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The impact of Biomimicry on sensory experience: an analysis of the relationship between human senses and nature in the design process in Architecture

Elton Cristovão da Silva Lima [(1)], Luís Miguel Cotrim Mateus [(2)] and Amilton José Vieira de Arruda [(3)]

Abstract: This article explores the field of biomimicry in architecture, focusing on the integration of nature-inspired solutions to enrich the sensory experience of users in built spaces. Based on the realisation that nature offers not only aesthetic but also functional inspiration, it investigates how architecture can benefit from these principles to create environments that promote well-being and inclusion through the senses. Recognising architecture as a predominantly visual art, this paper highlights the need for a more inclusive approach that engages all human senses, following the perspective of architects such as Peter Zumthor and Juhani Pallasmaa, who advocate a multi-sensory architectural experience. Using a methodology of bibliographical review and critical analysis, the study examines the existing literature that relates the concepts of biomimicry, biophilia and the sensory experience in architecture. In addition, it is presented case studies that exemplify the application of these principles, demonstrating how built environments can emulate and/or integrate the natural world while simultaneously meeting human needs in different contexts. The results suggest that the adoption of biomimetic and biophilic strategies can lead to the creation of spaces that improve both functionality and quality of life, promoting an immersive and enriching experience for users. Thus, biomimicry, although already considerably addressed in the architectural context, shows itself to be a promising field when thinking about architecture inspired by nature beyond aesthetics and functionality, but with the aim of creating environments that consider interaction and the sensory and emotional response of the user.

Keywords: Biomimicry - Architecture - Biophilia - Design Process - Bioinspired Design - Behaviour - Synaesthesia - Sensory Experience - Senses - Bibliographic Analysis

[Resúmenes en castellano y en portugués en las páginas 40-42]

[(1)] **Elton Cristovão da Silva Lima**, Architect and Urban Designer from the Federal University of Pernambuco (UFPE) - Brazil and with a recognition of degree as Master in Architecture by the University of Lisbon. Attended Master's Degree in Urbanism (Specialty in Digital Graphics) at the Federal University of Rio de Janeiro (UFRJ). Currently he is a PhD candidate in Architecture at the University of Lisbon (Specialty in Design and Computing) with double degree agreement with the Federal University of Pernambuco (PhD candidate in Design). Attended the Laboratoire Théorie des Systèmes en Architecture at the

Université Catholique de Louvain in Belgium, and the Università di Roma "La Sapienza" during two academic mobilities through Erasmus Program. He was an intern at BR Petrobras Distribuidora SA in the Architecture sector, a teaching assistant at the Department of Graphic Expression at UFPE in Graphic Geometry and Architectural Design courses, and Scientific Initiation Researcher. Developed research in the field of Biomimicry, Parametric Design, Shape Grammar, Space Syntax, Digital Fabrication, Graphic Expression, Social Housing, Ephemeral Architecture, and Sounds. ORCID ID 0000-0002-8076-7150. elton.lima@edu.ulisboa.pt

(2) **Luís Miguel Cotrim Mateus**, is an Assistant Professor at the Faculty of Architecture of the University of Lisbon. He teaches the courses of "Descriptive Geometry", "Generative and Geometric Modelling", and "3D Digitization, Virtual Reality and Animation". Member of the Research Center for Architecture, Urbanism and Design (CIAUD). Develops research in the "Design and computation Group" (http://dcg.fa.ulisboa.pt/) and in "ArcH-C3D" (http://archc3d.fa.ulisboa.pt/). Both research groups can host the present research proposal. Additionally, the research can benefit from the teaching environment at the faculty. Luís Mateus research is focused in two fields: i) the use of parametric modelling to architectural design, and ii) the application of reality capture methods to architectural documentation and representation. He participated in several projects of fundamental research, national and international, and applied research with multiple partners, public and private. He has experience in supervision (masters and PhD) and publishes widely. He is the head of the 3D Scanning Lab (http://ld3d.fa.ulisboa.pt/). The Faculty of Architecture also has a Digital Prototyping Lab (http://lpr.fa.ulisboa.pt/). Both labs have diversified equipment (3D scanners, 3D printers, milling machines, laser cutters) and software that can be used as resources for the present research project. ORCID ID 0000-0002-9492-8234. lmmateus@fa.ulisboa.pt

(3) **Amilton José Vieira de Arruda**, Graduation in Industrial Design Product Project by UFPE (1982), Master in Design and Bionics by IED in Milan (1992), Doctorate in Ricerca in Disegno Industriale - Ph.D by University of Milan Politecnico (2002) and postdoctoral in Design and Bionics at IADE European University UNIDCOM Lisbon (2018/2019), and postdoctoral in Bionics at University Luigi Vanvitelli Nápoles - IT (2021/2022). Since 1985 professor of the UFPE Design Course. He is currently associate professor IV. He coordinates the Research Group on Biodesign and Industrial Artifacts at UFPE. Organizer together with Edgard Blucher of the [DesignCONTEXTO] series design, culture and technology essays from the following books: (2017) 1. Design and Complexity; (2017) 2. Design and Social Innovation; (2018) 3. Design, Artifacts and Sustainable Systems; (2022) 4. Narratives and Languages in the creative process in Modeling and Prototyping. Always with Edgar Blucher he organizes the series [designNATUREZA] essays on design, bionics and biomimetics with the following book: (2018) Methods and Processes in Bionics and Biomimetics: the technological revolution by nature. With the publisher Insigh in (2019) we launched the following title: Topics in Design: Biomimetics, Sustainability and New Materials; and recently with Blucher (2020) the Book: Design and Bionics. Carmelo Di

Bartolo and Centro Ricerche IED: esperienze memorabili da 30 protagonisti. ORCID ID 0000-0003-4551-4497. arruda.amilton@gmail.com

Introduction

Biomimicry is an emerging field of research that seeks innovative solutions to complex problems, taking inspiration from nature (Benyus, 2006). Among the various fields in which Biomimicry has stood out, architecture and design have been significant ones for applying its principles, since the common goal between these areas is to create artefacts and structures that are efficient, functional, sustainable, and aesthetically pleasing.

According to Stevens, Laura, *et al.* (2022, p. 649), Biomimicry is an emerging discipline that seeks nature's advice and brings diverse stakeholders together to create designs that emulate the way nature functions, not just the way it looks. From this definition, it is possible to understand that Biomimicry seeks more than just to imitate the appearance or shape from nature, but also to understand its evolutionary processes, strategies, and mechanisms in order to find sustainable, and efficient solutions that can be applied to the human context.

Architecture, even though it is an art that involves many senses and stimulates total synaesthesia[1], is still considered a visual art (Granata, 2019, p. 78). Thus, sight is generally the most stimulating sense, and it is very important to be able to see the built environment in order to understand architectural materiality. In this sense, Finnish architect Juhani Pallasmaa, in his book The Eyes, questions why, when there are five senses, only one, sight, becomes so predominant in architectural culture and design (Farr & Macruz, 2020, p. 724).

However, existing literature has emphasised the importance of considering the sensory experience of users when designing spaces, since the human senses are responsible for transmitting information about the surrounding environment, allowing for a more complete understanding and apprehension of the world. It is therefore important for architecture to be in tune with nature and the human senses, so that the experience of being in a space becomes meaningful and immersive.

In this context, it is also important to address the concept of Biophilia. This term was coined by Edward Wilson in 1984 and describes an evolutionary approach from a phylogenetic perspective on the human connection to nature (Wilson, 2002, p. 134), and this connection can be incorporated into architecture to improve users' quality of life. Thus, biomimicry can be seen as a way of materialising this connection, using solutions inspired by nature to create more harmonious and beneficial environments for people.

Analysing the relationship between the human senses and nature in architecture is important for creating spaces that add value to users' sensory experience. As Pallasmaa states (1996, p. 50 as cited in Spence, 2020, p. 2), "Architecture is the art of reconciliation between ourselves and the world, and this mediation takes place through the senses ". In this context, Biomimicry can be an effective tool for architecture, because by imitating the processes and structures found in nature, it is possible to develop architectural structures that are also in tune with the human senses.

This connection between human-being and nature was also an important theme addressed by Peter Zumthor (2005) in his book "Atmospheres", in which he argues that buildings can create a unique sensory experience that provides a feeling of comfort and well-being. He also argues that in order to achieve this goal, it is necessary to pay attention to all five senses.

In addition, Zumthor (2005, p. 17) highlights the importance of sensitivity in architecture, addressing the sensory qualities of materials, texture, colour, temperature, and acoustics as fundamental to the architectural experience. In other words, in addition to the sense of sight, the other human senses are also important in the perception of architectural spaces.

> While architectural practice has traditionally been dominated by the eye/sight, a growing number of architects and designers have, in recent decades, started to consider the role played by the other senses, namely sound, touch (including proprioception, kinesthesis, and the vestibular sense), smell, and, on rare occasions, even taste (Spence, 2020, p. 3).

Based on this, given that some of the production of architecture far distanced from biomimicry already seeks this integration of the senses both in the design process and as a purpose of post-construction stimulation, it can be said that architecture developed with the aid of biomimicry can also be designed to stimulate all the senses, not just sight. The only thing that would change is the design method, and perhaps also the construction method, which with the help of biomimicry is always linked to a natural inspiration, be it visual, functional, or of any other nature. In this way, projects would have the possibility to incorporate sounds, textures, and aromas to create a complete and immersive sensory experience for users. For example, a project may use moving water to create soft, relaxing sounds, as well as reflecting light in a way that is pleasing to the eye.

An example of a project that integrates nature with the built space while providing the user with an immersive, multi-sensory experience through sound is the Living Chapel, located in the Botanical Gardens of Rome, Italy (Cipolla 2020; Sciortino, 2020) *(See Figure 1)*. The project was conceived as a living sanctuary, combining plant elements with architectural structures, where the local flora is integrated to create both a visually and acoustically rich environment *(See Figure 2)*. The user's experience is influenced by the sounds that permeate this living chapel; from the murmur of vegetation as it is touched by the wind to the sound of water flowing through its installations. These natural sound elements are amplified by the acoustic structure of the space, which creates an atmosphere of tranquillity and reflection.

In this way, it is clear that architecture may establish an intimate connection with the human senses and nature, and thus promote an interesting sensory experience. The application of biomimicry principles in architecture also has the potential to improve the built environment in both a functional and emotional sense, creating healthy and pleasant spaces for people to use and stay in.

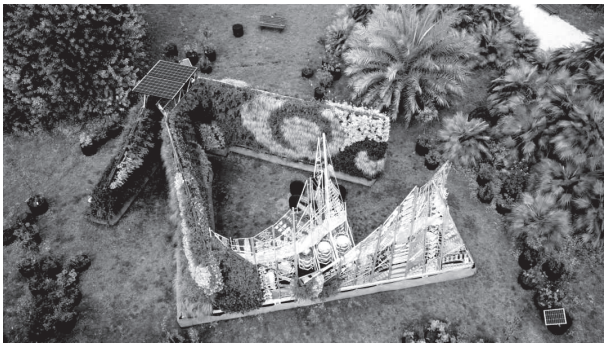

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Figure 1. Top view of the Living Chapel, in Rome, Italy (Source: Picture of R. Cappelli retrieved from Sciortino, 2020, available at https://metropolitanmagazine.it/living-chapel/). **Figure 2.** Metal mechanism Where the water drops fall and produce the sound (Source: Picture of Consuelo Fabriani retrieved from Cipolla, 2020, available at https://www.artribune.com/arti-visive/2020/06/the-living-chapel-installazione-ecologia-orto-botanico-di-roma/)

Methodology

This article aims to explore the impact of Biomimicry on the architectural sensory experience, analysing the relationship between the human senses and nature through a critical and bibliographical analysis.

The methodological path of the article presents a systematic mapping of concepts and ideas discussed in the literature that relate Architecture and Biomimicry, and Architecture and the human senses. Subsequently, strategic readings were carried out in order to outline the panorama of integration between architectural spaces, sensory aspects and Biomimicry.

To this end, it was sought to explore case studies that directly relate these three approaches, such as the Sagrada Familia Cathedral-Barcelona / Spain, the United Kingdom Pavilion "Seed Cathedral" - Shanghai / China, and the Eastgate Centre - Harare / Zimbabwe; as for other case studies, although biomimicry is not directly associated, it is possible to see a biophilic approach, in the sense of bringing nature into the built space, such as the Sound of Wind Chapel-Moriyama / Japan, the Bosco Verticale Building - Milan / Italy, and The Edible Schoolyard - New York City / United States; on the other hand, we also seek to discuss the temporal dimension as a sensory aspect, addressing the possibility of transience in both nature and architecture, and thus the Kolumba Museum - Cologne / Germany.

Thus, by presenting Biomimicry as an evolving discipline, both methodologically and in its intersection with various fields of study, we highlight the opportunity to broaden the spectrum of the relationship that already exists between Architecture and Biomimicry, also considering the human senses in order to provide sensory and synaesthetic experiences to the user of the built space.

Results and Discussion

The application of biomimicry principles in the field of architecture has emerged as an innovative approach promising optimised architectural solutions inspired by the shapes and processes of natural resources, often coupled with ideas of sustainability and resource efficiency.

This article sought to explore the discussion of how biomimicry can be used to enhance the sensory experience of users, as can be seen in table 1 below, emphasising a deeper synergy between human beings and natural environments. It was identified that, in addition to contributing to the sustainability and energy efficiency of buildings (Jamei & Vrcelj, 2021, p. 3), biomimicry –and biophilia– has significant potential to enrich the sensory quality of architectural spaces, positively impacting the well-being and satisfaction of users.

Table 1. Association of sensory aspects with the relationship between nature and architecture (Source: Author, 2024).

Sensory aspect	Inspiration or natural relationship	Potential benefit	Architectural reference
Sight Sight is the sense most commonly stimulated when talking about architecture, due to the possibility of perception and spatial recognition; experimentation through shapes, colours, textures and lighting; identification of the beautiful and the strange (which, although it can be said through the narration of characteristics by others, these characteristics are subjective and conditioned to personal interpretation through observation). Of course, some of these variables may also be perceived through other senses (such as the spaciousness of a room through echo, for example), but sight allows for a more instantaneous apprehension and together with the	Design inspired by the structural efficiency of tree and bones to maximise strength with minimal material.	Creates lighter, more resilient spaces and structures, reducing material costs and environmental impact.	The Sagrada Familia Cathedral by Antoni Gaudí was inspired by tree trunks and shell structures to create arches and columns that support the structure efficiently, minimising the use of materials and maximising structural strength. (Badarnah, 2012, p. 24;

other senses allows for a more complete apprehension.			Clementino *et al.*, 2021/2022, p. 182) (See Figure 3).
Auditory The focus of this aspect is on reproducing or amplifying sound environments that are reminiscent of nature, seeking to create an acoustic atmosphere that is relaxing and enveloping, inspiring or that stimulates users' concentration. In this sense, architecture can use materials and structural shapes to optimise the sound quality of the space.	Use of structures and materials that capture the sound nuances of nature.	It creates calmer, more natural environments, favouring concentration and reducing stress by immersing yourself in sounds that recall the tranquillity of nature.	Sound of Wind chapel, designed by RAA[2], whose shape allows for the control of the internal flow of wind that, when in contact with the steel strings at the top of the chapel, causes a symphony and makes the project work like a wind harp (RAA, n.d.) (See Figures 4 and 5).
Tactile The tactile aspect refers to the choice of materials and textures that can create spaces that offer diverse touch-sensitive experiences. By taking inspiration from soft surfaces such as flower petals or rough ones such as tree trunks, it is possible to create environments that stimulate touch and provide an intuitive connection with the space. To do this, it is possible to use biomaterials which, as well as being of natural origin, in some cases also have different textures similar to their material of manufacture.	Use of materials and structures that provide an organic tactile experience. In this case, the external structure is made up of transparent rods that simulate the lightness and texture of seeds.	It promotes a deeper connection with the environment by stimulating tactile and visual exploration, as well as providing an intimate, sensory interaction.	The United Kingdom Pavilion at Expo 2010, known as the 'Seed Cathedral', designed by architect Thomas Heatherwick, whose external structure emulates the texture of seeds, which seem to grow to form the skin of the building (Lehman, n.d.). In addition, each stem has real seeds (See Figure 6).
Olfactory Like taste, smell is often underestimated when it comes to perception and creating a memory of a space. Inspired by how plants emit odours that can affect human mood and well-being, architecture can incorporate ventilation systems that distribute natural essences or use materials that release fragrances over	Integration of plant elements capable of modifying their fragrances according to the changing seasons, diversifying the olfactory	Environments that subtly transform themselves and promote a sense of dynamism and connection with the natural cycle,	The Bosco Verticale building, designed by Boeri Studio, integrates vegetation into the façade and as a result offers seasonal

time, creating an olfactory identity for a space and thus also enhancing the sensory experience. In this sense, this aspect can be related to landscape architecture, which according to Szabo et al. (2022, p. 1), is a field in which art and nature intertwine, involving the conscious manipulation of elements to create spaces that satisfy human, aesthetic, and functional demands.	experience throughout the year.	as well as improving air quality and contributing to a feeling of relaxation.	aromas. The project also creates a microclimate suitable for capturing sunlight, combining a technological approach with mechanics and environmental sustainability. It also increases biodiversity and promotes the formation of an urban ecosystem (Archdaily, 2015) (See Figure 7).
Thermal Although the thermal aspect is not one of the human senses, thermal sensation is perceived through touch, yet it is still a relevant sensory aspect in the study of architecture. Thermal comfort is essential for a pleasant spatial experience and biomimicry can also offer solutions to this aspect by observing existing mechanisms in animals and plants to regulate temperature in response to the environment. In this sense, architecture can adopt insulation and ventilation strategies that mimic these natural processes.	Air conditioning systems inspired by the thermal self-regulation of termites, which maintain a stable internal temperature.	Energy efficiency and thermal comfort, reducing the need for heating and cooling systems.	Eastgate Centre, by architect Mick Pierce, which emulates the natural air conditioning system of termite colonies (Tavsan et a., 2015, p. 492) (See Figure 8).
Gustatory Among the five senses, taste may seem the most challenging to relate directly to architecture, given its close connection to the experience of eating and drinking, rather than the physical space itself. However, architecture can explore how the built environment may influence and enhance the taste experience. To do this, working together with the other senses through the use of visual, olfactory, and acoustic elements is important to promote a pleasant experience in spaces such as restaurants, for example.	Growing herbs and vegetables that offer people a direct connection to the source of their food and the natural environment even if transplanted into an unnatural environment.	It enriches the gastronomic experience, promoting awareness of the origin of food and encouraging healthy eating and sustainable practices.	The Edible Schoolyard, a project by WORKac in New York City, United States, integrates community gardens into an educational environment, providing hands-on learning about organic gardening and nutrition. (WORKac, 2014) (See Figure 9).

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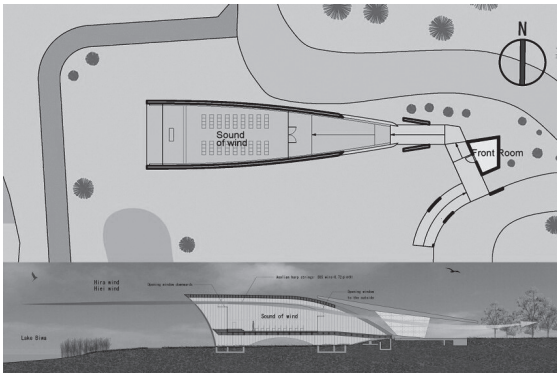

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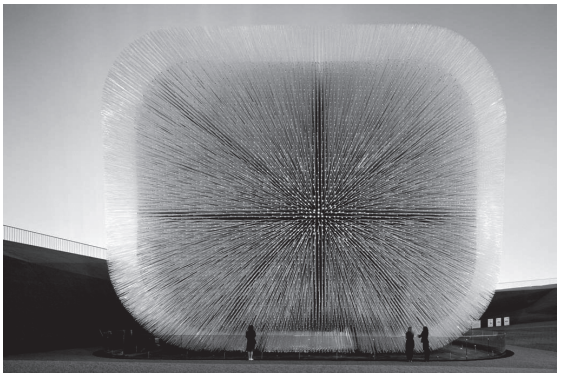

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Figure 3. Sagrada Familia Cathedral in Barcelona, Spain (Source: Author, 2023). **Figure 4.** Schematic plan and section of the project (Source: Architect, n.d., available at https://www.r-a-architects.com/prj/2013/sound-ofwind.html). **Figure 5.** External (left) and internal (right) views of the Sound of Wind chapel (Source: Architect, n.d., available at https://www.r-a-architects.com/prj/2013/sound-ofwind.html). **Figure 6.** The United Kingdom Pavilion for Expo 2010, known as the Seed Cathedral, in Shanghai, China (Source: Archello, n.d., available at https://archello.com/project/shanghai-expo-2010-british-pavilion).