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Figure 7. Bosco Verticale Building in Milan, Italy (Source: Picture of Paolo Rosselli retrieved from Archdaily, 2015, available at https://archello.com/project/shanghai-expo-2010-british-pavilion). **Figure 8.** (a) Office Building in Harare, Zimbabwe; (b) Termite mound; (c) Diagram of the termite mound ventilation system (Source: Richard Dahl, 2013, as cited in Tavsan *et al*., 2015, p. 492). **Figure 9.** Exterior view of the Edible Schoolyard in New York City, United States (Source: Picture of Iwan Baan and Bruce Damonte retrieved from WORKac, 2014, available at https://work.ac/work/edible-schoolyard-nyc-at-p-s-216/).

In addition to the table above, the taste aspect is in fact very complex to be associated with the built environment and then it is necessary to combine different factors so that the environment, although it does not offer a direct taste experience, can accentuate the taste experience of a dish served in a restaurant, for example. Regarding to this, it is possible to mention the Sublimotion restaurant *(See Figure 10)* in Ibiza, Spain, which combines culinary art and technological innovation with an original and attractive atmosphere (Koerner, 2022). In other words, the restaurant manages to provide a gustatory experience through the built space by the ability to enhance flavours by constantly changing the interior ambience through dynamic lighting and projection mapping on 360-degree screens that stimulate customers' senses (McQuarrie, 2014).

Figure 10.
One of the possible ambiences of the Sublimotion restaurant in Ibiza, Spain (Source: Koerner, 2022, available at https://lucept.com/2022/03/03/sublimotion/).

Additionally, as exemplified in the olfactory sensory aspect in the table above, Bosco Verticale manages to create a microclimate and increase local biodiversity by attracting birds and butterflies (Archdaily, 2015). Perhaps an often-underestimated aspect of the association of biomimicry with architecture is the potential to promote greater biodiversity in urban environments. Projects such as this, which imitate or integrate natural elements, not only improve the human experience, but can also offer a spontaneous opportunity for the repopulation of flora and fauna in the city.

Additionally, the temporal quality *(See Table 2)* of an architectural structure or installation is another aspect that could be considered as a user experience in space since architectural temporality or ephemerality can also arouse feelings and emotions in those who experience a work. Considering the temporal aspect already allows us to enter the discussion of ephemeral architecture, which can include temporary pavilions and architectural installations (Tunçbilek, 2013, pp. 66, 67 and 83), both of which can be assembled, disassembled, and transported, and can be built and rebuilt in different places. Tunçbilek (2020, p. 398)

also comments that temporal transience has the power to attract people's attention and invite them to observe, enter, touch, experience, interact, comment, and think about architecture (Tunçbilek, 2020, p. 398).

Table 2. Association of the temporal aspect with the possible relationship between nature and architecture (Source: Author, 2024).

Sensory aspect	Inspiration or natural relationship	Potential benefit	Architectural reference
Temporal Althought it is not one of the five Aristotelian senses[3], time can be considered a sensory aspect due to its ability to affect the spatial perception and emotional experience of users of the built space/installation. Thus, one could justify the inclusion of time in this discussion by considering that the experience of a space is not limited to an isolated instant but can be integrated with the change of natural cycles, provoking different sensations and possibilities for experiencing the space throughout the seasons. This transitory perception of architecture has the power to transform it into a dynamic experience, connecting occupants to natural rhythms and the passage of time. Furthermore, considering the transitory nature (both in the sense of structural ephemerality and in the sense of integration with the natural environment) forces architects to create spaces that do not just meet the immediate needs of a specific location, but think about and anticipate the user's interaction with the space, even when it has an expiry date in a given context.	Use of materials that get old naturally, reflecting the cycle of life and the passage of time, similar to what happens in nature.	It encourages appreciation for the beauty of non-permanence and the history of the space, as well as reinforcing users' emotional connection with the environment.	Kolumba Art Museum, a project by Peter Zumthor, whose use of materials such as bricks, mortar, plaster, and stone ruins from other historical periods reflects the transitory nature of time and the historical continuity of the space previously destroyed by war. The architect also explored the use of textures, colour, light and materiality in order to highlight the passage of time on the building's surface. In addition, this work is considered to be a museum of shadows that evolves with time and seasons (Kraus, 2017) (See Figure 11).

Figure 11. Outside and inside views of the Kolumba Art Museum in Cologne, Germany (Source: Pictures of Rasmus Hjortshøj - Coast retrieved from Kraus, 2017, available at https://divisare.com/projects/349228-peter-zumthor-rasmus-hjortshoj-kolumba-museum).

By exploring the relationship between the human senses and nature, biomimicry can also play an important role in the sensory experience during the architectural design process. It should also be emphasised that the interaction between architecture and nature has been the subject of discussion, highlighting the importance of aesthetics and ecology in designing spaces that promote harmonious integration between the built environment and the natural environment (Olivo & Meneguetti, 2021, pp. 3 and 7).

However, the sensory experience in architecture is not just limited to aesthetics but plays a relevant role in the health and well-being of users when it is also associated with nature. This perception reflects an understanding of how human beings have historically moulded nature to suit their needs and preferences, and also how they have extracted ecosystem services essential for survival and well-being. Over time, there has been an increased appreciation of the intangible qualities offered by natural environments, such as the benefits to mental and psychological health (Pasini, 2022, p. 3). This appreciation for the more subtle and less tangible aspects of nature highlights a paradigmatic shift in the way we conceive and interact with architectural spaces, emphasising the importance of creating environments that can meet both physical needs and nourish the senses and promote a psychological and emotional connection with the natural environment.

The concept of biomimicry, drawing inspiration from nature to solve human problems as discussed by Benyus (2006), is not only a strategy for achieving environmental sustainability, but linked to architecture it also works as a means of reconnecting individuals with the natural world, even if it is basically through the built shape or the 'replacement' of the natural environment into the built environment.

In addition, elements designed on the basis of natural patterns, structures and processes can enhance visual, auditory, olfactory, and tactile perception, thus creating a more im-

mersive experience for the user. This aspect of bringing the natural environment closer to people is particularly relevant at a time when increasing urbanisation often distances people from natural environments.

The analysis of architectural projects that incorporate these biomimicry principles has shown that biomimicry can offer aesthetic and functional solutions that go beyond the conventional, as in the case of the Eastgate Centre presented above, challenging existing architectural paradigms. Another example is the implementation of the exterior kinetic façade of the Al Bahar Towers *(See Figure 12)* in Abu Dhabi, United Arab Emirates, which mimics the opening and closing of a butterfly's wings in response to the movement of the sun in order to control the levels of heat and light inside (Elsakksa *et al*., 2022, p. 6). As well as improving the building's energy efficiency, this façade also transforms the way users experience the space, through the variation in light and shade that these kinetic structures provide throughout the day.

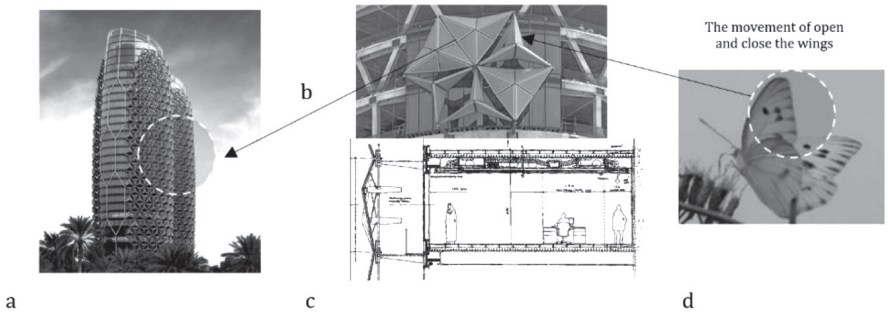

Figure 12. Biomimetic concept, inspired by the white butterfly, for the Al Bahar Towers project in Abu Dhabi, United Arab Emirates (Note. (a) Al Bahar Towers, (b) kinetic mechanism of the façade, (c) schematic section of the project (Karanouh, 2015, as cited in Elsakksa, 2022, p. 6), (d) white butterfly, inspiration for the project (https://butterfly-conservation.org/butterflies/green-veined-white) (Source: Elsakksa, 2022, p. 6).

However, the difficulty inherent in objectively measuring the impact of these strategies on the well-being of users of built space is emphasised, due to the subjectivity of sensory experiences. Therefore, it is recommended to adopt interdisciplinary research methods combining quantitative and qualitative techniques, to evaluate the effects of biomimicry architecture more comprehensively on the human experience. This approach could, however, include detailed case studies, sensory analyses and psychological assessments to capture a full range of human responses to built environments, such as people's behaviour within different types of environments (small, large, high, low, temperature-regulating, with ki-

netic structures, immersed in nature, bringing nature into the space), in face of obstacles, in spaces with different levels of lighting, acoustics, with different materials, colours and textures.

This reaffirms the importance of multidisciplinary collaboration in the development of biomimicry architectural projects. The integration of knowledge from biology, psychology, engineering, and design is fundamental to understanding and applying the principles of nature in a way that benefits the user of the space and facilitates the effective and optimised development of both the design and construction process.

Furthermore, the role of emerging technology in facilitating biomimicry design offers opportunities for exploring future research. Thus, with the advancement of digital parametric modelling and simulation tools, architects and designers have increasing opportunities and capabilities to develop complex and innovative solutions that replicate the adaptive strategies found in nature. Computational environments such as Rhinoceros[2] and Grasshopper[3] together, for example, can allow for greater precision in the implementation of biomimicry concepts, and also enable new approaches to experimentation with shapes, materials and interactions that can enrich the sensory experience of users.

Conclusion

It can be seen that while the intersection between architecture and sensory experience is already commonly discussed in the literature, with names such as Peter Zumthor and Juhani Pallasmaa as protagonists of this dialogue, the intersection between biomimicry and sensory experience in architecture is a potential field for further research.

The influence of nature in improving people's experience of built spaces is undeniable, and reinforces the idea that architecture inspired by natural elements and/or that brings nature into the space can be very effective in fostering environments conducive to human well-being and comfort.

Additionally, interaction with the various senses and the relationship established with each of them enables a deeper understanding of the space and its meaning, also aiming to revive values related to accessibility, thus promoting the inclusion of those with specific sensory limitations.

Based on the works and discussions of Peter Zumthor and Juhani Pallasmaa, it is possible to notice an eloquent defence of architecture as a deeply sensory and emotional experience. Zumthor, with his emphasis on materiality and the ability of materials to evoke sensory experiences, and on illumination through which he developed various approaches such as metaphor, fantasy, the obscure, and the material itself (Halim & Ekomadyo, 2022, p. 145). He also paid more attention to the quality of the building in reflecting personal emotions and experiences than to architectural trends (Jia & Liu, 2013, p. 1178). Pallasmaa, on the other hand, advocates multisensory architecture and focuses on the importance of tactile sensitivity and the involvement of the senses in the perception of space, as well as pointing out that the solution to the problems of contemporary architecture lies in providing architectural experiences (Chung, 2015, p. 43). Therefore, it can be seen that both

emphasise the need for an architecture that converses closely with human experiences and their works and theories stress that architecture must transcend functionality.
The integration of sensory aspects into architecture, as illustrated by the tables above, reveals the understanding that biomimicry and biophilia can improve the human experience in built spaces. By incorporating visual, auditory, tactile, olfactory and thermal stimuli inspired by nature, architecture is able to improve the functionality of environments, enhance the well-being of space users, and provide some way for users to connect themselves with the natural environment. This varied approach proposes a complete multi-sensory exploration, creating spaces that are fully experienced and not just inhabited.
It is clear that it is essential to adopt an empathetic stance in the design process, where the implementation of biomimicry strategies is aligned with an understanding of human subtleties, honouring the multiplicity of sensory experiences and perceptions. This approach emphasises the importance of anticipating the diverse possibilities of individual reactions to spaces, ensuring that the environments designed are accessible and welcoming to all.
It is therefore clear that the fusion of biomimicry and architectural sensibility has the potential to improve the way spaces are conceived and built, and the way users relate to, interact with, and experience these environments. Seeking inspiration in nature that allows emulation of more than shape or function to create buildings or installations that promote a deeper connection between human beings and their surroundings is an important step towards achieving truly cosy and comfortable architecture.

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Notes

1. Synaesthesia is a phenomenon whereby the perception of a particular sensory stimulus or cognitive concept triggers perceptual experiences that are not directly related to the original stimulus (Van Leeuwen *et al*., 2015, p. 1). This means that a stimulus, such as a sound or a letter, can involuntarily and automatically provoke an additional sensory response, such as the sight of a specific colour, without any sensory input to justify this association (Hochel and Milán, 2008, as cited in Van Leeuwen *et al.*, 2015, p. 1). Therefore, synaesthesia creates unusual connections between different senses or between sensory perceptions and abstract concepts.
2. Rhinoceros: 3D modelling computer environment.
3. Grasshopper: visual programming computer environment integrated with Rhinoceros.

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Resumen: Este artículo explora el campo de la biomímesis en la arquitectura, centrándose en la integración de soluciones inspiradas en la naturaleza para enriquecer la experiencia sensorial de los usuarios en los espacios construidos. Partiendo de la base de que la naturaleza no sólo ofrece inspiración estética, sino también funcional, investiga cómo la arquitectura puede beneficiarse de estos principios para crear entornos que promuevan el bienestar y la inclusión a través de los sentidos. Reconociendo que la arquitectura es un

arte predominantemente visual, este artículo destaca la necesidad de un enfoque más inclusivo que involucre todos los sentidos humanos, siguiendo la perspectiva de arquitectos como Peter Zumthor y Juhani Pallasmaa, que abogan por una experiencia arquitectónica multisensorial. Utilizando una metodología de revisión bibliográfica y análisis crítico, el estudio examina la literatura existente que relaciona los conceptos de biomimetismo, biofilia y experiencia sensorial en la arquitectura. Además, se presentan estudios de casos que ejemplifican la aplicación de estos principios, demostrando cómo los entornos construidos pueden emular y/o integrar el mundo natural al tiempo que satisfacen las necesidades humanas en diferentes contextos. Los resultados sugieren que la adopción de estrategias biomiméticas y biofílicas puede conducir a la creación de espacios que mejoren tanto la funcionalidad como la calidad de vida, promoviendo una experiencia inmersiva y enriquecedora para los usuarios. Así pues, la biomímesis, aunque ya se ha abordado considerablemente en el contexto arquitectónico, se muestra como un campo prometedor a la hora de pensar en una arquitectura inspirada en la naturaleza más allá de la estética y la funcionalidad, sino con el objetivo de crear entornos que tengan en cuenta la interacción y la respuesta sensorial y emocional del usuario.

Palabras clave: Biomímesis - Arquitectura - Biofilia - Proceso de diseño - Diseño bioinspirado - Comportamiento - Sinestesia - Experiencia sensorial - Sentidos - Análisis bibliográfico

Resumo: Este artigo explora o campo da biomimética na arquitetura, com foco na integração de soluções inspiradas na natureza para enriquecer a experiência sensorial dos usuários em espaços construídos. Com base na percepção de que a natureza oferece inspiração não apenas estética, mas também funcional, ele investiga como a arquitetura pode se beneficiar desses princípios para criar ambientes que promovam o bem-estar e a inclusão por meio dos sentidos. Reconhecendo a arquitetura como uma arte predominantemente visual, este artigo destaca a necessidade de uma abordagem mais inclusiva que envolva todos os sentidos humanos, seguindo a perspectiva de arquitetos como Peter Zumthor e Juhani Pallasmaa, que defendem uma experiência arquitetônica multissensorial. Usando uma metodologia de revisão bibliográfica e análise crítica, o estudo examina a literatura existente que relaciona os conceitos de biomimética, biofilia e a experiência sensorial na arquitetura. Além disso, são apresentados estudos de caso que exemplificam a aplicação desses princípios, demonstrando como os ambientes construídos podem imitar e/ou integrar o mundo natural e, ao mesmo tempo, atender às necessidades humanas em diferentes contextos. Os resultados sugerem que a adoção de estratégias biomiméticas e biofílicas pode levar à criação de espaços que melhoram tanto a funcionalidade quanto a qualidade de vida, promovendo uma experiência imersiva e enriquecedora para os usuários. Assim, a biomimética, embora já consideravelmente abordada no contexto arquitetônico, mostra-se um campo promissor ao se pensar a arquitetura inspirada na natureza para além da estética e da funcionalidade, mas com o objetivo de criar ambientes que considerem a interação e a resposta sensorial e emocional do usuário.

Palavras-chave: Biomimética - Arquitetura - Biofilia - Processo de design - Design bio-inspirado - Comportamento - Sinestesia - Experiência sensorial - Sentidos - Análise bibliográfica