-physiological needs [29]. 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, creating boredom, or hostile and generate alarm in the observer [30–34]. This recent discovery relies upon data gathered by tools developed for the advertising and medical fields.

Opposing today's prestigious buildings, millennia of human construction do in fact follow living geometry [35]. 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 system tries to erase informal buildings and substitute them with social housing schemes in the industrial-modernist style [36].

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 answer this question.

The argument outlined above implies that adults are expected to feel continuous anxiety and stress from inhabiting non-living geometries. This controversial claim is serious enough, yet its consequences are nothing compared to the damage those 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 inflict damage on our children. Interactive technologies can now be used to verify this assertion.

2. Outline of This Paper

Experiments 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.

"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 "symmetry-deficit disorder" (Section 3.4). Training AI programs to beat people at board games occurred by applying insights from human learning to train the software, yet this lesson has not been applied to improve children's environments. Spaces are not designed for children 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 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. Section 4 investigates the parallels between training AI programs and the process of self-learning in infants. This analogy underlines the need for raising a child in a harmonious informational environment containing complex yet ordered components.

Section 5 argues for implementing emotion and feedback in design. Applying emotional engineering to architecture follows its highly successful applications in medicine and other disciplines (Section 5.1). 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 5.2). Generative AI can now perform a 2-D Fourier transform of a visual online, which reveals the scale distribution creating an unconscious reaction. Departures from a fractal type of scale distribution (known as "scale-free") cause visual distress and headaches (Section 5.3). 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 5.4). Focusing on design that adapts to user emotions contrasts with the first applications of AI to design, which so far generate visually-impressive artistic forms but do not test for their psycho-physiological impact (Section 5.5).

Section 6 summarizes facts known about the adaptivity of space to human use, especially the needs of children, by subdividing the main space into smaller subspaces. 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 7 argues against the dominant industrial-modernist architecture because it departs from biological and natural structure. Applying AI validates traditional architectures that achieved adaptation intuitively.

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. Section 7 concludes with a useful list of points needing reform in architecture schools, which prevent young architects from learning about healing environments.

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. In the aural domain, musical enrichment is believed to help children's cognitive, emotional, linguistic, and social development [37,38]. 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 [39–42]. 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 [43,44]. 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.

Exposure to detailed visuals from an early age helps wire the brain for complex processing. This neural development is crucial for higher-order cognitive functions, such as analytical thinking and problem-solving. The complexity of perceived patterns in the environment contributes to shape cortical circuit structure and function [45–47]. It is necessary to provide engaging and sufficiently complex static information for the baby to focus upon over time. The optimal visual environment will start with bold black-and-white figures, then progress into more intricate detail as the baby grows.

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 [48].

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.

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 [49–51]. 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; with a paradigm-shifting win over the world champion Lee Sedol on March 2016 [52].

In an analogous application, developmental (or epigenetic) robotics construct an embodied cognitive system that learns through interactions with the world, copying child development [53]. 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 [54].

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 [55]. This effect of being unable to function with new data is known as "overfitting". An

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 November 2024 doi:10.20944/preprints202411.1342.v1

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 [56].

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.

3.4. Preventing Symmetry-Deficit Disorder

From 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 [57,58]. 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 [59]. A setting lacking living geometry in artificial structures proves to be inadequate 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 [60]. 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 [61,62]. Yet our society 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 shaping environments that 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.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 November 2024 doi:10.20944/preprints202411.1342.v1

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 fabricates positive neurological effects from favored buildings [63,64].

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 fundamental human needs like 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.

It is in society's interest to ask what geometrical factors define an optimal setting for conception and childbearing. 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 conditions of environmental influence are 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.

4. Applying AI Techniques of Learning to Understand Intelligence

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

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 November 2024 doi:10.20944/preprints202411.1342.v1

The AlphaGo software mentioned earlier, 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. MuZero uses reinforcement learning algorithms to enable planning, and learns entirely through self-play [65].

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 [66]. 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. In both contexts, 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" [67], 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 from a rich and continuous informational input from its environment. A recent breakthrough was to recognize that the process of self-supervised learning from the environment is entirely analogous to self-supervised learning that develops foundational models in machine learning [68].

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. New AI Tools for Assessing Adaptive Environments

5.1. Getting indirect EMOTIONAL Feedback

AI has achieved a breakthrough in utility by trying to incorporate emotion into its algorithms [69,70]. 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 [71,72]. Ironically, the way to re-introduce emotions into design is through interactive technologies and sensors, since an adult's conscious responses 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 [73,74]. Medical applications now use empathetic AI for verbal communication, helping set up mechanisms for engagement and feedback [75,76]. The analogous application for visual interactions is still being developed. 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 [77–79].

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.

Architectural modernism introduced the disengaging design method that generates designs abstractly, which dominates today. Despite the intense feedback and visceral response by the user to the physicality of a building, architects do not acknowledge emotion as entering the process of design and subsequent use [80]. The building industry's successful business model relies upon abstraction and emotional detachment. Therefore, the architects' technological but non-adaptive approach contrasts with information and communications technologies that find emotions extremely valuable.

5.2. 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 [81–83]. 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 [84]. 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 physio-psychological 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 [85,86]. 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 [87]., linking living geometry to measured "joy" [88]. Advertising and communication industries use this tool for evaluation, as well as to design computer-user interfaces and workspaces.

In a separate and complimentary development, 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 [89,90]. 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 life: they fell out of favor as looking too "old-fashioned". AI has broadened the spectrum of design possibilities to embrace elements that nurture and protect future generations through designing for the needs of children.

5.3. 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 substructure is evident at all magnifications, which in architecture means at all approaches, from far 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 [91–94]. 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.

Iconic and even ordinary commercial buildings in 20th Century architecture and later, however, deliberately avoid scale-free design. Up 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 analysis as indicated above to diagnose whether a building induces headaches in a user and passer-by.

5.4. ChatGPT as a Convenient Source of Knowledge

This paper collects and synthesizes architectural knowledge relevant to learning that comes from outside the official discipline. Arguing that child development needs are not met by mainstream architecture, an alternative geometrical setting is described. Later, it will be pointed out that dominant architectural culture does not care about this, as the system is interested only in isolated pieces of information that bolster favored visual styles. The situation requires a massive effort at public education to make people aware of what is going on, and to realize what is at stake.

Nevertheless, it is difficult to communicate critical scientific knowledge about architecture when the profession does not wish to hear about it. People face a dilemma of whom to believe: famous architects and architectural critics who praise today's fashionable buildings; or individuals outside architectural culture who claim that something is seriously wrong? The public usually trusts accepted authority and dismisses analysts seen to be situated on the system's margins.

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.

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.

 doi:10.20944/preprints202411.1342.v1

B. ***Low-intelligence*****:** Asymmetrical designs lacking balance and proportion appear random and preclude cognitive engagement. 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.

These responses summarize the results of this paper succinctly. Design as practiced in the last several decades corresponds to low-intelligence geometry. 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 unsupported opinions on this topic. Instead, the question was about geometry and intelligence.

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 [95]. 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.

The above correspondence presented by large-language models agrees with imagery-based AI agents that discover the possible neurological mechanism of computation and intelligence [96]. 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.

5.5. 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 [97]. Using continuous feedback during the design process could be called "cybernetic design". 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 [98,99]. 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. Most of those promises to revolutionize the field remain on a superficial level. Contemporary architects co-opt AI-assisted design to generate buildings as sculptural forms, prioritizing artistic expression above occupant needs [100,101]. Individuals coming from dominant architectural culture simply adopt AI to create visually-compelling abstractions that align with established industrial-modernist aesthetics. They harness the power of AI to promote what they already practice, but not allow AI to question the adaptation of a design [102].

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 [103,104]. Instead of using AI to adapt and innovate, this becomes an exercise in aesthetic and intellectual conformity.

6. 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 [105]. Those play spaces are characterized as "cozy" seen from the child's perspective and may sometimes define a semi-enclosed child "sanctuary space" [106]. Such affordances enable children to develop spatial awareness and motor skills.

Complex interior spaces that combine a variety of connected spaces of different sizes represent a fractal subdivision [107]. 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 [108]. A variety of connected, complex spaces scaled to a child's size is essential for providing diverse play opportunities that support different developmental areas like physical movement, 3-D problem solving, and spatial awareness.

Affordances are the potential actions or interactions that an environment offers [109]. Traditional architectural elements like 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. Spaces that lack nooks, crannies, 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 size — 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, causing cognitive dissonance.

The 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 like 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.

7. Discussion

With rare exceptions, much of what is built today contradicts both biological precedent as well as inanimate natural structures [110]. 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 aligns more closely with natural informational patterns. People will wish to know what to do to improve their current situation. 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.

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 [111]; while the various country chapters of the International Network of Traditional Building, Architecture and Urbanism (INTBAU) serve the same purpose globally [112].

 doi:10.20944/preprints202411.1342.v1

In many situations, it is impractical and prohibitive to alter the architectural configuration, 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 the appropriate choice of furnishings. It is relatively easy to bring in plant life indoors, thus introducing living geometry to living spaces.

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 be very serious [113]. Many traditional cultures have large stuffed floor cushions (poufs) and soft ottomans, which are far friendlier when a small child runs into them.

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 no 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). And 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.

Caring parents should expose their children to exterior structures that embody living geometry and avoid those buildings and urban spaces that violate it. Today's families in the developed world spend much time in commercial spaces of shopping. The informational content is usually rich, with colors, curves, fractal shapes, and a limited number of symmetries. But 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. 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.

Looking towards more institutional fixes for hostile design, there is formidable inertia and 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. That is an understanding that beliefs, regardless of how strongly held, are susceptible to revision [114]. Therefore, reform has to begin with restructuring the educational system [115–118]. Classroom dynamics in architecture schools have six intended effects that work against adaptative change:

(1) they reinforce reductionistic industrial-minimalist images — labeled "sophisticated" — in the minds of impressionable students [119],

(2) disseminate a made-up narrative whilst the curriculum excludes emotional (or affective) engineering for human-environment interactions [120],

(3) suppress epistemic humility that acts as a buffer against confirmation bias and encourages empathy towards the user [121],

(4) alienate students from outside learning by dismissing empirical knowledge as insignificant and a hinderance to design creativity [122],

(5) never prepare interested students in scientific literacy to be able to read and comprehend the relevant research literature [123], and

(6) isolate students from architectural knowledge derived outside the siloed profession by keeping them busy with design studios [124].

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 its justification or method. After accepting inadequate environments from the mainstream profession ever 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. The lesson to be drawn from this discussion is that people must take architecture and design into their own hands, for the good of themselves and their family.

8. Conclusions

This paper presented scientific evidence that questions the suitability of the dominant architectural aesthetic for raising children. The architecture discipline so far appears uninterested in this assertion, perhaps because the data come from outside a siloed profession. Architectural academics, who are expected to write about famous architects and buildings, have never been trained to conduct research or process scientific results. Many architecture professors come from design backgrounds with no exposure to science. People would assume somebody to be responsible for implementing necessary changes, but it is unclear who — if anyone — is filling that role.

As it has no intrinsic self-interest, AI can be focused on optimizing design solutions rather than pursuing the abstract forms preferred by mainstream practice. People should become active participants in shaping architecture. 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 an interpretation of the world that promotes disengaging buildings, interiors, and urban spaces.

Funding: This research received no external funding.

Acknowledgments: I thank Alexandros A. Lavdas for valuable comments and suggestions.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Alexander, C. Lecture by Christopher Alexander at Harvard, 1982. *Architexturez Imprints*: New Delhi, India. Available online: https://patterns.architexturez.net/doc/az-cf-177389 (accessed on 28 October 2024).
2. Alexander, C. *The Nature of Order, 1: The Phenomenon of Life*. Center for Environmental Structure: Berkeley, CA, USA, 2001.
3. Salingaros, N. A. *A Theory of Architecture*, 2nd edition. Sustasis Press: Portland, Oregon, USA, 2014.
4. 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).
5. Salingaros, N. A. Symmetry gives meaning to architecture. *Symmetry Cult. Sci.*, 2020, 31, 231–260. https://doi.org/10.26830/symmetry_2020_3_231
6. Salingaros, N. A. AI, living geometry, and Alexander's 15 fundamental properties, *Frontiers of Architectural Research*, 2024, submitted.
7. Kellert, S. R.; Heerwagen, J.; Mador, M. *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*. John Wiley: New York, USA, 2008.
8. Joye, Y. Architectural lessons from environmental psychology: The case of biophilic architecture, *Review of General Psychology*, 2007, 11(4), 305–328. https://doi.org/10.1037/1089-2680.11.4.305
9. Salingaros, N.A. The biophilic healing index predicts effects of the built environmenton our wellbeing. *Journal Biourbanism*, 2019, 8, 13–34. http://www.biourbanism.org/the-biophilic-healing-index-predicts-effects-of-the-built-environment-on-our-wellbeing/ (accessed on 26 October 2024).
10. Seresinhe, C. I.; Preis, T.; Moat, H. S. Using deep learning to quantify the beauty of outdoor places. *Royal Soc. Open Sci.*, 2017, 4, 170170. https://doi.org/10.1098/rsos.170170 (accessed on 28 October 2024).
11. Ellard, C. Neuroscience, Wellbeing, and Urban Design: Our Universal Attraction to Vitality. *Psychological Research on Urban Society*, 2020, 3(1), 6–17. Doi: 10.7454/proust.v3i1.81
12. 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. https://doi.org/10.3389/fpsyg.2022.750245

13. 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, *Journal of Environmental Psychology*, 2019, 62, 133–145. https://doi.org/10.1016/j.jenvp.2019.02.007 accessed on 28 October 2024).
14. Coburn, A.; Weinberger, A.; Chatterjee, A. How architectural design influences emotions, physiology, and behavior. Chapter 10 in: M. Skov and M. Nadal (Eds.), *The Routledge international handbook of neuroaesthetics*, Routledge: Oxfordshire, UK, 2023, 194–217. https://doi.org/10.4324/9781003008675 (accessed on 28 October 2024).
15. Elbaiuomy, E.; Hegazy, I.; Sheta, S. The impact of architectural spaces' geometric forms and construction materials on the users' brainwaves and consciousness status. *International Journal of Low-Carbon Technologies*, 2019, 14(3), 326–334. https://doi.org/10.1093/ijlct/ctx018 (accessed on 28 October 2024).
16. Karakas, T.; Yildiz, D. Exploring the influence of the built environment on human experience through a neuroscience approach: A systematic review, *Frontiers of Architectural Research*, 2020, 9(1), 236–247. https://doi.org/10.1016/j.foar.2019.10.005 (accessed on 28 October 2024).
17. Bower, I.; Tucker, R.; Enticott, P. G. Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: A systematic review. *Journal of Environmental Psychology*, 2019, 66, 101344. https://doi.org/10.1016/j.jenvp.2019.101344
18. St-Jean, P.; Clark, O. G.; Jemtrud, M. A review of the effects of architectural stimuli on human psychology and physiology. *Building and Environment*, 2022, 219, 109182. https://doi.org/10.1016/j.buildenv.2022.109182 (accessed on 28 October 2024).
19. Taylor, R.P. The Potential of Biophilic Fractal Designs to Promote Health and Performance: A Review of Experiments and Applications. *Sustainability* 2021, 13, 823. https://doi.org/10.3390/su13020823
20. 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. https://doi.org/10.1016/j.neuroimage.2014.03.064
21. 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. https://doi.org/10.1016/j.cortex.2016.08.016
22. Penacchio, O; Otazu, X; Wilkins, A.J.; Haigh, S.M. A mechanistic account of visual discomfort. *Front. Neurosci.* 2023, 17, 1200661 https://doi.org/10.3389/fnins.2023.1200661
23. Langlois, J. H.; Ritter, J. M.; Roggman, L. A.; Vaughn, L. S. Facial diversity and infant preferences for attractive faces. *Developmental Psychology, 27*(1), 79–84, 1991. https://doi.org/10.1037/0012-1649.27.1.79
24. Slater, A.; Von der Schulenburg, C.; Brown, E.; Badenoch, M.; Butterworth, G.; Parsons, S.; Samuels, C. Newborn infants prefer attractive faces. *Infant Behavior and Development*, 21(2), 1998, Pages 345–354. https://doi.org/10.1016/S0163-6383(98)90011-X
25. Baumeister, R. F.; Bratslavsky, E.; Vohs, K. D. Bad is Stronger than Good. *Review of General Psychology*, 2001, 5(4), 323–370. https://doi.org/10.1037/1089-2680.5.4.323
26. Ruggles, D. H. *Beauty, Neuroscience and Architecture: Timeless Patterns and Their Impact on Our Well-Being*. Fibonacci Press: Denver, USA, 2017.
27. Lavdas, A. A.; Salingaros, N. A. Architectural beauty: Developing a measurable and objective scale. *Challenges*, 2022, 13(2), 56. https://doi.org/10.3390/challe13020056
28. Salingaros, N. A.; Masden, K. G. Architecture: Biological Form and Artificial Intelligence, *The Structurist*, 45/46, 2006, 54–61. https://patterns.architexturez.net/doc/az-cf-172793 (accessed on 28 October 2024).
29. Heatherwick, T. *Humanize: A Maker's Guide to Designing Our Cities*. Scribner Books: New York, USA, 2023.
30. Sussman, A.; Hollander, J. B. *Cognitive Architecture: Designing for How We Respond to the Built Environment* (2nd ed.). Routledge: Oxfordshire, UK, 2021.
31. Sussman, A.; Ward, J. M. Game-changing eye-tracking studies reveal how we actually see architecture. *Common Edge*, 2017. https://commonedge.org/game-changing-eye-tracking-studies-reveal-how-we-actually-see-architecture/ (accessed on 3 November 2024).
32. 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 Science*, 2020, 4(2), 26. https://doi.org/10.3390/urbansci4020026
33. Lavdas, A. A.; Salingaros, N. A.; Sussman, A. Visual attention software: A new tool for understanding the 'subliminal' experience of the built environment. *Applied Sciences*, 2021, 11(13), 6197. https://doi.org/10.3390/app11136197

34. Valentine, C. Architectural allostatic overloading: Exploring a connection between architectural form and allostatic overloading. *Int. J. Environ. Res. Public Health*, 2023, 20, 5637. https://doi.org/10.3390/ijerph20095637
35. Alexander, C. *The timeless way of building*. Oxford University Press: New York, USA, 1979.
36. 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).
37. Rauscher, F.; Hinton, S. The Mozart Effect: Music Listening is Not Music Instruction. *Educational Psychologist*, 2006, 41(4), 233–238. Doi: 10.1207/s15326985ep4104_3
38. Saffran, J. R.; Loman, M.M.; Robertson, R. R. Infant memory for musical experiences. *Cognition* 2000, 77(1), B15-23. Doi: 10.1016/s0010-0277(00)00095-0
39. Aresta, M.; Salingaros, N. A. The importance of domestic space in the times of COVID-19. *Challenges*, 2021, 12(2), 27. https://doi.org/10.3390/challe12020027 (accessed on 28 October 2024).
40. Lavdas, A. A.; Salingaros, N. A. Can suboptimal visual environments negatively affect children's cognitive development? Challenges, 2021, 12(2), 28. https://doi.org/10.3390/challe12020028 (accessed on 28 October 2024).
41. 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)
42. 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).
43. 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(19). Doi: 10.1126/sciadv.adj8571
44. 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. *Developmental Sci.*, 2022, 25(1), e13155. https://doi.org/10.1111/desc.13155
45. Diamond, M. C. Response of the brain to enrichment. *Anais da Academia Brasileira de Ciências*, 2001, 73(2), 211–20. https://doi.org/10.1590/S0001-37652001000200006 (accessed on 28 October 2024).
46. Greenough, W. T.; Black, J. E. Induction of brain structure by experience: Substrates for cognitive development. In: M. R. Gunnar and C. A. Nelson (Eds.), *Developmental behavioral neuroscience*, Lawrence Erlbaum Associates: Mahwah, New Jersey, 1992, 155–200.
47. Quartz, S. R.; Sejnowski, T. J. The neural basis of cognitive development: a constructivist manifesto. *Behavioral and Brain Sci.*, 1997, 20(4), 537–56; discussion 556-96. https://doi.org/10.1017/S0140525X97001581 (accessed on 3 November 2024).
48. Sakai, J. How synaptic pruning shapes neural wiring during development and, possibly, in disease. *PNAS*, 2020, 117, 28. https://doi.org/10.1073/pnas.2010281117
49. Hassabis, D.; Kumaran, D.; Summerfield, C.; Botvinick, M. Neuroscience-Inspired Artificial Intelligence, *Neuron*, 2017, 95(2), 245–258. https://doi.org/10.1016/j.neuron.2017.06.011
50. Ullman S. Using neuroscience to develop artificial intelligence. *Science*, 2019, 363(6428), 692–693. Doi: 10.1126/science.aau6595
51. 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).
52. 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).
53. Cangelosi, A.; Schlesinger, M. From Babies to Robots: The Contribution of Developmental Robotics to Developmental Psychology, *Child Development Perspectives*, 2018, 12(3), 183–188. https://doi.org/10.1111/cdep.12282 (accessed on 26 October 2024).
54. 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, *Frontiers in Robotics and AI*, 2016, 3, Article 44. https://doi.org/10.3389/frobt.2016.00044 (accessed on 28 October 2024).
55. Zhao, W.; Queralta, J. P.; Westerlund, T. Sim-to-Real Transfer in Deep Reinforcement Learning for Robotics: A Survey. 2020 IEEE Symposium Series on Computational Intelligence (SSCI), Canberra, Australia, 1-4 December 2020, 737–744. https://doi.org/10.1109/SSCI47803.2020.9308468

56. 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).
57. Louv, R. *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*, Algonquin Books: Chapel Hill, North Carolina, USA, 2008.
58. Frumkin, H.; Bratman, G. N.; Breslow, S. J., et al. Nature Contact and Human Health: A Research Agenda. *Environmental Health Perspectives*, 2019, 125(7). https://doi.org/10.1289/EHP1663 (accessed on 28 October 2024).
59. 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).
60. Ernst, J. A. Early Childhood Nature Play: A Needs Assessment of Minnesota Licensed Childcare Providers. *Journal of Interpretation Research*, 2012, 17(1), 7–24. https://doi.org/10.1177/109258721201700102
61. Gill, T. The Benefits of Children's Engagement with Nature: A Systematic Literature Review. *Children, Youth and Environments*, 2014, 24(2), 10–34. https://doi.org/10.7721/chilyoutenvi.24.2.0010 (accessed on 3 November 2024).
62. 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?, Frontiers of Architectural Research, 2022, 11(5), 877–890. https://doi.org/10.1016/j.foar.2022.02.007
63. 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).
64. 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).
65. Schrittwieser, J.; Antonoglou, I.; Hubert, T.; et al. Mastering Atari, Go, chess and shogi by planning with a learned model. *Nature*, 2020, 588, 604–609. https://doi.org/10.1038/s41586-020-03051-4
66. 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).
67. Bommasani, R.; et al. On the Opportunities and Risks of Foundation Models, *Arxiv preprint*, 2022. https://doi.org/10.48550/arXiv.2108.07258 (accessed on 3 November 2024).
68. Cusack, R.; Ranzato, M. A.; Charvet, C. J. Helpless infants are learning a foundation model, *Trends in Cognitive Sciences*, 2024, 28(8), 726–738. Doi: 10.1016/j.tics.2024.05.001
69. Perez, C. E. *Artificial Intuition*, Intuition Machine, 2018.
70. Perez, C. E. *Artificial Empathy*, Intuition Machine, 2023.
71. 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, *Information Fusion*, 2024, 102, 102019. https://doi.org/10.1016/j.inffus.2023.102019 (accessed on 28 October 2024).
72. Li, Y.; Chan, J.; Peko, G.; Sundaram, D. An explanation framework and method for AI-based text emotion analysis and visualisation, *Decision Support Systems*, 178, 2024, 114121. https://doi.org/10.1016/j.dss.2023.114121
73. 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(19), 6532. https://doi.org/10.3390/s21196532 (accessed on 28 October 2024).
74. Ren, H.; Shi, M.; Zhang, J. Research Contents, Methods and Prospects of Emotional Architecture Based on a Systematic Literature Review. *Buildings*, 2024, 14, 997. https://doi.org/10.3390/buildings14040997 (accessed on 3 November 2024).
75. Paolo, G.; Gonzalez-Billandon, J.; Kégl, B. Position: A Call for Embodied AI, Proceedings of the 41st International Conference on Machine Learning, Vienna, Austria. PMLR 235, 2024, 1–16. Available online: https://openreview.net/pdf?id=e5admkWKgV (accessed on 3 November 2024).
76. 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. Doi: 10.3389/fpsyg.2022.971044

77. Lisetti, C. L.; Nasoz, F. Using Noninvasive Wearable Computers to Recognize Human Emotions from Physiological Signals. *EURASIP J. Adv. Signal Process.*, 2004, 929414. https://doi.org/10.1155/S1110865704406192
78. Gloor, P. Happymeter. Center for Collective Intelligence, MIT: Cambridge, MA, USA, 2022. Available online: https://www.happimeter.org (accessed on 28 October 2024).
79. 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(2), 868. https://doi.org/10.3390/su16020868 (accessed on 3 November 2024).
80. Kaur, S.; Jain, B.; Kaur, G.; Malik, M.; Chaudhary, A.; Rewliya, V. Space and Emotion, *International Journal of Social Science and Economic Research*, 2021, 6(6), 1910–1922. https://doi.org/10.46609/IJSSER.2021.v06i06.020
81. 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(9), e51199. doi: 10.2196/51199.
82. Lee, Y. K.; Suh, J., Zhan, H.; Li, J. J.; Ong, D. C. Large Language Models Produce Responses Perceived to be Empathic. *ArXiv preprint*, 2024. https://doi.org/10.48550/arXiv.2403.18148 (accessed on 28 October 2024).
83. Tu, T.; Palepu, A.; Schaekermann, M.; Saab, K., et al. Towards Conversational Diagnostic AI. *ArXiv preprint*, 2024. https://doi.org/10.48550/arXiv.2401.05654 (accessed on 28 October 2024).
84. Ren, H.; Shi, M.; Zhang, J. Research Contents, Methods and Prospects of Emotional Architecture Based on a Systematic Literature Review. *Buildings*, 2024, 14, 997. https://doi.org/10.3390/buildings14040997 (accessed on 3 November 2024).
85. Lavdas, A. A. Eye-Tracking Applications in Architecture and Design, *Encyclopedia*, 2024, 4(3), 1312–1323. https://doi.org/10.3390/encyclopedia4030086 (accessed on 15 September 2024).
86. Lavdas, A. A.; Sussman, A. Applications of Biometrics in Architectural and Environmental Design. In: Kühn, S. (ed.) *Environmental Neuroscience*. Springer: Cham, Switzerland, 2024, pages 227–254. https://doi.org/10.1007/978-3-031-64699-7_10 (Accessed 28 September 2024).
87. 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).
88. 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).
89. Apicella, A.; Arpaia, P.; Mastrati, G.; Moccaldi, N. EEG-based detection of emotional valence towards a reproducible measurement of emotions. *Sci Rep.* 2021, 11(1), 21615. Doi: 10.1038/s41598-021-00812-7
90. Galvão, F.; Alarcão, S.M.; Fonseca, M.J. Predicting Exact Valence and Arousal Values from EEG. *Sensors* 2021, 21, 3414. https://doi.org/10.3390/s21103414
91. Le, A. T. D., Payne, J., Clarke, C., Kelly, M. A., Prudenziati, F., Armsby, E., Penacchio, O., and Wilkins, A. J. Discomfort from urban scenes: Metabolic consequences, *Landscape and Urban Planning*, 160, 2017, 61–68. https://doi.org/10.1016/j.landurbplan.2016.12.003 (Accessed 28 July 2024)
92. Penacchio, O., Wilkins, A. J. Visual discomfort and the spatial distribution of fourier energy. *Vision Research*, 2015, 108, 1–7. https://doi.org/10.1016/j.visres.2014.12.013 (accessed on 28 July 2024)
93. Wilkins, A. J. Looking at buildings can actually give people headaches. *Conversation*, 5, 2018. Available online: https://www.cnn.com/style/article/why-looking-at-buildings-can-give-people-headaches/index.html (accessed on 13 August 2024).
94. Wilkins, A. J., Penacchio, O. and Leonards, U. The built environment and its patterns: A view from the vision sciences. *J. Sustain. Des. Appl. Res. Innov. Eng. Built Environ.*, 6(1), 2018, 42–48. https://doi.org/10.21427/D7VV5G (accessed on 13 August 2024)
95. Interaction Design Foundation. Concept Maps, *Interaction Design Foundation*, 16 June 2016. Available online: https://www.interaction-design.org/literature/topics/concept-maps (Accessed 28 October 2024).
96. Kunda, M. AI, visual imagery, and a case study on the challenges posed by human intelligence tests. *PNAS*, 2020, 117(47), 29390–29397. https://doi.org/10.1073/pnas.1912335117 (Accessed 28 October 2024).
97. Koehler D. More than anything: Advocating for synthetic architectures within large-scale language-image models. *International Journal of Architectural Computing*. 2023, 21(2), 242–255. Doi: 10.1177/14780771231170455

98. Silber, J. *Architecture of the Absurd: How Genius Disfigured a Practical Art*. Quantuck Lane Press: New York, USA, 2007.
99. Curl, J. S. *Making Dystopia: The Strange Rise and Survival of Architectural Barbarism*, Oxford University Press: Oxford, UK, 2018.
100. 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. https://doi.org/10.3390/virtualworlds2030015 (Accessed 28 October 2024).
101. Lavdas, A. A.; Mehaffy, M.; Salingaros, N. A. AI, the Beauty of Places, and the Metaverse: Beyond Geometrical Fundamentalism, *Architectural Intelligence*, 2023, 2, Article 8. Doi: 10.1007/s44223-023-00026-z
102. 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).
103. 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).
104. 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).
105. Gibson, E. J.; Pick, A. D. *An Ecological Approach to Perceptual Learning and Development*. Oxford University Press, Oxford, UK, 2003.
106. Weinstein, C. S.; David, T. G. *Spaces for Children: The Built Environment and Child Development*. Plenum Press: New York, USA, 1987.
107. Crompton, A. The fractal nature of the everyday environment. *Environment and Planning B: Planning and Design*, 2001, 28(2), 243–254. https://doi.org/10.1068/b2729 (accessed on 3 November 2024).
108. Berkley, E. L.; Berkley, R. A. *The Importance of Outdoor Play and Its Impact on Brain Development In Children*. University of Missouri, Kansas City, 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).
109. Salingaros, N. A. Why we need to "grasp" our surroundings: Object affordance and prehension in architecture, *Journal of Architecture and Urbanism*, 41(3), 2017, 163–169. Doi: 10.3846/20297955.2017.1376003
110. Soules, M. *Icebergs, Zombies, and the Ultra Thin. Architecture and Capitalism in the Twenty-First Century*. Princeton Architectural Press: New York, USA, 2021.
111. Institute of Classical Architecture and Art. https://www.classicist.org/about/ (accessed on 3 November 2024)
112. INTBAU global network, London, UK. https://www.intbau.org (accessed on 3 November 2024).
113. Tortorello, M. With Kids and Coffee Tables, It's Trip, Fall, Ouch. *The New York Times*, 29 Dec. 2010. https://www.nytimes.com/2010/12/30/garden/30tables.html (accessed on 3 November 2024).
114. Singhal, D. Rethinking Business School Education: A Call for Epistemic Humility Through Reflexivity, *Global Business School Network*, June 10, 2024. https://gbsn.org/rethinking-business-school-education-a-call-for-epistemic-humility-through-reflexivity/ (accessed on 3 November 2024).
115. Bashier, F. Reflections on architectural design education: The return of rationalism in the studio. *Frontiers of Architectural Research*, 2014, 3(4), 424–430. https://doi.org/10.1016/j.foar.2014.08.004
116. Tzonis, A. Architectural education at the crossroads, *Frontiers of Architectural Research*, 2014, 3(1), 76–78. http://dx.doi.org/10.1016/j.foar.2014.01.001 (accessed on 28 July 2024).
117. 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).
118. Aumjaud, S.; Allam, Z. Decolonising the architectural education narrative will render more inclusive and culturally appropriate design solutions. *New Design Ideas*, 4(1), 2020, 58–60. http://jomardpublishing.com/UploadFiles/Files/journals/NDI/V4N1/Aumjaud%20and%20Allam.pdf
119. 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).

 doi:10.20944/preprints202411.1342.v1

120. 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(19), 6532. https://doi.org/10.3390/s21196532 (accessed on 28 July 2024)
121. 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).
122. Mitrović, B. *Architectural Principles in the Age of Fraud*. Oro Editions: Novato, CA, USA, 2022.
123. 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).
124. Salingaros, N. A. Architectural Knowledge: Lacking a Knowledge System, the Profession Rejects Healing Environments That Promote Health and Well-being, *New Design Ideas*, 2024, 8(2), 261–299. https://doi.org/10.62476/ndi82261 (accessed on 3 November 2024).