博士論文(要約)

DESIGN STRATEGIES AND THE QUESTION OF INHABITABILITY IN ARCHITECTURE

(デザイン戦略と建築の居住性の問題について)

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ABSTRACT

Theories on the correlation between the spatial aspects of dwellings and human wellness have always pervaded architecture. Since Vitruvius (circa 15 BCE), architectural scholars repeatedly underlined the importance of formal design elements in relation to the human body - such as scale and proportion - articulating that the presence of essential mathematical harmonies is perceived instinctively by people and emotionally fulfilling, which highlights a deep concern over the question of spatial inhabitability. Today, however, a growing number of research in the human sciences, assisted by the progress of technology, have successfully demonstrated that specific design aspects of the built environment have a direct influence on the human body and psyche. Consequently, this thesis set out to explore, from a design point of view, how this scientific data could be translated into pragmatic architectural intents. Based on systematic review of scientific findings that have established a direct parallel between design conditions and human cognitive responses (such as spatial mapping and memory), physiological responses (such as oscillation in cortisol, adrenaline, and oxytocin levels), and biological and psychological reactions (such as alertness, focus, healing, well-being), thirteen design parameters that promote inhabitability were proposed and validated through case studies. The result is a framework of practical design strategies which compose a substantial resource for architects and designers who seek to consolidate their work on a human-centered approach to architecture and/or to objectively add qualities to the built environment. Furthermore, an expansive inhabitability reference review composed by the result of the case studies was established. In sum, this study proposes to eliminate the disconnection among current scientific-based researches and its practical application.

CHAPTER 1 – INTRODUCTION

1.1 BACKGROUND

Throughout history, the relevance of the theme of inhabitability has pervaded the architectural discourse. Since Vitruvius (circa 15 BCE), many attempted to develop a framework to tackle it by involving the human perspective into the design process. Scholars repeatedly underlined the importance of formal design elements in relation to the human body - such as scale and proportion - articulating that the presence of essential mathematical harmonies is perceived instinctively by people, and is emotionally fulfilling. However, history also shows that this human-centered framework fluctuated in being the focal point of architectural design: other matters at times were more prominent, like stylistic representation, aesthetic, functionalism, rationality, among others. Nevertheless, the discourse would eventually return towards the human-centered approach.

At the beginning of the 20th century, in particular, distinguished architects engaged and theorized about the humanization of architecture. With an approach which drew on analytical observation in combination with scientific reasoning, they attempted to explain the links between nature, space and human biology. Frank Lloyd Wright, for example, introduced the word 'organic' to denominate an architecture that reinterpreted natural systems and principles to be in harmony with man, humanity and its environment. Geoffrey Scott examined the relation between built spaces and human biology, and the way we instinctively look into our surrounding environment for physical conditions that are related to our own. Alvar Aalto argued that, by covering all fields of human activities and considering humanitarian and psychological aspects, the goal of architectural design is to mediate man and nature. And Richard Neutra, whose alarmist discourse urged that man-made environments were becoming a threat to our vitality and soundness of mind and body, and that the relationship with nature needed to be reestablished.

Meanwhile, civilization witnessed surprising consequences from the interaction with the built environment. Significant outcomes happened at the end of the nineteenth century with the sanitation crisis,[1] followed by the energy crisis and the outbreak of Sick Building Syndrome (SBS)[2] in the 1970s. Over time, multitudes of studies evidenced the crucial effects the environment has over our physical and psychological health. Many of the public health disturbances, including obesity, diabetes, asthma, cardiovascular disease, injury, anxiety, depression, violence, and social inequities, among others, were linked to the built environment. Furthermore, overpopulated cities have caused an escalation of problems such as smaller enclosed spaces, lack of sufficient natural elements and real estate bubbles. This goes without mentioning the impact of climate change, greenhouse gas emissions and the decrease of earth's natural resources.

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1 With increasing urbanization of the population in the nineteenth century, poor environmental conditions became common, and the spread of diseases spiked. However, advances in scientific knowledge on causes and prevention of diseases brought about unprecedented changes in public health and a sanitary revolution began to take place. Institute of Medicine (US) Committee for the Study of the Future of Public Health. The Future of Public Health. Washington (DC): National Academies Press (US); 1988.

2 Sick building syndrome is a medical condition where people in a building become symptomatic or feel unwell for no apparent reason. However, causes have been linked to flaws in the heating, ventilation, and air conditioning systems. The symptoms tend to increase as more time is spent in the building and disappear when they are away. The most common symptoms are headache, nausea, eye, nose, and throat sensitivity, lethargy, and vertigo. Sick Building Syndrome; https://en.wikipedia.org/wiki/Sick_building_syndrome Accessed May 2nd, 2019.

The green building rating systems that emerged in the 1990s were a response to the problems related to construction and sustainability. In general, they focus on evaluating the performance of buildings within a sustainability framework which evaluates indoor environmental quality, water and energy usage, and management of natural resources. Such building assessment systems have multiplied over the years, and, by promoting measures that were sometimes complex and costly to apply in the past, are responsible for transforming the construction industry. In consequence, they also managed to improve the general building standards and raised the status of buildings.

Yet, the green building movement brought about a backlash: it evidenced that besides sustainability, a framework which ensures the inhabitability of buildings is of utter importance and urgently needed. Hence that highly rated buildings in sustainability standards do not necessarily account for buildings which are good for its inhabitants. This issue has been raised by many, especially in consideration of the lack of knowledge over practical strategies to achieve more human-centred designs.

Parallelly, recent developments in the sciences are changing the entire body of human knowledge. It is correct to say that more has been learned about our biological selves in the past half-century than in all of human history.[3] These developments, especially those determined by technological advancements, have forced major fields of study to go through a radical restructuring of agenda. And, within this scenario, many studies from different fields are contributing towards a human-centred framework for architectural design, either directly and indirectly. Experimental research in neuroscience, cognitive science, psychiatry, psychology, physiology, and anthropology, for example, are effectively producing unprecedented empirical evidence on how inhabitable space is according to the practical strategies used in a building's formal design. Through newly existing technologies, like brain imaging techniques, virtual reality programs, and specialized sensors, along with traditional analytical tools, researchers are able to measure behavioral, cognitive, and emotional reactions, as well as physiological markers and brain activity in relation to our surrounding environment. Results show that, for instance, humans are programmed to prefer curved forms over straight ones[4]; monotonous repetition is unsatisfying[5]; and being in contact with materials from nature improves the sense of comfort[6], decreases blood pressure[7], and improves creative performance[8]. A specific study proved that increased air quality and flow results in increased work performance, reduction of SBS symptoms, reduction of absence, and improved thermal comfort for office workers, besides raising their cognition in strategic tasks. Moreover, it demonstrated positive

3 Harry Francis Mallgrave in Pallasmaa, J., & Robinson, S. (2015). Mind in architecture - neuroscience, embodiment, and the future of design. MIT Press. Pg. 18
4 Sussman, Ann, and Justin B. Hollander. Cognitive Architecture: Designing for How We Respond to the Built Environment. Routledge, 2015.
5 A. Salingaros, Nikos. (2011). Why Monotonous Repetition is Unsatisfying. arXiv:1109.1461v1
6 Tsunetsugu, Yuko & Miyazaki, Yoshifumi & Sato, Hiroshi. (2007). Physiological effects in humans induced by the visual stimulation of room interiors with different wood quantities. Journal of Wood Science. 53. 11-16.
7 Tsunetsugu, Yuko & Miyazaki, Yoshifumi & Sato, Hiroshi. (2007). Physiological effects in humans induced by the visual stimulation of room interiors with different wood quantities. Journal of Wood Science. 53. 11-16.
8 Lichtenfeld, Stephanie & J Elliot, Andrew & Maier, Markus & Pekrun, Reinhard. (2012). Fertile Green: Green Facilitates Creative Performance. Personality & social psychology bulletin. 38. 784-97.

economic aspects by evidencing the ventilation rate can increase the productivity of an employee manifold a year.[9]

To recognize relevant design strategies based on scientific findings as such has the aptitude of pointing out practical parameters for achieving more substantial and informed design outcomes, as well as more positive post-occupancy evaluations. It also promotes an expanded understanding with the potential to assist in designing environments that are more responsive to human needs, consequently making architecture more inhabitable.

1.2 PROBLEM STATEMENT

"Architectural curricula remain one of the few programs in the humanities on campus without any serious examination of its underlying tenets….[specifically] how we engage with the built environment and how the built environment in turn shapes us."
- Harry Mallgrave [10]

The human environment is brimming with information about who and where we are, what we need, and if we are safe and well[11]. It is not a coincidence that we prefer environments that impact us positively: we, as human beings, have a strong connection to the space around us. This connection - termed inhabitability in this thesis - happens especially in places that we are in for long hours. It involves our conscious and unconscious embodied cognition - our mental constructs and performance on various tasks - and has a direct effect on our physical and emotional wellbeing. Recently, and as old civilizations deduced, it has been proved that increasing physical/psychological health issues and disturbances are connected to the built spaces we inhabit, indicating the powerful effect our surrounding environment has over our individual lives and in society as a whole[12]. The physical foundations of this relationship have been the scope of a large number of different fields of research - as already mentioned - with practical findings already being employed for decades in areas such as marketing and in the entertainment industry. In the field of architecture, practical findings have been generally applied to the design of specialized healthcare facilities.

Within this increased interest and range of scientific research investigating the relationship on how built environments shape, influence and impact human experience, architects (in general) are far behind in the engagement to understand how a person's body and mind truly experiences and reacts to the spaces being designed by them. The reason for this delay might be that, despite established facts,

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9 Allen, Joseph G. "Research: Stale Office Air Is Making You Less Productive." Harvard Business Review, 21 Mar. 2017, hbr.org/2017/03/research-stale-office-air-is-making-you-less-productive.
10 Mallgrave, Harry. (2018). From Object to Experience: The New Culture of Architectural Design. Bloomsbury Publishing. New York.
11 Mehaffy, M., & Salingaros, N. (2012, February 25). Science for Designers: Intelligence and the Information Environment. Retrieved from https://www.metropolismag.com/uncategorized/science-for-designers-intelligence-and-the-information-environment/
12 Jackson, Richard J. (2013) "The Impact of the Built Environment on Health: An Emerging Field." American Journal of Public Health, vol. 93, no. 9, 2003, pp. 1382–1384.

many architects accept the romantic approach to the profession, believing it to be based on intuition and creativity, where artistry sensibilities should not be limited or controlled.[13] There is also the economical excuse, which by contrast, has been discarded because increasing user wellbeing through building design was proved to economically benefit governments and companies in the long run.[14] Adding that stakeholders have been increasingly requesting for employee, students and patients outcomes to be improved through the design of buildings, the question remains on the reasons why architects are still not embracing the scientific discoveries being made in parallel fields in the last decades.

Since there is still no appropriate theoretical and practical framework in architecture which objectively tackles the influence of design strategies on users, it is essential to explore and integrate the outcomes of the growing empirical knowledge from other influential fields of studies into architecture in order to improve/promote inhabitability. Studies in human health and cognition together with the theory of architecture may start to provide the foundations for involving such issues with design strategies towards a more human-centred approach to architecture. Unfortunately, results of research developed in scientific and academic settings are seldomly brought into the practical realm of the architecture profession, and it is not common for professionals to read scientific papers from other fields or search for answers in journals and databases.

There are many potential margins to tackle this setback. An integrative model, where relevant findings within this new body of knowledge are merged, could benefit architects in obtaining practical knowledge into more human-centred design practices. Additionally, it has the potential to guide future scientific research. To consider the substantial amount of existing data on human/space behavior and incorporate it in the design of the built space is an important step which will assist in our constant design challenges. With so many great achievements and developments taking place, and with all the available database and data-driven intelligences, we as professionals should not be intimidated to explore new ways of promoting inhabitability within our designs.

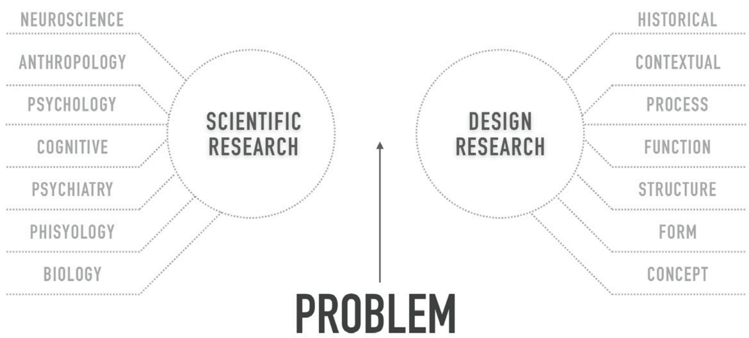

fig. 1 - Problem Diagram

13 Hart, Robert Lamb. "Reinvigorating Architecture With the Sciences: It's Time To Get On With It." Common Edge, commonedge.org/reinvigorating-architecture-with-the-sciences-its-time-get-on-with-it/

14 Macnaughton, Piers, et al. "Economic, Environmental and Health Implications of Enhanced Ventilation in Office Buildings." International Journal of Environmental Research and Public Health, vol. 12, no. 11, 2015, pp. 14709–14722.

1.3 RESEARCH OBJECTIVE

"It's not just about doing a building, it's figuring out what power it has to make a positive difference. " - Jeanne Gang[15]

Instinctive responses to space, form, surfaces, and details fundamentally shape how architecture is experienced, and, although people spend more than ninety percent of their lives in built environments[16], we, as architects, have little practical knowledge on how design decisions can influence human health, behavior, emotions and overall well-being. Decisions are often based on individual aesthetic inclinations, suppositions, functionalism, generalizations or tradition, demonstrating a need for a more structured design framework to support the physical, psychological, and social health and well-being of people in buildings and in the built environment. As the main designers of this built environment, architects must become more aware of the intricacies between design decisions and the human complexity to be able to design more inhabitable spaces.

Inhabitability in architecture concerns not only spaces which are fit to be occupied/ lived in, but spaces that are centered on humans and which positively affect what we think, feel and do. This thesis bases itself on the precedent that by acknowledging how the human brain assimilates the awareness and affection for environments, it is possible to intentionally design a more human-centred architecture. This human-centricity entails our conscious experience through our actions and uses of a built environment, like how well a building performs towards providing its occupants with physical well-being for everyday tasks such as working, studying, cooking, relaxing, sleeping, etc. And it also entails our subconscious experience, like how well a built environment performs towards promoting psychological well-being, e.g positive feelings.

The recent interdisciplinary studies developed in the fields of architecture and life sciences, which approach the human/space behavior relationship, are revealing important findings towards spatial inhabitability. Therefore, as to propose a method to tackle the issue of inhabitability in architecture, this research will engage in an investigation of studies in architecture and from relevant scientific research in various fields in order to identify, within this broader body of knowledge, relevant data that can be utilized for successful design outcomes. Based on available literature and in scientific data, the research intends to explore the correlation and integration of concepts and findings, and summarize them into an objective framework composed of practical strategies which could have a direct impact on the design process and building outcomes.

By encouraging the utilization of existing knowledge into the process, this methodology proposes to integrate diverse fields of study, and to eliminate the

15 Robathan, Magali. "Jeanne Gang." CLAD, http://www.cladglobal.com/architecture-design-features?codeid=31800&source=home.

16 Roberts, T. (2016, December 15). We Spend 90% of Our Time Indoors. Says Who? Retrieved from https://www.buildinggreen.com/blog/we-spend-90-our-time-indoors-says-who disconnection among current scientific-based research and its practical application in architecture. Likewise, it aims to help inform, instigate and legitimize designers, planners, engineerings, policymakers, decision-makers, clients and all stakeholders involved in the design process into considering the effectiveness of built spaces.

In sum, the objective of this thesis is to delve on a framework based on design strategies to approach the subject of spatial inhabitability in architecture. In order to reach this objective it will important to address the following issues:

- To contextualize the concept of inhabitability within history as to establish its significance within the discourse of architecture;
- To identify the supporting role of the sciences and interdisciplinary fields towards a human-centred approach to architectural design;
- To identify the positive and negative outcomes of attempts to institute objective frameworks towards building performance;
- To investigate and gather studies on the subject of the human/environment relation developed in the field of architecture and other disciplines;
- To systematize relevant findings;
- To propose a framework for promoting spatial inhabitability;
- To correlate the relation between architectural design and qualities of inhabitable spaces.

Furthermore, this thesis explores the relationship between the design of the built environment and its effects on the human body and its physical/mental health. It is critical to understand the weight of design decisions on buildings' occupants. What kind of design strategies in schools enhance children's focus and the ability to learn? What kind of design strategies in workplaces can make workers more productive? What kind of design strategies in hospitals could lead patients to faster recovery time? These are questions that need to be addressed. This thesis does not intend to answer them categorically, but to provide a general framework for promoting overall well-being in built environments.

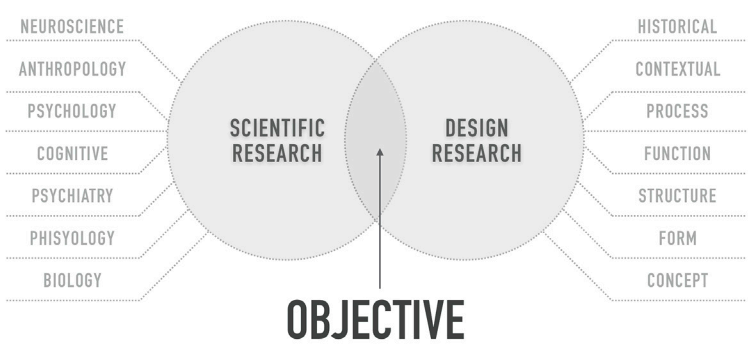

fig. 2 - Objective Diagram

1.4 METHODOLOGY

People are intrinsically related to the environment they inhabit, and the quality of this environment has a direct power to impact the cognitive and organic functions in our bodies. To determine the types of design strategies that ensures qualities to a built environment has the potential to assist architects in the proposal of more inhabitable spaces. Since inhabitability is defined by conscious and unconscious experiences in space, a thorough interdisciplinary research on the history and findings on the theme is necessary in order to identify what type of features an inhabitable space possesses. The resulting data should enable the establishment of a framework to promote inhabitability, aiming at providing a base for analysis and a model that contributes to the design process and assist architects in ensuring their design decisions.

Accordingly, a methodology was established to achieve this research objective. As to define and contextualize the concept of inhabitability, first, it was important to detect the occurrence and relevance of the theme throughout the history of architecture. Therefore, a literature review was conducted with the intention to gain information on the evolution of the theme along time, and insights on how architects have objectively approached the human/space behavior relation. This was carried out by identifying important theories/concepts/arguments on publications and events related to the theme which had a prominent impact in their current historical period and in the overall architectural discourse.

Following in the contextualization of the theme, the supporting role of the sciences to the human-centred approach to architectural design was analyzed. The emergence of interdisciplinary fields linked to human/space behavior was investigated, and their role as providing evidence for a human-centred approach to architecture was established.

Lastly, the implementation of criteria for healthcare buildings and the role of existing standards, rating systems, labels and guidelines that evaluate building performance was investigated. Their importance within the contextualization of the concept of inhabitability lies in the proposal of instituting objective frameworks to tackle the improvement of buildings.

Subsequently, a method for approaching inhabitability within a design framework was proposed. First, a review was conducted on scientific studies developed in the field of architecture and in the sciences which identify relevant design strategies towards spatial inhabitability. The criteria for considering the studies were their 1) relevance to the topic, 2) clear research methodology, 3) objective evidence. Their analysis is crucial for understanding the recent and accelerated interest on the theme, which is mostly due to advancements in technology and neuroscience. The procedure was to first locate and analyze as many existing research related to human/space behavior - and the neuroscience/architecture relation - currently available. Then, identify within that body of knowledge findings which could lead to parameters based on practical design strategies to be utilized for enhancing the human/space behavior relation in built environments.

Finally, after parameters for inhabitability were established, there was a need to verify their validity. Two types of case study analysis were proposed to assist in the validation: one based on cross-examination of buildings submitted into popular voting against the inhabitability parameters, and another based on cross-examination of renowned buildings. Both analyses were developed by a matrix-points based correlation. The intention was for the results to demonstrate compatibility between the inhabitability parameters and the design strategies used in the featured buildings.

By encouraging the utilization of existing knowledge into the process, this methodology proposes to integrate diverse fields of study, and to eliminate the disconnection among current scientific-based research and its practical application in architecture. Likewise, it aims to help inform, instigate and legitimize designers, planners, engineerings, policymakers, decision-makers, clients and all stakeholders involved in the design process into considering the effectiveness of built spaces.

1.4.1 RESEARCH PHASES

Five core phases helped define the theme of inhabitability in architecture, approach it within a broader context of knowledge, and allow it to be assessed objectively in the architectural practice:

- What is inhabitability;
- Historical contextualization of inhabitability;
- Analysis of scientific studies related to inhabitability;
- Definition of parameters for inhabitability based on scientific studies;
- Validation of defined parameters for inhabitability through case studies;

These phases assisted in elucidating the broader scope throughout the research, and as subsequent and specific questions and findings were revealed, additional topics were engaged.

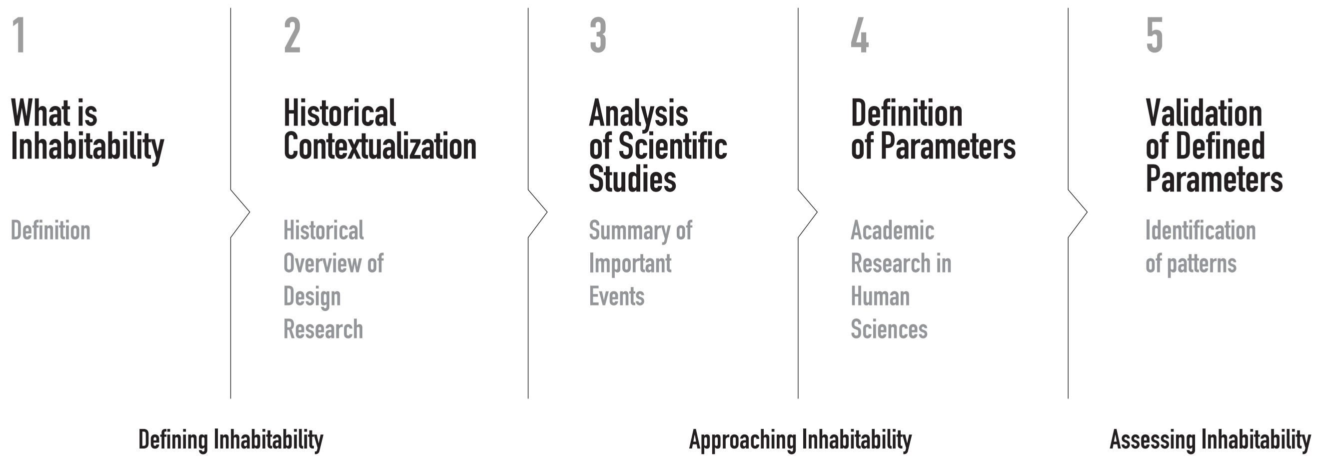

fig. 3 - Research Phases

1.5 SCOPE

What do architects know about human beings as generic clients to inhabit a space? What do they know about human biology, biological influences, neuro reactions, and cognitive behaviour? How do they suggest designs for people from different cultures? And finally, can scientific research give answers to support inhabitability in space design?

The intent of this research is to answer these questions by delving into findings on human responses to the built environment. Long before objective design methodologies were pursued, architects and planners were already attempting to create spaces to support our health and wellbeing. Their approach would always be to connect architecture to nature, however, without empirical backup that the outcomes would promote the intended benefits. Yet, nothing has essentially been added to this architectural approach. Richard Neutra, in 1954, was already urging architects to incorporate the "current organic research" and "brain physiology" into designs, to explore our multisensory interconnection with the built world, as well as to undertake research in areas of "sensory significance".[17]

Today, the life sciences have come a long way. Research has produced unprecedented empirical evidence on the link between characteristics of built environments and our physical and mental wellbeing. As the knowledge increases over questions on the human/environment relationship, to consider an interdisciplinary approach with architecture is imperative.

This approach is not suggesting that architects should renounce or inhibit other design imperatives, historical background, technical requirements or creative thinking. However, it does implicate on the object-image-base focus of architecture. Richard Neutra was asked about which style should be the most appropriate for the new century, with technologies, steel frames and so on. He replied: "Style is not the point, rather architecture's primary task - it's most noble and unique task - is to understand space as physiological and psychological experience. The body moving in space - rather than a static form or a historical style."[18]

Architects need to be reminded that people experience space through an ensemble of stimuli of their biological senses. The experience and biological interpretations that occur consequently start even before the person reflects about the building. Architecture is a multi-sensory experience consisting of 1- visual and navigation systems, 2- place mapping systems, 3- proprioceptive and spatial systems, 4- sensory-motor, mirror, and effective systems, 5- social and cultural dimensions. These systems and dimensions are responsible for our reaction to materials' texture of floors and walls, the touch of the texture, the touch of handrail and handles, the smell of materials, the hand of fabrics, the resonance of space, presence of light, spatial relations, formal proportions, scale, patterns, rhythms, tactical values, etc. Not to mention those related

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17 Neutra, Richard Joseph. (1954). Survival through Design. Oxford University Press.
18 In "Richard Neutra: Creating Canvases for Linking Nature to Body, Mind, and Sensory Perception" presented by Dr. Barbara Lamprecht for the Driehaus Foundation Built Environment Symposium 2017.

to matters of comfort, convenience, craftsmanship, presence, warmth, and beauty, which occur unconditionally to individual's logic and understanding of architectural.

Although the question of the subjectivity of these interpretations, and the variation between individual experiences can be considered an issue for objective analysis, scientific studies supported by empirical evidence include a general approach which is based on the premise that our reactions are embedded within us as a species, which in turn naturally belongs to the existing environment.

By interpreting results of current research production into practical design strategies, this newly acquired information has the potential to offer architects means to rethink their approach and provide design within a more secure theoretical and informed basis. Consequently, designers will no longer have to rely simply on stylistic, utilitarian and/or economic influences. This research aims to make an impact on design decisions towards more inhabitable built environments.

1.6 SIGNIFICANCE OF RESEARCH

As architectural designs need to respond to new challenges and opportunities presented by a range of social, environmental, technological and economic motivators, architects are demanded to work across different scopes and scales; and to possess specialized expertise while maintaining a broad contextual grasp of the discipline. Furthermore, architecture cannot be judged by its formal constructability, its accomplishment of programmatic requirements or its performance in terms of technical parameters, since these issues are fundamental. However, architects must strive to enrich their conceptualizations by understanding and articulating the experience built environments can provide to its occupants.

As a discipline, architecture has been operating almost autonomously over the past half-century. Meanwhile, interdisciplinary fields in the life sciences are having unprecedented success in gaining knowledge about the relation between human behaviour and the built environment, evidencing that humans are biologically drawn/ influenced to certain environments based on their design characteristics. Design characteristics can produce increase and decrease levels of anxiety, stress, alertness, calmness, focus, can make people happy, sad, productive, and can physically impair or injure a person. This means that architects have a level of responsibility for the wellbeing of users of the spaces they create that is greater than is commonly realized.

As a response to this prominent issue, the translation of scientific findings on human/ space behaviour into a design framework aims at providing architects with practical strategies that support physical/mental health and wellbeing. The possibility to merge knowledge from different disciplines and explore it in new design approaches is a necessity for the development of architecture and an excitement prognosis for professionals. The more information about human/space behavior, the better the design can become. The objective is not to prescribe a solution or justify a style, but rather inform on the possibilities and outcomes, and put the emphasis on the experience of design. By drawing upon a range of sources, and emphasizing the far-reaching implications of new neuroscientific discoveries and models, this thesis intends to bring insights and clarity over findings that are fast becoming accepted in architecture.

Furthermore, this research entails the exploration of more systematic methodologies in architectural design, which has been sought by many. Systematization does not infer in lack of creativeness or standardization of design. In fact, it is the opposite: designers can benefit from an objective methodology which provides opportunities to focus on the development of original and innovative solutions within a reliable framework to enhance user's wellbeing. It also contributes to stimulating debates on approaches that may add to the discussion.

Human behavior is directly related to its environment and cannot be understood apart from its context. The objective is to identify opportunities to improve and expand the knowledge about human-centered design in diverse cross-sector dialogues and potential collaborations. Looking to ease the integration into design these approaches and design strategies. Since most of our lives are spend inside buildings, investigation on human response to its context has the potential to expand our understanding of what architecture is today and what it can become tomorrow.

MOTIVATION

WHAT MAKES A GOOD BUILDING?

HOW TO DESIGN BETTER SPACES?

PROBLEM	→	OBJECTIVE
GAP BETWEEN SCIENTIFIC DISCOVERIES AND ARCHITECTURAL DESIGN		PROMOTE A DESIGN FRAMEWORK FOR SPATIAL INHABITABILITY

METHOD

HOW TO TRANSLATE SCIENTIFIC

FINDINGS INTO A DESIGN FRAMEWORK?

1.7 THESIS OUTLINE AND FRAMEWORK

The thesis is outlined as to guide into the development process of the theme in a comprehensive overview. It is structured in 3 parts, which determine the context, methods and results, and are distributed in 7 linked chapters as follows:

PART I - DEFINING INHABITABILITY {Context}

PART II - APPROACHING INHABITABILITY {Methods}

PART III - ACCESSING INHABITABILITY {Results}

PART I - DEFINING INHABITABILITY

Part I presents the description of the research theme, with key concepts, and overall contextualization by analysing the historical, theoretical and methodological foundation of inhabitability in architecture. Chapter 2 presents an overview of the research with the origins, terminology, definition, literature review, and a chronological investigation to identify relevant events in architecture which are related to inhabitability. In Chapter 3, important collaborative approaches between architecture and the human sciences which are related to the concept of inhabitability in architecture are introduced.

PART II - APPROACHING INHABITABILITY

Part II introduces methods to approach the research theme. In Chapter 4, present-day examples demonstrate the importance of objective frameworks that tackle the improvement of buildings. In Chapter 5 a framework of design strategies based on scientific investigation and evidence on the relation of human/space behavior is proposed.

PART III - ASSESSING INHABITABILITY

Part III presents a methodology to assess inhabitability. In Chapter 6, the proposed framework of design strategies based on human/space behavior relation is evaluated through case studies. Results and findings are analysed.

The final conclusion in Chapter 7 complements the precedent analysis. Conclusions are outlined and the future outlooks of research on the theme are proposed.

APPENDIX

Complementary data and material are available in the appendix.
Appendix I - 324 Scientific Studies
Appendix II - Synthesis of Parameters

FRAMEWORK

CHAPTER I – Introduction

PART I
DEFINING **INHABITABILITY**

CHAPTER II - Historical Overview of Design Research

CHAPTER III – Studies in Human Sciences

PART II
APPROACHING **INHABITABILITY**

CHAPTER IV – Inhabitability in Architecture

CHAPTER V - Design Strategies and Inhabitability Parameters

PART III
ACCESSING **INHABITABILITY**

CHAPTER VI – Evidence of Inhabitability in Architecture

CHAPTER VII – Final Conclusions

fig. 4 - Framework Diagram

PART 1 – DEFINING INHABITABILITY

Part I presents the description of the research theme, with key concepts, and overall contextualization by analysing the historical, theoretical and methodological foundation of inhabitability in architecture. Chapter 2 presents an overview of the research with the origins, terminology, definition, literature review, and a chronological investigation to identify relevant events in architecture which are related to inhabitability. In Chapter 3, important collaborative approaches between architecture and the human sciences which are related to the concept of inhabitability in architecture are introduced.

CHAPTER 2 – ORIGINS OF INHABITABILITY IN ARCHITECTURE

This chapter begins with the definition of the concept of inhabitability as used in this thesis. It then outlines, briefly, historical events which are considered important to provide a foundation for understanding the progression of reasoning towards an inhabitability approach to architecture. This outline is intended to serve as a basic literature review. It is not intended to be a detailed historical background or evaluation of the approaches taken in the events featured in it.

2.1 DEFINITION OF INHABITABILITY

Inhabitability, as used in this thesis, is a concept based on an environmental condition concerned with human spatial appropriation and adaptation. This condition is determined by people's physiological, biological and psychological factors in correspondence to the dominating physical elements within a given space or place, in a quest for overall satisfaction and fundamental well-being. Therefore, inhabitability is thought of as a positive response to the variables affecting human beings and their innate necessities as defined by a spatial configuration - hence the intrinsic understanding of inhabitability as pertaining to the notion of architecture and human dwellings. Based on this framework, the architect is responsible for the outcomes of user`s architectural conceptualizations, with the role of understanding what distinguishes and promotes an inhabitable space. This fundamental consideration is, therefore, crucial for a human-centred approach to architecture. Furthermore, in the logic of advancing the development of architecture as well as improving human well-being, design concepts based on the concept of inhabitability allows for more informed and successful spatial outcomes.

2.2 HISTORICAL OVERVIEW

Theories on the correlation between spatial aspects of dwellings and human wellness have always pervaded architecture. Since Vitruvius, architectural scholars repeatedly underlined the importance of formal design elements in relation to the human body - such as scale and proportion - articulating that the presence of essential mathematical harmonies are perceived instinctively by people and emotionally fulfilling. These concerns highlight a deep regard over the human/environment relation and the question of spatial inhabitability. This human-centred framework, which involves the human perspective into the design process, is a reaction to a design methodology based solely on the architect's aesthetic inclinations or the basic programmatic functions of a space. Although it may seem obvious that architecture design should be centered around its inhabitants, history shows that was not always the case.

Thoughts on what architecture is or should be evolved over millenniums. In certain periods, alongside other forms of art, architecture was solely being discussed in regards to stylistic representation and aesthetic. Nevertheless, important scholars influenced architecture with their theories - characterizing influential historical events which consistently combined art and science - leading to a deeper understanding and development of the field, and consequently, towards inhabitability in architecture.

2.2.1 INFLUENTIAL HISTORICAL EVENTS

The writings of Vitruvius, from around 26 BCE, was the only treatise on architecture to survive from antiquity, becoming a canon of classical architecture. De architectura, also known as The Ten Books on Architecture, proclaimed that a structure must exhibit three essential qualities: firmitas, utilitas, venustas - structural strength and stability;

utility, commodity and proper spatial adaptation; beauty, delight and attractive appearance.[19] This system underlined, most significantly, the importance of formal design elements in relation to the human body such as scale and proportion, and is how Vitruvius articulated that architecture is an imitation of nature, with the presence of essential mathematical harmonies being perceived instinctively by people, and being emotionally fulfilling. Although such considerations to inhabitability were already a crucial factor in the ancient architecture discourse, throughout history, this search for knowledge on design parameters that promote such relationship oscillated in being the focal point in architecture.

Fifteen centuries later, in 1435, author, artist, architect and philosopher Leon Battista Alberti writes Della pittura. Inspired by the work of Vitruvius and Pythagoras, Alberti regarded nature as the essential source of beauty, where harmony was revealed through numbers, proportions, and arrangement. He argued that mathematics was the common ground between the arts and sciences, and described how optics determines perspective and is the instrument of artistic and architectural representation.[20] And as Vitruvius, he considered the ideal building to be the representation of the human body. He later wrote De re aedificatoria, the first architecture treatise of the Renaissance, where he extends his theory to engineering and the philosophy of beauty.

Around 1490, Leonardo Da Vinci's produces the drawing of the Vitruvian Man - his attempt to relate man to nature. The drawing is based on the correlations of geometry and the ideal proportions of the human body as described by Vitruvius in De architectura, and demonstrates the integration of mathematics and art during the Renaissance, as well as Da Vinci's profound interest in proportion.[21]

In the 16th century, architect Andrea Palladio wrote Four Books of Architecture, one of the most influential literature in the history of architecture. Palladio was influenced by Vitruvius and Italian Renaissance architects to delineate his architecture concepts, which illustrated the problematic reciprocity between structure, function, and art in architecture in this period. He determined two types of systematic rules for buildings: design rules (based on appearance) and construction rules (based on the logic of construction).[22] The intended results yield a clear identity of proportion and composition based on physical construction and visual style to express perfection and beauty. These concepts were based on mathematical rules with the purpose of stimulating positive psychological integrity in humans, and to provide a sense of calmness, harmony, and dignity through design strategies. He was also concerned about the financial value of the constructions and enumerated rules that could be applied for ordinary buildings to achieve beauty without utilising expensive materials. For him, other than being based in the sciences, architecture was related more to craft than art in the sense that it could be learned and not be dependant on chance, genius or luck.

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19 Vitruvius Pollio., and M. H. 1859-1910 Morgan. Vitruvius: The Ten Books On Architecture. New York: Dover Publications, 1960.

20 Alberti, Leon Battista, 1404-1472. (2011). Leon Battista Alberti : On painting : a new translation and critical edition. New York: Cambridge University Press.

21 "The Vitruvian man". leonardodavinci.stanford.edu. Retrieved 30 April 2019.

22 Palladio, Andrea, 1508-1580. (1965). The four books of architecture. New York: Dover Publications

Throughout the 17th century Baroque in France, Italy, and Spain, the architectural reasoning was still rooted in the predicaments of forms, numbers, proportions and to the human embodiment from ancient treatises. However, these classical predicaments were applied by most without a scientific foundation, but rather with a bias on mythological and symbolic claims. Within this scenario, the writings of philosopher, mathematician and scientist René Descartes' unfinished treatise Rules for the Direction of the Mind, on scientific method and philosophical thinking (written around 1628), made an impact in all fields. It promoted the conflict of this current system of value, based on inherited tradition, with a new system based on a universal method of deductive reasoning. Inherent within this new system was the principle known as "Cartesian doubt," which implied that knowledge should not be based on previous beliefs or speculation. The modern critical mind, in contrast, should approach each problem on the basis of empirical results.[23] "Such critical skepticism was necessary, the philosopher insisted, both to separate modern science from the prejudices of late scholastic and ancient thought and to ground it anew on clear and distinct ideas."[24]

Descartes' Cartesianism pioneered a scientific revolution that permeated all circles by the mid 17th century, also reflecting in the arts. In 1650, architect Roland Fréart de Chambray wrote the Parallel of Antient Architecture with the Modern inspired by the new stream of thought. In the book, Fréart de Chambray conversely argued that contemporary architecture should abandon the traditional thinking imposed by antiquity, and be set free "to invent, and follow our Genius…". [25]

Yet, the 17th-century text that proposed a shift towards a new architectural epistemology based in the sciences was Claude Perrault's Ordonnance for the Five Kinds of Columns After the Method of the Ancients. Written in 1683, the work emphasized the use of scientific methodology into the current traditional sphere of architectural theory. Perrault debated on the arbitrary application of the classical orders and made an unprecedented discrimination between "positive beauty" - which regarded solidity, craftsmanship and materiality - and "arbitrary beauty" - regarding style, proportions, symmetry. As a consequence of Perrault's ideas, architects and theorists turned to nature in an attempt to develop a new rationale for the universal validity of the classical system. Architecture theory itself shifted into rationalism, with functional concerns over problems of logic, control, and efficiency.

By the 18th century, rationalism about beauty was the preeminent logic of belief. In 1753, priest and architectural theorist Marc-Antoine Laugier writes Essay on Architecture, proposed a rationalist approach to aesthetic. His theory was that the process of architectural creation should not merely be controlled by instinct - it needed logical reasoning and experience in the ways of beauty. He rejected the opulence of Neoclassicism and Rococo with his concept of the Primitive Hut, arguing that architecture derives from functionality, simplicity, nature, proportion and three basic elements: column, entablature, and pediment.

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23 Sepper, D. (2015). Rules for the Direction of the Mind. In L. Nolan (Ed.), The Cambridge Descartes Lexicon(pp. 661-663). Cambridge: Cambridge University Press.

24 Mallgrave, H. (2005). Modern Architectural Theory: A Historical Survey, 1673–1968. Cambridge: Cambridge University Press.

25 Roland Fréart de Chambray, Parallèle de l'architecture antique avec la moderne (Paris: Martin, 1650), 1–2; cited from the English translation of John Evelyn, A Parallel of the Antient Architecture with the Modern (London: Roycroft, 1664), 1–2.)

Conversely, this rationalist scenario began to change. British philosophers working within an empiricist framework began to develop theories of taste as a corrective to the rise of reason as the chief source and test of knowledge. The fundamental idea behind such theories is that judgments of beauty cannot be mediated by inferences from principles or applications of concepts, but rather originate from our sensory judgments.[26] In 1757, statesman, author, orator, political theorist and philosopher, Edmund Burke writes A Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful. Burke's treatise on aesthetics suggested that emotions incited by beauty and sublimity were related with the tensioning and relaxation of the optic nerve rather than with the classical dogma of numerical proportions or harmonic ratios.

Such aesthetic theories began to gradually shift the basis of architectural inquiry from objective nature to the subjective mind. Studies on human behavior became the focal point for understanding architectural form, leading the classical trinity to be considered obsolete in expressing the human mind.[27] An example of this shift is Nicolas Le Camus de Mézières' The Genius of Architecture or The Analogy of That Art with Our Sensations. The book written in 1780 explores the sentimental and expressive value of form, arguing that the aim of architecture is to satisfy the senses and the mind.

When philosopher Arthur Schopenhauer writes The World as Will and Representation in 1819, the new discourse of the 19th century on utility and pleasure, rule and imagination, and cognition and perception, was in motion. His theories on aesthetic, which associated architecture with the mind's subjective will, redefined the current notions of function, beauty, and structure. With a non-instrumental framework, Schopenhauer denied artistic meaning to architecture's functional role, arguing that perception is not passive. The brain actively constructs its world through a complex series of neurological operations. Architecturally, he translated the brain reading the forms of and within buildings as a conflict between gravity and rigidity: "For Architecture, considered only as a fine art, the Ideas of the lowest grades of nature, that is gravity, rigidity, and cohesion, are the proper theme, but not, as has been assumed hitherto, merely regular form, proportion, and symmetry. These are something purely geometrical, properties of space, not Ideas; therefore they cannot be the theme of a fine art."[28] Schopenhauer was well aware that buildings are not only the subject of fine art, since they can be built with different geometries and principles of construction, utilize various materials, and attend a range of functions. But for him, architecture was more than just buildings - it should, above all, promote an aesthetic impact.

In mid-19th century British art critic, patron and philanthropist John Ruskin writes The Seven Lamps of Architecture. The book, from in 1849, opens with the affirmation: "Architecture is the art which so disposes and adorns the edifices raised by man for

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26 Shelley, James, "The Concept of the Aesthetic", The Stanford Encyclopedia of Philosophy (Winter 2017 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/win2017/entries/aesthetic-concept/>

27 Schwarzer, M. (1996). Schopenhauer's philosophy of architecture. In D. Jacquette (Ed.), Schopenhauer, Philosophy and the Arts (Cambridge Studies in Philosophy and the Arts, pp.277-298). Cambridge: Cambridge University Press.

28 Watson, V. (2017). On the Matter and Intelligence of the Architectural Model: Arthur Schopenhauer's Psychophysiological Theory of Architecture and Konrad Wachsmann's Design of a Space Structure. ARENA Journal of Architectural Research, 2(1) whatsoever uses, that the sight of them contributes to his mental health, power, and pleasure."[29] The importance of this book is on Ruskin's elaboration on how design principles/parameters had associational values for Beauty, Truth, Sacrifice, Power, Life, Obedience, and Memory. To express Beauty, for example, the design of a building should stem from the natural environment, with lines and shapes deriving from nature. Truth in a building is defined by not hiding its flaws under decorative notions. Common buildings should have just structures to express Sacrifice. As for Power, architects should consider the building's vantage points, position, location in reference to the horizon, and the bounding line as to promote continuity.

Parallel to this European context, in the United States, architecture was evolving to become an organized profession. In 1857, a group of architects laid the foundations for establishing architecture as a profession by launching The American Institute of Architects. The AIA focused on developing standards of ethical conduct, standardization of contracts, and policies for training and credentialing of architects. Furthermore, it recognised and stressed the importance of the scientific method to collect measurable and empirical evidence for the development of architecture.

In 1873, German philosopher Robert Vischer writes the Doctoral thesis On the Optical Sense of Form: A Contribution to Aesthetics. His writings provided an overview of what came to be later known as psychological aesthetics. Vischer coined the concept of empathy to describe how we understand visual forms and environments by bestowing them with life. His work concerned the combination of these psychological and physiological insights into the subjective experience of art. He articulated that when people experience a great work of art, the combination of psychological and physiological insights of the subjective experience generates an intensification of their vital sensations.[30]

Influenced by Robert Vischer's concept of empathy, Swiss art historian Heinrich Wölfflin writes Prolegomena toward a Psychology of Architecture in 1886. Wölfflin's writing is considered to be a founding text of the architectural and art psychology discipline. The dissertation opens with the question: "How is it possible that architectural forms are able to invoke an emotion or a mood?", placing the discussion of space at the core of the experience of architecture.[31] He claimed that, psychologically, architecture had its basis on form through the empathetic response of human form, where the impression of a building is mirrored by the expression of the object. He explored the idea that architecture is composed of elements of gravity and rigidness, which are braced by proportions between length and width along horizontal and vertical planes, and where the relationship between extension and height determine the perception of a building as being awkward, light, flexible or static.

In 1908, Frank Lloyd Wright introduced the word 'organic' to denominate his architectural philosophy. Adverse to the modernist slogan "form follows function" - which derived as a reaction to the excessive use of ornamentation in the 1900s -

29 *Ruskin, J. (1969). The seven lamps of architecture. London: Dent.*
30 *Vischer, R., Mallgrave, H. F., & Ikonomou, E. (1994). Empathy, form, and space: Problems in German aesthetics, 1873-1893.*
31 *Pallasmaa, J., & Robinson, S. (2015). Mind in architecture - neuroscience, embodiment, and the future of design. MIT Press.*

Wright proposed the phrase "form and function are one" - which defined his unique view on the integration of nature into architecture. His organic architecture, which was also a reaction to the technology-oriented modernist mind-set, took on the meaning of a reinterpretation of natural systems and principles, where build forms are in harmony with humanity and its environment, and become more natural than nature itself. It involves respect to materials, to the relationship between the form/ design and the building's function, and to the integration of time-context-site-structure-spaces into a coherent whole. In 1957, he published the book A Testament, addressing ideas about the relationship of the human scale to the landscape, and the development of a building's architectural "character" - which was his response to the notion of style. He explored the grains of wood and texture of brick and stone as part of the ornamentation with his abstract design of plants. Wright was a pioneer in opening the interior for an interesting sequence of spaces, providing prospect views and refuge. Another facet of Wright's approach to architecture was his strategy to connect to his clients in order to understand how they lived, so he could identify and resolve problems through design. His intention was to understand buildings not as independent objects, but as a whole, including even MEP systems and construction details. [32]

In the early 20th century, developments in psychological aesthetics continue, revealing important finding for architecture. In 1912, writer Vernon Lee and art theorist Clementina Anstruther-Thomson write Beauty and Ugliness and other Studies in Psychological Aesthetics. In a study of the facade of the church of Santa Maria Novella, Lee and Anstruther-Thomson recorded how its proportions altered and moderated breathing patterns, exerted certain pressures on the feet and head, and ultimately uplifted the viewer with a feeling of "harmonious completeness."[33]

In 1913, Austrian-American architect Rudolph Michael Schindler writes Modern Architecture: A Program. The book demonstrates Schindler's initial exploration of the concept of space in architecture and his concerns towards the environmental qualities it should entail: "The comfort of the dwelling no longer resides in its formal development, but in the possibility of controlling within its confines light, air, and temperature."[34] Decades later, in 1934, Schindler compiles his theories in another book entitled Space Architecture, where he explains the contemporary meaning of space by contrasting it to past architecture, where space was just considered as a by-product of building. He emphasized the difference between architects who create space centered around human life from architects who only consider functionality - who consequently disregard the true meaning of architecture.[35]

The book was written by architect Geoffrey Scott entitled The Architecture of Humanism - a Study in the History of Taste was first published in 1914 and examines the relation between built spaces and human biology. He explored the concept of "unconscious mimetic instinct", which is the way we instinctively look into our surrounding

32 Wright, F. L. (1991). Frank Lloyd Wright. Arizona: Frank Lloyd Wright Foundation.
33 Lee, V. and Anstruther-Thomson, C. (1912). Beauty & ugliness and other studies in psychological aesthetics. Theclassics Us.
34 Rudolph M. Schindler, (1913) "Modern Architecture: A Program", in March and Sheine, R. M. Schindler, 10.
35 Park, J. (1996). Schindler, Symmetry and the Free Public Library, 1920. Architectural Research Quarterly, 2(2), 72-83.

environment for physical conditions that are related to our own.[36] He described how we tend to naturally follow lines into paths to trace out their orientation and extension, until they resolve into patterns of larger setting of space and mass. Mass, with its contours light and shade, we comprehend in terms of unity and proportion. And space, we perceive its configuration in terms of our body's movement.[37] His avant-garde theories are popular in the current neuroscience debate, being confirmed by embodied simulation and mirror neurons. They are also considered by many as the beginning of patterns in architecture, which have been scientifically endorsed as a new base of the architectural approach.

In 1940, architect Alvar Aalto writes The Humanizing of Architecture. In the article, Aalto argued that design should complement the "unbalanced formula between form and function" in architecture by considering humanitarian and psychological aspects, as a critique to the current technology-oriented rationalism. "Technical functionalism is correct only if enlarged to cover even the psychophysical field. That is the only way to humanize architecture."[38] For him, true rationalism should cover all fields of human activities, and is where architecture mediates man and nature.

In 1948, the Swiss-French architect Le Corbusier introduced his concept of Le Modulor. The Modulor was the result of his twenty years of research in an ambitious attempt to create an universal system of proportions, following the long tradition of Vitruvius, Da Vinci and Alberti of speculation on the mathematical relationship between human dimensions and nature. Corbusier's alleged that his system could provide the measurements for all aspects of design - from a small scale, like door handles, to a large scale, like the planning of cities - where proportions could be scaled up or down to infinity using Fibonacci's progression, and be applied to improve both appearance and function of architecture. But the true importance of the Modulor laid in the return of the human form to the centre of design.[39]

Austrian-American architect Richard Neutra was also very much concerned with psychological, physiological, and anthropological implications of design, leading him to write Survival through Design in 1954. In the book, Neutra sets off to explore what he believes are the problems of the current state of architectural design: the health effects of visual and environmental pollution, sensory overload, and the lack of concern over human well-being in design. He, therefore, urged architects to incorporate the findings of "current organic research" and "brain physiology" into designs by addressing the breadth of neurological responses to color, lighting, space, sound, and haptic sensations, as to explore multisensory interconnection with the built world. His theory is elementary: "Acceptance of design must turn from a commercial into a physiological issue. Fitness for assimilation by our organic capacity becomes a guiding principle for judging design because such fitness aids the survival of the individual, the community, the race itself."[40]

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36 Scott, Geoffrey. (2010). The Architecture of Humanism A STUDY IN THE HISTORY OF TASTE. Nabu Press.
37 Robert Lamb Hart in Architecture: The Body-Centered Art.
https://www.metropolismag.com/architecture/architecture-the-body-centered-art accessed on May 2nd, 2019.
38 Kim, Hyon-Sob. (2009). Alvar Aalto and Humanizing of Architecture. Journal of Asian Architecture and Building Engineering - J ASIAN ARCHIT BUILD ENG. 8. 9-16. 10.3130/jaabe.8.9.
39 Le Corbusier (2004) [First published in two volumes in 1954 and 1958.]. The Modulor: A Harmonious Measure to the Human Scale, Universally Applicable to Architecture and Mechanics. Basel & Boston: Birkhäuser
40 Neutra, R. (1954). Survival through design. New York: Oxford University.

In 1959, architect and urban planner Steen Eiler Rasmussen writes Experiencing Architecture. Rasmussen argued that in order to design spaces that are beautiful and useful, architecture should be understood and experienced as an art form. He presents sets of parameters to qualify buildings, and describes good design as coming from everyday experience of architecture in real-time and as a sensuous (visual, tactile and auditory) and psychological art, which is accessible through form and space, and enhanced by factors as such as light, colour, texture, rhythm, and material effects.[41]

In 1960, urban planner Kevin Lynch writes The Image of the City. Motivated by the idea that a clear understanding of the urban environment is needed to counter disorientation, the book focused on analyses research on mental maps. He was able to identify five patterns - edges, paths, nodes, districts and landmarks - which humans naturally use as mental images, and correlate to social, nature and senses factors to understand how to orient ourselves in cities. Cities that have a clear representation of the five patterns are able to provide individual emotional security, a framework for communication and conceptual organization, and an intensification of the everyday human experience.[42]

A year later, in 1961, journalist and activist Jane Jacobs writes The Death and Life of Great American Cities, which is a more explicit critique of the current rationalist urban planning in the USA. Jacobs blames planners for using deductive reasoning to find principles on how to plan cities, which created unnatural urban spaces and consequently rejected human beings and communities. Jacobs proposed "generators of diversity" as strategies to conduct the current "organised and efficient" urban design and planning into a more human-centred direction.[43]

In 1962, the first Conference on Design Methods is held, which marks the birth of the design methods movement. Organised by engineer/designer Christopher Jones and mechanical engineer Bruce Archer at the Imperial College London, it is generally regarded as the event which marked the launch of design research as a field of enquiry. In the beginning of the movement, the intention was to apply a rational approach to design based on system analysis and theory. However, as the movement evolved, the reasoning shifted: in order to optimize design, methods should be based on decision-making and creativity techniques, involving both designers and clients (and other stakeholders), towards the recognition of satisfactory and appropriate problem-solution types.[44]

Architect Christopher Alexander, which was involved in the design methods movement, concludes the dissertation Notes on the Synthesis of Form in 1964, the first on the subject. His research argued on a new approach to architectural thinking through design methods and theory information, where the same set of laws determine the structure of a city, a building, or a single room. His proposed approach to solving such universal problems relied on scientific reasoning, where design problems were divided into small solvable patterns through information theory, sorted and resolved

41 Rasmussen, S. E. (1959). Experiencing architecture. Cambridge [Mass.: M.I.T. Press, Massachusetts Institute of Technology.
42 Lynch, Kevin. (1982). The Image of the City. M.I.T. PR.
43 Jacobs, J., & Epstein, J. (1961). The death and life of great American cities. New York: Modern Library.
44 Cross, Nigel. (1993). A History of Design Methodology

between the components within and among patterns. A few years later, Alexander himself reacted against his proposed methodology rethinking them as simplistic and not capable of solving real-world complex problems.[45]

In 1972, architects and urbanists Denise Scott Brown, Robert Venturi and Steven Izenour write Learning from Las Vegas. The book, an exploration of the artificiality of the city of Las Vegas, challenges architects to put away their egos, idealism, and pre-conceptualizations, and instead focus on the relationships human beings and the environment, and in concepts of adaptivity and flexibility. In a criticism to the current scenario of architecture, the authors defend the idea of looking for the existing landscape in a more tolerant way, referring into the history and tradition of the place to move forward, and highlight the importance of ornaments and decorative elements in architecture as a means to provide context and denote purpose.[46]

In 1977, Christopher Alexander et al. propose a new design approach in the book A Pattern Language: Towns, Buildings, Construction. Focusing on architecture, urban design and inhabitability, it was influenced by investigations on design and computer programming. The book is a planning instrument which includes 253 patterns found on how human beings interact with built forms and environment. The authors defined problems and proposed practical methods and solutions for constructing better designs, which are in accordance with local customs, society, and climate.[47]

In 1984, Edward Wilson writes the book Biophilia. Wilson popularised the hypothesis that biophilia, which is our natural affinity for all living system, is the very essence of humanity. He argues that humans are attracted and instinctively want to connect with natural environments due to biological and psychological processes that are inherent to humankind, and in architecture, it is characterized by the use of naturalistic dimensions, which is geometric coherency of the physical - built and natural - spaces with human dimension.[48]

In 1996, Juhani Pallasmaa writes The Eyes of the Skin: Architecture and the Senses. In the manifesto, Pallasmaa questions the separation between architectural philosophy and practice, and argues that the dominance of the visual realm and the suppression of the other four senses diminishes the spatial experience of architecture. He explains the historical development of the ocularcentric emphasis since the Greeks - and its impact on the experience of the world and the nature of architecture - and points the way towards a multi-sensory and holistic design, which is able to enhance the sense of integration and belonging.[49]

During the 1990s, extensive developments in neuroimaging technology were made. The improvement of the PET scans (positron emission tomography) along with the development of the fMRI (functional magnetic resonance imaging) enabled brain

45 *Alexander, C. (1964). Notes on the synthesis of form. Cambridge, Mass: Harvard Univ. Press.*
46 *Venturi, R., Scott, B. D., & Izenour, S. (1972). Learning from Las Vegas.*
47 *Alexander, C., Ishikawa, S., & Silverstein, M. (1977). A pattern language: Towns, buildings, construction. New York: Oxford Univ. Pr.*
48 *Wilson, E. O. (1984). Biophilia. Cambridge, Mass.: Harvard University Press.*
49 *Pallasmaa, J. (1996). The eyes of the skin: Architecture and the senses. Chichester: Wiley.*

mapping. By the early 2000s, neuroimaging allowed a direct communication between the human brain and computers for monitoring the structure and function of our nervous system. This was a breakthrough for various fields of study, especially for cognitive neuroscience, which was primarily built on research on cognitive psychology, behavioral conditioning, psychophysics, and brain science based on knowledge from animal studies. Since functional imaging enables the direct visualization and processing of information by regions in the human brain, it allows the examination of links between specific psychological processes and neural activity, as well as dynamic patterns of connectivity between them. Research on how space alters the brain began to lead to evidence-based findings that were directly related to architecture, allowing for a deeper understanding of the influence of the environment on human experience. From these findings, specific research in the neurosciences began looking into how elements of a built space could eventually change people's frame of mind.

Christopher Alexander publishes a four-volume work between the years 2002~2005 entitled The Nature of Order: An Essay on the Art of Building and the Nature of the Universe. Based on his previous work on the formulation of principles of design solutions, Alexander came to the realization that, in order to promote lively buildings and cities, a "morphogenetic" understanding of the whole is necessary.[50] This morphogenetic approach is accompanied by 15 essential geometric properties that he narrowed down from the previous 253 patterns proposed in Pattern Language.

With this ample development of the neurosciences, in 2003, the Academy of Neuroscience for Architecture (ANFA) was founded. ANFA's objective is to develop, validate and disseminate knowledge linking current research in neuroscience and architecture as to promote an understanding of human responses to the built environment through scientific methods.

Mathematician and theorist Nikos Salingaros published A Theory of Architecture in 2006. Based on Christopher Alexander's Notes on the Synthesis of Form, A Pattern Language, and The Nature of Order, Salingaros proposes methods to achieve more pleasing design outcomes. He introduces science-based aesthetic rules for approaching design from fractal theory, with mathematical laws for scaling, and rules of subdivisions.[51]

In 2010, urbanist Jan Gehl writes Cities for People. The book is about the importance of architects in understanding how people move around the environment, how they inhabit spaces and how spaces influence people's lives. Combining research on architecture and psychology, Gehl describes criteria for assessing space quality originating from the human body and the human senses like how people move and how our senses work.[52]

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50 Alexander, Christopher. The Nature of Order: An Essay on the Art of Building and the Nature of The Universe, Book One, The Phenomenon of Life. Berkeley, Calif.: Center for Environmental Structure, 2002.
51 Salingaros, N. (2006). A Theory of Architecture, with contributions by M. Mehaffy, T. Mikiten, D. Tejada, and H. Yu, Umbau-Verlag, Solingen, Germany.
52 Gehl, J. (2010). Cities for people. Washington, DC: Island Press.

Most recently, in 2011, Harry Mallgrave writes The Architect's Brain: Neuroscience, Creativity, and Architecture. The book was the first of its kind and lead the way of other publications on the topic. It depicts how the findings in the field of neuroscience can promote scientifically founded understanding of design and the architectural process. He argues that these empirical data should assist in delineating useful from speculative theory, and in order to demonstrate that, he presents neurological justification based on current research for architecture's timeless dogmas and current paradigms.[53]

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53 Mallgrave, H. F., & John Wiley & Sons. (2011). The architect's brain: Neuroscience, creativity, and architecture. Malden, Mass: Wiley-Blackwell.

2.2.2 HISTORICAL TIMELINE OF INHABITABILITY

table 1 - Timeline of important events in history related to the concept of Inhabitability.

year	event	description
26 BC	Vitruvius writes *De architectura*, known today as **The Ten Books on Architecture.**	*De architectura* proclaimed that a structure must exhibit three essential qualities: *firmitas, utilitas, venustas* - structural strength and stability; utility, commodity and proper spatial adaptation; beauty, delight and attractive appearance. This system underlined, most significantly, the importance of formal design elements in relation to the human body such as scale and proportion.
1435	Leon Battista Alberti writes ***Della pittura***.	Inspired by the work of Vitruvius and Pythagoras, Alberti regarded nature as the essential source of beauty, where harmony was revealed through numbers, proportions and arrangement. He argued that mathematics was the common ground between the arts and sciences.
≈1490	**The Vitruvian Man** drawing is produced by Leonardo da Vinci.	Vitruvian Man was Da Vinci's attempt to relate man to nature. The drawing is based on the correlations of geometry and the ideal proportions of the human body as described by Vitruvius.
1570	Andrea Palladio writes **The Four Books of Architecture.**	Palladio was influenced by Vitruvius and Italian Renaissance architects to delineate his architecture concepts, which illustrated the problematic reciprocity between structure, function, and art in architecture in this period. He determined two types of systematic rules for buildings: design rules (based on appearance) and construction rules (based on the logic of construction).
≈1628	René Descartes writes **Rules for the Direction of the Mind.**	It promoted the conflict of this current system of value, based on inherited tradition, with a new system based on a universal method of deductive reasoning. Inherent within this new system was the principle known as "Cartesian doubt," which implied that knowledge should not be based on previous beliefs or speculation.
1650	Roland Fréart de Chambray writes **A Parallel of the Ancient Architecture with the Modern.**	Inspired by cartesianism, Chambray argued that contemporary architecture should abandon the traditional thinking imposed by antiquity, and be set free "to invent, and follow our *Genius…"*.
1683	Claude Perrault writes **Ordonnance for the Five Kinds of Columns After the Method of the Ancients.**	The work emphasized the use of scientific methodology into the current traditional sphere of architectural theory. Perrault debated on the arbitrary application of the classical orders and made an unprecedented discrimination between "positive beauty" - which regarded solidity, craftsmanship and materiality - and "arbitrary beauty" - regarding style, proportions, symmetry.
1753	Marc-Antoine Laugier writes the **Essay on Architecture.**	Laugier proposed a rationalist approach to aesthetic. His theory was that the process of architectural creation should not merely be controlled by instinct - it needed logical reasoning and experience in the ways of beauty.
1757	Edmund Burke writes **A Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful.**	Burke's treatise on aesthetics suggested that emotions incited by beauty and sublimity were related with the tensioning and relaxation of the optic nerve rather than with the classical dogma of numerical proportions or harmonic ratios.
1780	Nicolas Le Camus de Mézières writes **The Genius of Architecture or The Analogy of That Art with Our Sensations.**	Le Camus explores the sentimental and expressive value of form, arguing that the aim of architecture is to satisfy the senses and the mind.
1819	Arthur Schopenhauer writes **The World as Will and Representation.**	Schopenhauer theories on aesthetic, which associated architecture with the mind's subjective will, redefined the current notions of function, beauty, and structure. With a non-instrumental framework, Schopenhauer denied artistic meaning to architecture's functional role, arguing that perception is not passive. The brain actively constructs its world through a complex series of neurological operations.

1849	John Ruskin writes **The Seven Lamps of Architecture.**	The book opens with the affirmation: "Architecture is the art which so disposes and adorns the edifices raised by man for whatsoever uses, that the sight of them contributes to his mental health, power and pleasure."
1857	The **American Institute of Architects** is founded.	A group of architects laid the foundations for establishing architecture as a profession by launching The American Institute of Architects. It recognised and stressed the importance of scientific method to collect measurable and empirical evidence to the development of architecture.
1873	Robert Vischer writes **On the Optical Sense of Form**, in the book Empathy, Form, and Space: Problems in German Aesthetics.	Vischer's writings provided an overview of what came to be later known as psychological aesthetics. He coined the concept of empathy to describe how we understand visual forms and environments by bestowing them with life.
1886	Heinrich Wölfflin writes **Prolegomena toward a Psychology of Architecture.**	Wölfflin's writing is considered to be a founding text of the architectural and art psychology discipline. The dissertation opens with the question: "How is it possible that architectural forms are able to invoke an emotion or a mood?", placing the discussion of space at the core of the *experience* of architecture.
1908	Frank Lloyd Wright introduces the word **"organic".**	Wright introduced the word 'organic' to denominate his architectural philosophy. Adverse to the modernist slogan "form follows function" - which derived as a reaction to the excessive use of ornamentation in the 1900s - Wright proposed the phrase "form and function are one" - which defined his unique view on the integration of nature into architecture.
1912	Vernon Lee and Clementina Anstruther-Thomson write **Beauty and Ugliness and other Studies in Psychological Aesthetics.**	In a study of the facade of the church of Santa Maria Novella, Lee and Anstruther-Thomson recorded how its proportions altered and moderated breathing patterns, exerted certain pressures on the feet and head, and ultimately uplifted the viewer with a feeling of "harmonious completeness."
1913	Rudolph Michael Schindler writes **Modern Architecture: A Program.**	The book demonstrates Schindler's initial exploration of the concept of space in architecture and his concerns towards the environmental qualities it should entail: "The comfort of the dwelling no longer resides in its formal development, but in the possibility of controlling within its confines light, air, and temperature."
1914	Geoffrey Scott writes **The Architecture of Humanism - a Study in the History of Taste**	Scott examines the relation between built spaces and human biology. He explored the concept of "unconscious mimetic instinct", which is the way we instinctively look into our surrounding environment for physical conditions that are related to our own.
1940	Alvar Aalto writes **The Humanizing of Architecture.**	Aalto argued that design should complement the "unbalanced formula between form and function" in architecture by considering humanitarian and psychological aspects."Technical functionalism is correct only if enlarged to cover even the psychophysical field. That is the only way to humanize architecture."
1948	Le Corbusier publishes *Le Modulor.*	The Modulor was Le Corbusier's attempt to create an universal system of proportions, following the long tradition of Vitruvius, Da Vinci and Alberti of speculation on the mathematical relationship between human dimensions and nature.
1954	Richard Neutra writes **Survival Through Design.**	Neutra urged architects to incorporate the findings of "current organic research" and "brain physiology" into designs by addressing the breadth of neurological responses to color, lighting, space, sound, and haptic sensations, as to explore multisensory interconnection with the built world.
1959	Steen Eiler Rasmussen writes **Experiencing Architecture.**	Rasmussen argued that in order to design spaces that are beautiful and useful, architecture should be understood and experienced as an art form. He presents sets of parameters to qualify buildings, and describes good design as coming from everyday experience of architecture.
1960	Kevin Lynch writes **The Image of the City.**	Motivated by the idea that a clear understanding of the urban environment is needed to counter disorientation, the book focused on analyses research on mental maps. He was able to identify five patterns - edges, paths, nodes, districts and landmarks - which humans naturally use as mental images, and correlate to social, nature and senses factors to understand how to orient ourselves in cities.

1961	Jane Jacobs writes **The Death and Life of Great American Cities.**	Jacobs blames planners for using deductive reasoning to find principles on how to plan cities, which created unnatural urban spaces and consequently rejected human beings and communities. Jacobs proposed "generators of diversity" as strategies to conduct the current "organised and efficient" urban design and planning into a more human-centred direction.
1962	The first **Conference on Design Methods** is held.	The first Conference on Design Methods marks the birth of the design methods movement. In the beginning of the movement, the intention was to apply a rational approach to design based on system analysis and theory. However, as the movement evolved, the reasoning shifted: in order to optimize design, methods should be based on decision-making and creativity techniques.
1964	Christopher Alexander concludes his dissertation **Notes on the Synthesis of Form.**	Alexander's research argued on a new approach to architectural thinking through design methods and theory information, where the same set of laws determine the structure of a city, a building, or a single room.
1972	Denise Scott Brown, Robert Venturi and Steven Izenour **write Learning from Las Vegas.**	The book challenges architects to put away their egos, idealism and pre-conceptualizations, and instead focus on the relationships human beings and the environment, and in concepts of adaptivity and flexibility.
1977	Christopher Alexander et al. write **A Pattern Language: Towns, Buildings, Construction.**	Focusing on architecture, urban design and inhabitability, it was influenced by investigations on design and computer programming. The book is a planning instrument which includes 253 patterns found on how human beings interact with built forms and environment.
1984	Edward Wilson writes **Biophilia.**	Wilson popularised the hypothesis that biophilia, which is our natural affinity for all living system, is the very essence of humanity. He argues that humans are attracted and instinctively want to connect with natural environments due to biological and psychological processes that are inherent to humankind.
1996	Juhani Pallasmaa writes **The Eyes of the Skin: Architecture and the Senses.**	Pallasmaa questions the separation between architectural philosophy and practice, and argues that the dominance of the visual realm and the suppression of the other four senses diminishes the spatial experience of architecture.
1990~ 2000	Development of positron emission tomography - **PET scan** - and function magnetic resonance imaging - **fMRIs.**	Neuroimaging technologies were developed allowing the recording of neurological aspects of the working human brain. It became possible to isolate particular areas of the brain involved with the perception of buildings, landscapes, and their spatial properties.
2002~ 2005	Christopher Alexander publishes a four-volume work entitled **The Nature of Order: An Essay on the Art of Building and the Nature of the Universe.**	Based on his previous work on the formulation of principles of design solutions, Alexander came to the realization that, in order to promote lively buildings and cities, a "morphogenetic" understanding of the whole is necessary.
2003	The **Academy of Neuroscience for Architecture** is founded.	ANFA's objective is to develop, validate and disseminate knowledge linking current research in neuroscience and architecture as to promote an understanding of human responses to the built environment through scientific methods.
2006	Nikos Salingaros publishes **A Theory of Architecture.**	Based on Christopher Alexander's theories, Salingaros proposes methods to achieve more pleasing design outcomes. He introduces science-based aesthetic rules for approaching design from fractal theory, with mathematical laws for scaling, and rules of subdivisions.
2010	Jan Gehl writes **Cities for People.**	Combining research on architecture and psychology, Gehl describes criteria for assessing space quality originating from the human body and the human senses like how people move and how our senses work.
2011	Harry Mallgrave writes **The Architect's Brain: Neuroscience, Creativity, and Architecture.**	Mallgrave argues that these empirical data should assist in delineating useful from speculative theory, and in order to demonstrate that, he presents neurological justification based on current research for architecture's timeless dogmas and current paradigms.

2.3 DISCUSSION

As disclosed hitherto, theories on the correlation between spatial aspects of dwellings and human wellness have always pervaded architecture. The objective of this chapter was to indicate the progression of design approaches over the human body/space relation and about the inhabitability concept over time. In certain periods, history shows that these concerns were not considered focal points: other matters were more prominent, like stylistic representation, aesthetic, functionalism, rationality, among others. Nevertheless, the discourse would eventually return to aim its attention on a human-centred approach, focusing on matters of inhabitability.

The chapter also demonstrated that architecture was always driven by larger intellectual contexts, employing interdisciplinary reasoning in a critical way. From Vitruvius to the Renaissance, architecture had the human figure as its embodiment and its theories were closely related to the sciences. "The line dividing science and architecture at this time was virtually indistinguishable."[54] Architecture was tackled as an objective system which embodied art and mathematical reasoning, with the premise that architectural elements and structure should be based on nature. Eventually, during the eighteenth century, the architectural rationale began to shift from objective nature to the subjective mind. Influenced by the philosophical status quo, the focus was turned into the study of human behavior as fundamental to understanding architectural form. Later, influenced by technology, the reasoning of modern architecture delved around systemization and architectural space.

From then, constant efforts have been made to provide design with a more cohesive approach, with appropriate grounding and a critical framework. Progress in several fields of science, such as biology, physiology, and psychology, are providing compelling research, with findings that could often be directly applied to a better understanding and improvement of the human/ environment relationship. This is leading to the inference that interdisciplinary theoretical and methodological approaches, as historically implied, are the ultimate framework for the development of architecture as a discipline and for reaching inhabitability in built spaces.

54 Harry Francis Mallgrave in Pallasmaa, J., & Robinson, S. (2015). Mind in architecture - neuroscience, embodiment, and the future of design. MIT Press. pg 11.

CHAPTER 3 – ADVANCEMENTS TOWARDS INHABITABILITY

Recent remarkable progress within the life sciences brought out new perceptions of human biology. The development of neurotechnologies, in particular, is providing a superior comprehension of our bodies' internal systems, especially of the sensorimotor area of the brain which is responsible for the recognition of action, space, and form. In the past, the biological disciplines considered mental systems particularly complex due to the difficulty in obtaining measurable data when compared to other health structures with more objective results. For this reason, the new advancements have been a breakthrough. They are enabling professionals to gain a deeper understanding of our behavioral and mental processes, how environmental circumstances affect us, and how to consider ways to promote and improve our overall health and well-being.

Furthermore, the progress in the area of human cognition is bringing about a new meaning to old theories, especially for architecture. The previous chapter presented an overview of the evolution of architectural concepts, demonstrating that science always had a powerful influence over its development. Alongside architecture, humans' interrelation with the environment is also an intrinsic subject of research in areas such as biology, psychology, physiology, sociology, and philosophy, among others. However, in these areas, investigations on spatial and embodied cognition, behavior and unconscious neuro reactions to the environment have traditionally been studied on a much deeper level than in architecture. Consequently, important interdisciplinary collaborations began to take place as to phase out this knowledge gap. These approaches are leading to impactful changes in the understanding of human perception in relation to the experience of space like never before, as well as contributing to deeper investigations of natural systems and structures.

3.1 INTERDISCIPLINARY APPROACHES

Within this growing body of knowledge, interdisciplinary approaches linked to the natural and built environment are currently being acclaimed. Evidence-based Design, Environmental Psychology, Biomimicry, and others - which will be described in this chapter - are examples of interdisciplinary approaches which rely on the interaction between different disciplines in order to tackle problems within multiple perspectives. The following approaches are featured in this dissertation due to their important link to architecture and to inhabitability, and also for informing distinct concepts in relation to space and human dynamics which integrate and expand theoretical definitions. Although some have existed for decades and others only for a few years, they are being highlighted because architecture should not ignore these developments and the findings they bring - which may be crucial for its progress - allowing architects to purposely embrace new approaches to design which considers the human interaction with the environment more incisively. This is essential for architects who look to address the improvement of the spaces they create, for tackling long-lasting architectural enquiries, and for gaining solid knowledge about what promotes inhabitable built environments.

The featured approaches are the result of the interaction between the following disciplines:

Evidence-Based Design - combines neuroscience, psychology, psychiatry, environmental psychology, medicine, immunology, management, education, architecture, interior design, landscape design, urban planning;
Cognitive Science and Cognitive Architecture - combines linguistics, psychology, artificial intelligence, philosophy, neuroscience, anthropology, architecture, interior design, landscape design, urban planning;
Neuroscience and Neuroarchitecture - combines biology, cognitive science, cognitive psychology, neurology, neuropsychology, mathematics, architecture, interior design, landscape design, urban planning;
Environmental Psychology - combines sociology, political science, anthropology, economics, cognitive science, developmental psychology, industrial and organizational psychology, psychobiology, psychoanalysis, social neuroscience, architecture, interior design, landscape design, preservation, urban planning;
Biophilia and Biophilic Design - combines biology, biomimicry, evolutionary psychology, environmental psychology, ecology, architecture, landscape design, urban planning;
Biomimicry and Biomimetic Design - combines biology, ecology, ecosystem ecology, engineering, reverse engineering, architecture, landscape design, urban planning;
Baubotanik - combines biology, ecology, ecosystem ecology, architecture, landscape design;
Bionics and Adaptive Auto-Response Design - combines biology, biophysics, electronics, engineering, computer science, architecture;
Ecological Design - combines biology, ecology, ecosystem ecology, engineering, architecture, interior design, landscape design, urban planning.

3.1.1 EVIDENCE-BASED DESIGN

The term evidence-based design (EBD) is defined by The Center for Health Design as "the deliberate attempt to base building decisions on the best available research evidence, with the goal of improving outcomes and of continuing to monitor the success or failure for subsequent decision-making." It is a process in which decisions about the physical environment are made based on credible research to achieve the best possible outcomes for its users. Furthermore, it increases the body of knowledge of certain scenario by producing evidence data and applying them as to achieve an optimal design, and can be used as a scientific support of design decisions towards the improvement of overall well-being in built environments. It is particularly used by environmental psychology and neuroscience as a method to collect information from outcomes of the design strategies.

Essentially, the design issues are translated to research questions which should be answered and gather with the outcomes to set up the evidence-based design data. This is the findings for each specific scenario of the design approach. Therefore, in theory, architects are in essence, used to translate the design issues into questions, but not taking the appropriate action to turn the findings into an evidence-based design data. Which should be approached with a critical interpretation of the evidence and appropriate literature`s review of the subject, project and design concepts. Therefore, with the relevant evidence, the design decisions should be made by implementing a proper design approach approved or disapproved by previous measurements, reports, hypothesis and data results.

The roots of EBD can be traced back to 1860 when the English social reformer and statistician Florence Nightingale recognized the importance of fresh air, appropriate luminosity, clean water, and a quiet and warm environment in aiding in the recovery patients in hospitals. Her findings were based on statistical evidence that she collected, and which later on led to advances in sanitation. More than a century later, the book Effectiveness and Efficiency: Random Reflections on Health Services[55] published in 1972 is credited as the cornerstone of the EBD movement, where evidence from restricted experiments related to built environment were gathered and translated. However, EBD only became popularized by the critical report written by Roger Ulrich in 1984 which evidenced the impact of window views on patient recovery.[56] Having always been intrinsically related to health design, today, EBD has become increasingly applied to different domains such as workplaces, learning centers, financial and organizational institutions aiming at optimal building performance and user satisfaction. This human-centred approach is increasingly being directed towards promoting safety, stress reduction, productivity, sustainability, ecological health, among other benefits, and, and has been able to prove the effect of built environment on patients and staff, like the psychological effects of lighting, flooring,

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55 *Cochrane, A. L. Effectiveness and Efficiency.: Random Reflections on Health Services. Nuffield Provincial Hospitals Trust, 1972.*

56 *Ulrich, Roger. (1984). View Through a Window May Influence Recovery from Surgery. Science (New York, N.Y.). 224. 420-1.*

and noise on critical-care patients[57] the consequences of hospital layout in personnel performance.[58][59]

Currently, there are thousands of studies published on the subject, from systematic literature reviews to practical guidelines on how to apply its methodology. EBD can also include post-occupancy research, which is based on interviews, reviews, reports and post-occupancy analysis of building after being inhabited.

3.1.2 COGNITIVE SCIENCE AND COGNITIVE ARCHITECTURE

Cognition is defined as "the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses"[60] and as "a perception, sensation, idea, or intuition resulting from the process of cognition"[61], or in other words: the awareness of embodied experience which leads to perception and intuition. It comes from the Latin word cognoscere which means 'get to know'. As for Cognitive Science, it began as an intellectual movement in the 1950s, which is often referred to as the cognitive revolution. It is an interdisciplinary field of research which studies the mind and how the nervous system processes information and integrates approaches from cognitive psychology, computer systems, and neuroscience, among others. Its main focus is on the brain's levels of structural acquisition, organization, representation, and usage of knowledge, especially when learning, making decisions, logic reasoning and planning. The purpose is to gain a better understanding of the mind - and how it behaves - and the principles of intelligence as to, consequently, be able to develop intelligent devices.

Part of the research developed within the cognitive sciences is based on measuring behavioral responses to different stimuli, like behavioral traces, observations, and choice.[62] This typically involves psychophysical experiments on making judgments of environments and its physical properties - where individuals' express preferences or dislikes to color, texture or sound for example - and eye-tracking methods - where the individual's focus of attention supplies insight on how the mind is processing information. These experiments, in particular, are very important for architecture because they are based on an approach to understand the relation between ourselves and the built environment, and are related to environmental cognition - which is concerns the interaction and diagnostics of the environment around us - and to spatial cognition - which concerns the assistance in the process of navigation through the space.[63] For that reason, Ann Sussman and Justin Hollander coined the term Cognitive

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57 Ulrich, Roger S.; Zimring, Craig; Zhu, Xuemei; DuBose, Jennifer; Seo, Hyun-Bo; Choi, Young-Seon; Quan, Xiaobo; Joseph, Anjali (2008-01-01). "A review of the research literature on evidence-based healthcare design". HERD. 1 (3): 61–125.

58 Clipson CW, Johnson RE (1987). "Integrated approaches to facilities planning and assessment". Planning for Higher Education. 15 (3): 12–22.

59 Zimring, CM (2002). "Post-occupancy evaluation: Issues and implementation". In Bechtel RB. Handbook of environmental psychology. New York: Wiley. pp. 306–23.

60 Cognition. (2019) In the Oxford Dictionary. https://en.oxforddictionaries.com/definition/cognition

61 Cognition. (2019) In the Oxford Dictionary. https://en.oxforddictionaries.com/definition/cognition

62 Lewandowski, Gary; Strohmetz, David (2009). "Actions can speak as loud as words: Measuring behavior in psychological science". Social and Personality Psychology Compass. 3 (6): 992–1002.

63 Kopec, David Alan. (2018). Environmental Psychology for Design. Fairchild Books, an Imprint of Bloomsbury Publishing Inc.

Architecture in 2014, in their book Cognitive Architecture – Designing for how we respond to the built environment.

Cognitive Architecture typically refers to a theory employed in the field of Artificial Intelligence and Computational Cognitive Science, that analyses the structure of the human mind in parallel to computational models. However, as approached by Sussman and Hollander, this interdisciplinary branch addresses the human-environment relationship, analysing human behavioural and cognitive needs within built environments. Research is based on how people perceive and memorize their surroundings, and on how they orient themselves and find their way inside buildings, with methods including real-world observation, virtual reality experiments, and behavior simulation in design. The aim is to promote knowledge towards a human-centered approach to design.

3.1.3 NEUROSCIENCE AND NEUROARCHITECTURE

Neuroscience is a multidisciplinary branch of the biological sciences which combines psychology to understand the properties of neurons and neural circuits.[64] Its scope stretches from molecular and cellular studies to imaging of the motor, sensory and cognitive tasks in the brain. Neuroscientists endeavor the acknowledgment of behavior, perception, learning, memory, and consciousness through the exploration of brain cells in parallel to the observation of cognitive activities, as to provide insights on the connection of neurobiological facts and environment.

Neuroscience as a field of research has gone through important developments due to advancements in electrophysiology, molecular biology, and computational neuroscience. The technical advances in medical imaging machines also have had a special influence, with their constant upgrade since the nineties. This progress has allowed specialists to interpreted many neurological processes and precisely locate areas of the brain related to a range of activities. Consequently, it became possible to elucidate the relationship between environment and behaviors through neurons impulses of perceptions in the brains. These impulses of perceptions in the brains are important because they imply our translation of the environment through our embodied cognition, allowing us to navigate across the space while absorbing and processing its physical inputs.

Discoveries in neurobiology established the role of the hippocampus and its hippocampal system - a complex brain structure positioned in the middle of our head - in the shaping and recovering memories, as well as its involvement in navigation through the environment[65], demonstrating its crucial function in the relation between recollection and sense of place. The hippocampal system is driven by specific neurons called place cells and grid cells, which are activated by reflex to map the space we

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64 Shulman, Robert G. (2013). "Neuroscience: A Multidisciplinary, Multilevel Field". Brain Imaging: What it Can (and Cannot) Tell Us About Consciousness. Oxford University Press. p. 59.
65 Jeffery, K.j., and R. Hayman. "Plasticity of the Hippocampal Place Cell Representation." Reviews in the Neurosciences, vol. 15, no. 5, 2004.

are experiencing. Place cells were discovered in 1971 by O'Keefe and Dostrovsky[66], when in a study with rats, they detected cells that speedily fired in the rats' brain when they entered a new environment when a new object was added or removed, when the rats passed through different environment regions and when they reached a certain location. The experiment was able to demonstrate the importance of place cells to assist in understanding the influence of architectural spaces in our neural system.[67] In contrast to place cells, which generally represent a particular location in the environment, grid cells are in charge of creating a spatial modular grid pattern of the environment. This mental grid is reused repeatedly and collectively, producing a general and adaptable system for mapping space. Grid cells were detected by Edvard Moser and May-Britt Moser in 2005.[68] Their findings awarded them with the Nobel Prize in Physiology or Medicine, together with John O'Keefe with his discovery of place cells.

Basically, the place and grid cells are associated in generating the spatial maps in the brain which lead to the sense of place and assist in the navigation ability. The place cells happen on top of the grid cells, adding meaning for certain locations. Other cells like head direction cells - a natural compass for the direction of the head is pointed to, and border cells - the sense of limits inside of space; are also related to the navigation system in the brain, which altogether result in a cognitive map - a personal mental representation of the physical environment. The cognitive map is generated in the hippocampus by the complex network combination of neurons which act in our spatial memory and navigation. In other words, the cognitive map means our awareness of where we are.[69] Whenever you enter into a new space, cognitive maps are being designed by all the cells involved in the process of navigation and spatial information, storing details and generating structured geometry maps.

These outstanding findings are crucial to understand our navigation, position, and memory within the environment for our spatial perception. These perceptions change while we move through spaces in constant activity. These discoveries in neuroscience have benefits to all humanity and the relevance for architecture is undeniable. These advancements are being observed and described as the most exciting frontier of human knowledge since the Renaissance.[70]

The increased interest on how to explain the architectural environments through psychological approaches, together with the fast expansion of cognitive neuroscience, induced the formation of a new discipline called Neuroarchitecture. Neuroarchitecture comprehends the study of how the brain reacts to built environments, and how these environments impact our behavior and wellbeing. Although it seems like a collaborative research between neuroscience and architecture, it is currently a sub-discipline within neuroscience's scope, which is advancing from the growing

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66 O'Keefe, John (1978). The Hippocampus as a Cognitive Map. Oxford: Claredon Press.

67 Sternberg, Esther M., and Matthew A. Wilson. (2006). "Neuroscience and Architecture: Seeking Common Ground." Cell, vol. 127, no. 2, 2006, pp. 239–242.

68 Hafting, T.; Fyhn, M.; Molden, S.; Moser, M. -B.; Moser, E. I. (2005). "Microstructure of a spatial map in the entorhinal cortex". Nature. 436 (7052): 801–806.

69 O'Keefe J, Nadel L (1978). The Hippocampus as a Cognitive Map. Oxford University Press. Retrieved 2009-11-05.

70 ANFA Mission, 21 Mar. 2019, anfarch.org/board-of-directors/mission/.

studies on the effects of the built environment in our cognition.[71] The link between neuroscience and architecture is allowing for a better understanding of built spaces based on scientific evidence, and has been producing information on the enrichment of environments.

The discovery of mirror neurons has further increased the interdisciplinary research of neuroscience and architecture. Mirror neurons are responsible for the main part to understand others actions and absorb new abilities by mimicry. It relates to our empathy capacities in seeing another self, as a possibility to learn, cooperate, build trust and translate behaviors. Its importance comes from the reasoning that it can lead to better design approaches when considering other people's needs. In other words, mirror neurons support our empathy towards others by improving our potentiality to better behave and design to another self.
In the same way, embodied cognition is responsible for our perception of feelings and sensations that we already experienced. You imagine the situation and feel the effect without being on it. For example, you feel cold and know the sensation of chilly while looking at an image of a snowstorm. The same thing happens when we notice the complexity of details from certain creation which induces us how arduous it was to make such achievement. We envision ourselves doing it, we engage and have an empathy with the creation and its relationship with the whole environment. This allows architects to decrease the negative effects on emotions and motivations.

Jonas Salk was a remarkable medical researcher who credited his success creating the vaccine for polio to the time he was in a 13th-century monastery in Italy. Salk was feeling tired and lost in trying to find a cure in his small enclosure laboratory at the University of Pittsburgh when he chose to take a break and refuge himself in the Basilica of San Francesco d'Assisi - a Franciscan monastery in a quiet hill of central Italy with a delightful composition of Romanesque and Gothic approaches, white-washed bricks, colonnade with semi-circular arches, natural light from large windows and extraordinary fresco paintings from old centuries."The spirituality of the architecture there was so inspiring that I was able to do intuitive thinking far beyond any I had done in the past. Under the influence of that historic place, I intuitively designed the research that I felt would result in a vaccine for polio. I returned to my laboratory in Pittsburgh to validate my concepts and found that they were correct."[72] Salk's reasoning on empathy as one potential benefit of built spaces envisioned in 1957, a place where researchers could engage in intuitive research, delight themselves in a collaborative environment, investigate basic life principles and be stimulated to achieve discoveries. In 1960 the research center Salk Institute - designed by Louis I. Kahn - was founded. Kahn designed a symmetrical concrete building with a large travertine courtyard, ocean view and natural light in response to Salk's requirements to create a welcoming, inspiring, spacious and adaptive space with simple, durable and strong materials to stimulate the discoveries of scientists. The building has a bold

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71 Sternberg, Esther M., and Matthew A. Wilson. (2006). "Neuroscience and Architecture: Seeking Common Ground." Cell, vol. 127, no. 2, 2006, pp. 239–242.
72 Norman L. Koonce, FAIA, President of AAF, 'Jonas Salk's Assisi Retreat', in Human Experiences With Architecture. Online. Washington, DC; The American Architecture Foundation, no date. Available at http://ameracrchfoundation.com/Salk.htm (24 May 2000).

exposed and unfinished concrete structure, with huge glass windows to enable the most amount of daylight and open voids with glass panels for airy settings. [73]

The Salk Institute for Biological Studies was later replaced by the Academy of Neuroscience for Architecture (ANFA), founded in 2003. Its mission is to encourage the advancement of neuroscience to explain the human interaction with the built environment, in order to better inform the design of buildings, in the areas of: "Sensation and Perception (how do we see, hear, smell, taste, etc?); Learning and Memory (how do we store and recall our sensory experiences?); Decision making (how do we evaluate the potential consequences of our actions?); Emotion and affect (how do we become fearful or excited? or what makes us feel happy or sad?); Movement (how do we interact with our environment and navigate through it?)".[74] Healthcare facilities were the type of buildings that started to gather neuroscientific evidence, followed by educational facilities, aging, sacred spaces, research laboratories, correctional facilities, offices spaces and so on.

A certificate program called "Certificate in Neuroscience for Architecture", also created in 2003 at the NewSchool of Architecture in San Diego/USA, was also a consequence of ANFA and their intention to integrate neuroscientific and architecture. Although the course is not a mandatory part of the architectural curriculum, they intend to familiarize students to neuroscience methods and vocabulary, as one of the most important fields for architects today. Through the understanding of the scientific evidence about our embodiment of space, architects are able to improve the design process and decision making aiming at a more suitable architectural output. "One of the really exciting things about this science is that we now have an incredibly strong set of tools that we can use to measure physiological responses to place."[75] Neuroarchitecture, therefore, is placed at the forefront to make design less about formal architecture and more about integrating people.

3.1.4 ENVIRONMENTAL PSYCHOLOGY

Environmental psychology is a relatively recent field of study inside the psychology discipline, with environmental psychologists believing that the physical and social environment affects human's actions, attitudes and perceptions.[76] Scientists from the Department of Psychology at the University of Sheffield Christopher Spencer and Kate Gee dated the roots of Environmental Psychology to 1272 when Marco Polo questioned a wise man the reason why people from Kerman were positively different from the adjacent Persian region. The wise man answered that the reason lay in the soil.[77] This could be referred to environmental psychology due to the influence of place on the individual.

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73 *"About Salk Architecture." Salk Institute for Biological Studies, www.salk.edu/about/visiting-salk/about-salk-architecture/.*
74 *Eberhard, John P. "Applying Neuroscience to Architecture." Neuron, vol. 62, no. 6, 2009, pp. 753–756.*
75 *Fairley, Julia. "Neuroarchitecture: The New Movement at the Forefront of Design." Houzz, Houzz, 20 May 2018, www.houzz.com.au/ideabooks/102817508/list/neuroarchitecture-the-new-movement-at-the-forefront-of-design.*
76 *Gifford, R. (2007). Environmental psychology: Principles and practice (4th ed.). Colville, WA: Optimal.*
77 *Spencer, Christopher, and Kate Gee. "The Roots and Branches of Environmental Psychology." The Roots and Branches of Environmental Psychology | The Psychologist, thepsychologist.bps.org.uk/volume-22/edition-2/roots-and-branches-environmental-psychology, February 2009, Vol.22, pp.180-183.*

Nevertheless, its origin is attributed to the German physician and psychologist Willy Hellpach (1877-1955) who first employed the term Environmental Psychology. He published a book in 1911 entitled GeoPsyche, where he investigated the effects of the sun and the moon on people's activities; and micro to macro levels of geographical effects, from urban microclimates and extreme environments. His focus was on the psychological and physiological influences we experience from the natural environment, the social environment, and the built environment. In 1939, urban factors such as rush, crowding, overstimulation, alertness, and continuous change became the subject of Hellpach's research. "According to him, the urban environment is ambivalent: on the one hand it frees people, allowing for their independence, yet, on the other hand, it leads to isolation."[78] He delved on the different impact that urban versus rural environments have on people.

The term Environmental Psychology gained scientific recognition only in 1964 when academic William Ittelson used it in a conference. In 1970, the first textbook on the subject - edited by Ittelson, Harold Proshansky, and Leanne Rivlin, and published by The City University of New York - came out as a theoretical groundbreaker in the field of psychology. It linked behavior and environmental sciences, and design, with experiments applied to room layout in hospitals, questioning how design influences patients.[79] In this period, environmental psychology was directed to architecture, and as a result, the term Architectural Psychology emerged, along with Environmental Design and Human Behavior, Ecological Psychology and Space Psychology. Furthermore, the architect Roger Bailey together with the psychologist Calvin Taylor and the psychiatrist Hardin Branch created the first educational course for architects and psychologists called: "Architectural Psychology and Psychiatry".[80]

Environmental psychology is a collaborative field of study from social and physical sciences to comprehend the effects of the environment in our behaviour, emotions, and cognition through our neurobiological responses. Neurochemicals are associated and in constant interaction within environmental elements, allowing us to collect biological evidence to explain our reactions. It is a science that exclusively examines the interrelation between humans and their environments. Behavior itself is triggered in the nervous systems by some prior output stimulus which most of the time happens unconsciously on preceding moments, hours and even days. It is also a response of the human body to evolutionary pressures which are embedded in our genes as a survival reaction to succeed and expand the race. The term environmental behavior can be defined as actions and attitudes which are triggered by the environment. Taking this into consideration, architecture is directly linked to environmental behavior, since its characteristics shape the context and influence perception and human behavior.[81]

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78 Pol, Enric. (2006). "Blueprints for a History of Environmental Psychology (I): From First Birth to American Transition." Medio Ambiente y Comportamiento Humano, 2006, Editorial Resma.
79 Spencer, Christopher, and Kate Gee. (2009). "The Roots and Branches of Environmental Psychology." The Roots and Branches of Environmental Psychology | The Psychologist, thepsychologist.bps.org.uk/volume-22/edition-2/roots-and-branches-environmental-psychology, February 2009, Vol.22, pp.180-183.
80 Pol, Enric. (2006). "Blueprints for a History of Environmental Psychology (II): From First Birth to American Transition." Medio Ambiente y Comportamiento Humano, 2006, Editorial Resma.
81 Rapoport, Amos. (1990). The Meaning Of The Built Environment: A Non Verbal Communication Approach. Tucson: University of Arizona Press.

Today, the research areas described in the Journal of Environmental Psychology are: Psychological and behavioral aspects of people and nature; Psychological and behavioral aspects of people and nature; Cognitive mapping, spatial cognition and way-finding; Ecological consequences of human actions; Theories of place, place attachment, and place identity; Environmental risks and hazards: perception, behavior, and management; Perception and evaluation of buildings and natural landscapes; Effects of physical and natural settings on human cognition and health; Theories of pro-environmental behavior, norms, attitudes, and personality; Psychology of sustainability and climate change; Psychological aspects of resource management and crises; Social use of space: crowding, privacy, territoriality, personal space; and Design of, and experiences related to, the physical aspects of workplaces, schools, residences, public buildings and public space.[82]

The findings from Environmental Psychology have a deep meaning for architecture and design since the potential influence of natural space in the healing and restoration of vitality and peace. The interrelation of human and environment have been providing a wide range of knowledge on the subject from space layout, form and shape, acoustics, lighting, ergonomics, branding, proportions, materials, colors, void spaces, complexity, organization and so on. It is part of the architecture daily life to take decisions which lead to implications for a wide range of people, situations and environments. These consequences are part of designers decisions responsibilities as an essential environmental psychology approach to deal with an important challenge outcome. Since the actual human psychology is deteriorating with the unappropriated living conditions in almost all big cities, which causes a denigration of people's behavior. Environmental Psychology can help with data outcomes, effects and causes on what is happening to people around the world who could not have a decent amount of daylight, proper space, clear air and water; to show to politicians and policymakers to advance actions and standards on social structures, organizations and values linked to the built space.

In 2010 the American Institute of Architects embedded the statement "driving positive change through the power design" to stress the potential of built space. Practical applications of Environmental Psychology could be considered in different approaches as to influence people towards a more environmentally sustainable behaviour, focusing on the improvement of the built environment, in helping shaping cities, making them more navigable, pleasant, and restorative. Fred Gage studies at the Laboratory of Genetics at the Salk Institute, revealed findings that neurons are in constant production in adults' brains. He wrote: "As neuroscientists, we believe that the brain is the organ that controls behavior, that genes control the blueprint, but the environment can modulate the function of the genes, and ultimately the structure of our brain, but the environment can modulate the function of the genes, and ultimately the structure of our brain. Changes in the environment change the brain and therefore they change our behavior. Architectural design changes our brain and our behavior."

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82 "Journal of Environmental Psychology." Elsevier, www.journals.elsevier.com/journal-of-environmental-psychology.

Environmental Psychology, has four main stances: Geographical Determinism - the interconnection of place, climate and nature; Ecological Biology - the interdependence between organisms and their environment; Behaviorism - the effects of environmental and personal context in one's behavior; and lastly Gestalt Psychology - with the analysis of personal perception and cognition of space, being the opposite of behaviorism. In addition, other six sub-concepts are continually being explored on the topic of how the environment affects us and how we affect the environment: Attention - stimuli which requires our attention and the stimuli which we are ready to aim our attention; Perception and Cognitive Maps - internal network of perceptions and experiences which assist with recognition and comprehension of our surroundings to support our space exploration; Ideal Environments - the competent feeling of engagement someone has within a context which needs unity, legibility, complexity, and mystery of the surrounded space; Environmental Stress and Managing - stress and lack of control of the space; Involvement - the interaction and engagement with the environment; and Protective Behavior - proper management and protection of the environment.[83]

3.1.5 BIOPHILIA AND BIOPHILIC DESIGN

Innumerable evidence indicates the instinctive attraction humans have to nature. The intense variation of patterns, textures, colors, lights, forms, configurations found in nature are admired in cultures worldwide. This appreciation is perhaps due to the era when humans used to have a close relation to natural environments. However, with the expansion of cities and of man-made environments, our connection to nature has significantly decreased.

In the book The Anatomy of Human Destructiveness,[84] written in 1973, the term Biophilia was described by Erich Fromm as psychological orientation of being attracted to everything that is alive and crucial for life. A decade later, the denomination was explored by Edward O. Wilson's biophilia hypothesis, in the book Biophilia,[85] which suggests the native biologic tendency and attraction of humans to look for the connection to the natural world. A good example of this concept happens in Japan with the tradition to immerse oneself in the woods and be exposed to natural systems and elements. This tradition of forest bathing, which is called shinrin-yoku in Japanese, roots deep in the culture and in Japanese religions. A range of studies granted by the Japanese Government attained proof of the benefits of this custom, like the decrease of cortisol levels, heartbeat, blood pressure, and sympathetic nerve activity, as well as measured the spark of the sympathetic nerves.[86]

With the advancements and intersection of neuroscience and architecture, biophilic design has been gaining importance. The reason is that, through neuroscience,

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83 Ackerman, C. What is Environmental Psychology? Positive Psychology, 19th December 2018. https://positivepsychology.com/environmental-psychology
84 Fromm, Erich. (1973). The anatomy of human destructiveness.
85 Wilson, E. O. (1984). Biophilia. Cambridge, Mass.: Harvard University Press.
86 Park, Bum Jin, et al. (2009). "The Physiological Effects of Shinrin-Yoku (Taking in the Forest Atmosphere or Forest Bathing): Evidence from Field Experiments in 24 Forests across Japan." Environmental Health and Preventive Medicine, vol. 15, no. 1, 2009, pp. 18–26.

researchers could confirm the positive benefits nature has upon us, and also prove how this connection between ourselves and nature occurs. Since the famous findings about the benefits of views to nature for healing patients in hospitals after surgery[87], an influx of research that supports our instinctive appeal to the presence of nature came out. Many of these scientific studies verified the effects of nature in our behavior, productivity, relations, physical and mental well-being. Most people feel calmer and relaxed when in nature, with faster stress recovery rates[88], increased empathy[89], decreased cortisol levels and heartbeat, and raised positive feelings[90].

Biophilia has been acknowledged by design professionals with evidence of the positive interaction between nature and the built environment. Although recent, biophilic design is an approach that has been growing in architecture, with a rise in awareness of the potential improvement of the space, and for being considered a complementary concept to the guiding principles of sustainable and green architecture. It is related to biophilia concept of biological-based connection humans have to nature in virtue of one's well-being and health improvements, and focuses on increasing occupant connectivity to nature through direct and indirect contact in space and place conditions, being applied to both building and urban environments. As well as in hospitals, scientific evidence has demonstrated the impact of biophilic design in schools, where students performed better tests scores, and in offices, where office workers became more productive. Moreover, economic benefits were also evidenced: "Integrating views to nature into an office space can save over $2,000 per employee per year in office costs, whereas over $93 million could be saved annually in healthcare costs as a result of providing patients with views to nature."[91]

Although biophilic design seems to be a simple and straightforward approach that could be easily implemented in built environments, especially because natural elements, which display aesthetics harmony, have generally been favoured by architects. But in reality, the principles of biophilic design are barely applied in present-day designs. It is important to progressively develop new means to incorporate this link to nature. Architectural designs can benefit from this concept to achieve healthier and optimized environments by using strategies as natural light, large windows, views of nature, fresh air, plants, natural materials, textures, patterns, and green spaces. As an encouragement action, the International Living Future Institute developed a Biophilic Design Initiative which is a guidebook to assist in building design and includes a database with a range of case studies, a map locating the projects that utilize biophilic design principles around the world, and further information on the topic.[92] The spread of the biophilia concept will facilitate its implementation in building designs and will be beneficial especially in hospitals, schools, museums, big corporation headquarters. Stephen Kellert et al. state that we can experience sensory

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87 Ulrich, Roger. (1984). View Through a Window May Influence Recovery from Surgery. Science (New York, N.Y.). 224. 420-1.

88 O. Ryan, Catherine & D Browning, William & O Clancy, Joseph & L Andrews, Scott & B Kallianpurkar, Namita. (2014). Biophilic design patterns: Emerging nature-based parameters for health and well-being in the built environment. Archnet-IJAR. 8. 62-76.

89 Kweon, B.S., Sullivan, W.C., & Wiley, A.R. (1998). Green common spaces and the social integration of inner-city older adults. Environment and Behavior, 30(6), 832-858.

90 Cowen, P.J. (2002). Cortisol, serotonin, and depression: All stressed out? British Journal of Psychiatry, 180, 99-100.

91 "The Economics of Biophilia." Terrapin Home - Terrapin Bright Green, 1 May 2014, www.terrapinbrightgreen.com/reports/the-economics-of-biophilia/

92 Biophilic Design Initiative. (2019). Retrieved from International Living Future Institute https://living-future.org/biophilic-design/

deprivation, lethargic feelings, and even depression after being in a windowless room, with artificial light, unseemly white walls and without natural airflow. Exposure to natural daylight is a crucial condition, he says, which elevates our well-being and regulates sleep hormones. Besides these benefits, there is the additional feeling of delight upon arriving in a space with green plants, water and full of daylight which has an indispensable role in our wellbeing.[93]

3.1.6 BIOMIMICRY AND BIOMIMETIC DESIGN

The word biomimicry means the imitation of natural systems. The word comes from the combination of bios, which means living things and mimesis which is imitation, imitate and act. Differently, from the Biophilic Design approach, the concept of biomimicry revolves around the idea of acquiring knowledge from natural systems and processes, as to apply them as design solutions by mimicking nature. Even though Leonardo da Vinci (1452-1519) analysed birds and bat wings to propose a design for a flying machine[94]; Filippo Brunelleschi studied the strength of eggshells to proposed a lighter dome for a renaissance cathedral in Florence concluded, in 1436[95]; and the Wright Brothers developed the first airplane in 1903 after studying pigeons and their methods of lateral control[96], biomimicry is still an innovative approach in architecture and engineering.

In 1982, the term biomimicry gained publicity with the book Biomimicry - Innovation Inspired by Nature, which suggested new approaches to design encouraged by natural systems, processes, forms, and shapes. The author proclaimed it to be a "new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems"[97], also advocating a sustainable approach of nature as one of the main ideas.

In architecture, the studies on termite and its capacity to maintain temperature and humidity in Africa's harsh weather inspired scientists to research the intrinsic features of their internal thermal condition. The findings were later applied in the Eastgate Centre Building in Zimbabwe, built in 1996, which achieved the ability to stay cool even in the high temperatures of Africa, without the need of air conditioning by mimicking the structure and function of termite mounds. The building also uses materials with high thermal capacity to store heat from warming daytime and release it during the cool nighttime.[98] The results achieved by the building's design went even beyond, with an impressive 10% decrease in energy usage compared to a regular similar building.

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93 Kellert, S. R., Heerwagen, J., & Mador, M. (2008). Biophilic design: The theory, science, and practice of bringing buildings to life. Hoboken, N.J: Wiley.
94 Romei, Francesca (2008). Leonardo Da Vinci. The Oliver Press. p. 56
95 Pawlyn, M. (2016). How biomimicry can be applied to architecture. Retrieved from Financial Times website; https://www.ft.com/content/e2041a1e-0d32-11e6-b41f-0beb7e589515?utm_medium=website&utm_source=archdaily.com
96 Compare: Howard, Fred (1998). Wilbur and Orville: A Biography of the Wright Brothers. Dober Publications. p. 33.
97 Benyus, Janine (1997). Biomimicry: Innovation Inspired by Nature. New York, NY, USA: William Morrow & Company, Inc.
98 Turner, J. S., & Soar, R. C. (2018). Beyond biomimicry: What termites can tell us about realizing the living building. First International Conference on Industrialized, Intelligent Construction (I3CON).

Another famous example of biomimetic design is Beijing's National Stadium designed by the architects Herzog & de Meuron in 2003. It is usually referred to as the Bird's Nest because of its interlocking structure, which generates an integrity stable structural unity. Inspiration in a natural system can be found in many structural elements in architecture. Specialists have described the Eiffel Tower structural system hierarchy as similar to the ones found in the femur bone. The structure was designed to have an optimized sequence of elements to support different types of loads while employing minimum material [99]

For many supporters of biomimetic design, the performance of biological systems, process and materials could help us to make a safer, sustainable and optimized structures, with much more appropriate efficacy than an ordinary box with straight simple lines.[100] The Biomimicry Institute founded in 2006, has a mission to spread the ideas, designs, and strategies from biology to the general public, turning popular sustainable solutions and approaches to design. In 2008 they introduced an awarded catalog website to assist people to sustainable design examples of nature's solutions. "The core idea is that nature has already solved many of the problems we are grappling with. Animals, plants, and microbes are the consummate engineers. After billions of years of research and development, failures are fossils, and what surrounds us is the secret to survival."[101]

3.1.7 BAUBOTANIK

Different from Biomimicry in concept, but with a similar idea of taking advantage of plants' structures, Baubotanik does not mimic the natural world. Instead, the idea is to use the strengths and physical conditions of natural structures as part of the design in combination with man-made materials. This approach brings plants as a fundamental part of the construction by simply using their structural attributes in the part of the erection of the building essentially by maintaining the plants alive and without compromising them and their essential condition to the environment.

The term Baubotanik comes from the German word bau, meaning construction, and botanik relates to botany. Baubotanik architecture is the construction of buildings that implicate the use of living trees. The craft of tree shaping goes back to ancient times, with examples all over the world, like the European topiary from the Roman period, Japanese bonsai from the 6th century, and the famous living root bridges in India that date back up to 600 years.[102] These bridges were built by the intervention of people who would intertwine theirs from trees. However, this process of fusion roots, trunks, and branches between trees, called Inosculation, happens despite the human intervention, by a friction between the parts which ended up in a joining connection.

99 Bhatia, A. (2015). What Your Bones Have in Common With the Eiffel Tower. Retrieved from https://www.wired.com/2015/03/empzeal-eiffel-tower/
100 Tonn, S. (2015, November 11). Architecture Builds on the Intricate Structure of Bone. Retrieved from https://www.wired.com/2015/11/architecture-builds-on-the-intricate-structure-of-bone/
101 "What Is Biomimicry? – Biomimicry Institute." (2019) Retrieved from biomimicry.org/what-is-biomimicry.
102 Rogers, Patrick A. (2015). "Evenfewergoats: The Undiscovered Living Root Bridges of Meghalaya Part 2: Bridges Near Pynursla".

Reference for this approach were John Krubsack, who in 1914, grew and sculpted a "chair" from trees, and farmer Axel Erlandson (1884-1964) who documented his experiments in shape trees.[103]

Inspired by inosculation, past examples, and different traditions in shaping trees to reach spanned gaps, Dr. Ferdinand Ludwig developed in 2005 the concept of baubotanik as a living plant construction by turning a living plant organism into a building by taking advantage of its natural structural system as a frame in a direct relationship with the construction and the final object.[104] "The primary flexible and sensitive "semi-finished" turns through the subsequent growing process into a viable, solid and resilient plant structure."[105] To test out his concept, he built the Baubotanical Footbridge, which has a deck and handrails directly supported by the trunks and branches of willow trees, which after manipulations during the growth, become load-bearing elements. Ludwig's approach incorporates not only the tree elements, but also building materials to blend them into the trees in a natural growth. With time the joints keep getting stronger and without the need to cut down the trees. A few years later, he and his team completed the first tower with a height up to 6.6 meters, called the Baubotanical Tower, followed by Plane-Tree-Cube Nagold, which was the first project within the urban context. Plane-Tree-Cube Nagold is a multi-story green structure cube formed by more than 1000 plane trees, which will grow until it reaches the trees' canopies, generating green walls around the internal open space.[106]

The Baubotanik concept interrelates with other theories like Arbortecture, which means growing our tools instead of crafting and making them, and Botany Building, which implies a living structure to construct a building.

3.1.8 BIONICS AND ADAPTIVE AUTO-RESPONSE DESIGN

Bionics refers to the application of natural and biological systems into design and engineering, as defined: "the studies of electronics systems which function in the manner of organic systems."[107] It is also the interchange of technology between two different organisms towards evolutionary pressure to turn into a highly optimized and efficient organism/system. The term was first coined by Jack E. Steele in 1958 while working at a research lab related to psychiatry and neurology, and investigating stress of motion, sound, and wind.[108]

While the terms biomimicry and biomimetic are usually applied to technology disciplines, bionics involves the biological and medical approach to the advancement of the organic system. In a way to improve, regenerate or fix an element to develop

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103 Shirvani, S. (2017). WHAT IS ARBORTECTURE? Retrieved from https://www.arch2o.com/what-is-arboreal-architecture/
104 Oommen, A. (2015, October 23). Baubotanik: The Botanically Inspired Design System that Creates Living Buildings. Retrieved from https://www.archdaily.com/775884/baubotanik-the-botanically-inspired-design-system-that-creates-living-buildings
105 Ludwig, F. (2014) BAUBOTANIK - Designing Growth Processes. In: Symposium "Form-Rule/Rule-Form 2014", University of Insbruck.
106 Ludwig, F. (2017) Plane Tree Cube Nagold. In: BACH, D.A. Architecture Today: Landscape, Loft Publications.
107 Bionics. Retrieved from; Online Etymology Dictionary.
108 Roth, R. R. (1983). "The Foundation of Bionics". Perspectives in Biology and Medicine. 26 (2): 229–242.

a certain task. The term cyborg also relates to bionics and concerns organisms with enhanced abilities or revitalized functions as a result of the implementation of external component or technology.[109]

Bionics, combined with architecture, engineering, and biology, can contribute to design as building requirements increase. The terms may sound complex and not related to architecture but if we consider each building as an organism, bionic and cyborg denominations may help us understand the addons and improvements a building needs to keep its function or even to be adapted to a new program. Therefore, it can constitute a body of knowledge towards a new architectural approach that responds for different building requirements throughout its life-time, different seasons and weather conditions.

In the same subject, Microorganisms are also being explored as an auto-response design in architecture. One of the ways is to approach sustainability in construction with different livable means. Microorganisms together with architecture and engineering have been responsible to develop a cutting-edge approach with the ethos of biological organisms to be adopted in the process and production of architecture. It has also been explored as living organisms in construction materials, like living bricks, living concrete, bioplastic, etc.

As stated by Neri Oxman for the magazine Wallpaper in 2018 "Through our design work and research as part of the MIT's Mediated Matter Group, my team and I have expressed a new model of the world of design: the World-as-Organism. This new model stands in contrast to the paradigm of the original Industrial Revolution, or the World-as-Machine. It strives to impart a living quality into objects, buildings, and cities. Unlike the Industrial Revolution, which was ecology-agnostic, this new model, and the revolution under its wings are tightly linked to the natural environment."[110] New model is emerging to one day become the new standard. She adds the question on how some buildings are still being built with practices and traditions from the industrial era. Our advancements in hacking natural processes may enable us to create revolutionary possibilities.

Based on concepts of biomimicry, bionics, cyborgs, and kinetic architecture, together with the exploration of material behaviours and sensitivities, this research intends to instigate new concepts of how buildings can be dynamic; how buildings can adapt to different local environments, energy demands and season conditions; and how turning buildings from static objects to dynamic architecture through natural material, form and structure.

"Wood is alive"[111]. This statement confirms the behaviour of the material according to specific circumstances and natural environment characteristics. Wood's behaviour is attractive due to its natural composition and anisotropy attribute. A proper example

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109 Carvalko, Joseph (2012). The Techno-human Shell-A Jump in the Evolutionary Gap. Sunbury Press.

110 Oxman, N. (2018, October). Mothering Nature. Wallpaper, 235, 298-334.

111 Mayo, Joseph. (2015). Solid Wood: Case Studies in Mass Timber Architecture, Technology and Design. New York, NY: Routledge, 2015. p3 to illustrate the inter behavior of wood is the hygroscopic natural feature, a natural reaction to variations of humidity to a certain condition. Another example of physical reaction is the smart materials - shape memory alloys (SMA)[112], which changes its shape as a response to variation in temperature. In the study Climate-Responsive Shading Systems with Integrated Shape Memory Alloys (SMA), the researchers believe the incorporation of this type of material can lead to a positive impact on ecological influence, due to the potentialities of efficiency and feasibility.[113] These theories evidence the possibilities of intrinsic materiality to be utilised in the future as a new architecture paradigm.

Another material exploration is the A-Ring project built-in 2009. The structure is based on aluminium frames/pipes which also function as a thermal control system and service duct shaft. The thermal control system functions by alternating the water that runs within the pipes. A geothermal station outside the house exchanges the atmospheric cold air into underground hot air and consequently changes the water's temperature inside the pipes. This results in a 70% reduction in utility costs compared to a typical house. The efforts in using aluminium were to demonstrate the possibilities of the material in the building industry as an environmentally friendly material which is recyclable, easy to reuse, resistant and lightweight.[114]

The kinetic system is a concept of adaptive design that enables buildings to be dynamic and respond to a certain stimulus or command by moving elements without affecting the structural integrity. The possibilities of application are endless and embrace automation and mechanical systems. Examples range from small buildings rotation of the axis, sunshades that open and close, solar wings, movable walls, adaptable partitions, and so on. It is worth pointing out the cutting-edge design of One Ocean by Soma Architecture in South Korea with its kinetic facade system; the Bahar Towers in Abu Dhabi by Aedas Architecture and its facade screens with solar panels and photovoltaic cells which adapts for optimized efficiency; and The Shed with the moving adaptable roof structure designed by studio Diller Scofidio + Renfro in collaboration with Rockwell Group.

Many variations of different systems can emerge through the process of understanding new behaviours to new demands, such as open-close, extract-subtract, increase-decrease, static-react, rotation, foldable, among others. Based on these variations, designers are able to employ the adequate process and material to create building functions in a smart way due to local characteristics and technologies, together with the native conditions, towards a better living built environment.

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112 Rogers, Craig. (2013). "Intelligent Materials." Scientific American Sept. 1995: 154-157.
113 Chamilothori, K., Kampitaki, A., & Oungrinis, K. (2013). Climate-Responsive Shading Systems with Integrated Shape Memory Alloys (SMA). 8th Energy Forum on Solar Building Skins.
114 Yamashita, Y. (n.d.). A-ring. Retrieved from http://www.tekuto.com/en/works/a136_a-ring/

3.1.9 ECOLOGICAL DESIGN

Throughout history, human shelters were dependent on the availability of local materials. Function and form were also in response to the natural topography and regional weather conditions. The responses to the availability of local ecology combined with cultural assets resulted in an architecture known as vernacular, which provided a deep connection between inhabitants and landscape.

Since the industrial revolution, unsustainable developments emerged in almost all sectors of our society. As a result, some natural-friendly approaches were created and also re-discovered from past civilizations to counterbalance the destructive model. Attempts have been made to approximate nature with a 'natural architecture' with a more appropriate and compatible relationship between nature and mankind. In a broad sense, the ecological design intends to mitigate the interruption of the human - nature relationship, which happened with the abnormal change after the industrial revolution.[115] These ecological and biological design movements are also a type of activism instead of protesting by considering the importance and significance to design with nature in mind.

Sim Van der Ryn and Stuart Cowan in the book 'Ecological Design' explain the term vernacular as "any form of design that minimizes environmentally destructive impacts by integrating itself with living processes"[116], and today it is being used to denominate a range of integrative ecological design approaches, like green architecture, ecodesign, eco-tech, eco-city, sustainable agriculture, permaculture, environmental design, energy-efficient design, ecological engineering, ecological restoration, biotecture, niche construction and nudge architecture. Local life cycle models with the use of native materials and reduced energy resources are the base of the ecological design approach, which emulates models inspired by nature and its natural ecosystems - since the balance of different organisms results in a symbiotic relation among them.

Permaculture is one of the ecological design approaches that attempts to reconcile human and local nature, by providing ethical and holistic support for a sustainable culture. Many authors helped in the development of this approach. One of them was Russel Smith, who in 1929 wrote the book Tree Crops: A Permanent Agriculture[117], explaining his experience on planting combinations of fruit trees and nut trees in an optimized mixed system. However, the term Permaculture was first publicly applied by David Holmgren and Bill Mollison in their book Permaculture One in 1978.[118] It is used to denominate a set of design strategies and principles focusing the whole life-cycle system by utilizing patterns obtained from natural ecosystems to acquire knowledge and thinking tools which could lead to a more ecological resilience. In Holmgren's second book, he explains permaculture as deriving from three basic ethics - care for the earth, care for people, and fair share - with 12 principles: Observe and Interact,

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115 McHale, J. (1969), An Ecological Overview, in The Future of the Future, New York; George Braziller, pp. 66-74
116 Van der Ryn, S. and Cowan, S. (1996). Ecological Design. Island Press, p.18
117 Smith, J. R. (1929). Tree crops: A Permanent Agriculture. New York: Harcourt, Brace and Co.
118 Holmgren, D. and Mollison, B. (1978). Permaculture One. Transworld Publishers. p. 128.

Catch and Store Energy, Obtain a Yield, Apply Self Regulation and Accept Feedback, Use and Value Renewable Resources and Services, Produce No Waste, Design From Patterns to Details, Integrate Rather Than Segregate, Use Small and Slow Solutions, Use and Value Diversity, Use Edges and Value the Marginal, and Creatively Use and Respond to Change.[119] As architecture involves securing the health and safety of its users while interacting with their structures, the principles of permaculture are being adopted by many architects in their practice. An architecture design based on permaculture focuses on arranging all elements of a system to work together and reach their highest efficiency. This is possible by stacking functions, ensuring that elements perform more than one job, and by providing back-up systems where more than one element can perform the same function.

Niche Construction is a biological theory on the process of alteration of the environment by living organisms, and how environmental changes lead to the modification of their genetic structures and behavioral patterns, supporting the idea of the evolutionary process of natural selection. Physicist Erwin Schrödinger in his essays 'What is Life?' and 'Mind and Matter' foresaw this theory behind niche construction in 1944. Nonetheless, only in 1988, John Odling-Smee used the term 'niche construction', and was the first to elaborate the specific explanation of the importance of the environment on the evolutionary process, with its multiple systems of interacting relationships.[120] In nature, examples of niche construction are birds' nests, dams built by beavers, burrows, and shades created by the wind and cycling of plants, among others.

Humans, because of our language, developed a mental capacity that allows us to adapt to multiple environments by learning different processes. We have a quicker genetic, behavioral and environmental alterations, without acknowledging the consequences of evolutionary survival passed from genes to genes.[121] No other species has this ability since they rely on basic instinct to adapt in an unfamiliar habitat. Therefore, the adaptationist character of niche construction is very useful for us and architecture - it may provide a more detailed operational model for adaptable building systems.

3.2 DISCUSSION

"Nothing is in the imagination that was not first in the senses." [122]

The overview of the interdisciplinary approaches which are related to architectural design demonstrated some important progress towards the understanding of the relationship between humans, natural systems and the built environment. Together with biological and psychological studies, neurotechnologies have been great

119 Holmgren, David (2002). *Permaculture: Principles & Pathways Beyond Sustainability.* Holmgren Design Services. p. 1.
120 Odling-Smee, F. J. (1988). "Niche constructing phenotypes". In Plotkin, H. C. (ed.). *The Role of Behavior in Evolution.* Cambridge (MA): MIT Press. pp. 73–132.
121 Odling Smee, John; Laland, Kevin; Feldman, Marcus (2003). *Niche Construction: The Neglected Process in Evolution.* Princeton: Princeton University Press.
122 Descartes, R., & Cottingham, J. (1990). *Meditations on first philosophy.* Cambridge: Cambridge University Press.

supporters of ideas related to space. By comprehending our neurobiological responses to the environment, architects will be able to better predict behaviours and be more conclusive when proposing designs. Hence, informing design decisions through research, in collaboration with neuroscientists, psychologists, physicians, among others, is one of the most coherent approaches to create an optimized environment and enhance the quality of life through design.

The way we perceive places by our cognitive experience affects not only how we sense them but, as architects, also how we envision them. In many cases, architects tend to make design decisions based on a simplistic viewpoint or ignoring the complexity of a design problem. Although architects are trained to deal with those complexities, they should also rely more on scientific data to back up their design decisions.

In the past decades, many individuals, groups, organizations, and regulatory agencies have been improving the built environment through evidence-based design. In spite of that, the majority of the findings attest that the innate common sense we all have proceeds: people prefer clean, uncluttered and organized spaces, with proper lighting, open views to the outside, easy to navigate, with some privacy, with the presence of nature in any form, secure, socially adequate, cultural correlated, economically suitable, environmentally responsible, among others. It also must be stated that evidence-based design does not always lead to the expected outcomes. Research has also shown that some outcomes of good design intentions are not always a success. For this reason, more specific studies need to be conducted, and findings need to be published in order to increase the database related to the subject, aiming for better future application of the design decisions within local conditioners.

Research outcomes rely on the gathering of quantitative data coming from questionnaires, surveys, polls, post-evidences documents, interviews, hospital records, prescriptions, referrals, attendances, etc. collected over time. Thus, a more complete diagnostic can absorb all direct and indirect data related to the human/ environment relationship. The results may account for the continuous development of discrete variable knowledge. For this reason, the assembly of data across the globe is important to achieve a sizable population and enabling specialists to access the information and decide the better interpretation of each scenario.

It is of great importance that architects engage in the search for knowledge which may present efficient solutions for the integration between nature, environment, and architecture, and for suggesting new possibilities for design and construction. Many architects are open to increase their body of knowledge about design, but do not engage in finding evidence on their design decisions could enhance building users' overall health, wellbeing, and performance. However, as data availability increases and technologies become cheaper, architects should eventually engage in cross-disciplinary studies as a tool to improve their designs.

PART II – APPROACHING INHABITABILITY

Part II introduces methods to approach the research theme. In Chapter 4, present-day examples demonstrate the importance of objective frameworks that tackle the improvement of buildings. In Chapter 5 a framework of design strategies based on scientific investigation and evidence on the relation of human/space behavior is proposed.

CHAPTER 4 – INHABITABILITY IN ARCHITECTURE

Chapter 4 introduces the present-day trials to implement a human-centered approach to architecture design, as well as experiments in healthcare buildings from the 19th century, databases of scientific research concerning the built environment, evidence-based methods and tools, and the importance of consistent frameworks to tackle the improvement of buildings.

4.1 IMPLEMENTATION OF CRITERIA TOWARDS INHABITABILITY

The current building codes across the world are found to be outdated, with inadequate requirements for people's actual needs. One example is about daylight and views to the outside, which in many countries is still not mandatory - codes state that as long as the air is circulating through air conditioners, ducts and/or fans, a window is not necessary. The same issue is true to lighting, where, if there is appropriate artificial light, daylight is not an obligation.[123] This chapter will present evidence that many have tried to make appropriate changes to such conditions for a long time. However, this lack appropriate regulation on the basic elements that architecture should provide is not easily achievable due to economical interests and bureaucratic precepts.

A shift in the building industry must happen, where adequate building codes are created to certify basic design requirements according to users needs. As for any constitutional transformation, strong evidence needs to be demonstrated. And this is what has been happening for years already: pieces of evidence have proved the importance of healthy habits not only concerning food or physical activities, but also in terms of the built environment and our relation to our habitat. It is imperative to ban spaces which do not provide the minimal qualities to ensure that human tasks can be conducted within them with safety and comfort.

4.1.1 INHABITABILITY IN HEALTHCARE BUILDINGS

During classical times, the Greco-Roman god of medicine Asclepius pronounced that temples should be built on the top of hills, overlooking the sea, and far from towns, because he believed that nature was important to healing.[124]

Healthcare facilities are complex ecosystems with multiple technical and logistical challenges, as well as stakeholders. The unsafe and unhealthy conditions of healthcare facilities reflected on major changes in the architecture design of these buildings in the nineteenth century. The benefits of large windows facing south and solariums where patients could experience natural light and fresh air were proved and implemented as design strategies. The big windows allowed open field view and daylight to get inside the rooms since electric light was not reliable. People believed that sunlight and natural airflow were powerful against infectious diseases since antibiotics were not uncovered yet. Dr. Thomas Kirkbride was a specialist in mental illness and framed a guideline in 1854 to recommend that hospitals should have natural ventilation, a certain number of patients, rural site location in the vicinity of a city with farming and gardens for patients. He believed the building itself could help in recovery and healing.[125]

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123 Sturgeon, Amanda. "To Improve Our Health and Happiness We Must Connect to Nature | Trim Tab." Trim Tab Online Magazine, ISSUE 33 | HEALTH WELLNESS, 5 Apr. 2018, trimtab.living-future.org/trim-tab/issue-33/to-improve-our-health-and-happiness-we-must-connect-to-nature/.
124 Sternberg, Esther M. (2010). Healing Spaces: The Science of Place and Well-being. Cambridge, MA: Belknap Press of Harvard University Press.
125 Otto, Thomas (May 2013). "St. Elizabeths: A History". U.S. General Services Administration. Retrieved April 3, 2014.

In 1860, Florence Nightingale wrote about the importance of fresh air, large and bright rooms, to help patients treatment as a manly aspect of nursing. In addition, she mentioned that a quiet and warm environment with clean water must be a requirement for healthcare units.[126]

A notable paper exploring that sunlight could kill bacteria and prevent transmission and reinfection of the patients, was submitted in 1877 to the Royal Society in London by Arthur Downes and T P Blunt.[127] The discovery of tubercle bacillus by the bacteriologist Robert Koch in 1882, led him to verify that these could be killed by sunlight.[128] And in 1903 the first clinic devoted exclusively to the treatment of tuberculosis with sunlight was opened in the Swiss Alps by the common called "Sun Doctor" - Dr. Auguste Rollier, who was the most celebrated practitioner and an avid enthusiastic about the healing properties of the sun. He explored the theme of Heliotherapy and wrote an important book on the topic, which consists of treatment of skin conditions by natural sunlight.

Le Chalet was the name of the Rollier's clinic, which he proposed to be the model for future sanatorium approach. The building had large balconies faced south on the first floor, enabling patients in bed with wheels to be easily taken to the sun, plus movable partition walls to create spacious dormitories, and all with large windows. On the second floor, a large solarium facility allowed patients to sunbathe from sunrise to dawn.[129]

Les Chamois was a tourist hotel renovated that also become a healthcare facility to have the heliotherapy approach. It was opened in 1909 and the main restructure of the building were the addition of solariums on each floor on the southwest extremity of the building with compartments that bed patients could be wheeled, since the main balconies of the rooms were not receiving sun in part of the afternoon during summer and not in the early morning during the winter.

Le Frênes is considered the first large healthcare structure built in Europe for the heliotherapy. The building erected in 1911 consisted of a south facade central block with two large wings, one facing south-west with uncovered terraces and the other south-west with individual covered balconies. A solarium covering the whole roof of the building, provided a covered area for shelter when needed.

It was well known by that time the crucial role of sunlight and natural well-ventilated buildings in diverse health treatments. And these examples were stated here to show that more than a century ago, scientific evidence helped architects in designing adequate healthcare buildings. People believed that the air from high altitudes was fresher and would eradicate the infection, all those constructions were placed out of

126 Nightingale, F. (1858). Notes on Matters Affecting the Health, Efficiency and Hospital Administration of the British Army. Retrieved from https://www.rct.uk/collection/1075240/notes-on-matters-affecting-the-health-efficiency-and-hospital-administration-o

127 DOWNES, A., & BLUNT, T. P. (1877). The Influence of Light upon the Development of Bacteria 1. Nature, 16(402), 218–218.

128 Ransome A, Delepine S. (1894). On the influence of certain natural agents on the virulence of the tubercle-bacillus. Proc R Soc Lond; 56:51e56.

129 Auguste Rollier, (1923). 'Tuberculosis finds cure in the Leysin heliotherapy clinics', Mod. Hosp., 21 (3): 255-60, p. 255.

town in a beautiful and isolated hill setting with views of natural surroundings. Rollier's approach was not only hospitals but also in homes should have adequate sunlight.[130]

Sir Henry Gauvain was a surgeon and clinical assistant who actively participated in the design with the architect H.C. Smart, of the new hospital which would be replacing the former clinic that he used to work. It is notable Gauvain convictions, recommendations, and concepts on the design and use of balconies. The new hospital was completed in 1933 facing south-east with full early morning sunlight.[131] He also attested that not only patients but also children and should live in an open, cross-ventilated and with high ceiling rooms in all kinds of buildings, hospitals, residences, private houses, and schools. "There is no doubt that living under such conditions many hospitals patients would be restored to health more speedily, that the pupils in schools would be sturdier, healthier, happier and less prone to infectious diseases than at present, and that the community as a whole would benefit." [132] Gauvain with his significant impact on the architectural discipline was recognized by the Royal Institute of British Architects in the first guidance publication to architects and planners how to approach sunlit design strategies.[133]

The tuberculosis sanatorium designed by Alvar Aalto in Finland was finished in 1932 and became the model for later hospitals. The building faced south with a natural view of pine forest and a bright resting lounge with large windows. He carefully selected a pleasant and calm site and surroundings within a beautiful and natural setting. Aalto with patient's comfort in mind, also designed the chairs of the sanatorium in laminated-wood. All of Aalto's design approach in the sanatorium, not only turned to be a standard for an appropriate healthcare building approach but also he applied biophilic early design strategies.

Aalto had a clear idea on how the design of a building could positively influence health and healing. This belief strongly influenced early modern architects which had the tuberculosis sanatoriums as explicit examples. Although the architect Richard Neutra admitted in following Frank Lloyd Wright's principles of Prairie School, he advanced the idea in a unique approach with lighter, brighter and airier structures with a lot of overlapping between inside and outside and glass walls. In 1929 he designed the Lovell Health House in Hollywood Hills with a spectacular overview of Los Angeles, for the physician Philip Lovell and his wife to match the health requirements they believed at that time. Lovell Health House has open sunbathing areas for the rooms, open-air fitness suite and view of nature in all sides. Neutra believed that his architecture was therapeutic and insisted that it could heal his clients from psychological neuroses, by producing a natural smooth articulation of interior and exterior. As a student, he was already engaged in psychology with a particular interest in the work of Wilhelm Wundt: "Principles of physiological psychology". Later on, he was fascinated by Freud's ideas on the unconsciousness, especially the hypothesis of "repressed physical energy" look for a way out by projection. His architecture approach is still nowadays a reference for understanding the interconnection among buildings and psychology.

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130 Hobday R.A. (1997). Sunlight therapy and solar architecture. Medical history, 41(4), 455–472.
131 H. J. Gauvain, (1938). 'Planning a hospital', Lancet, ii: pp.95-8.
132 H. J. Gauvain, (1933). 'Open-air country hospitals for children', Lancet, i: 321-5, p.321.
133 The Orientation of Buildings, Being the Report, with Appendices, of the R.I.B.A. Joint Committee on the Orientation of Buildings. Royal Institute of British Architects, (1933).

Despite that, only in the eighties with Doctor Roger Ulrich's studies, the correlation of a range of approaches and situation could be proved with new technologies and measuring devices, that the theories from the beginning of the century were all right regarding sunlight, airflow, greenery and view of nature and natural landscapes. He evidenced many positive improvements due to these design strategies.

In the present day, there are more than a thousand research studies relating to the impact of design on the improvements of patients outcomes. The studies utilized a range of procedures, methods, and approaches but the principal was Evidence-Based Design with its principles regarding: improvement of patient outcomes; improvement of patient safety; increase patient, family, and staff satisfaction; improve efficiency and effectiveness of staff; and accommodate today's best practices, with flexibility to adapt to the future.[134]

According to the neuroscientist Pert, it is not difficult to comprehend how a healthcare environment can affect the emotional state in the patients.[135] And he explained that the sad feeling produces hormones which affect the functions of our internal organs.[136] Besides, in another study from Glaser et al., they demonstrate the great number of stress and anxiety from postoperative pain which could be lessened by the environment.[137] However, it is still complicated to conduct rigorous research on this subject, while hospitals are complex environments with a range of different aspects to isolate each factor that impacts a certain outcome. Because of this, it is extremely important to advance with more studies and proofs that we could tackle specific problems. By the late twentieth century, hospitals properties were mainly designed to provide adequate space for cutting-edge equipment, with poorly sequence of functions, small and windowless rooms, without care of view, nature, daylight, and airflow.

Nowadays, new healthcare buildings have been trying to increase patient's healing, recovery and general well-being as well as its work staff and family visitors as an extra advantage of a particular institution. A successful evidence-based decision has increased the value of choosing a building since the results are not only beneficial for everyone involved in healthcare but also in economical and wealth terms.

According to Stefan Lundin excellent research "Healing Architecture: Evidence, Intuition, Dialogue", he stressed the importance of seven recommendations for healing architecture which accounts for: "Promote dignity!; Encourage normalcy!; Create a free and open atmosphere!; Promote social interaction!; Promote patients´ independence!; Offer views to the outside and free access to the outdoor environment!; and Balance the demands for safe and healing health-care environment!"[138]

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134 Silvis, J. (2011). Applying Evidence-Based Design at the New Parkland Hospital. Retrieved from https://www.healthcaredesignmagazine.com/architecture/applying-evidence-based-design-new-parkland-hospital/

135 Pert, C. (1997). Molecules of emotion. New York: Scribner.

136 Pert, C. (1990). The wisdom of the receptors: Neuropeptides, the emotions, and body-mind. In Healing brain: A scientific reader, eds. R. Ornstein and C. Swencionis, 147–158. New York: The Guilford Press.

137 Kiecolt-Glaser, J. K., G. G. Page, P. T. Marucha, R. C. MacCallum, and R. Glaser. (1998). Psychological influences on surgical recovery: Perspectives from psychoneuroimmunology. American Psychologist 53(11):1209–1218.

138 Lundin, S. (2015). Healing architecture: Evidence, intuition, dialogue. Göteborg: Chalmers University of Technology.

Hospital for elderly and Alzheimer patients is an example of a specific approach that architects brought new design strategies to improve patients experience of the environment. John Zeisel is an architect, researcher on environmental design and developer of an innovative approach to Alzheimer care. His works account for more than two decades of awards on design and planning guidebooks, prototype facilities and successful developments. He demonstrated that with simple design approaches as easily recognizable paths/rooms in a building and walking in therapy gardens, we can tackle and simplified the life of those people with memory loss. Some of the attitudes from mental disorder patients are related to physical disorder. Therefore, the environment is a part of the treatment.

Children healthcare buildings is another example of a proper design approach, which includes specific solutions as ease navigation through the space to encourage the children to feel confident, using vivid colors to stimulate, social spaces for interaction, appropriate scale and comprehension of children's memory processing and variable os stimuli to engage the experience and memory of the place due to the plasticity of their brains which could easily assimilate new inputs but also easily forget the directions. In addition, different therapies need an efficient variety of enriched spaces to sometimes concentrate or play, with specific acoustics and light for improving cognition levels.

A good example is the "Groot Klimmendaal Children's Rehabilitation" in Holland, situated among trees, surrounded by natural patterns, and considered by many therapists as a spa instead of a rehabilitation center. The building provides relaxation of patients and workers, with a considerable decrease in stress hormones and efficiency in advancements of treatments with reducing healing time. Although the building is remarkable in healthcare architecture, little attention is given by architecture media and professionals. Some are still critical of the benefits of evidence-based design, but at least agree with the indirect benefits of nature view.

Another exemplary successful approach to healthcare architecture is the case of Maggie's Centers, which are spaces that offer free support emotional and physical wellbeing to those affected by cancer, and their families and friends. They have a special program that does not intend to replace conventional cancer therapy but to provide within a caring built environment, positive support with a practical approach to encourage strength and confidence in people. It was founded and named under Maggie Keswick Jencks, who fought against breast cancer for eighteen months until 1995 when she passed away. The idea came after she received the prognosis in such neglected, thoughtless and draining waiting room with fluorescent lights. She questioned how it could have been less painful to receive such news in silent, comfortable and private space, full of natural light.[139]
She was an avid appreciator of gardening, with a special interest in the Chinese landscape gardening and its philosophy, which led her to write a book "The Chinese Garden", published in 1978. Her deep knowledge about the theme promoted her

139 Keswick, M. (1995). A View From The Front Line. Maggies Cancer Caring Centre.

to be on-demand for lectures and consultancy.[140] Her husband was the architectural historian, theorist, critic, and writer Charles Jencks who, as his wife, believed in the ability of built environments to inspire, restore and encourage. The first Maggie Center was designed in 1996 by Richard Murphy in the city of Edinburgh. The building is full of color, natural light, and sliding doors which makes the spaces flexible and comfortable like a private home. Today there are 22 Maggie Centers across the United Kingdom, one in Hong Kong and another in Tokyo, plus 6 more planned to open. The buildings have been designed by renowned architects such as Zaha Hadid, Richard Rogers, Frank Gehry, Rem Koolhaas, Kisho Kurokawa, Norman Foster among others. In 2014, Charles Jencks stressed how beautiful, different and remarkable buildings they designed so far.[141]

A growing number of architecture offices who design healthcare facilities have been employing medical doctors as consultants to assist in the development of research, hypothesis, to review design strategies and gather clinical data. They are also in charge of the post-occupancy evaluation reports to increase the knowledge of such speciality projects.[142]

4.2 CURRENT INITIATIVES TO INSTITUTIONALIZE CRITERIA TOWARDS INHABITABILITY

The following part provides an overview of the attempts to set a framework to approach issues related to the built space. Within this scenario, various rating systems, labels, and certification programs appear with different scopes, targets, and significance as attempts to institutionalize criteria towards more inhabitable buildings.

4.2.1 BUILDING ASSESSMENT SYSTEMS

Today, there is a proliferation of rating systems, labels, and certification programs in the market to ensure standards and increase the performance of buildings. These assessment systems began to emerge in the 1990s as a response to the problems related to construction and sustainability. In general, they focus on evaluating the performance of buildings within a sustainability framework which evaluates indoor environmental quality, water and energy usage, and management of natural resources. Such building assessment systems have multiplied over the years, and, by promoting measures that were sometimes complex and costly to apply in the past, are responsible for transforming the construction industry. In consequence, they also managed to improve the general building standards and raised the status of buildings.

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140 Keswick, M. (1995). A View From The Front Line. Maggies Cancer Caring Centre.
141 Medina, S. (2014). The Story of Maggie's Centres: How 17 Architects Came to Tackle Cancer Care. Retrieved from https://www.archdaily.com/498519/the-story-of-maggie-s-centres-how-17-architects-came-to-tackle-cancer-care
142 Geboy, L., and A. B. Keller. (2007). Research in practice: The design researcher's perspective. Implications Newsletter 4(11).

4.2.1.1 GREEN BUILDINGS

The World Green Building Council is a non-profit global network organization of national Green Building Councils that aims to empower the sustainable approach to built environments and communities. Buildings considered GREEN, refers to the application of an environmentally responsible process with efficiency in management and application of resources through the building's life-cycle. Green buildings go beyond the requirements of local codes to improve sustainable performance and life-cycle impact. Some characteristics of a green building are ventilation systems with efficient heating and cooling, effective use of space, minimal harm to the local habitat, maximizing solar energy and sunlight, application of native vegetation and materials, use of renewable energy sources, optimization of winds and placement on the site with a proper space utilization, application of recycled materials, energy-efficient lighting and appliances, non-synthetic and toxic materials, rainwater harvesting, greywater reuse and responsibly harvested woods. People tend to mistake the idea that a green building requires greenery on the roof and all around. However, with vertical gardens, green walls and green roof approaches, the designers are facilitating the building to achieve green building qualities.

Since they stated in 2015 that a new approach in the user within the green buildings are emerging towards human experience, health, and wellness.

4.2.1.2 LEED

Leadership in Energy and Environmental Design (LEED) is the most widely adopted rating system based on certification with a point system criteria, and it is the most recognized of them, has certified 29,000 buildings in its 16 years.[143] Although it was developed by the U.S. Green Building Council (USGBC), it is internationally recognized and requires different conditions of new built space and maintenance of the existing ones with the aim to improve performance across the most important sustainability concerns as energy savings, water efficiency, reduction of CO2 emissions, enhancement of indoor environmental quality and responsible employment of resources and its impacts. Overall, the requirements concern a range of design strategies with the purpose of stimulation the green building approach and its reduction of negative impact on climate, resources and natural environment.

Many extent building typologies could be applied to the LEED system, since its flexible approach of lifecycle which accounts for design and construction, operations and maintenance and occupants adaptations. The point system awards the building from the certified, silver, gold or platinum; and it is classified in five main areas: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality.[144]

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143 Cedeño-Laurent, J., Williams, A., Macnaughton, P., Cao, X., Eitland, E., Spengler, J., & Allen, J. (2018). Building Evidence for Health: Green Buildings, Current Science, and Future Challenges. Annual Review of Public Health, 39(1), 291-308.
144 LEED green building certification. (n.d.). Retrieved from https://new.usgbc.org/leed

Although LEED contains several criteria regarding human health and wellness, the overall approach consists of deeply specific details that do not always lead to an adequate human-centred built environment. Some of the approaches lack an appropriate method to achieve the desired results concerning daylight, indoor air quality, and thermal comfort. That being said, revisions have been improving the LEED system which is now in version 4 with improvements of requirements. One example concerns daylight: with the new version, projects need to perform with higher luminance levels during different seasons and minimizing potential glare. It resulted in the application of more complex and sophisticated solutions from the design.

In addition, LEED also has a pilot credit where they test new requirements with potential to be part of a new updated version. Some examples of the actual pilot credits refer to the promotion of health, improvement of thermal comfort controls, better acoustic performance and so on. Nevertheless, is widely spread that you can achieve higher scores with simple approaches that do not mean the building will be green, healthier and sustainable. The architect Steve Mouzon even proposed an Anti-LEED system to prove that LEED lost its main focus and it is now becoming a marketing without purposes.[145]

4.2.1.3 LIVING BUILDING CHALLENGE

The International Living Future Institute (ILFI) is the organization which developed and accredited the Living Building Challenge (LBC) certifications. LBS evaluates the connection of the user with natural daylight, air, nature, food, and a healthy community, through the built space. Nowadays, their approach is the most advanced system in terms of overall sustainability, requiring not only quantitative criteria, but also requirements related to qualitative aspects that the built environment produces/ inspires to its users, such as aesthetics, happiness, justice, and wellbeing.

The main idea about the Living Building Challenge consists of "reconnecting occupants with nature".[146] It aims for a net-positive energy performance, free of toxic materials and minimum energy footprint, and its certified projects are evaluated for at least one year of regular occupation. LEED and other green building rating systems have a similar approach to sustainability performance. However, for LBC, the built environment must achieve all the requirements, being considered the most rigorous rating system.

LBC can also be used as a design tool to conduct the projects to have an ecological, restorative and enriched built environment with regards to equity and respect for humans and natural systems.

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145 Mouzon, S. (2014, October 15). Is It Time For the Anti-LEED? Retrieved from https://www.archdaily.com/557605/is-it-time-for-the-anti-leed
146 Programs Overview. (2018, April 20). Retrieved from International Living Future Institute: https://living-future.org/programs-overview/

ILFI also has other standards which concern products - Living Product Basics, and community - Living Community Challenge. Moreover, a Living Food Challenge is under pilot phase and it tackles the overall impact related to food, such as waste, loss of topsoil, hunger, food miles, farmworker rights, factory farming, GMOs, and more. And in addition to these standards and certifications, ILFI also has three label programs to provide a complete framework for projects to incorporate healthier strategies for a more civilized and humane living in the built environment. The Declare label is a platform and product database to assist the designers to find healthier building products, it is called a nutrition label for products.[147] The Reveal is a label that reveals the building energy performance. And the label called Just, which evaluates organizations about social justice and equity.

4.2.1.4 PASSIVE HOUSE

The Passive House certification accounts for the leading standard in energy-efficient buildings, with a focus on reducing energy consumption for heating and cooling through new design approaches to reach proper thermal comfort. One of the strong points of the Passive House is to explore the heat from the sun as a source, since it was a reaction to the complication of energy resources and oil crisis which started in 1973.[148]

To achieve the required energy consumption levels, Passive House developed the Passivhaus Planning Package (PHPP) - a computer simulation software to be used during the design process. The standard includes some approaches for the design process to employ as passive solar design, superinsulation, advanced window technology, airtightness, ventilation, electrical appliances, space heating, and space lighting.[149]

A passive house usually presents a project with fresh and clean air, consistent and slow changes in temperature, high resistance to heat and fast option to cross-ventilation by opening windows and doors.

4.2.1.5 WELL

The International WELL Building Institute (IWBI) is the company behind WELL building standard certification that concentrates around advancements on human health and wellness in the built environment. It was conceived to combine scientific research about human behavior and health outcomes to built space design. WELL was developed under the LEED framework which facilitates its popularity. The system started with some precondition requirements and optional strategies for optimization

147 Declare Products. (2017, December 07). Retrieved from https://living-future.org/declare/
148 Kettell, S. (2016, May 27). Oil crisis. Retrieved from https://www.britannica.com/topic/oil-crisis
149 Gröndahl, Mika; Gates, Guilbert (September 25, 2010). "The Secrets of a Passive House". The New York Times. Retrieved September 27, 2010.

which is distributed among seven sections as Air; Water; Nourishment; Light; Fitness; Comfort; Mind. Although, today WELL advanced into version 2 after a revision of requirements, removing Fitness and Comfort, but adding Movement, Thermal Comfort, Sound, Materials, and Community.

In Air concept, the built space need to have an enriched indoor air quality by applying proper strategies as a measurement of performance, microbe and mold control, filtration, ventilation and operable windows, management of building pollution, smoke ban, among others. High-Quality drinking water and management is expected in the Water concept with proper treatment, legionella control, metrics performance, management of moisture, promotion of drink water and handwashing. Under Nourishment approach, they encourage good eating habits by offering healthier choices and proper food environment with abundance in fruits and vegetables, clear nutrition facts and education about food, adjustment of special diets, ingredients restrictions, management of portion, proper eating spaces, food source and preparation guidelines. Light is another concept that requires a proper visual balance and light quality, daylighting access, control of glare, lighting design to enhance the circadian system, visual balance, and acuity, with the education about the importance of light and occupants control possibility to increase the benefits of daylight and lighting system in the occupants to enhance the experience and promote optimization a better sleep. In Movement concept, the idea is to promote activity through the built environment with proper circulation spaces and elements, ergonomics, active furniture and commuting, encouragement of physical activity through adequate space and promotion, besides a self-monitoring activity tracker. Inside the Thermal Comfort, the idea is to improve the thermic sensation of the built space by providing proper comfort with measurement of the performance, the possibility of user controls, ongoing monitoring, thermal zones, cooling, heating and humidity management. In Sound concept, built space needs to improves acoustic performance by proper absorption, barriers, masking, mapping, and spaces zones. Materials account for the use of minimum hazardous substances found in the building materials by supervising the materials emissions, safety, precautions, cleaning protocols, waste management, pesticide application, outdoor structures, and VOC reduction. Mind concept is required to support cognitive and emotional health by providing access to nature and natural elements, tobacco prevention, emergency plans, support of proper focus and sleep. And finally, Community concept which the idea is to engage and integrate the community with the parents, mother and family support, universal design, ready for emergencies, proper bathroom accommodations, and immunity.

A building must achieve a minimum score in all seven sections to be certified. Like LEED, the certification range from Silver, Gold or Platinum according to the score rank. However, while LEED and Passive House focus mainly on sustainability, healthy environments are a consequence rather than the main objective. In WELL certification, the primary focus is to enhance the occupant’s health.

4.2.1.6 ACTIVE DESIGN GUIDELINES

Created by the Center for Active Design with aiming to promote ordinary physical activity through design strategies. The guidelines have four focus points; circulation systems; individual elements; programming; activity spaces. And it also could be applied in combination to other rating systems, standards and labels, since its target is physical activity. LEED and Active Design Guidelines have overlapping checklists of requirements and advise to facilitate the integration and application of both as complementary approach.

Circulation systems examples could be the improvement of corridors, specifically programmed spaces, halls, lobbies, and stairs, while individual elements account for appealing, accessible and comfortable stairs, corridors, exercise rooms, drinking places and so on. Programming means how the functions and spaces were designed to encourage movement between destination. And finally, the activity spaces which are spaces to promote physical activities like exercise and multipurpose rooms.

4.2.1.7 GRESB

The Global Real Estate Sustainability Benchmark (GRESB) is a global standard towards environmental, social and governance sustainable functioning of real estate. In 2016 GRESB started a new Health & Well-being Module to promote health and well-being through internal and external procedures by recognizing the importance of the current debate about health and well-being as a reliable source of information for owners, investors, and companies.[150]

4.2.1.8 FITWEL

The Center for Active Design launched Fitwel certification standard to encourage healthier built environments to enhance health, productivity, and wellbeing of the occupants. It is a unique and low-cost certification which provides to buildings and most workplaces, the baseline of evidence-based to improve employee performance through wellness and healthier places.

Fitwel affects seven Health Impact Categories: Impacts Community Health, Reduce Morbidity + Absenteeism, Supports Social Equity for Vulnerable Populations, Instills Feelings of Wellbeing, Provides Healthy Food Options, Promotes Occupant Safety, Increases Physical Activity. And its categories are divided into 12 sections: Location, Building Access, Outdoor Spaces, Entrances & Ground Floor, Stairwells, Indoor Environment, Workplaces or Dwelling Units, Shared Spaces, Water Supply, Cafeteria or Restaurants, Vending Machines, and Snacks Bar, Emergency Procedures.[151]

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150 Pyke, C (October 4, 2016) Five Key Takeaways from the New GRESB Health & Well-being Module.
151 What are the Fitwel Standards? (n.d.). Retrieved from https://fitwel.org/standard

The certification is awarded in three levels of stars; one-star range the punctuation from 90 to 104, two stars from 105 to 124 and three stars from 125 to 144 points. And it has more than 55 evidence-based design and strategies to improve buildings by demonstrating the impact on the user's health. Their strong point is the interconnected system of points which address the set of categories and not a single and dominant focus.

4.2.1.9 BREEAM

The Building Research Establishment Environmental Assessment Method (BREEAM) was launched in 1990 to set a standard for the environmental performance of buildings in terms of design, specification, construction, and operation. It was the first assessment method for buildings.[152] The assessment is based on a scoring system within nine criteria; energy, land use and ecology, water, health and wellbeing, pollution, transport, materials, waste, and management. The projects under the BREEAM rating system need to achieve a minimum score to be achieved and rated from unclassified, pass, good, very good, excellent or outstanding.[153]

A pre-evaluation is an optional assessment to assist designers on the improvements and understanding of the system to achieve a desirable rating. And they also have a scheme that provides an action plan about performance and management during the use of the building. And in 2016, the Building Research Establishment presented the alignment with WELL building standard and BREEAM to facilitate the projects which aspire to have both of them.

4.2.1.10 GREEN STAR

Established in 2003 by the Green Building Council of Australia (GBCA), the Green Star sustainable rating system aims to promote healthy, resilient and positive environments for people. The purpose is to educate, advocate and certify sustainable built environment in Australia. The system includes four Green Star rating tools; Design and As-Built, Interiors, Communities, and Performance; to guide, transform, improve and support every building type.

Each project can be assessed in nine categories: Management, Indoor Environment Quality, Energy, Transport, Water, Materials, Land Use & Ecology, Emissions, and Innovation. Within the categories, the projects can be graded from one to six stars; one star means minimum practice, two stars - average practice, three stars - good practice, four stars best practice, five stars, Australian excellence; and six stars - world leadership. The system aims to encourage sustainable design and construction

152 The world's leading sustainability assessment method for master planning projects, infrastructure, and buildings. (n.d.). Retrieved from https://www.breeam.com/

153 BRE Group. (2019, March). BREEAM Wiki Part of Designing Buildings Retrieved from https://www.designingbuildings.co.uk/wiki/BREEAM through new approaches to building practices with concern in human health, productivity and cost savings.[154]

However, some environmentalists have been seeing the Green Star rating system with not transparent intention since it was financially supported by property developers.

4.2.1.11 RELI

The RELi certification was developed by a collaboration with architectural professionals, experts, university students, and researchers in 2014. It has five 'living design metapatterns' which includes Resilience, Restoration, Regeneration, Sustainability, and Wellness as design criteria with a guideline of a to-do list. The aim is to develop a resilient society that can rebuild itself by embracing planning, anticipation, and adaptation to the future.

4.2.1.12 CASBEE

The Comprehensive Assessment System for Built Environment Efficiency (CASBEE) is the Japanese building rating system to evaluate environmental performance. It was developed in 2001 by a research committee of members from industry, academia, and governments. CASBEE aims to enhance the quality of people's lives and minimizing the life-cycle resource in the built environment. It can be applied from a singular house to a whole city.

CASBEE is formed by collectively assessment tools divided into four families; housing scale, building scale, urban scale, and city scale. Inside the housing scale, there are the tools for new detached houses, existing detached houses, housing units, housing renovation checklist, and housing health checklist. In the building scale, there are tools for new construction, existing buildings, renovation, locally customized edition for municipalities, interior space, temporary construction, heat island relaxation, schools, and real estates. In the urban scale, there are two tools; one for urban developments and other for community health checklist. And finally, on the city scale, there are tools for cities and another one for the cities-pilot version to use worldwide.

4.2.1.13 HQE

The Haute Qualité Environnementale (HQE) is the France green building standard developed in the concepts of sustainability, which were a development from the 1992 Earth Summit. The HQR certification promotes sustainability through best practices in buildings with guidance during the lifetime of the project. It involves the awards of building construction, management, and urban scale projects.

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154 Green Building Council of Australia. (n.d.). Introducing the Green Star.

4.2.1.14 DQI

Design Quality Indicator (DQI) is an assessment to measure, evaluate and advance the design quality of buildings. It was developed by the Construction Industry Council (CIC) from the United Kingdom to tackle the problem of poor design quality in buildings in the United Kingdom. It was derived by the affluence of Key Performance Indicators which evaluates topics related to the construction process as duration, safety, and financial constraint. DQI is based on the ideas of Marcus Vitruvius from the 1st century BC who demonstrated the importance of Firmits (durable), Utilitas (useful) et Venustas (beautiful) to describe the architectural design. These three qualities were translated to present terms as Build Quality (Firmitas), Functionality (Utilitas) and Impact (Venustas). The assessment is divided into 5 stages of organization in the course of the project lifecycle. After each stage, a report is provided with details of the results and suggestion for further improvements.

4.2.1.15 DATABASES

Conscious Cities is a concept which focuses on the relation of the built environment towards its occupants by applying artificial intelligence, data analysis, and through the implementation of behavior science. It resulted from a practical approach with the manifesto "A Manifesto for Conscious Cities"[155] written by the architect Itai Palti and the neuroscientist Moshe Bar in 2015. After that, a number of events and publications have encouraged new approaches to the design of built space. They launched a Journal to facilitate the publication of research.[156]

The Centre for Urban Design and Mental Health (UD/MH) was launched in 2015 aiming to research on mental health and urban environments, and how can we design better built environment with a focus on the improvement of habitants mental health. The core mission is to assist in the information, stimulation and empowerment of planners, designers, policymakers and public health professionals to shape urban environments with better mental health designs and approaches. They also have a journal and an online platform to review and summarize research, motivate interdisciplinary discussion and exchange, exposure new and effective concepts, and produce feasible evidence-based counsel.

Some specialized databases were used range from journals, organizations, associations and reviewed researches. Such as the "Environmental Psychology Journal", Annual Review of Psychology series; the BRIK - The Building Research Information Knowledge, is base which is a curated and professionally-reviewed web-based directory for built environment-related research; The Conscious Cities conferences; The InformeDesign, online platform which offers tutorial on research, glossary of terms, implications of the research and so on as a decision-making tool for the design process.
And Journal of Environmental Psychology.

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155 Palti, I., & Bar, M. (2015, August 28). A manifesto for conscious cities: Should streets be sensitive to our mental needs? Retrieved from https://www.theguardian.com/cities/2015/aug/28/manifesto-conscious-cities-streets-sensitive-mental-needs
156 https://www.theccd.org/

Some of the leaders in reviewing and publishing research about buildings affecting behavior are the architectural journals: World Health Design, Environment Behavior, and Health Environments Research & Design Journal (HERD). Besides ANFA and its congress papers and posters database with a wide range of subjects about the relation between built environment and neuroscience. Another important database regarding scientific information about the built environment is the InformeDesign website.

4.3 TOOLS

Groundbreaking research on human-centered design, embodiment and advances in technology, are triggering the development of new tools to measure and explore with substantial precision a range of different stimuli: visual, tactile, olfactory, neural, gustatory, pleasure, stress hormones, sense of comfort, efficiency, air quality, temperature, natural feeling, movement tracking, peripersonal space, biological responses, forms, colors, proportions, textures, light, materials, elements, among other variables from built environment.

Nevertheless, architecture has been exploring new areas of neurological and physiological research to uncover the architecture experience. Function Magnetic Resonance Imaging (fMRI) and Electroencephalography (EEG) are the main technologies in neuroimaging which have been allowing us to access revolutionary discoveries in our brains. The fMRI is still a complex and large mechanism that turns impracticable to use it in the different built spaces. While the EEG is becoming smaller, cheaper and easy to obtain. It reads the transdermal electrical signals through the scalp, heart-rate, blood pressure, body temperature, skin conductance - a method that measure of sweat glands and demonstrate the arousal. brain waves, eye tracking. The information technology on electronic health records (EHR) have also been in great development and shifting the healthcare industry with valuable data, to track health, wellness and outcomes. In addition, sensors and trackers can collect real-time data and also monitoring the outcomes by building analytics of the built space, and occupants outcomes.

It is already popular among architectural companies to utilize simulation tools and virtual reality to preview design outcomes concerning issues such as building temperature, radiance, heat, wind, ventilation, weather conditions, speed of evacuation, speed of resistance in case of fire, acoustics, shades, structure resistance, material resistance, building degradation, water and energy consumption, among others. Furthermore, high-performance buildings are also using sensors to understand the performance of the building in real-time and during different occasions and events, day and night, and all year long.

Post Occupancy Evaluation (POE) is another method that has been increasingly applied to appraise design outcomes. Occupants provide feedback about the performance and other issues related to the built space. The importance of the POE is undeniable, even being mandatory on some public buildings. The POE assists in costs, wellbeing and even business efficiency by highlighting and addressing problems to be solved, identifying difficulties in building operation, as a database to future design decisions, and as benchmarking aid to follow the designs over time. POEs can be applied in different forms, such as through questionnaires, tests, surveys, etc. It also documents the project data of the building as a resource, and provides important information to owners as well as occupants to better understand and operate their buildings to achieve the desired optimization, efficiency and outcome. Known POE methods are: AMA Workware Toolkit; BUS Occupant Survey; CIBSE TM22 energy survey; Design Quality Method (DQM); Housing Evaluation and Performance Studies (HEAPS); Office Productivity Network (OPN) Survey; Overall Liking Score (OSL); PROBE - Post-occupancy Review Of Buildings and their Engineering; School Works; Soft Landings. They vary on building typologies, methods of questionnaires, evidence of performance, functionality, overall satisfaction, productivity, energy savings, experiences, system performance and so on.

In a 2015 Post Occupancy Evaluation Survey Report from Skidmore, Owings & Merrill, Julie Hiromoto outlined the potentials of POE and demonstrated resources that may assist the implementation and development of POE with fundamental assessment components.[157] Everyone in the built industry has much to gain with POE, with many clients noticing the importance of the evaluation to the development of management strategies. It can generate an empiric track record for designers and stakeholders which they can learn from and benefit from previous solutions in a forward conscious process.

4.4 DISCUSSION

The development of standards towards healthier buildings is of significant importance nowadays, with solutions to enhance building performance as a whole. However, many argue that the current rating systems do not tackle the issue of the quality of space. Indeed, the current standards mainly focus on the technical performance of buildings, and vaguely consider issues regarding user experience. In response, a few rating systems have implemented some complimentary labels, modules, and requirements that focus on users' health and wellness. These responses indicate the recognition of the lack of a humanist approach regarding the design of the built environment. Such humanistic approach has been consistently overlooked by many involved in the building industry. The rating systems along with lawmakers and decision-takers usually focus on requirements such as water management, energy performance, and material selection, and usually make a blind eye for performance requirements related to thermal comfort, indoor air quality, and ventilation rates, for example, which directly affects occupants' health and wellbeing.

Nonetheless, the World Green Building Council declared in 2015 that a new demand with a focus on human experience, health and wellness is emerging and should be

157 Hiromoto, J. (2015). Post Occupancy Evaluation Survey Report(Architect & Design Sustainable Design Leaders, Rep.). New York, NY: Skidmore, Owings & Merrill LLP. http://www.som.com/ideas/research/post_occupancy_evaluation_survey_report the focus of a green building process.[158] Recent findings demonstrate that, although buildings may have labels, won awards and certificates, they are not necessarily healthy for their occupants. With the increasing accessibility to knowledge and information, added to people's expectations on what architecture should provide, rating systems, standards, and guidelines ought to be upgraded. One approach to address this issue could be the incorporation of a wider range of qualitative and quantitative factors into the evaluation criteria instead of principles targeting only average requirements. Another approach is to take independent measures, like the case of the Mcewen School of Architecture. Since the LEED criteria was not deemed adequate to provide the right assessment for the site and for their innovative sustainable construction methods used in the project, the designers developed their own Sustainable Design Manifesto as to includes a suitable feedback to the "region's limited local labour force and extreme seasonal shifts".[159]

"Architecture is about people, not building".[160] A critical reflection on architectural design outcomes can initiate an extensive debate on how to develop new design approaches which may produce positive effects building users. This can be achieved by exploring practice-based research, evidence, and literature review of existing scientific data. By establishing a solid base for knowledge exchange between scientists, architects, engineerings, clients and stakeholders, future design proposals can be refined and better articulated as to minimize arbitrary solutions. By conducting a critical evaluation, questioning and promoting discussion, each part of the design process can contribute with evidence to achieve better designs on inhabitants experience, optimization, healing, health, and wellbeing.

158 *(2014) Health, Wellbeing, and Productivity in Offices: The Next Chapter for Green Building. World Green Building Council*
159 *McEwen School of Architecture. (2018, May). OAA Awards 2018. Canadian Architect*
160 *Hochberg, A. T. (2016.). The future of applied neuroscience research in architecture education. Journal of Urban Design and Mental Health 2016;1:3.*

table 2 - Journals and databases

year	name	publisher	description	focus
1887	Japan Architectural Review	Architectural Institute of Japan.	the official peer-reviewed journal of the Architectural Institute of Japan.	The journal covers all aspects of architectural design and building sciences, including perspectives offered through the lens of science, technology, engineering, economics, social science and human-centered design, architectonics and other related fields.
1950	Annual Review of Psychology	Annual Reviews	peer reviewed Journal / Magazine / Newspaper, Internet Resource	significant developments in the field of psychology, including: biological bases of behavior, sensation and perception, cognitive processes, animal learning and behavior, human development, psychopathology, clinical and counseling psychology, social psychology, personality, environmental psychology, community psychology, and more.
1958	Architectural Science Review	Founded at the University of Sydney in 1958 by Professor Henry Cowan and published by Taylor & Francis	is an international, peer-reviewed journal publishing high-quality, original research.	environmental issues, covering topics such as thermal comfort, lighting, and sustainable architecture, contributing to this extensive field of knowledge by seeking papers from a broad geographical area.
1969	Environment and Behavior (EAB)	Environmental Design Research Association	peer reviewed jorunal which examines relationships between human behavior and the natural and built environment.	Research topics include environmental experiences (e.g., restorativeness, place attachment/identity, environmental perception/cognition); environmental outcomes (e.g., pro-environmental behaviors such as recycling; health-supportive environments; design preferences); and processes linking environments and behaviors that support or thwart human well-being.
1974	Landscape Planning / Landscape and Urban Planning	Elsevier Ltd.	An international journal aimed at advancing conceptual, scientific,and applied understandings of landscape in order to promote sustainable solutions for landscape change.	The journal is based on the premise that landscape science linked to planning and design can provide mutually supportive outcomes for people and nature.
1975	Building Science / Building and Environment	Elsevier Ltd.	publishes original papers and review articles on building research and its applications, and on the social, cultural and technological contexts of building research and architectural science.	The Journal is focused on new knowledge, rigorously verified with measurement and analysis, related to the environmental performance of the built environment in a wide range of spatial scales, ranging from cities, communities, buildings, to building systems and assemblies as well as other built environments such as those related to transportation.
1979	Design Studies	Elsevier Ltd.	international academic journal focused on developing understanding of design processes.	It studies design activity across all domains of application, including engineering and product design, architectural and urban design, computer artefacts and systems design. It therefore provides an interdisciplinary forum for the analysis, development and discussion of fundamental aspects of design activity, from cognition and methodology to values and philosophy.
1981	Journal of Environmental Psychology	Elsevier Ltd.	the journal publishes some of the most influential papers in the discipline that reflect the scientific development of environmental psychology. Contributions on theoretical, methodological, and practical aspects of all human-environment interactions are welcome, along with innovative or interdisciplinary approaches that have a psychological emphasis.	•Psychological and behavioral aspects of people and nature •Cognitive mapping, spatial cognition and wayfinding •Ecological consequences of human actions •Theories of place, place attachment, and place identity •Environmental risks and hazards: perception, behavior, and management •Perception and evaluation of buildings and natural landscapes •Effects of physical and natural settings on human cognition and health •Theories of proenvironmental behavior, norms, attitudes, and personality •Psychology of sustainability and climate change •Psychological aspects of resource management and crises •Social use of space: crowding, privacy, territoriality, personal space •Design of, and experiences related to, the physical aspects of workplaces, schools, residences, public buildings and public space
1983	Behavioral Neuroscience (BEHAV NEUROSCI)	American Psychological Association.	Journal / Magazine / Newspaper, Internet Resource	publish original research papers in the broad field of the biological bases of behavior.
1995	arq: Architectural Research Quarterly	Cambridge University Press	it is a journal for practitioners in industry and consultancy as well as for academic researchers.	Contents include building design, urbanism, history, theory, environmental design, construction, materials, information technology, and practice.
2003	InformeDesign	co-created by Denise Guerin, PhD and Caren Martin, PhD at the University of Minnesota, in the Department of Design, Housing, and Apparel.	Database InformeDesign was created to bring design research and practice together. They range from the most rigorous, peer reviewed journal research findings transformed into evidence-based design criteria to postings of the most recent doctoral dissertations and intra-company industry reports. All are provided as a means by which to enable design practitioners to engage in evidence-based design (EBD).	The designers of the built environment face a multitude of complex challenges that are resource, social, environmental, behavioral, and design in nature.
2003	The Academy of Neuroscience for Architecture (ANFA)	American Institute of Architects (AIA)	is a nonprofit organization with its database of research, whose mission is to promote and advance knowledge that links neuroscience research to a growing understanding of human responses to the built environment.	body of knowledge connecting neuroscience and architecture
2004	Cognitive Processing (Cognit Process)	Springer Berlin Heidelberg	a peer-reviewed international journal that publishes innovative contributions in the multidisciplinary field of cognitive science.	the manifold disciplines concerned with the different aspects of cognitive processing in natural and artificial systems: artificial intelligence, computer science and knowledge engineering, linguistics, mathematics, neuroscience, philosophy and cognitive anthropology, psychology, robotics.
2007	Frontiers in Systems Neuroscience	Frontiers	peer-reviewed research that advances our understanding of whole systems of the brain, including those involved in sensation, movement, learning and memory, attention, reward, decision-making, reasoning, executive functions, and emotions.	The study of brain systems includes the analysis of individual regions, as well as multiple levels and nodes of information processing.
2007	Health Environments Research & Design Journal (HERD)	Center for Health Design	is an international, interprofessional, peer-reviewed journal that features research and methodology papers, theory articles, case studies, and book reviews focused on the effects of health environments and design on patient, provider, and organizational outcomes.	articles and research papers on the relationships among health and environmental design and organizational, provider, and patient outcomes.
2008	World Health Design	The International Academy for Design and Health	stimulates debate and promotes the values, wisdom and knowledge of the academy's network and community to business, government and other public organizations.	Research, professional and business practice relating to the field of design and health,
2009	Perkins+Will Research Journal	Perkins+Will	peer-reviewed publication dedicated to documenting and and presenting practice-related research associated with buildings and their environments.	how built environments affect the human experience, discovering the latest energy efficiency strategies, or finding the most innovative, resilient, and healthy building materials and technologies,

2010	Active Design Guidelines	The Center for Active Design (CfAD)	It is a guidelines provides architects and urban designers with a manual of strategies for creating healthier buildings, streets, and urban spaces, based on the latest academic research and best practices in the field.	Urban design strategies for creating neighborhoods, streets, and outdoor spaces that encourage walking, bicycling, and active transportation and recreation Building design strategies for promoting active living where we work and live and play, through the placement and design of stairs, elevators, and indoor and outdoor spaces Discussion of synergies between active design with sustainable and universal design initiatives such as LEED and PlaNYC
2013	Archidoct	European Network of Heads of Schools of Architecture-ENHSA, an EU funded Network in the framework of the Lifelong Learning Programme	is a peer-reviewed e-journal aiming at fostering, enhancing and promoting doctoral research in architecture.	The first point that underlines the originality of this endeavour is that the authors of the essays published are doctoral students in architecture. The second point that underlines this originality is that the journal is a mentoring, educational tool that aims at improving the writing skills of the authors as this will be advised by the peer reviewers towards academically coherent and rigorous writings.
2013	BRIK - The Building Research Information Knowledge	A collaborative effort of the American Institute of Architects and the National Institute of Building Sciences,	an interactive portal offering online access to peer-reviewed research projects and case studies in all facets of building, from predesign, design, and construction through occupancy and reuse.	creating the built environment—from researchers to clients to builders to designers to occupants
2015	Conscious Cities	The Centre for Conscious Design	Movement and as a hub for human-centred and science-informed architecture and urbanism. Anthologies, journal, website and database of articles	integration of technology and science-informed design to create a healthier, more inclusive, and democratic built environment by using design to address urban issues facing society today and in the future.
2015	Building Healthy Places Toolkit	Urban Land Institute's (ULI)	this toolkit is a practical guide for real estate developers that expands on the growing practice of using health evidence to inform design thinking.	physical activity, healthy food/drinking water, and healthy environment/social well-being. Building Healthy Places is the outcome of extensive research and literature reviews, ensuring that all proposed strategies are rooted in evidence or industry best practices.
2015	Active Design Toolkit for Schools	Partnership for a Healthier New York City in collaboration with New York City's Departments of Health and Mental Hygiene, Education, and Transportation.	provides ideas and resources to incorporate active design into schools in NYC.	Many of the ideas presented are simple, but have immense potential to improve the overall success, health and well-being of students.
2015	The Centre for Urban Design and Mental Health (UD/MH)	Layla McCay	a central repository and global go-to resource and platform for policymakers, architects, transport planners, urban planners, developers, designers, engineers, geographers, and others who want to design better mental health into cities, and drive integration of mental health into urban design as standard.	Share knowledge Increase knowledge Increase cross-sector communication Empower practical action
2016	Assembly Project Orientation.	The Center for Active Design (CfAD)	resource for city leaders and designers who seek to strengthen their communities by harnessing design to support civic life.	how place-based design informs a range of civic engagement outcomes: 1) civic trust and appreciation, 2) participation in public life, 3) stewardship of the public realm, and 4) informed local voting.
2016	Policy Brief: Impact In Affordable Housing	The Center for Active Design (CfAD)	This policy brief is a set of recommendations	a multitude of successful design projects serve as case studies that demonstrate how design can be used to promote health in unique community contexts.
2017	Nature Human Behaviour	Nature Research	online-only monthly journal dedicated to the best research into human behaviour from across the social and natural sciences.	*Nature Human Behaviour* features a broad range of topics, including (but not limited to) perception, action, memory, learning, reward, judgment, decision-making, language, communication, emotion, personality, social cognition, social behaviour, neuropsychiatric/ neurodevelopmental/neurological disorders, economic & political behaviour, belief systems, social networks, social norms, social structures, behaviour change, collective cognition and behaviour, culture, public policy.
2018	Civic Design Guidelines	The Center for Active Design (CfAD)	*Guidelines,* a groundbreaking playbook for creating well-designed and well-maintained public spaces as a force for building trust and healing divisions in local communities.	to provide evidence-based design and maintenance strategies for creating cities where people trust each other, have confidence in local institutions, and actively work together to address local priorities.
2019	The Journal of Science-Informed Design (SIDe)	The Centre for Conscious Design	peer-reviewed resource for the architecture and urban design sectors. By bridging research and practice, SIDe aims to inform the design of people-centred spaces and places.	insights into the behavioural, physiological and cognitive effects of the built environment.

CHAPTER 5 – DESIGN STRATEGIES AND INHABITABILITY PARAMETERS

All our surrounding environment affect us by stimulating our neurons. These neurons process information and quickly provide feedback on what is happening around us. Synapses and impulses allow neurons to pass electrical and/or chemical signals to other neurons, discharging reactions to our entire bodies. These reactions affect us in numerous ways, like inducing or helping to overcome disorders, diseases, and injuries, make us excited or bored, anxious or calm, opened to social interaction or not. These are involuntary reactions which happen on a subconscious level.

Accordingly, architecture is always stimulating our neurons, and in one way or another, affecting us. Even though being usually processed as a background, architectural space is processed in our brains by the activation of all our senses, which instantly absorbs the information and interprets it. Some spaces may make us instantaneously feel hostile, uncomfortable, anxious from the stimuli their features produced in our brains. Other spaces can induce a delayed feeling of power, and even heal us from an illness. But what are the features that cause these effects? Can we predict our brain reactions according to the features of a space?

The following investigation aimed at answering these questions. Basing itself on findings that indicate the correlation between human/space behavior, the research focused on features in space that produce positive brain reactions. Since most of the research on this theme has been conducted in fields of the life sciences, much of the evidence of these features had to grouped into parameters and translated into practical design strategies. The result was a framework of parameters, which indicate design strategies that cause positive effects on the people who inhabit it. The term inhabitability parameters is rooted in that premise.

5.1 INHABITABILITY PARAMETERS

It is vital for the design process to comprehend the desire target objective, priorities, intentions, and outcomes of the proposal. The designers need to identify strategies to approach the problems. It is already an arduous job to collect all the detail information about the project, not mention researching about scientific data, its findings and how to practically applied it in the design. For that reason, it was noticed a need to develop an objective list of parameters as a vigour baseline for the designer.

The methodology applied to reach the inhabitability parameters, concerns in searching for the most relevant and objective studies in relation to architecture. This was done by collecting and gathering data from scientific journals, appropriated books, and databases. The following analyses intend to validate these parameters, explaining what they are, the outcomes, the theories and studies behind it, as well as some examples of practical application. Hence, all the parameters discussed in this study are supported with a table of reference of the research, to facilitate the overall understanding of the parameter, authors, the design strategies and above all; the effects of applying it.

Being aware of the surrounding environment is a crucial aspect of the human body and its activities within the space. And architecture aspects can determine the type of influence the built environment is making on its inhabitant. Therefore, investing in design concepts, principles, elements organization, scale, proportion, hierarchy, materials, and luminescence are fundamental strategies to the design process. And to understand these approaches, an analysis of the most relevant strategies based on scientific evidence were done. With the analysis of 382 scientific studies together with the literature review, it was able to classify the different approaches to the subject into four groups. Nature and Outdoor, Cognitive Performance, Structure and Spatial Identity.

It was extracted from the literature review that the design organization will be divided into four categories. The first is the relation to nature and how we process systems that define the general potential to link nature and ourselves. The second refers to the cognitive performance effects on us and the potentials to develop cognitive strategies. The third involves the spatial structure and the set of elements that are responsible for the formation of the space. And the fourth accounts for the identity of the space, its logic and stability. These are the main themes converted into four group parameters that are responsible for the organization of the present scientific studies support. And from the four groups, 13 inhabitability design parameters emerged. It is important to mention that the parameters were named that could easily be associated as a design strategy by the professionals, to be applied as practical design strategies and have an impact on the wellbeing of the occupants.

Still, there is no singular, sequence or straight forward approach to applying the parameters as design strategies. Some of them complement each other, or it is possible to achieve one through another since the human response of the built space happens in many biological ways and stimulus.

Understanding and using the parameters do not limit the creativity of architects, in fact, it is the opposite. It ables architects to explore direct creative approaches to tackle specific aspects of the design for the desired outcome. The parameters intention is to objectively enhance the architect's design and style, to keep developing and evolving the design quality towards a human-centred architecture.

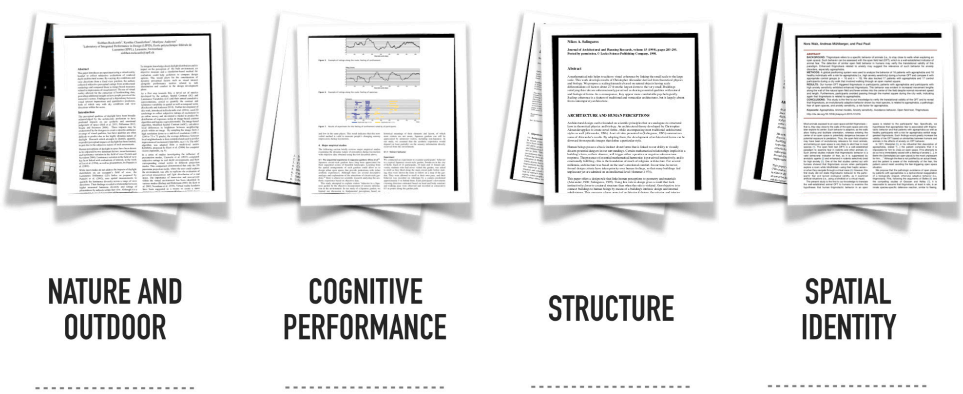

fig. 5 - Groups from Scientific Studies

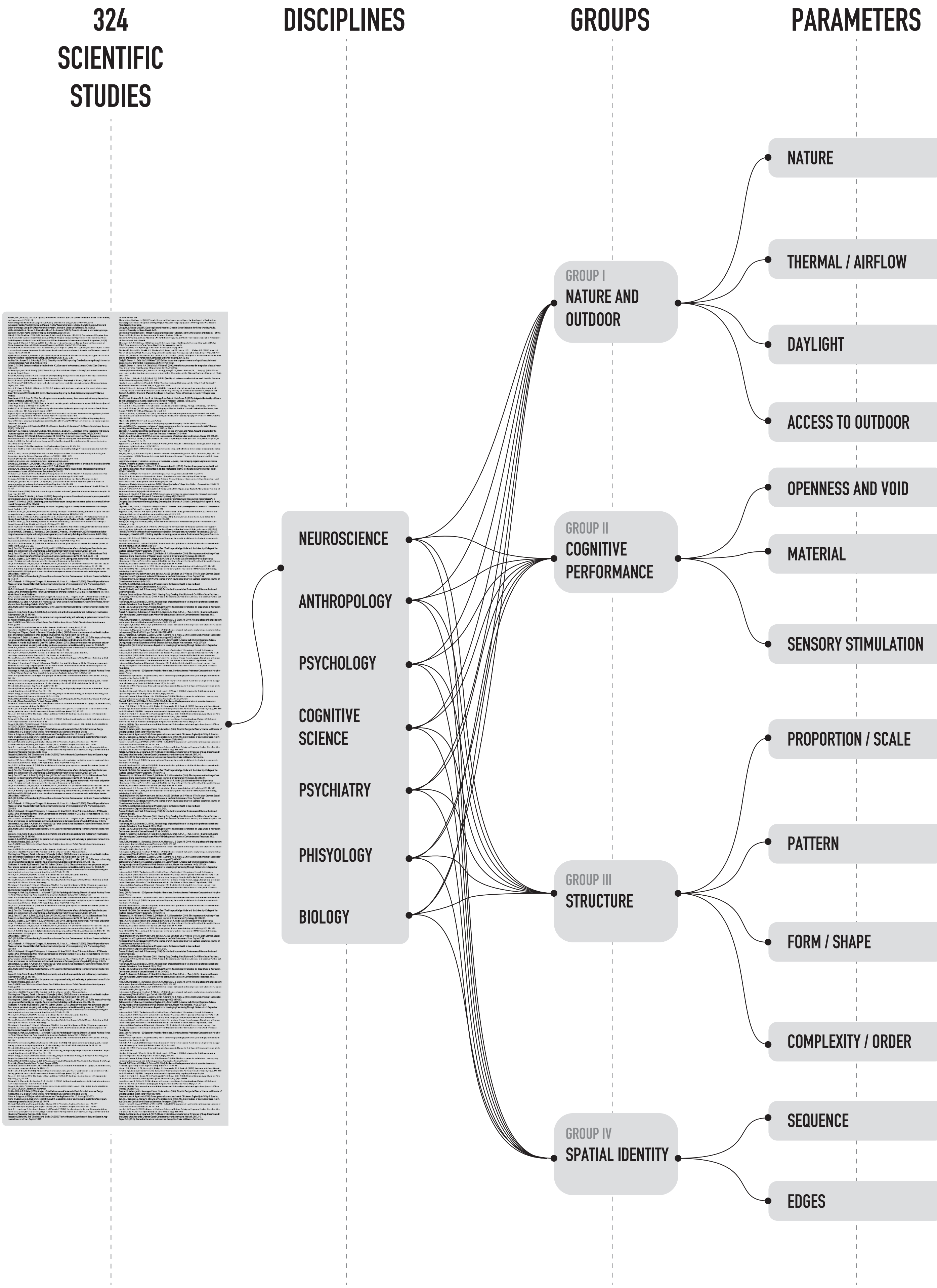

fig. 6 - Diagram of Methodology on how to achieve Groups and Parameters

fig. 7 - Inhabitability Parameters

5.1.1 GROUP 1 – NATURE AND OUTDOOR

The first group - Nature and Outdoor - addresses the condition, within a built environment, of connection between occupants and natural elements. It can happen through physical contact, like seeing a tree, indirect stimuli, like the smell of a flower brought by the wind, and/or temporary perception, like a gust of wind. This group is categorized by the experience of interactions with elements of nature and meteorological conditions.

The benefits of nature and the outdoors to our wellbeing was always considered as common sense. Consequently, many architects, throughout history, constantly attempted to integrate the built and the natural environment. One example is the garden city concept, which was first proposed by Ebenezer Howard in 1898[161]. His Garden of To-morrow supported the theory that people would be happier and workers would be more efficient if they lived within nature. Many other architects were inspired by this concept and proposed their own versions of garden cities.

Within this group, four parameters were recognized: Nature, Thermal/Airflow, Daylight and Access to Outdoor. Nature parameter accounts for the general relation to natural elements, living systems, and natural processes. Thermal/Airflow parameter is related to temperature conditions, humidity, and natural ventilation. Daylight parameter refers to the direct or indirect luminescence from the sun. Access to Outdoor parameter refers to the spatial interrelation between inside and outside.

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161 Howard, Ebenezer. (1898). To-morrow: A Peaceful Path to Real Reform.

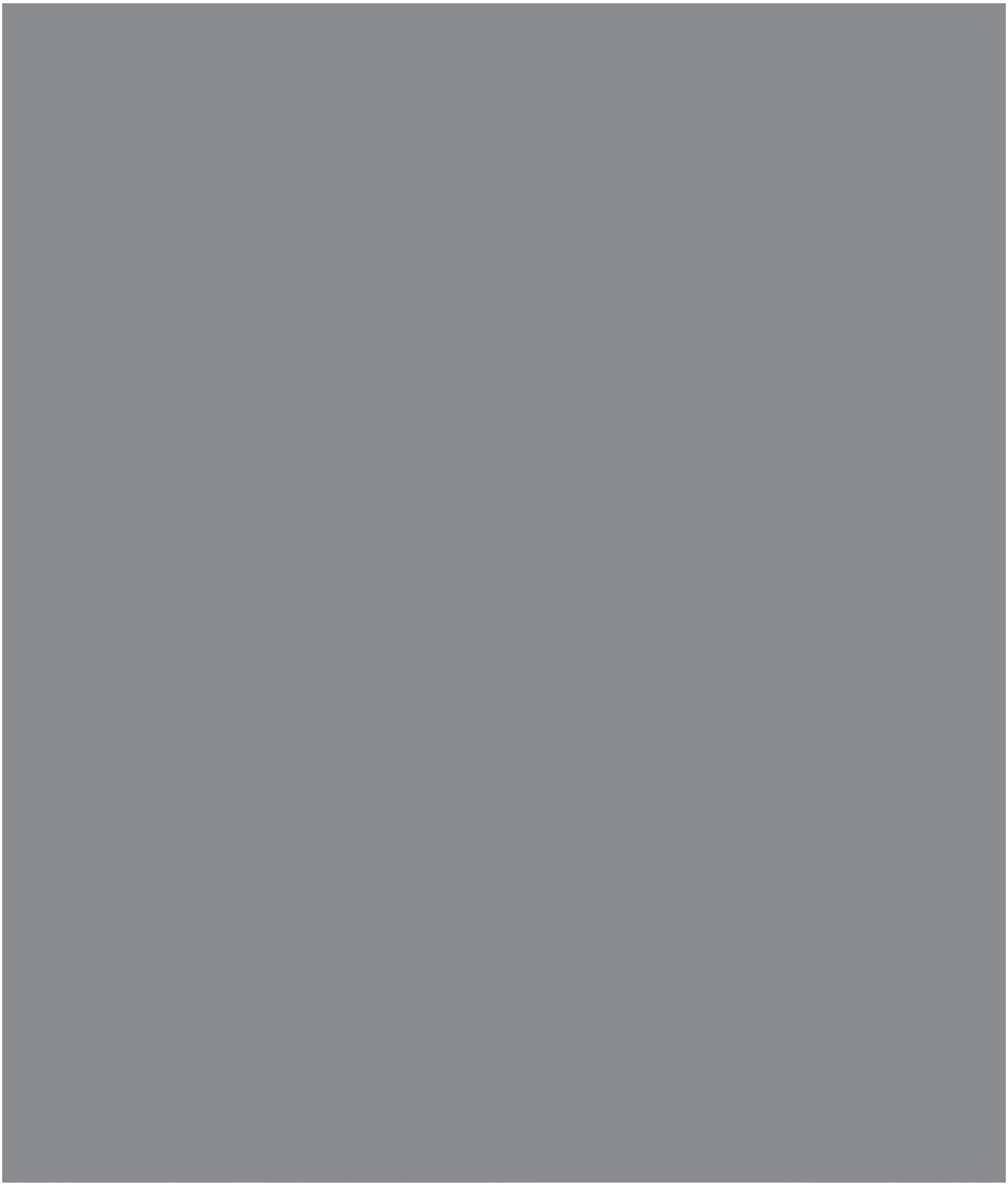

fig. 8 - Waterside Buddist Shrine - ARCHSTUDIO

5.1.1.1 NATURE

WHAT IT IS:

Nature parameter is associated to the human/environment/nature relation, which allows the inhabitants of a built environment to appreciate and benefit from natural elements. This relationship occurs through visual connection with nature, living systems or natural processes, including the presence of water, greenery, gardens and so on.

Nature is the parameter featured in the highest number of studies, which demonstrate the health benefits it brings, the positive responses it generates, and our preference to natural elements, systems, and process. Nature also enhances our involvement with a place and captivates our subconscious, even when we are not intentionally acknowledging it or processing it in the background.

OUTCOME:

Contact with nature has been linked to a range of scientific evidence that validates its positive outcomes in three main areas: psychological, physiological and cognitive. Nature promotes psychological well-being, with supporting outcomes ranging from emotional state restoration, mood improvements, self-esteem, concentration, attention, alertness, adaptability, and general wellbeing. Nature promotes physiological health, the favorable outcomes accounting for general physical comfort, relaxation and restoration of the muscular, respiratory and circadian system, assisting in lowering stress hormones. Nature promotes cognitive performance, with positive outcomes including improvements in memory, learning, creativity, mental processing, and restoration.

Studies show that visual connections with nature lowered blood pressure and heart rate, resulting in faster stress recovery time. Also reduced attentional fatigue, sadness, anger, and aggression; improved mental engagement/ attentiveness, attitude and overall happiness.

THEORIES AND STUDIES:

The notion that nature is important for healing is common sense, and has been theorized for thousands of years—going back to classical times, when temples to Asclepius, the Greek god of healing, were built far from towns, high up on hilltops overlooking the sea. In the 3rd century BCE, Chinese Taoists also attested the beneficial powers of gardens on human's health.[162]

Nature and natural elements produce a range of stimulus that positively boost different neurological activities in our brains. However, since most people live in

162 *Wilson, Edward O. (2006). The Creation: An Appeal to Save Life on Earth. New York City: W. W. Norton & Company,*

urban environments nowadays, many have become deprived of nature's benefits. The lack of green spaces is associated with a nature deficit disorder. Richard Louv, who wrote many books about the importance of nature for our health, wellbeing and to enrich life, calls our necessity for nature as "vitamin N".[163] He predicts that: "The future will belong to the nature-smart - those individuals, families, businesses, and political leaders who develop a deeper understanding of the transformative power of the natural world and who balance the virtual with the real. The more high-tech we become, the more nature we need."[164]

Forest is one of the most complex natural systems and one that we can simply walk into as to escape civilization. In Japan, there is a common and ancient tradition to immerse yourself in the woods and benefit from it by walking and appreciating of the forest as a system and individual elements. The tradition of "forest bathing", called shinrin-yoku in Japanese, was formally conceived in 1982 by the government in an effort to publicly promote its health benefits and conservation. A range of studies already proved the benefits of this tradition: decrease of cortisol level, heartbeat, diastolic blood pressure, pulse rate, tension, depression, anger, fatigue, confusion, tension, and suppression of sympathetic nerve activity. It also produces a spark of the sympathetic nerves, increases anticancer protein production, boosts the natural killer cells in the immune system, improves general mood, vigor, vitality, and energy.[165] The Japanese government provided almost the equivalent amount of four million dollars on research in the period of 2004 to 2012 to prove the benefits of shinrin-yoku. Today Japan has about 62 official sites for "forest bathing" therapy across the country.[166] Japanese scientists have been working on understanding what actually happens to our cells and neurons by applying hormone analysis, field tests, and brain-imaging technology.[167] Another recent study outside Japan revealed that after three days of camping and hiking in the wilds, students scored 50% higher scores in creativity tests, attesting a boost in their performance.[168] Urinary adrenaline amount was the object of another research, which verifies the decrease level after walking in a park with trees.[169]

The overall cognition, depression and major depressive disorder (MMD) can be deeply improved by walking in natural environments as demonstrated in a study, which also proved the simple, accessible, affordable and effective method to decrease anxiety even when reminded about complicated anxiety moments by the team.[170] In this other study, they suggested the decrease impulsiveness in decision-making

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163 Louv, Richard. (2016). Vitamin N: The Essential Guide to a Nature-rich Life. Algonquin Books.

164 Louv, Richard. (2011). The Nature Principle: Human Restoration and the End of Nature-deficit Disorder. Chapel Hill, NC: Algonquin Books of Chapel Hill.

165 Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2009). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. Environmental Health and Preventive Medicine, 15(1), 18–26.

166 62 Forests across Japan. (2016). Retrieved from Forest Therapy Society https://www.fo-society.jp/quarter/cn49/62forest_across_japan.html

167 Li, Q. (2010). Effect of forest bathing trips on human immune function. Environmental Health and Preventive Medicine, 15(1), 9–17.

168 Atchley, R. A., Strayer, D. L., & Atchley, P. (2012). Creativity in the Wild: Improving Creative Reasoning through Immersion in Natural Settings. PLoS ONE, 7(12), e51474.

169 Li, Q., Otsuka, T., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., … Kagawa, T. (2011). Acute effects of walking in forest environments on cardiovascular and metabolic parameters. European Journal of Applied Physiology, 111(11).

170 Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., … Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. Journal of Affective Disorders, 140(3), 300–305.

when participants were exposed to scenes of natural environments compared to built environments. Attention was also part of the findings since the deficit of attention results in impulsiveness.[171]

Growing up surrounded by green space can provide mental health benefits as demonstrated by a recent study concluded in 2019: "Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood"[172]. Researchers mapped the presence of green space around the homes of almost one million children, and from 1985 to 2013 analysed the occurrence of mental disorders among them. Children who grew up surrounded by less presence of green spaces had a 55% higher risk of developing a mental disorder, besides other health risks. The research concluded that the presence of green spaces may reduce the rise of psychiatric disorders worldwide.

In the same manner, in another study, 342 individuals were analyzed on how a communal green vacant land can affect adults' mental health. Participants were tracked during 18 months before and after a green lot received improvement interventions. The findings were also impressive: participants reported a decrease in depression of 41.5%, a poor mental health condition lowered 62.8% in overall participants.[173]

Dr. Roger Ulrich is an awarded professor, researcher, and specialist in healthcare design and one of the most important and cited scientist about evidence-based design in healthcare. He is responsible for improving patients outcomes all over the world for the direct impact in hospitals design and its costs. His researchers include how nature, gardens, and art can decrease pain, stress, staying and healthcare costs; the critical impact of hospital noise on patients and staff; and on how to decrease infection transmission through hospitals design.[174] In a study, he tracked the recovery level of patients post-surgery. He concluded that patients in hospital beds facing windows with views to trees stayed less time in the hospital, took less pain medicine and also had fewer post-surgery complications in comparison to those with windows facing a wall.[175] And in another study by the recognized environmental psychologist Rachel Kaplan, revealed the effects of nature on hospital workers and patients, which became more satisfied when they had views to nature, compared to ones without.[176]

Some stakeholders still question the health benefits of green spaces in large projects due to cost. However, increasing evidence shows that green spaces not only bring direct health benefits but also the indirect affect profits through the increase of

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171 Berry, M. S., Sweeney, M. M., Morath, J., Odum, A. L., & Jordan, K. E. (2014). The Nature of Impulsivity: Visual Exposure to Natural Environments Decreases Impulsive Decision-Making in a Delay Discounting Task. PLoS ONE, 9(5), e97915.

172 Kristine Engemann, Carsten Bøcker Pedersen, Lars Arge, Constantinos Tsirogiannis, Preben Bo Mortensen, Jens-Christian Svenning. (2019). Residential green space in childhood is associated with a lower risk of psychiatric disorders from adolescence into adulthood. Proceedings of the National Academy of Sciences.

173 South, E. C., Hohl, B. C., Kondo, M. C., MacDonald, J. M., & Branas, C. C. (2018). Effect of Greening Vacant Land on Mental Health of Community-Dwelling Adults. JAMA Network Open, 1(3), e180298.

174 Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H.-B., Choi, Y.-S., … Joseph, A. (2008). A Review of the Research Literature on Evidence-Based Healthcare Design. HERD: Health Environments Research & Design Journal, 1(3), 61–125.

175 Ulrich, Roger S. (2002). Health Benefits of Gardens in Hospitals, Paper presented at Plants for People Conference, Intl. Exhibition, Floriade.

176 Kaplan, R (1993).The role of nature in the context of the workplace. Landscape and Urban Planning. 26 workers and students productivity. Productivity in the work environment has been proven through even indirect contact with nature as an image.[177] In a study with furniture company Herman Miller, the environmental psychologist Heerwagen el tal., revealed that people had higher scores in memory and problem-solving analysis when having landscape images in front of their desks compared to individuals with gray and geometric fabrics.[178] Another study with students and classrooms with views of nature experienced faster recovery from mental fatigue and stress with improvements in overall performance compared to windowless classrooms.[179]

Stephen Kaplan et al. have shown that cognitive functioning and control were improved with short and simple connection with nature.[180] However, the reverse effect is also true. A study demonstrated that individuals with low doses of nature in urban areas have worse health.[181] With our lives immersed in urban and technological environments, our need for reconnection to nature is essential for a healthier life. Some of the studies showed the improvement of productivity and creativity have a big impact by different approaches of nature. Large cutting-edge companies such as Apple, Amazon, Google, and Facebook, all implemented those findings in their work environment and new buildings headquarters. They understand the great value of producing an innovative space that aims to inspire creativity, encourage collaboration, stimulate motivation, promote pleasure, restore mental health, improve relaxation, support wellbeing, advocate for movement and boost productivity. They know that casual collision between the employees generate inspiration and, in consequence, economic growth. Besides the direct beneficial effects over diseases such as depression, diabetes, colorectal cancer, osteoporosis, cardiovascular and cerebrovascular diseases. With this confirmation on mental health improvement and lasting psychological advantages,[182] such environments also prevent people to become unable to work.

All studies on the restorative effect of the environment on our bodies and mind have shown that our cognitive skills prefer and are encouraged by "living" environments. These environments are interpreted as exciting because we engage our attention and forget the fatigue while exploring all its intricacies. By activating brain areas of involuntary attention, nature promotes high restorative outcomes.[183] Twenty minutes in contact with nature has been proved enough to restore stress levels by reducing cortisol levels[184], and a short viewing of 40 seconds of a green external area can

177 Kellert, S. R. (2005). Building for life: designing and understanding the human-nature connection. Washington D.C.: Island Press.
178 Heerwagen, J., Hase B & (2001). Building biophilia: connecting people to nature. Environmental Design and Construction, April 2001, 30-34.
179 Li D, Sullivan WC. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. Landsc. Urban Plann. 148:149–58
180 Berman, M. G., Jonides, J., & Kaplan, S. (2008). The Cognitive Benefits of Interacting With Nature. Psychological Science, 19(12), 1207–1212.
181 Cox, D. T. C., Shanahan, D. F., Hudson, H. L., Fuller, R. A., & Gaston, K. J. (2018). The impact of urbanisation on nature dose and the implications for human health. Landscape and Urban Planning, 179, 72–80.
182 Lee, A. C. K., & Maheswaran, R. (2010). The health benefits of urban green spaces: a review of the evidence. Journal of Public Health, 33(2), 212–222.
183 Kaplan, Rachel; Stephen Kaplan (1982). Humanscape: Environments for People. Ann Arbor, Mich.: Ulrich's Books.
184 Hunter, M. R., Gillespie, B. W., & Chen, S. Y.-P. (2019). Urban Nature Experiences Reduce Stress in the Context of Daily Life Based on Salivary Biomarkers. Frontiers in Psychology, 10.

already increase concentration levels.[185] These findings highlight the importance of our connection to nature in different situations and levels. They also evidence that through design interventions that take these considerations into account, built environments can have a direct impact on people's behavior, health, and wellbeing. Author Nicholas Humphrey also suggests that, since nature also comprehends the natural dynamics of weather, season and day/night, designers should go to the natural environment and learn by experiencing what we as human beings like to see, the beauty of the structures and all sensitivity aesthetic involved.[186]

PARAMETER APPLICATION:

The application of the Nature parameter should happen in every situation possible where natural elements can be introduced: ranging from gardens, vertical gardens, green living walls, internal gardens, combination of stones, garden of stones, planters, water, pond, fountain, aquariums, soil, earth, view to trees, artwork and videos with natural sceneries. The designer should encourage occupants to be in an area with biodiversity, with some visual connection to the natural elements, design spaces, layouts, and floor plans which uphold restorative views, with preference to real nature over simulated.

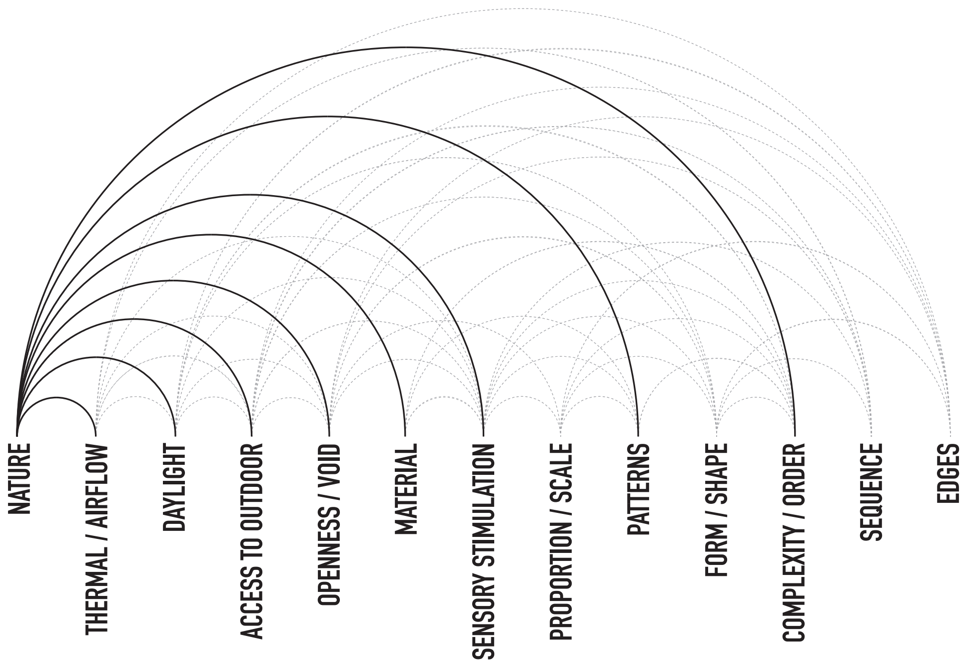

fig. 9 - Diagram of Parameters Interrelations

185 K.E Lee et al (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. Journal of Environmental Psychology, 42:182-189

186 Humphrey, N. (1980). Natural Aesthetics. In B. Mikellides (Ed.) Architecture for People. London: Studio Vista.

table 3 - Scientific Studies related to Nature Parameter

effect	relevant studies	findings
•**Health** •**Mental Health** •**Wellbeing**	Abbass, O.A., Sailor, D. J., & Gall, E.T. (2017). Effectiveness of indoor plants for passive removal of indoor ozone. Building and Environment, 119, 62–70.	Indoor vegetation improves health
	Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. BMC Public Health, 10(1).	positive impact on wellbeing
	Brooks, A. M., Ottley, K. M., Arbuthnott, K. D., & Sevigny, P. (2017). Nature-related mood effects: Season and type of nature contact. Journal of Environmental Psychology, 54, 91–102.	nature improves mood and wellbeing
	Cox, D. T. C., Shanahan, D. F., Hudson, H. L., Fuller, R. A., & Gaston, K. J. (2018). The impact of urbanisation on nature dose and the implications for human health. Landscape and Urban Planning, 179, 72–80.	people in urban areas with a low nature dose tend to have worse health across multiple domains
	Gascon, M., Zijlema, W., Vert, C., White, M. P., & Nieuwenhuijsen, M. J. (2017). Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies. International Journal of Hygiene and Environmental Health, 220(8), 1207–1221.	a positive association between greater exposure to outdoor blue spaces (lakes, rivers, sea, etc)
	Kahn, Jr. P.H. & S.R. Kellert (2002). Children and Nature: Psychological, Sociocultural, and Evolutionary Investigations. Cambridge: MIT Press.	incorporation of nature in children's life produce a range of positive outcome from cognitive science, developmental psychology, ecology, education, environmental studies, evolutionary psychology, political science, primatology, psychiatry, and social psychology.
	Kaplan, R (1993).The role of nature in the context of the workplace.. Landscape and Urban Planning. 26	workers and patients were more satisfied when they had views to nature.
	Korpella, K.M., & Ylén, M. (2007). Perceived health is associated with visiting natural favorite places in the vicinity. *Health & Place, 13*(1), 138–151.	natural settings serve as a resource for regulating negative feelings and coping with perceived stress.
	Kristine Engemann, Carsten Bøcker Pedersen, Lars Arge, Constantinos Tsirogiannis, Preben Bo Mortensen, Jens-Christian Svenning. (2019). Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. Proceedings of the National Academy of Sciences, 2019; 201807504	children who grew up with the lowest levels of green space had up to 55% higher risk of developing a psychiatric disorder independent from effects of other known risk factors.
	Largo-Wight, E., Chen, W.W., Dodd, V., & Weiler, R. (2011). Healthy Workplaces: The Effects of Nature Contact at Work on Employee Stress and Health. Public Health Reports, 126(1_suppl), 124–130.	nature contact workplace is a healthy exposure
	Lee, A. C. K., & Maheswaran, R. (2010). The health benefits of urban green spaces: a review of the evidence. Journal of Public Health, 33(2), 212–222.	view that green space have a beneficial health effect.
	Lee, J., Park, K.T., Lee, M.S., Park, B.J., Ku, J.H., Lee, J.W. Oh, K.O., An, K.W. & Miyazaki, Y. (2011b). Evidence-based Field Research on Health Benefits of Urban Green Area. J Korean Insti Landsc Archit, Vol. 39, No.5, pp. 111-118	health benefits of green areas
	Louv, R. (2008). Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. New York: Algonquin Books. pp390.	nature immersion experiences could address the risk of "nature-deficit disorder," improve health, and prepare future environmental leaders.
	Marcus, C. C., & Barnes, M. (1995). Gardens in healthcare facilities: Uses, therapeutic benefits, *and design recommendations*. Concord, CA: The Center for Health Design.	therapeutic benefits of the garden spaces
	Negami, H. R., Mazumder, R., Reardon, M., & Ellard, C. G. (2019). Field analysis of psychological effects of urban design: a case study in Vancouver. Cities & Health, 1–10.	simple green urban design interventions can increase subjective well-being
	Rawcliffe, C. (2008). Delectable sights and fragrant smells: Gardens and health in late mediaeval and early modern England. *Garden History, 36*(1), 3–21.	gardens constituted a frontline defence in the battle against disease. medicinal benefits of green space, and the healthy engage in recreation for mind and body.
	Russell, R., Guerry, A. D., Balvanera, P., Gould, R. K., Basurto, X., Chan, K. M. A., … Tam, J. (2013). Humans and Nature: How Knowing and Experiencing Nature Affect Well-Being. Annual Review of Environment and Resources, 38(1), 473–502.	experiencing nature makes us generally happier, healthier people.
	Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environmental Research, 166, 628–637.	meta-analysis found statistically significant decreases in incidence of diabetes, all-cause and cardiovascular mortality.
	Tyrväinen, L., Pauleit, S., Seeland, K. & de Vries, S. (2005). Benefits and uses of urban forests and trees. In: Urban Forests and Trees in Europe A Reference Book. Nilsson, K., Randrup, T.B. & Konijnendijk, C.C. (Eds.), Springer Verlag. pp. 81-114.	urban forests and trees improve physical and menthal health
	Valtchanov, D., Barton, K. R., & Ellard, C. (2010). Restorative Effects of Virtual Nature Settings. Cyberpsychology, Behavior, and Social Networking, 13(5), 503–512.	restorative effects such as increased positive affect, decreased negative affect, and decreased stress.
	Van den Berg, M., Wendel-Vos, W., van Poppel, M., Kemper, H., van Mechelen, W., & Maas, J. (2015). Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. Urban Forestry & Urban Greening, 14(4), 806–816.	living in greener environments is associated with better mental health and lower all-cause mortality.

	White, M. P., Alcock, I., Wheeler, B. W., & Depledge, M. H. (2013). Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data. Psychological Science, 24(6), 920–928.	nature benefits on mental health and wellbeing.
•Restorative **•Stress Reduction**	Ali, B., Al-Wabel, N. A., Shams, S., Ahamad, A., Khan, S. A., & Anwar, F. (2015). Essential oils used in aromatherapy: A systemic review. Asian Pacific Journal of Tropical Biomedicine, 5(8), 601–611.	natural olfactory has positive impact on treatment of central nervous system disorder.
	Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., … Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. Journal of Affective Disorders, 140(3), 300–305.	walking in natural environments proved the simple, accessable, affordable and effective method to decrease anxiety
	Berto, R. (2014) The Role of Nature in Coping with Psycho-Physiological Stress: A Literature Review on Restorativeness. *Behav. Sci. 4*, 394-409.	natural environments and recovery from physiological stress and mental fatigue, giving support to both *Stress Recovery Theory* and *Attention Restoration Theory*
	Brown, D.K., J.L. Barton, & V.F. Gladwell (2013). Viewing Nature Scenes Positively Affects Recovery of Autonomic Function Following Acute-Mental Stress. *Environmental Science & Technology, 47*, 5562-5569.	Overall, this suggests that nature can elicit improvements in the recovery process following a stressor.
	Hunter, M. R., Gillespie, B. W., & Chen, S. Y.-P. (2019). Urban Nature Experiences Reduce Stress in the Context of Daily Life Based on Salivary Biomarkers. Frontiers in Psychology, 10.	the efficiency of a nature pill per time expended was greatest between 20 and 30 min, after which benefits continued to accrue, but at a reduced rate.
	Kaplan, R.; Stephen K. (1982). Humanscape: Environments for People. Ann Arbor, Mich.: Ulrich's Books.	restorative potentials by activating brain areas of involuntary attention
	Kaplan, S. (1996). The restorative beneits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15*(3), 169–182.	natural environments turn out to be particularly rich in the characteristics necessary for restorative experiences.
	Kristine Engemann, Carsten Bøcker Pedersen, Lars Arge, Constantinos Tsirogiannis, Preben Bo Mortensen, Jens-Christian Svenning. (2019). Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. Proceedings of the National Academy of Sciences.	Green spaces has a strong association with mental health improvement and it can help in reducing the rising of psychiatric disorders
	Lee, J., Park, B.-J., Tsunetsugu, Y., Kagawa, T., & Miyazaki, Y. (2009). Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. Scandinavian Journal of Forest Research, 24(3), 227–234.	forest environments had significantly lower values of salivary cortisol concentration (an index of stress response), diastolic blood pressure, and pulse rate.
	Li D, Sullivan WC. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. Landsc. Urban Plann. 148:149–58	classroom views to green landscapes cause significantly better performance on tests of attention and increase student's recovery from stressful experiences.
	Li, Q., Otsuka, T., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., … Kagawa, T. (2011). Acute effects of walking in forest environments on cardiovascular and metabolic parameters. European Journal of Applied Physiology, 111(11).	decrease of adrenaline levels after walking in the park with trees.
	Louv, Richard. (2016). Vitamin N: The Essential Guide to a Nature-rich Life. Algonquin Books.	lack of green spaces is associated to a nature deficit disorder and insuficient wellbeing.
	Matsunaga, K., Park, B.-J., Kobayashi, H., & Miyazaki, Y. (2011). Physiologically Relaxing Effect of a Hospital Rooftop Forest on Older Women Requiring Care. Journal of the American Geriatrics Society, 59(11), 2162–2163.	rooftop forest is an environment where they can experience natural stimulation and be restored
	Naderi, J. R., & Shin, W.-H. (2008). Humane design for hospital landscapes: A case study in land- scape architecture of a healing garden for nurses. *Health Environments Research & Design Journal, 2*(1), 82–119.	contact with nature and privacy encourage the benefits.
	Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2009). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. Environmental Health and Preventive Medicine, 15(1), 18–26.	boosts the natural killer cells which boost the immune system, improves general mood, vigor, vitality and energy
	South, E. C., Hohl, B. C., Kondo, M. C., MacDonald, J. M., & Branas, C. C. (2018). Effect of Greening Vacant Land on Mental Health of Community-Dwelling Adults. JAMA Network Open, 1(3), e180298.	after green lot improvement interventions, participants related a decrease in depression
	Tsunetsugu, Y., Park, B.J. & Miyazaki, Y. (2011). Physiological effects of visual, olfactory, auditory, and tactile factors in the forest environment. In : Forest Medicine, Q. Li, (Ed.), pp. 169-181, Nova Science Publishers, NY.	the five senses, providing sense stimulation of various kinds such leading to a positive effect on human physiology.
	Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environmental Research, 166, 628–637.	meta-analysis showed statistically significant reductions in diastolic blood pressure, salivary cortisol and heart rate.
	Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. Journal of Environmental Psychology, 38, 1–9.	restorative effects of short-term visits to urban nature environments.
	Ulrich, R. (1999). Effects of gardens on health outcomes: Theory and research. In *Healing gardens*, eds. C. Cooper Marcus and M. Barnes, 27–86. New York: John Wiley & Sons Inc.	restorative impact from gardens

	Ulrich, R. (2002). Health Benefits of Gardens in Hospitals, Paper presented at Plants for People Conference, Intl. Exhibition, Floriade.	ones in hospital rooms with windows facing trees stayed less time in the hospital, had fewer pain medicine and also with less complications, compared to those with windows facing a wall
	Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H.-B., Choi, Y.-S., … Joseph, A. (2008). A Review of the Research Literature on Evidence-Based Healthcare Design. HERD: Health Environments Research & Design Journal, 1(3), 61–125.	nature, gardens and art can decrease pain, stress, staying and healthcare costs
	White, M., A. Smith, K. Humphryes, S. Pahl, D. Snelling, & M. Depledge (2010). Blue Space: The Importance of Water for Preference, Affect and Restorativeness Ratings of Natural and Built Scenes. *Journal of Environmental Psychology. 30* (4), 482-493.	As predicted, both natural *and* built scenes containing water were associated with higher preferences, greater positive affect and higher perceived restorativeness than those without water.
•Cognition Improvement	Atchley, R. A., Strayer, D. L., & Atchley, P. (2012). Creativity in the Wild: Improving Creative Reasoning through Immersion in Natural Settings. PLoS ONE, 7(12), e51474.	after of three days of camping and hiking in the wilds, students had a performance of 50% better scores in creativity tests
	Berman, M. G., Jonides, J., & Kaplan, S. (2008). The Cognitive Benefits of Interacting With Nature. Psychological Science, 19(12), 1207–1212.	walking in nature or viewing pictures of nature can improve directed-attention abilities
	Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., … Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. Journal of Affective Disorders, 140(3), 300–305.	demonstrating the cognitive and affective benefits of interacting with nature to individuals with major depressive disorder
	Berry MS, Sweeney MM, Morath J, Odum AL, Jordan KE (2014) The Nature of Impulsivity: Visual Exposure to Natural Environments Decreases Impulsive Decision-Making in a Delay Discounting Task. PLoS ONE 9(5): e97915.	Visual Exposure to Natural Environments Decreases Impulsive
	Cameron-Faulkner, T., Melville, J., & Gattis, M. (2018). Responding to nature: Natural environments improve parent-child communication. Journal of Environmental Psychology, 59, 9–15.	natural environments improve parent-child communication.
	Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., … Sunyer, J. (2015). Green spaces and cognitive development in primary schoolchildren. Proceedings of the National Academy of Sciences, 112(26), 7937–7942.	beneficial association between exposure to green space and cognitive development among schoolchildren
	Heerwagen, J., Hase B & (2001). Building biophilia: connecting people to nature. Environmental Design and Construction, April 2001, 30-34.	people had higher scores in memory and problem-solving analysis when having landscape images in front of their desks compared to individuals with gray and geometric fabrics
	K.E Lee et al (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. Journal of Environmental Psychology, 42:182-189	green external area for as short as 40 seconds already increase the concentration level.
	Kellert, S. R. (2005). Building for life: designing and understanding the human nature connection. Washington D.C.: Island Press.	indirect contact with nature in offices improve productivity.
	Valtchanov, D., & Ellard, C. G. (2015). Cognitive and affective responses to natural scenes: Effects of low level visual properties on preference, cognitive load and eye-movements. Journal of Environmental Psychology, 43, 184–195.	nature significantly influenced preference, cognitive load, and eye-movements.
	Williams, K. J. H., Lee, K. E., Hartig, T., Sargent, L. D., Williams, N. S. G., & Johnson, K. A (2018). Conceptualising creativity benefits of nature experience: Attention restoration and mind wandering as complementary processes. Journal of Environmental Psychology.	natural contact improves cognition
•Healing •Immune Improvement	Hickman, C. (2009). Cheerful prospects and tranquil restoration: The visual experience of land- scape as part of the therapeutic regime of the British asylum, 1800–60. *History of Psychiatry, 20*(4), 425–441.	the passive experience of viewing the landscape and the location of the asylum within a rural have a therapeutic role.
	Li, Q. (2010). Effect of Forest Bathing Trips on Human Immune Function. *Environmental Health and Preventive Medicine, 15* (1), 9-17.	forest bathing trips resulted in an increase human immune function
	Li, Q., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., Hirata, Y., … Miyazaki, Y. (2009). Effect of Phytoncide from Trees on Human Natural Killer Cell Function. International Journal of Immunopathology and Pharmacology, 22(4), 951–959.	trees exposure decreased stress hormone levels and contribute to increased human immune function
	Li, Q., M. Kobayashi, H. Inagaki, Y. Wakayama, M. Katsumata, Y. Hirata, Y. Li, K. Hirata, T. Shimizu, A. Nakadai, & T. Kawada (2012). Effect of Phytoncides from Forest Environments on Immune Function. In Q. Li (Ed.). *Forest Medicine* (157-167). ebook: Nova Science Publishers.	trees exposure decreased stress hormone levels and contribute to increased human immune function
•Violence Reduction	Burley, B. A. (2018). Green infrastructure and violence: Do new street trees mitigate violent crime? Health & Place, 54, 43–49.	inclusion of new street trees in underserved neighborhoods may be one solution to the endemic of violence
•Cardiovascular Improvement •Metabolic Improvement	Li, Q., Otsuka, T., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., … Kagawa, T. (2011). Acute effects of walking in forest environments on cardiovascular and metabolic parameters. European Journal of Applied Physiology, 111(11), 2845–2853.	walking in forest environments may lower blood pressure by reducing sympathetic nerve activity and have beneficial effects on blood adiponectin and DHEA-S levels
•Birth outcomes	Hystad, P., Davies, H. W., Frank, L., Van Loon, J., Gehring, U., Tamburic, L., & Brauer, M. (2014). Residential Greenness and Birth Outcomes: Evaluating the Influence of Spatially Correlated Built-Environment Factors. Environmental Health Perspectives.	increased residential greenness was associated with beneficial birth outcome.

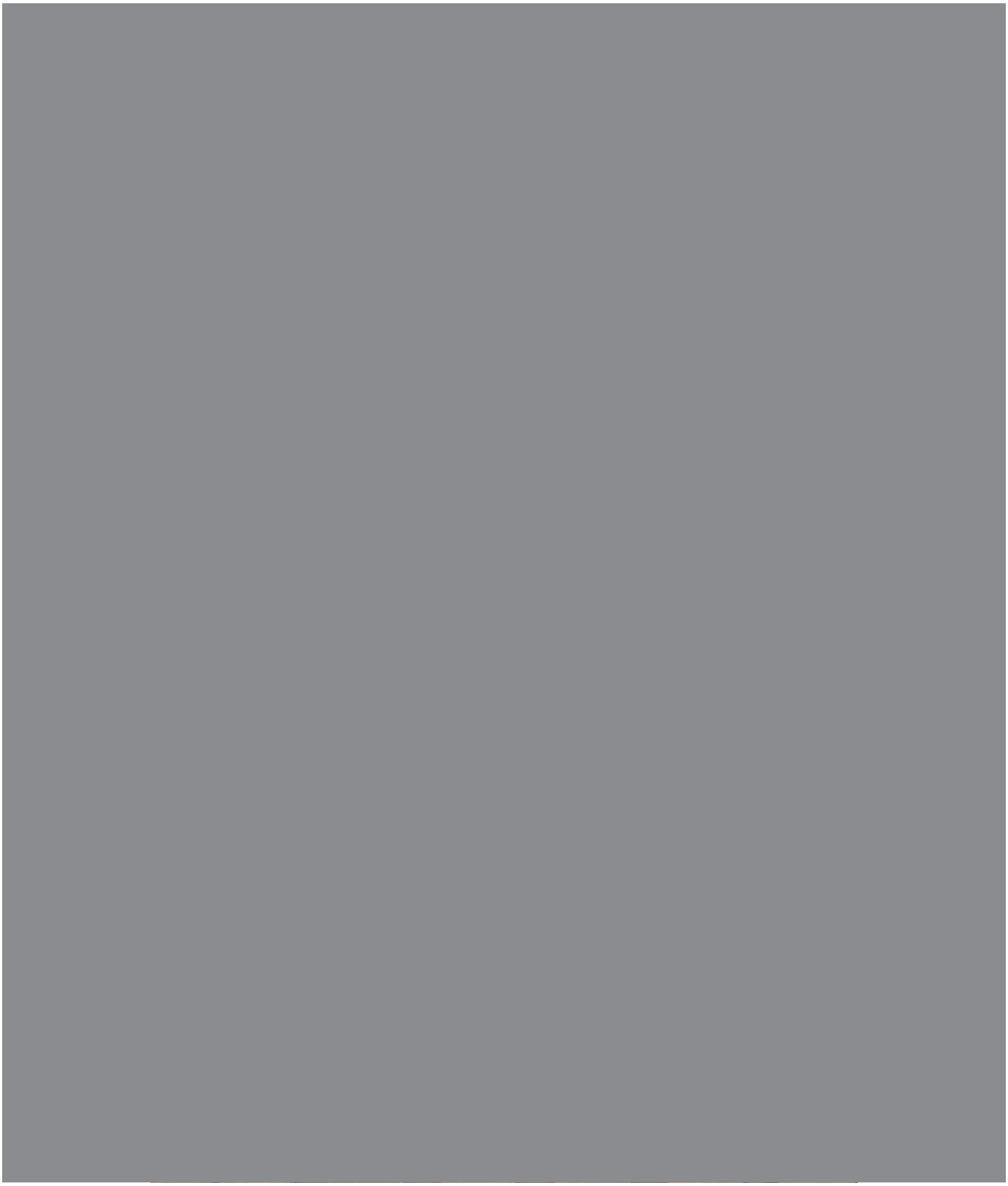

fig. 10 - Rwanda Cricket Stadium - Light Earth Designs

5.1.1.2 THERMAL / AIRFLOW

WHAT IT IS:

The Thermal/Airflow parameter has evolved from research measuring the effects of air quality, temperature, natural ventilation, and its resulting thermal regulation variability, on people's comfort, well-being, and productivity. Overall, it concerns the achievement of target zones of temperature, humidity, light breezes, and airflow.

OUTCOME:

An environment with the appropriate thermal condition and natural airflow cause a sensation of invigoration, comfort, liveliness, refreshment, concentration, alliesthesia (spatial pleasure), with influences in the increase in productivity and overall performance.

THEORIES AND STUDIES:

The notion that appropriate thermal condition and natural airflow is important has been around for Millenium. Evidence from the Paleolithic period already showed the hazardous caused by chemicals on individuals who were affected by smoke from indoor caves.[187]

Chafe et al. demonstrated that indoor pollution is one of the major causes of diseases in the developing world.[188] And one of the most effective ways to solve this problem is providing the option of natural ventilation in the built environments. Indoor Air Quality is a common term to measure the impact of the air inside built spaces and its impact on human health, comfort and productivity by analyzing all the chemicals, biological, radiological and physical pollutants of the space. Inadequate indoor air quality is related to many health issues such as asthma, headache, sinus congestion, cough, itchy, watery eyes, throat irritation, sneezing, dizziness, fatigue, annoyance, discomfort, a different type of inflammation and even cancer, depending on the pollutant exposure.[189] [190] Poor indoor air quality is also associated with absenteeism[191] and infection transmission[192], which are all associated with economic impacts.[193] [194] Natural

187 Hardy K, Radini A, Buckley S, Sarig R, Copeland L, et al. 2016. Dental calculus reveals potential respiratory irritants and ingestion of essential plant-based nutrients at Lower Palaeolithic Qesem Cave Israel. Quat. Int. 398:129–35

188 Chafe ZA, Brauer M, Klimont Z, Van Dingenen R, Mehta S, et al. (2014). Household cooking with solid fuels contributes to ambient PM2.5 air pollution and the burden of disease. Environ. Health Perspect. 122:1314

189 Cincinelli, Alessandra, and Tania Martellini. (2017). "Indoor Air Quality and Health." International Journal of Environmental Research and Public Health.

190 Mendell MJ, Lei-Gomez Q, Mirer AG, Seppänen O, Brunner G. (2008). Risk factors in heating, ventilating, and air-conditioning systems for occupant symptoms in US office buildings: the US EPA BASE study. Indoor Air 18:301–16

191 Milton DK, Glencross PM, Walters MD. (2000). Risk of sick leave associated with outdoor air supply rate, humidification, and occupant complaints. Indoor Air 10:212–21

192 Hoge CW, Reichler MR, Dominguez EA, Bremer JC, Mastro TD, et al. (1994). An epidemic of pneumococcal disease in an overcrowded, inadequately ventilated jail. N. Engl. J. Med. 331:643–48

193 Cedeño-Laurent, J.g., et al. "Building Evidence for Health: Green Buildings, Current Science, and Future Challenges." Annual Review of Public Health, vol. 39, no. 1, (2018), pp. 291–308.

194 Heerwagen, J.H. (2006). Investing In People: The Social Benefits of Sustainable Design. Rethinking Sustainable Construction. Sarasota, FL. September 19-22, 2006.

ventilation is crucial to help in Indoor Air Quality since it assists in the regulation of the air temperature, humidity, pollutant concentration, and airspeed. Besides, natural ventilation allows the fresh air to get in and out in a cross ventilation approach, giving the occupants a better refreshing feeling and significant improvements in cognitive performance.[195] Since the indoor accumulation of pollutants is usually higher than outside.[196] Many distinct studies demonstrated that buildings which increase natural ventilation have lower degrees of pollutants.[197] And also an improvement in the occurrence of health problems.[198]

Environmental thermal comfort is directly influenced by air temperature, airspeed, humidity, and radiant temperature.[199] You need to feel comfortable inside the built space. And Natural ventilation together with airflow can strongly contribute to thermal comfort, health, performance, and wellbeing. De Dear et al. address the importance of natural ventilation in buildings to achieve thermal comfort of the occupants by stating new standards to improve the design and operation of buildings: Satisfaction and inter-individual differences - personal implications; Climatic context - outdoor climate; The role of control - individual thermal control; Beyond thermal neutrality - minimizing discomfort; and Beyond thermal comfort - integrative comfort.[200] De Dear also evidenced the importance of an adaptive approach to thermal comfort and the growing dissatisfaction of the current concept that minimizes variability of temperature, humidity, and airflow.[201] Heerwagen's study discussed ventilation and temperature control and the effects of having the ability to control the environment according to personal needs and preferences.

A study on air pollutant damages, estimated an upwards of ten million dollars in costs due to the poor indoor air quality[202], since problems with indoor air quality are also associated with temporary leave.[203] On the other hand, the economical profits in savings and productivity gains exclusively in the US are around twenty-five to a hundred and fifty billion dollars per year.[204][205] Dr. Joseph Allen, director of the Healthy Buildings Program and faculty of Harvard Education and Research Center for Occupational Safety & Health, stated that most of the buildings do not have the proper ventilation and quality, because the standards are undervalued, instead of designing the building for superior cognitive performance.[206] He has done a

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195 MacNaughton P, Pegues J, Satish U, Santanam S, Spengler J, Allen J. (2015). Economic, environmental and health implications of enhanced ventilation in office buildings. Int. J. Environ. Res. Public Health 12:14709–22

196 Shendell DG, Winer AM, Weker R, Colome SD. (2004). Evidence of inadequate ventilation in portable classrooms: results of a pilot study in Los Angeles County. Indoor Air 14:154–58

197 Noris F, Adamkiewicz G, Delp WW, Hotchi T, Russell M, et al. (2013). Indoor environmental quality benefits of apartment energy retrofits. Build. Environ. 68:170–78

198 Maddalena R, Mendell MJ, Eliseeva K, Chan WR, Sullivan DP, et al. (2015). Effects of ventilation rate per person and per floor area on perceived air quality, sick building syndrome symptoms, and decision-making. Indoor Air 25:362–70

199 de Dear R. 2004. Thermal comfort in practice. Indoor Air 14:32–39

200 de Dear, R. & G. Brager (2002). Thermal comfort in naturally ventilated buildings. Energy and Buildings, 34, 549-561.

201 de Dear, R., G. Brager, & D. Cooper (1997). Developing an Adaptive Model of Thermal Comfort and Preference, Final Report. ASHRAE RP- 884 and Macquarie Research Ltd.

202 Pervin T, Gerdtham U-G, Lyttkens CH. (2008). Societal costs of air pollution-related health hazards: a review of methods and results. Cost Eff. Resour. Alloc. 6:19

203 Sundell J, Levin H, Nazaroff WW, Cain WS, Fisk WJ, et al. (2011). Ventilation rates and health: multidisciplinary review of the scientific literature. Indoor Air 21:191–204

204 Fisk WJ, Rosenfeld AH. (1997). Estimates of improved productivity and health from better indoor environments. Indoor Air 7:158–72

205 Fisk, W. J., Black, D., & Brunner, G. (2011). Benefits and costs of improved IEQ in U.S. offices. Indoor Air, 21(5), 357–367.

206 MacNaughton, P., Satish, U., Laurent, J. G. C., Flanigan, S., Vallarino, J., Coull, B., … Allen, J. G. (2017). The impact of working in a green-certified building on cognitive function and health. Building and Environment, 114, 178–186.

sequence of studies on the impacts of ventilation on office workers.[207] And one of the findings is very straight forward: when they double the ventilation capacity, workers also have double the cognitive performance in the applied tests. According to the study, there is an estimative of US$6,500 in raise of productivity for each worker a year. Moreover, to double the ventilation capacity value was from US$14 to US$40 per year by worker.[208] Allen stated that they want to impact the world with their approach to improve inhabitants health by changing the market with the proper scientific data approach: "I think we can do better, especially now that we know how important it is. When someone is too hot or too cold, studies show their performance slips. It means disentangling ventilation from the temperature setting in a building."[209] In a study about personal control, stress, and health, Steptoe et al. showed that occupants were less stressed when they had options and choices to control the thermal air and airflow in the ambient since they have the autonomy to regulate the ambience according to their desire.[210] Laurent et al. also demonstrated the significant impact of window operation autonomy in the behavior of the occupant for healthier air quality.[211]

Indoor pollutants are responsible for various health conditions and also as a potential transmitter of diseases. Some of the pollutants are bacterias, fungi, dust, mold, mildew, carbon dioxide, carbon monoxide, endotoxins, formaldehyde, nitrogen oxide, phthalates, volatile organic compounds, among others,[212] which cause allergy, asthma and other respiratory and skin diseases.

With the desire to acquire good LEED ratings, designers have been focusing on increasing natural ventilation, as to minimize energy costs, which consequently makes buildings more comfortable for the occupants. However, this issue needs to be emphasized further, with additional research to reinforce building owners, decision-makers and investors of the necessities and advantages to apply design strategies to optimize buildings and have a positive influence on its occupants' health and well-being.

PARAMETER APPLICATION:

Forms of applying the thermal/airflow parameter ranges from the simple orientation of the building as to prevent or allow direct sunlight to affect buildings' internal temperatures, the use of operable windows, cross-ventilation systems, window shades, opened spaces, to complex technologies and mechanisms to support building occupants' control of temperature, humidity and airflow.

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207 Allen, J. G., MacNaughton, P., Satish, U., Santanam, S., Vallarino, J., & Spengler, J. D. (2015). Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments. Environmental Health Perspectives, 124(6).

208 MacNaughton, P., Pegues, J., Satish, U., Santanam, S., Spengler, J., & Allen, J. (2015). Economic, Environmental and Health Implications of Enhanced Ventilation in Office Buildings. International Journal of Environmental Research and Public Health, 12(11), 14709–14722.

209 Walsh, Colleen. "Your Building Might Be Making You Sick. Joe Allen Can Help." Harvard Gazette, (26 Nov. 2018), news.harvard.edu/gazette/story/2018/02/your-building-might-be-making-you-sick-joe-allen-can-help/.

210 Steptoe, A., and A. Appels, eds. (1989). Stress, personal control, and health. Chichester, England: John Wiley & Sons Inc.

211 Cedeno Laurent, J. G., Samuelson, H. W., & Chen, Y. (2017). The impact of a window opening and other occupant behavior on simulated energy performance in residence halls. Building Simulation, 10(6), 963–976.

212 Dales, R., Liu, L., Wheeler, A. J., & Gilbert, N. L. (2008). Quality of indoor residential air and health. Canadian Medical Association Journal, 179(2), 147–152.

table 4 - Scientific Studies related to Thermal / Airflow Parameter

effect	relevant studies	findings
•Health •Mental Health •Wellbeing	Cincinelli, Alessandra, and Tania Martellini. (2017). "Indoor Air Quality and Health." International Journal of Environmental Research and Public Health.	Indoor Air Quality is a common term to measure the impact of the air inside built spaces which address the impact on human health, comfort and productivity
	de Dear R. 2004. Thermal comfort in practice. Indoor Air 14:32–39	environmental thermal comfort is directly influenced by air temperature, air speed, humidity and radiant temperature.
	de Dear, R. & G. Brager (2002). Thermal comfort in naturally ventilated buildings. Energy and Buildings, 34, 549-561.	natural airflow causes satisfaction, wellbeing and comfort.
	de Dear, R., G. Brager, & D. Cooper (1997). Developing an Adaptive Model of Thermal Comfort and Preference, Final Report. ASHRAE RP- 884 and Macquarie Research Ltd.	adaptive approach to thermal comfort and the growing dissatisfaction of current concept that minimizing temperature, humidity and airflow variability
	Fisk, W. J., Black, D., & Brunner, G. (2011). Benefits and costs of improved IEQ in U.S. offices. Indoor Air, 21(5), 357–367.	air quality improvement lead to improved general health and wellbeing
	Heerwagen, J.H. (2006). Investing In People: The Social Benefits of Sustainable Design. Rethinking Sustainable Construction. Sarasota, FL. September 19-22, 2006.	personal control of airflow and temperature lead to wellbeing and comfort.
•Restorative •Stress Reduction	Hartig, T., G.W. Evans, L.D. Jamner, D.S. Davis, & T. Gärling (2003). Tracking Restoration in Natural and Urban Field Settings. *Journal of Environmental Psychology, 23,* 109–123.	Natural ventilation and motion affect attention restoration
	Hartig, T., M. Mang, & G.W. Evans (1991). Restorative Effects of Natural Environment Experience. *Environment and Behavior, 23*, 3–26.	Natural ventilation and motion affect attention restoration
	Kaplan, R. & S. Kaplan (1989). The Experience of Nature: A Psychological Perspective. Cambridge: Cambridge University Press.	Natural ventilation improves attention restoration
	Steptoe, A., and A. Appels, eds.(1989). Stress, personal control, and health. Chichester, England: John Wiley & Sons Inc.	occupants were less stressful when they had options and choices to control the thermal air and airflow in the ambient.
•Cognition Improvement	Allen, J. G., MacNaughton, P., Satish, U., Santanam, S., Vallarino, J., & Spengler, J. D. (2015). Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments. Environmental Health Perspectives, 124(6).	natural ventilation improves workplace comfort and productivity.
	Cedeno Laurent, J. G., Samuelson, H. W., & Chen, Y. (2017). The impact of window opening and other occupant behavior on simulated energy performance in residence halls. Building Simulation, 10(6), 963–976.	significant impact of window operation type in the behavior of the occupant
	Fisk WJ, Rosenfeld AH. (1997). Estimates of improved productivity and health from better indoor environments. Indoor Air 7:158–72	air quality improvement lead to improved productivity
	MacNaughton P, Pegues J, Satish U, Santanam S, Spengler J, Allen J. (2015). Economic, environmental and health implications of enhanced ventilation in office buildings. Int. J. Environ. Res. Public Health 12:14709–22	fresh air provide a refresh feeling which significantly improve cognitive performance and productivity.
	MacNaughton, P., Satish, U., Laurent, J. G. C., Flanigan, S., Vallarino, J., Coull, B., … Allen, J. G. (2017). The impact of working in a green certified building on cognitive function and health. Building and Environment, 114, 178–186.	impact of green certified building on cognitive performance.
	Tham, K.W. & H.C. Willem (2005). Temperature and Ventilation Effects on Performance and Neurobehavioral- Related Symptoms of Tropically Acclimatized Call Center Operators Near Thermal Neutrality. *ASHRAE Transactions,* 687-698.	natural ventilation results in worker comfort, well-being and productivity.
	Walsh, Colleen. "Your Building Might Be Making You Sick. Joe Allen Can Help." Harvard Gazette, (26 Nov. 2018).	when someone is too hot or too cold, studies show their performance slips.
	Wigö, H. (2005). Technique and Human Perception of Intermittent Air Velocity Variation. KTH Research School, Centre for Built Environment.	natural ventilation results in worker comfort, well-being and productivity.
•Healing •Immune Improvement	Cedeño-Laurent, J.g., et al. "Building Evidence for Health: Green Buildings, Current Science, and Future Challenges." Annual Review of Public Health, vol. 39, no. 1, (2018), pp. 291–308.	poor indorr air quality is associated to economic impacts
	Chafe ZA, Brauer M, Klimont Z, Van Dingenen R, Mehta S, et al. (2014). Household cooking with solid fuels contributes to ambient PM2.5 air pollution and the burden of disease. *Environ. Health Perspect.* 122:1314	providing the option of natural ventilation in the built space to prevent diseases
	Dales, R., Liu, L., Wheeler, A. J., & Gilbert, N. L. (2008). Quality of indoor residential air and health. Canadian Medical Association Journal, 179(2), 147–152.	Indoor pollutants are responsible for plentiful of health conditions and also as a potential transmitter of diseases.
	Hoge CW, Reichler MR, Dominguez EA, Bremer JC, Mastro TD, et al. (1994). An epidemic of pneumococcal disease in an overcrowded, inadequately ventilated jail. N. Engl. J. Med. 331:643–48	poor indoor air quality is linked to infection transmission

Maddalena R, Mendell MJ, Eliseeva K, Chan WR, Sullivan DP, et al. (2015). Effects of ventilation rate per person and per floor area on perceived air quality, sick building syndrome symptoms, and decision-making. Indoor Air 25:362–70	natural ventilation improvement on occurrence of health problems.
Mendell MJ, Lei-Gomez Q, Mirer AG, Seppänen O, Brunner G. (2008). Risk factors in heating, ventilating, and air-conditioning systems for occupant symptoms in US office buildings: the US EPA BASE study. Indoor Air 18:301–16	Inadequate indoor air quality are related to many health issues such as asthma, headache, sinus congestion, cough, itchy, watery eyes, throat irritation, sneezing, dizziness, fatigue, annoyance, discomfort, different type of inflammation and even cancer, depending the pollutant exposure
Milton DK, Glencross PM, Walters MD. (2000). Risk of sick leave associated with outdoor air supply rate, humidification, and occupant complaints. Indoor Air 10:212–21	Poor indoor air quality is associated to absenteeism
Noris F, Adamkiewicz G, Delp WW, Hotchi T, Russell M, et al. (2013). Indoor environmental quality benefits of apartment energy retrofits. Build. Environ. 68:170–78	buildings which increase natural ventilation have lower degrees of pollutants.
Pervin T, Gerdtham U-G, Lyttkens CH. (2008). Societal costs of air pollution–related health hazards: a review of methods and results. Cost Eff. Resour. Alloc. 6:19	poor indorr air quality is associated to economic impacts
Shendell DG, Winer AM, Weker R, Colome SD. (2004). Evidence of inadequate ventilation in portable classrooms: results of a pilot study in Los Angeles County. Indoor Air 14:154–58	indoor accumulation of pollutants are usually higher than outside.
Sundell J, Levin H, Nazaroff WW, Cain WS, Fisk WJ, et al. (2011). Ventilation rates and health: multidisciplinary review of the scientific literature. Indoor Air 21:191–204	Poor indoor air quality is associated to absenteeism

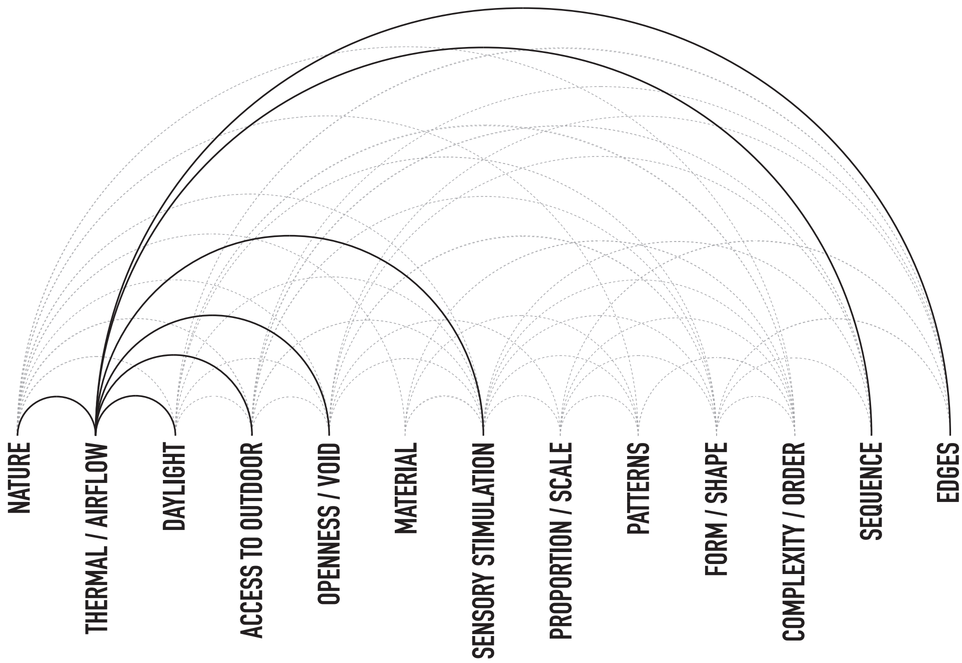

fig. 11 - Diagram of Parameters Interrelations

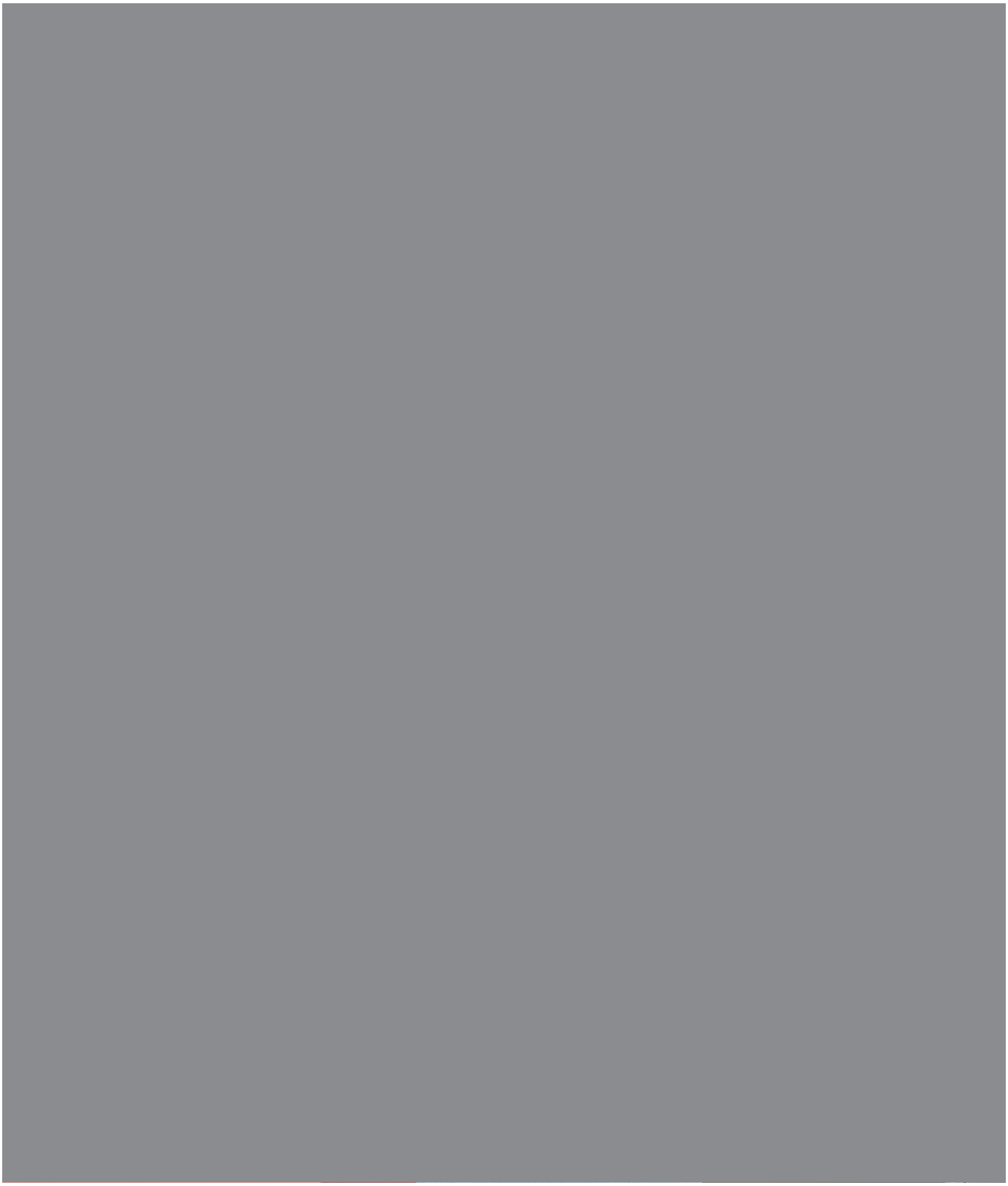

fig. 12 - Airbnb Office - 999 Brannan - Airbnb Environments

5.1.1.3 DAYLIGHT

WHAT IT IS:

Most people consider a space with a window enough to be daylit. However, in order for windows to light up an environment, they have to be located in an appropriate location and be of appropriate size as to be able to harness daytime illumination. The daylight parameter is based on that, referring to the use of natural light in built space. As the human perception of the space depends on the incidence of light, daylight, however, helps us to understand space not only in visual terms but also thermally. It also assists us to be connected to phenomena occurring outdoor/in nature by approximating us to natural conditions of radiance.

OUTCOME:

The importance of natural light in the environment is its vital physiological contribution to our sleep patterns and mood. Research also shows that productivity is higher in workplaces which take advantage of daylight to light indoor spaces, sales are higher in daylit stores, and children perform better in daylit classrooms with views.

THEORIES AND STUDIES:

Historically, one of the most common problems in buildings is related to lighting. Nonetheless, as architects and engineers explored different design approaches and techniques to incorporate more daylight into building design, and as construction technologies have evolved, this issue has practically been resolved.

The benefits of daylighting on physical and psychological health, as well as over people's efficiency and productivity on performing tasks have been a subject of various research. Nicklas et al performed an important analysis about the relation between classrooms with proper daylight illumination and classrooms with artificial lighting. They noted that students in classrooms that were daylit had better performance and a significantly better mood when compared with students in classrooms with artificial lighting. Those students were also healthier in general and attended school more days per year. And due to the additional vitamin D, they also had 9 times less dental problems and were 2.1 cm higher in height than students with average lighting. Likewise, school libraries with superior lighting have significantly less noise due to students being more concentrated.[213] Reports from Heschong Mahone Group, which is a specialized consultant in the field energy efficiency in buildings, stated that, besides children performing better in classrooms with daylight, sales are higher in the stores that are daylit, employers were more pleased and more motivated in daylit workplaces, besides the savings with energy.[214] [215] However direct light and glare

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213 Nicklas, M.H. & G.B. Bailey (1996). Student Performance in Daylit Schools. Innovative Design.
214 Heschong Mahone Group (1999). Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance. Pacific Gas and Electric Company: California Board for Energy Efficiency Third Party Program.
215 Heschong Mahone Group (2003). Windows and Classrooms: A Study of Student Performance and the Indoor Environment. Pacific Gas and Electric Company: California Board for Energy Efficiency Third Party Program.

condition were reported to disturb the occupants and made it harder to focus and concentrate. [216]

As stated, the effects to the exposure to light increase attentiveness and performance. Light is an essential regulator of alertness and cognition by assisting the control of the circadian system. The circadian system controls the circadian rhythm, which helps to understand the duration of the day and send signals to parts of the body has a direct effect from the exposure to daylight.[217] Problems to the circadian system are linked to some disease disorder like cancer.[218] Light also regulates neuroendocrine function and neurobehavioral activity, through inherent photosensitive retinal ganglion cells. However, some blind individuals without any conscious eyesight disclosed to be able to sense the presence of light, reaffirming that despite the lack of sight, activity in cognitive brain areas was noted.[219]

Eating disorders, depression, variation on circadian rhythm, Alzheimer's disease and sensory stimulation are also linked to lack of natural light.[220] However, research on patients with Alzheimer's disease indicated that higher interior daylight exposure decreased their agitation levels while compared to environments with less light.[221] And psychiatric patients with serious depression stayed shorter periods in hospitals with rooms which had higher amounts of daylight. Hospitals staff also reported better health, higher satisfaction and less work-related stress from spaces with daylight compared to environments without it.[222]

Besides the cognitive and health benefits, research shows that rent is 20% lower in commercial rooms without windows.[223] This demonstrates that people has the common sense that windowless environments faulty. Buildings have to support its occupants' health and wellbeing with proper daylight diffusion, by avoiding glare and excessive solar gain, with the means of tools which support the design process and predict the effects of daylight in the space.[224]

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216 Elzeyadi, I.M.K. (2012). Quantifying the Impacts of Green Schools on People and Planet. Research presented at the USGBC Greenbuild Conference & Expo, San Francisco, November 2012, 48-60.
217 Figueiro, M.G., J.A. Brons, B. Plitnick, B. Donlan, R.P. Leslie, & M.S. Rea (2011). Measuring circadian light and its impact on adolescents. Light Res Technol. 43 (2): 201-215.
218 Beckett, M. & L.C. Roden (2009). Mechanisms by which circadian rhythm disruption may lead to cancer. South African Journal of Science 105, November/December 2009.
219 Vandewalle, G., Collignon, O., Hull, J. T., Daneault, V., Albouy, G., Lepore, F., … Carrier, J. (2013). Blue Light Stimulates Cognitive Brain Activity in Visually Blind Individuals. Journal of Cognitive Neuroscience, 25(12), 2072–2085.
220 Joseph, A. (2006). The Impact of Light on Outcomes in Healthcare Settings. The Center for Health Design, 2.
221 Sloane, P. D., Mitchell, C. M., Preisser, J. S., Phillips, C., Commander, C., & Burker, E. (1998). Environmental Correlates of Resident Agitation in Alzheimer's Disease Special Care Units. Journal of the American Geriatrics Society, 46(7), 862–869.
222 Beauchemin KM, Hays P. 1998. Dying in the dark: sunshine, gender, and outcomes in myocardial infarction. J. R. Soc. Med. 91:352–54
223 Adamsson, Mathias, Thorbjörn Laike, and Takeshi Morita. "Seasonal Variation in Bright Daylight Exposure, Mood and Behavior among a Group of Office Workers in Sweden." Journal of Circadian Rhythms16, no. 1 (2018).
224 Cedeño-Laurent, J., Williams, A., Macnaughton, P., Cao, X., Eitland, E., Spengler, J., & Allen, J. (2018). Building Evidence for Health: Green Buildings, Current Science, and Future Challenges. Annual Review of Public Health, 39(1), 291-308.

PARAMETER APPLICATION:
Some of the methods to integrate daylight with design are: consider the incidence of daylight from more than one side of the space; consider building layout and configuration to received good amount of daylight throughout the day; carefully locate the building to avoid excessive solar heat and direct sunlight and glare; locate rooms where occupants stay the longest in to be where there is most incidence of daylight; consider that daylight coming in from openings at the highest parts of the wall, as well as from the top, penetrate further in the space.

The increasing body of knowledge about the effects of daylight design on improving general occupant satisfaction, mood, productivity, and overall physical and psychological well-being, urges designers to find the right balance between daylight and unwanted direct sun exposure. The most commonly used design strategies and technologies are louvers, dynamic shading systems, and facade systems.

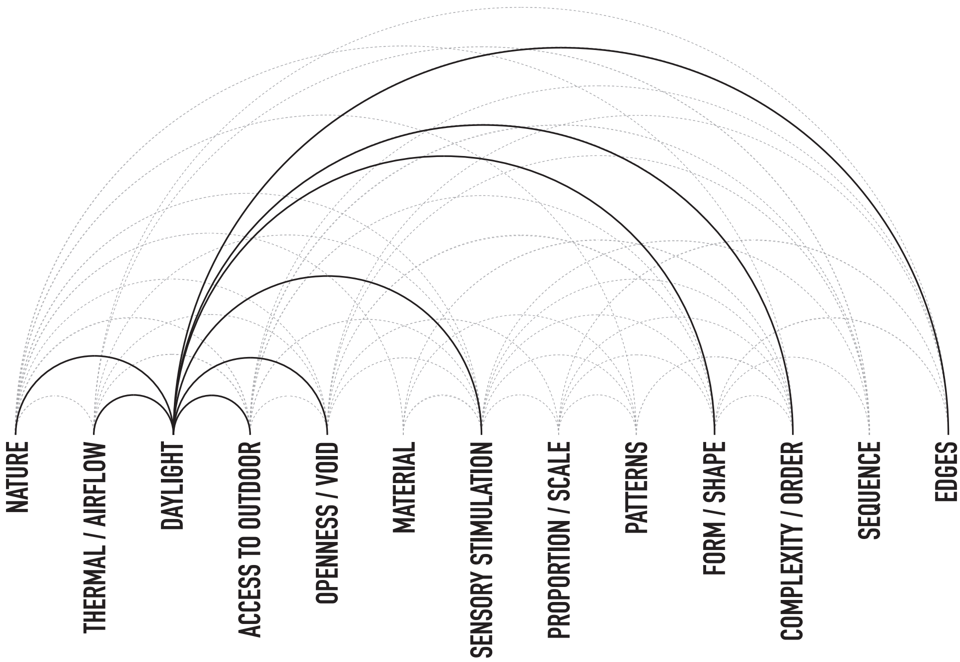

fig. 13 - Diagram of Parameters Interrelations

table 5 - Scientific Studies related to Daylight Parameter

effect	relevant studies	findings
•Health •Mental Health •Wellbeing	Adamsson, Mathias, Thorbjörn Laike, and Takeshi Morita. "Seasonal Variation in Bright Daylight Exposure, Mood and Behavior among a Group of Office Workers in Sweden." Journal of Circadian Rhythms16, no. 1 (2018).	light radiation and the lit environment have a major influence on human physiology, psychology and health-related quality of life in addition to work performance and work satisfaction
	Cedeño-Laurent, J., Williams, A., Macnaughton, P., Cao, X., Eitland, E., Spengler, J., & Allen, J. (2018). Building Evidence for Health: Green Buildings, Current Science, and Future Challenges. *Annual Review of Public Health, 39*(1), 291-308.	daylight difusion without glare and excessive heat support inhabitants health and wellbeing
	Figueiro, M.G., J.A. Brons, B. Plitnick, B. Donlan, R.P. Leslie, & M.S. Rea (2011). Measuring circadian light and its impact on adolescents. Light Res Technol. 43 (2): 201-215.	Circadian rhythm, which helps to understand the duration of the day and send signals to parts of the body has a direct effect from the exposure to daylight.
	Heschong Mahone Group (1999). Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance. Pacific Gas and Electric Company: California Board for Energy Efficiency Third Party Program.	Improvement in health, mood, arousal levels, and behavior.
	Kim, S.Y. & J.J. Kim (2007). effect of fluctuating illuminance on visual sensation in a small office. *Indoor and Built Environment 16* (4): 331–343.	Daylight influences task performance and visual comfort.
	Leslie, R. P. (2003). Capturing the daylight dividend in buildings: why and how? Building and Environment, 38(2), 381–385.	Daylighting supports human health and activities
	Nicklas, M.H. & G.B. Bailey (1996). Analysis of the Performance of Students in Daylit Schools. Innovative Design.	a. the students in full-spectrum light were healthier and attended school 3.2 to 3.8 days more per year; b. libraries with superior light resulted in significantly lower noise levels; c. full-spectrum lighting induced more positive moods in students; and d. because of the additional vitamin D received by the students in full-spectrum light, they had 9 times less dental decay and grew in height an average of 2.1 cm more (over the two year period)
	Veenstra, L., & Koole, S. L. (2018). Disarming darkness: Effects of ambient lighting on approach motivation and state anger among people with varying trait anger. Journal of Environmental Psychology.	daylit produces motivation and enhance emotion.
•Restorative •Stress Reduction	Beauchemin, K. M. & Hays, P. (1996). Sunny hospital rooms expedite recovery from severe and refractory depressions. *Journal of Affective Disorders, 40*(1), 49–51.	daylight therapy is an effective treatment for seasonal affective disorder, an uncommon condition marked by mild winter depression.
	Joseph, A. (2006). The impact of light on outcomes in healthcare settings. Concord, CA: The Center for Health Design.	strong evidence that light is critical to human functioning and can be extremely beneficial to patients as well as staff in healthcare settings
	Leather, P., M. Pyrgas, D. Beale & C. Lawrence (1998). Windows in the workplace: sunlight, view, and occupational stress. Environment and Behavior, 30 (6): 739+. Expanded Academic ASAP. Web. 3 May 2010.	The results showed a significant direct effect for sunlight penetration on job satisfaction, intention to quit, and general well-being
	Sloane, P. D., Mitchell, C. M., Preisser, J. S., Phillips, C., Commander, C., & Burker, E. (1998). Environmental Correlates of Resident Agitation in Alzheimer's Disease Special Care Units. Journal of the American Geriatrics Society, 46(7), 862–869.	patients with alzheimer indicated that higher interior daylight exposure decreased the agitation levels
•Cognition Improvement	Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning.	daylight affect improvement of the pupils' academic achievement
	Browning, W.D. & J.J. Romm (1994). Greening the Building and the Bottom Line. Rocky Mountain Institute.	productivity were higher with an appropriate daylight
	C. Kenneth Tanner, (2009) "Effects of school design on student outcomes", Journal of Educational Administration, Vol. 47 Issue: 3, pp.381-399.	The study's findings regarding natural light, and classrooms have implications in the students performance.
	Elzeyadi, I.M.K. (2012). Quantifying the Impacts of Green Schools on People and Planet. Research presented at the USGBC Greenbuild Conference & Expo, San Francisco, November 2012, 48-60.	direct light and glare condition were reported to disturb the occupants and making harder to focus and concentrate.
	Gaggioni, G., Maquet, P., Schmidt, C., Dijk, D.-J., & Vandewalle, G. (2014). Neuroimaging, cognition, light and circadian rhythms. Frontiers in Systems Neuroscience, 8.	These data provide new insights into the contribution of daylit with the sleep-wake cycle, circadian rhythmicity and brain functioning.
	Heschong Mahone Group (2003). Windows and Classrooms: A Study of Student Performance and the Indoor Environment. Pacific Gas and Electric Company: California Board for Energy Efficiency Third Party Program	Skylights are related to student performance stands out sharply and also to be positively and significantly correlated to higher sales in retail stores.
	Kandel, e.R., J.H. Schwartz, T.m. Jessell, S.A. Siegelbaum, & A.J. Hudspeth (2013). *Principles of Neural Science,* Fifth edition. new York: mcGraw Hill.	impacts of lighting on the circadian system functioning

	Nicklas, M.H. & G.B. Bailey (1996). Student Performance in Daylit Schools. Innovative Design.	Results show that students attending daylit schools outperformed students attending artificially lighted schools by 5 to 14 percent.
	Vandewalle, G., Collignon, O., Hull, J. T., Daneault, V., Albouy, G., Lepore, F., … Carrier, J. (2013). Blue Light Stimulates Cognitive Brain Activity in Visually Blind Individuals. Journal of Cognitive Neuroscience, 25(12), 2072–2085.	light stimulates higher cognitive brain activity, independently of vision, and engages supplemental brain areas to perform an ongoing cognitive process.
•Healing **•Immune Improvement**	Beauchemin, K. M. & Hays, P. (1996). Sunny hospital rooms expedite recovery from severe and refractory depressions. *Journal of Affective Disorders, 40*(1), 49–51.	daylight therapy is an effective treatment for seasonal affective disorder, an uncommon condition marked by mild winter depression.
	Beauchemin, K. M., & Hays, P. (1998). Dying in the dark: sunshine, gender and outcomes in myocardial infarction. *Journal of the Royal Society of Medicine*, *91*(7), 352–354.	illumination may be relevant to outcome in myocardial infarction
	Beckett, M. & L.C. Roden (2009). Mechanisms by which circadian rhythm disruption may lead to cancer. South African Journal of Science 105, November/December 2009.	problems to circadian system are also linked to some disease disorder as cancer.
	Mead, M.N. (2008). Benefits of Sunlight: A Bright Spot for Human Health. *Environmental Health Perspectives, 116* (4), 161-167.	The sun may be best known for boosting production of vitamin D, but there are many other UVR-mediated effects which leads to immune improvement.

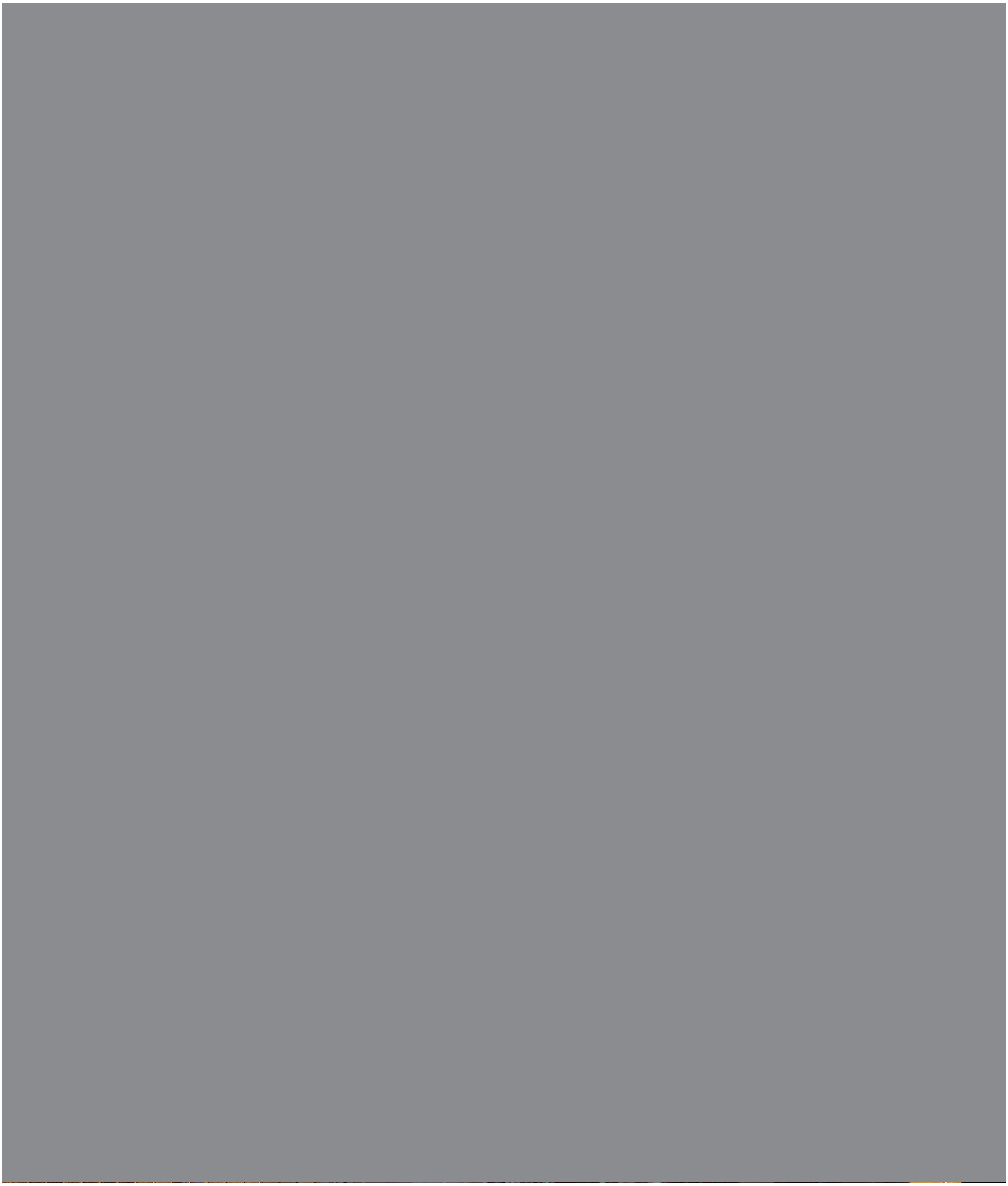

fig. 14 - Shinsegae International - Olson Kundig

5.1.1.4 ACCESS TO OUTDOOR

WHAT IT IS:

Access to outdoor parameter is very simply a means to the outdoors within the built space, as in a terrace, balcony, rooftop, open yard, and inner garden.

OUTCOME:

Studies have proved that exposure to outdoors is important for human's mental health and crucial to child development. There is a link to attention deficit hyperactivity disorder in children with no access to outdoor. Overall worker productivity and well-being are improved in offices with outdoor seating spaces.

THEORIES AND STUDIES:

Studies demonstrate that we get vitalized from being outdoors, even if it is within a built space.[225] The experience of being directly exposed in the open air increases cognitive activity, impacts in attention restoration, restores calmness and energy levels, improves productivity and overall wellbeing. Hartig et al. tracked the stress recovery and attention restoration in outside environments. They noticed a rapid decrease in diastolic blood pressure, which means a higher stress reduction, improvement on attention performance, drop in anger and a gain in positive wellbeing.[226]

Pearson and Craig also demonstrated how impactful it is to be outdoor to our mental health. To be in green spaces and natural surroundings is ideal. However, their research showed that, after being enclosed in a space for some hours, it is refreshing and restorative to be outdoors even if it is not in nature. Just giving the building's occupants a means to be outdoors so that they can feel fresh airflow, natural luminescence, and a general feeling of not being enclosed is enough to raise their wellbeing.[227]

Lee et al. produced important findings on the role of micro-breaks to restore attention. Based on neuroscience techniques, they showed that breaks as quick as 40 second in green roofs were enough to restore attention and cognitive function of workers.[228] In another study, they engaged in the link between micro-breaks, nature, mood and performance, and its contribution to the work environment. Besides the benefits from micro-break, the results highlighted the importance of being able to access the outdoors in workplaces, as well as the importance of nature within the

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225 Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., & Gagné, M. (2010). Vitalizing effects of being outdoors and in nature. Journal of Environmental Psychology, 30(2), 159–168.
226 Hartig, T., G.W. Evans, L.D. Jamner, D.S. Davis, & T. Gärling (2003). Tracking Restoration in Natural and Urban Field Settings. Journal of Environmental Psychology, 23, 109–123.
227 Pearson, D. G., & Craig, T. (2014). The great outdoors? Exploring the mental health benefits of natural environments. Frontiers in Psychology.
228 Lee, K. E., Williams, K. J. H., Sargent, L. D., Williams, N. S. G., & Johnson, K. A. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. Journal of Environmental Psychology, 42, 182–189.

cityscape.[229] In addition, Carter and Fowler also stress the importance of green roofs as an infrastructural approach to environmental policies, since built environments barely supply opportunities of restorative spaces to occupants.[230]

By comparing the difference in taking a break indoors versus outdoor spaces, a research on the health benefits of gardens in hospitals reaffirmed the importance of taking daily work breaks outdoors to avoid burnouts and stress-related outcomes.[231] In the same manner, significant improvement in restorative mental state and overall satisfaction of nurses was noticed from outdoor breaks.[232] Studies also demonstrated that spending time outdoors is an important factor for children's development and physical/ mental health, and also linked the absence of being outside to attention deficit hyperactivity disorder.[233]

PARAMETER APPLICATION:

Urban rooftops can be very effective at providing access to outdoors, especially if dispensed with greenery. Other design strategies that explore the access to outdoors parameter are balconies, varandas, terraces, and courtyards.

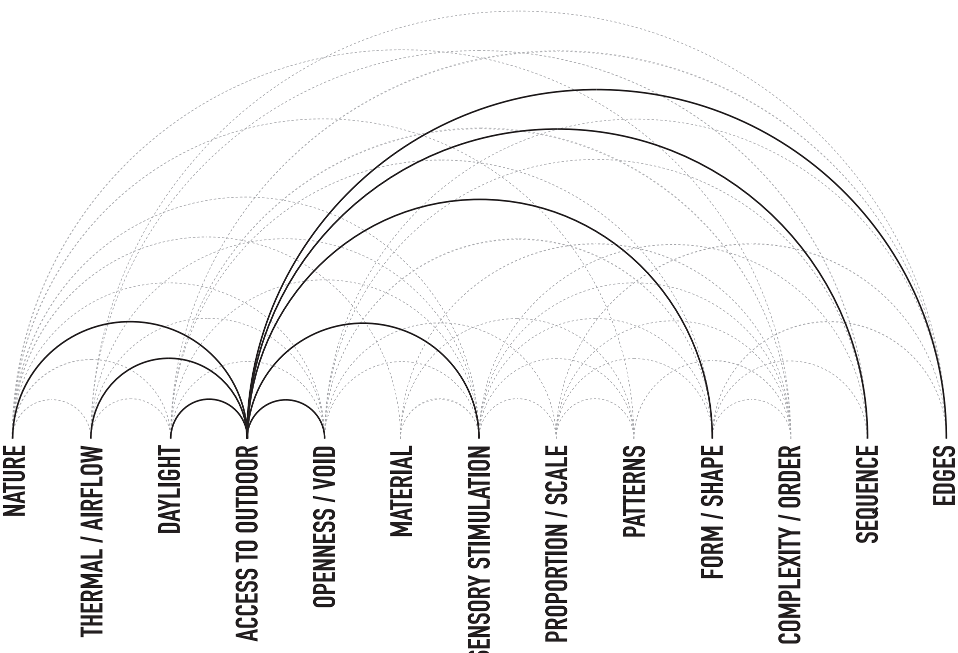

fig. 15 - Diagram of Parameters Interrelations

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229 Lee, K. E., Sargent, L. D., Williams, N. S. G., & Williams, K. J. H. (2018). Linking green micro-breaks with mood and performance: Mediating roles of coherence and effort. Journal of Environmental Psychology.
230 Carter, T., & Fowler, L. (2008). Establishing green roof infrastructure through environmental policy instruments. Environmental Management, 42(1), 151e164.
231 Ulrich. R.S. (2002) Health Benefits of Gardens in Hospitals. Plants for People International Exhibition Florida, Florida, USA.
232 Board, R. (2018). Clinical Pearls. American Journal of Critical Care, 27(6), 444–444.
233 Wilson, Edward O.(2006). The Creation: An Appeal to Save Life on Earth. New York City: W. W. Norton & Company.

table 6 - Scientific Studies related to Access to Outdoor Parameter

effect	relevant studies	findings
•Health •Mental Health •Wellbeing	Pearson, D. G., & Craig, T. (2014). The great outdoors? Exploring the mental health benefits of natural environments. Frontiers in Psychology.	Not all locations have the opportunity to be near a park, a watery place or a forest, that's why the importance to give the occupants chances to be in outdoor that they can feel fresh airflow, natural luminescence, and general feeling of not being enclosure.
	Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environmental Research, 166, 628–637.	outdoor exposure is associated with numerous health benefits in intervention and observational studies.
•Restorative •Stress Reduction	Beauchemin, K. M. & Hays, P. (1996). Sunny hospital rooms expedite recovery from severe and refractory depressions. *Journal of Affective Disorders, 40*(1), 49–51.	outdoor exposure from inside the building leads to recovery
	Board, R. (2018). Clinical Pearls. American Journal of Critical Care, 27(6), 444–444.	significant improvement in restorative mental state and overall satisfaction were noticed in outside breaks.
	Carter, T., & Fowler, L. (2008). Establishing green roof infrastructure through environmental policy instruments. Environmental Management, 42(1), 151e164.	green roof as an infrastructure approach to restoration since built environments barely supply opportunities of restorative spaces to occupants.
	Cordoza, M., Ulrich, R. S., Manulik, B. J., Gardiner, S. K., Fitzpatrick, P. S., Hazen, T. M., … Perkins, R. S. (2018). Impact of Nurses Taking Daily Work Breaks in a Hospital Garden on Burnout. American Journal of Critical Care, 27(6), 508–512.	Taking daily work breaks in an outdoor garden may be beneficial in mitigating burnout for nurses working in hospital environments.
	Hartig, T., G.W. Evans, L.D. Jamner, D.S. Davis, & T. Gärling (2003). Tracking Restoration in Natural and Urban Field Settings. Journal of Environmental Psychology, 23, 109–123.	fast stress recovery, positive wellbeing and attention restoration in outside environments.
	Lee, K. E., Sargent, L. D., Williams, N. S. G., & Williams, K. J. H. (2018). Linking green micro-breaks with mood and performance: Mediating roles of coherence and effort. Journal of Environmental Psychology.	outdoor micro-breaks in workplace drastically improves mood and performance
	Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., & Gagné, M. (2010). Vitalizing effects of being outdoors and in nature. Journal of Environmental Psychology, 30(2), 159–168.	Vitalizing effects of being outdoors.
	Ulrich, R.S. and R.F. Simons. (1986). Recovery from stress during exposure to everyday outdoor environments. In: J. Wineman, R. Barnes, and C. Zimring (eds.). The costs of not knowing: Proceedings of the Seventeenth Annual Conference of the Environmental Design Research Association. Environmental Design Research Association, Washington, DC	recovery from stress during exposure to everyday outdoor environments
	Ulrich. R.S. (2002) Health Benefits of Gardens in Hospitals. Plants for People International Exhibition Florida, Florida, USA.	daily work breaks in a gardens to avoid burnouts and stress related outcomes.
	van den Berg, A. E., Jorgensen, A., & Wilson, E. R. (2014). Evaluating restoration in urban green spaces: Does setting type make a difference? Landscape and Urban Planning, 127, 173e181.	outdoor micro-breaks improves mood and performance
•Cognition Improvement	Lee, K. E., Williams, K. J. H., Sargent, L. D., Williams, N. S. G., & Johnson, K. A. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. Journal of Environmental Psychology, 42, 182–189.	green external area for as short as 40 seconds already increase the concentration level.
	Suzuki, T., & Murase, S. (2010). Influence of Outdoor Activity and Indoor Activity on Cognition Decline: Use of an Infrared Sensor to Measure Activity. Telemedicine and e-Health, 16(6), 686–690.	deprive to go in short outside moment tend to decrease cognitive function
	Wilson, Edward O.(2006). The Creation: An Appeal to Save Life on Earth. New York City: W.W. Norton & Company.	spending time outdoor is an important factor to child general health, mental health and development.

5.1.2 GROUP 2 – COGNITIVE PERFORMANCE

In the cognitive performance group, three parameters were recognized: Openness/Void, Material, and sensory stimulation. Openness/Void parameter regards the experience of unobstructed areas of space. The Material parameter implies the sensorial experience promoted by materiality. Sensory Stimulation parameter concerns momentary experiences induced by a wide range of sensorial aspects.

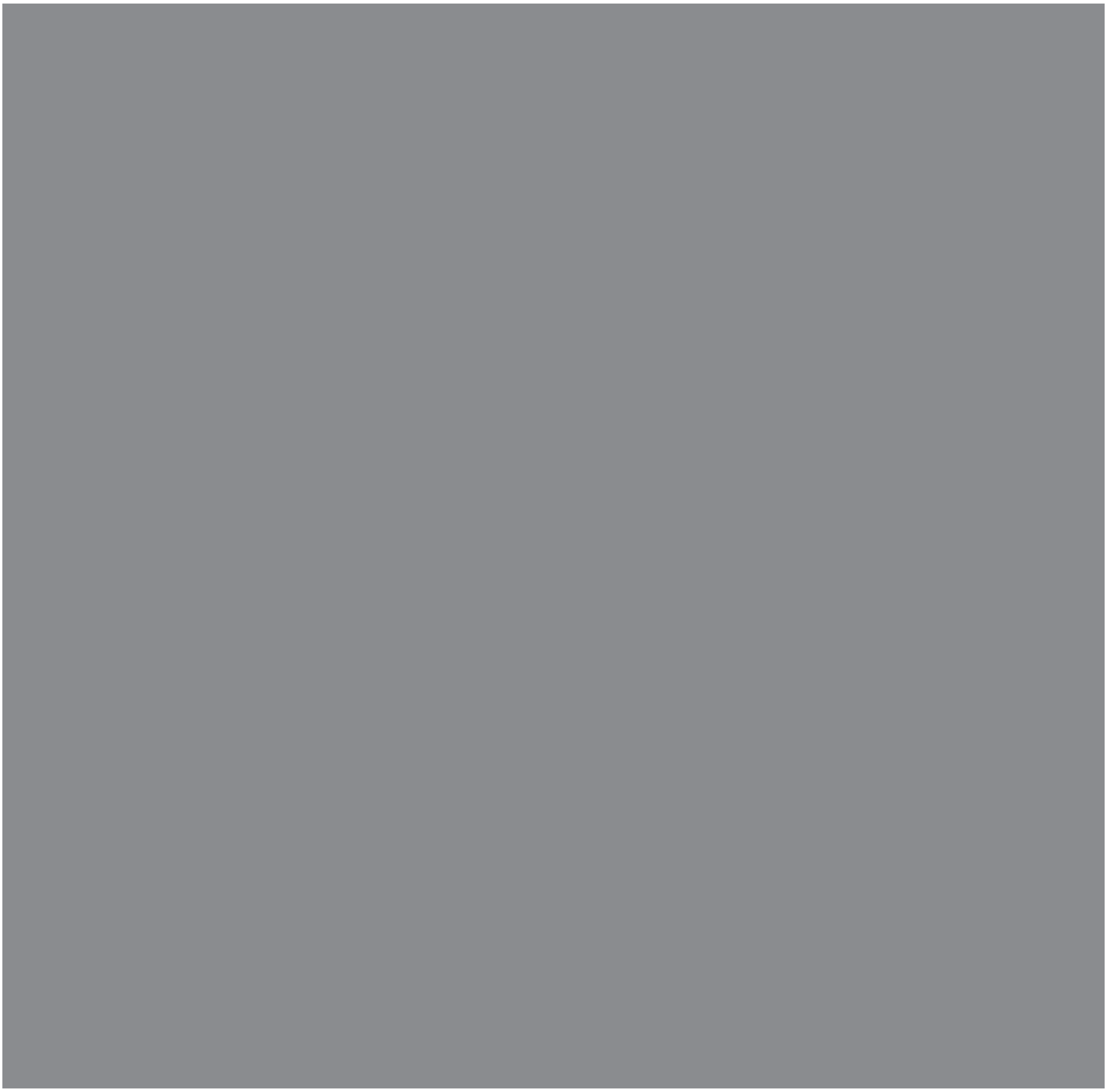

fig. 16 - Oberholz Mountain Hut Peter Pichler Architecture + Pavol Mikolajcak

5.1.2.1 OPENNESS / VOID

WHAT IT IS:

Openness/Void is characterized by intentional portions of unobstructed spaces. The Openness/Void parameter implies the importance of open areas where emptiness in necessary to balance regions of intense elements, activity and/or detail. As our place-cells and their role in creating spatial cognition maps are triggered by our awareness of the surrounding environment, openness and void play a fundamental part in our behavior and positively impact our cognition. By triggering a different stimulus in the brain with the opportunity to understand the complexity of the built space as a whole, the parameter contributes to enrich the built environment by allowing our brain a break from the processing of information. As a result, our opportunity for interaction increases and the openness/void make us self awareness of our relationship with the built environment.

New approaches to the design of openness and void in built spaces help in multiple ways. Since a strong void implies focus and attention, its boundaries work to lead the focus on that specific region. This reinforces different aspects of the environment, making us noticing the luminance, structural and material, for example. Furthermore, these spaces become more welcoming and encourage social interaction. In architectural theory, voids are used to emphasize monumentality, transparency, and permeability, with spatial functions in entrances, corners, circulations, transitions, terraces, atriums, and courtyards.[234]

OUTCOMES:

Through the parameter of Openness/Void, our unconscious cognition can interpret an environment as a whole, leading to a sense of recognition which results in security.

THEORIES AND STUDIES:

Research found the uniqueness of our brains' cognition and sensorial capabilities by analyzing the impact of navigation throughout the environment. In 2014, John O'Keefe received the Nobel prize for his discovery of "place-cells" which constitute a positioning system in our brains.[235] Together with his colleagues at the University College in London, they were among the first to identify these cells and their role in creating spatial maps.[236] These spatial maps are responsible for our sense of orientation, which functions by creating internal maps of the space we are, among other attributes. The discovery was made in 1971, by analyzing signals in rats' brains

234 Kulolu, Nilgün, and Tülay amlıolu. (2012). "Perceptual and Visual Void on the Architectural Form: Transparency and Permeability." Architectoni.ca1, no. 2: 131-37.

235 "The Nobel Prize in Physiology or Medicine 2014." Nobelprize.org, www.nobelprize.org/prizes/medicine/2014/okeefe/biographical/.

236 Hartley, T., Lever, C., Burgess, N., & O'Keefe, J. (2014). Space in the brain: how the hippocampal formation supports spatial cognition. Philosophical transactions of the Royal Society of London. Series B, Biological Sciences, 369(1635), 20120510.

from nerve cells in the hippocampus. Place cells react differently according to the visual stimuli of the environment which triggers different behavior and learning capacity.[237] [238] This stimulus is amplified by openness and void in a built space affecting our bodily senses, termed embodiment. Therefore, we can link the embodiment and perception of space to multisensory aspects.[239] [240] Openness/Void generates a unique experience, where our brain interprets the environment as a background with form and materiality, and the void as space.

Besides influencing individuals' spatial cognition, the apprehension of the environment promoted by Openness/Void also interferes in our sense of self and how the physical environment affects our identity. Proulx et al. exemplifies the importance of architectural structure on affecting the self by encouraging people to reconsider the strong effects between the damage of cognition outlook and a healthy social development and emotional self-confinement, and between the lack of mobility and freedom of movement in space: "Where we are might mold who we are."[241] They also report on this positive impact of opened spatial configuration on psychological development, spatial and social cognition in the development of children, when compared to enclosed spaces.

We perceive our environment in different ways, explains another Nobel Prize, Eric Kandel.[242] Our memories are based on specific proteins and chemicals which are formed and stored in the brain. As a consequence, tangible signals provide means for evaluation and analysis by particular situations and on a personal basis. Our individual persona is also shaped by how long we stay inside of an environment, with the built space being able to contribute or impair the development of our spatial cognition: as confined spaces limit our freedom of movements, they also interfere in the experience of different paths and perspectives time and time again.

Enclosed spaces can be considered claustrophobic by many, triggering feelings of fear and oppression, especially if comparing a cubicle room with artificial lights in contrast to a boundless space with plentiful natural light.[243] This exemplifies the importance of openness inside built environments. Humans, as well as animals, were used to be free in the natural world and this might explain our frustration when feeling confined, and opposite feeling of joy and creativity in large open spaces.

Transparency is also related to the concept of openness and void for allowing the visual connection between the spaces, and between inside and outside of a building. This connection has an impact on our behavior, cognition, usage, and perception of

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237 Epstein, R., and Kanwisher, N. (1998). A cortical representation of the local visual environment. Nature 392, 598–601.

238 Epstein, R., Harris, A., Stanley, D., and Kanwisher, N. (1999). The parahippocampal place area: recognition, navigation, or encoding? Neuron 23, 115–125.

239 Lopez, C., Halje, P., and Blanke, O. (2008). Body ownership and embodiment: vestibular and multisensory mechanisms. Neurophysiol. Clin. 38, 149–161.

240 Tsakiris, M., Costantini, M., and Haggard, P. (2008). The role of the right temporo-parietal junction in maintaining a coherent sense of one's body. Neuropsychologia 46, 3014–3018.

241 Proulx MJ, Todorov OS, Taylor Aiken A and de Sousa AA (2016) Where am I? Who am I? The Relation Between Spatial Cognition, Social Cognition and Individual Differences in the Built Environment. Front. Psychol. 7:64.

242 Eric Kandel, (2006). In Search of Memory: The Emergence of a New Science of Mind, New York: W. W. Norton.

243 Bertram D. Lewin (1935) Claustrophobia, The Psychoanalytic Quarterly, 4:2, 227-233.

the built space. A study suggested that good visibility between spaces decreases aggressiveness in psychiatric wards. Visibility possibly enhances patients with a sense of security, awareness and having more personal space.[244] The same happens to hospital staff, who prefer to be located in a central space and have the patients around them, as to be able to visually apprehend the totality of the environment, if compared to the corridors dominated designs.[245]

Christopher Alexander, architect, and theorist about the nature of human-centered design mentions the importance of the void in architecture and urban spaces describing it as an emptiness which needs to exist in the field to preserve the balance between calmness and emptiness.[246] Later, mathematician Nikos Salingaros reinterprets Alexander's concept by describing the importance of the void using fractals structure. He implies the void as an open middle center for the balance of complex and intense boundary arrangements. "The void can be identified with plain structure at the largest scale of a fractal. The largest open component of a fractal survives as the void. It is not possible to fill in all of a fractal with detail. In "implied" centers, a complex boundary focuses on the open middle—the void. Therefore, an empty portion in necessary to balance regions of intense detail." [247]

PARAMETER APPLICATION:

Design strategies for Openness/Void parameter should consider the visual and functional permeability voids promote in buildings, the activities it will encourage, as well as the resulting effects in the comprehension of spatial unity, perception of form and complexity. Openness/Void can be represented in the design of entrances, corner spaces, transitional spaces, circulation, atriums, and be accentuated by the effects of light. The use of glass, windows, doors and curtain walls can be used to transmit spatial transparency.

244 Jenkins, O., Dye, S., & Foy, C. (2014). A study of agitation, conflict, and containment in association with change in ward physical environment. Journal of Psychiatric Intensive Care, 11(01), 27–35.
245 Sheehan, B., Burton, E., Wood, S., Stride, C., Henderson, E., & Wearn, E. (2013). Evaluating the Built Environment in Inpatient Psychiatric Wards. Psychiatric Services, 64(8), 789–795.
246 Christopher Alexander proposed Fifteen Fundamental Properties that give life to architecture.
Christopher Alexander (2002) The Nature of Order: An Essay on the Art of Building and the Nature of the Universe, Book One, The Phenomenon of Life, The Center of Environmental Structure, Berkeley, California.
247 Salingaros, Nikos A., and Christopher Alexander. Unified Architectural Theory: Form, Language, Complexity: a Companion to Christopher Alexander's "The Phenomenon of Life - The Nature of Order, Book 1". Vajra Books, 2013.

table 7 - Scientific Studies related to Openness / Void Parameter

effect	relevant studies	findings
•Health **•Mental Health** **•Wellbeing**	Bertram D. Lewin (1935) Claustrophobia, The Psychoanalytic Quarterly, 4:2, 227-233,	claustrophobic space triggers oppression feelings
	Christopher Alexander (2001) "Fifteen Fundamental Properties", Chapter 5 of The Phenomenon of Life: Book 1 of The Nature of Order, Center for Environmental Structure, Berkeley, California.	empty portion in necessary to balance regions of intense detail.
	Gehl, J. et al. (2006), Close encounters with buildings, Urban Design International 2006-11, p. 29-47	the ground floor facades must have openness with special and welcoming design
	Salingaros, Nikos A., and Christopher Alexander. Unified Architectural Theory: Form, Language, Complexity: a Companion to Christopher Alexander's "The Phenomenon of Life - The Nature of Order, Book 1". Vajra Books, 2013.	void-middle open center for the balance of complex and intense boundaries arrangements
	Sheehan, B., Burton, E., Wood, S., Stride, C., Henderson, E., & Wearn, E. (2013). Evaluating the Built Environment in Inpatient Psychiatric Wards. Psychiatric Services, 64(8), 789–795.	internal wards spaces and noncorridor design increase user satisfaction.
•Restorative **•Stress Reduction**	Ulrich, R. (1984). View through a window may influence recovery from surgery. *Science* 224: 420–421.	a room with a window view of a natural setting have restorative influences.
•Cognition Improvement	Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning.	Big building area can provide diverse opportunities for alternative learning activities that relate to the improvement of the pupils' academic achievement
	Epstein, R., and Kanwisher, N. (1998). A cortical representation of the local visual environment. *Nature* 392, 598–601.	openness triggers the behavior and learning.
	Epstein, R., Harris, A., Stanley, D., and Kanwisher, N. (1999). The parahippocampal place area: recognition, navigation, or encoding? *Neuron* 23, 115–125.	openness triggers the behavior and learning.
	Hartley, T., Lever, C., Burgess, N., & O'Keefe, J. (2014). Space in the brain: how the hippocampal formation supports spatial cognition. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *369*(1635).	openness assist in the creation of spatial map and cognition.
	Lopez, C., Halje, P., and Blanke, O. (2008). Body ownership and embodiment: vestibular and multisensory mechanisms. *Neurophysiol. Clin.* 38, 149–161.	openness amplify the embodiment of the space
	Proulx MJ, Todorov OS, Taylor Aiken A and de Sousa AA (2016) Where am I? Who am I? The Relation Between Spatial Cognition, Social Cognition and Individual Differences in the Built Environment. Front. Psychol. 7:64.	the impact of psychological development, spatial and social cognition in a growing mind of a children within enclosure architectural spaces opposed to openness ones.
	Tsakiris, M., Costantini, M., and Haggard, P. (2008). The role of the right temporo-parietal junction in maintaining a coherent sense of one's body. *Neuropsychologia* 46, 3014–3018.	openness amplify the embodiment of the space
•Violence Reduction	Jenkins, O., Dye, S., & Foy, C. (2014). A study of agitation, conflict and containment in association with change in ward physical environment. Journal of Psychiatric Intensive Care, 11(01), 27–35.	levels of arousal and aggression among patients in unoppened spaces.
	Ulrich, R. S., Bogren, L., Gardiner, S. K., & Lundin, S. (2018). Psychiatric ward design can reduce aggressive behavior. Journal of Environmental Psychology, 57, 53–66.	designing better psychiatric buildings using reasoned theory and the best available evidence about openness can reduce the major patient and staff safety threat posed by aggressive behavior.

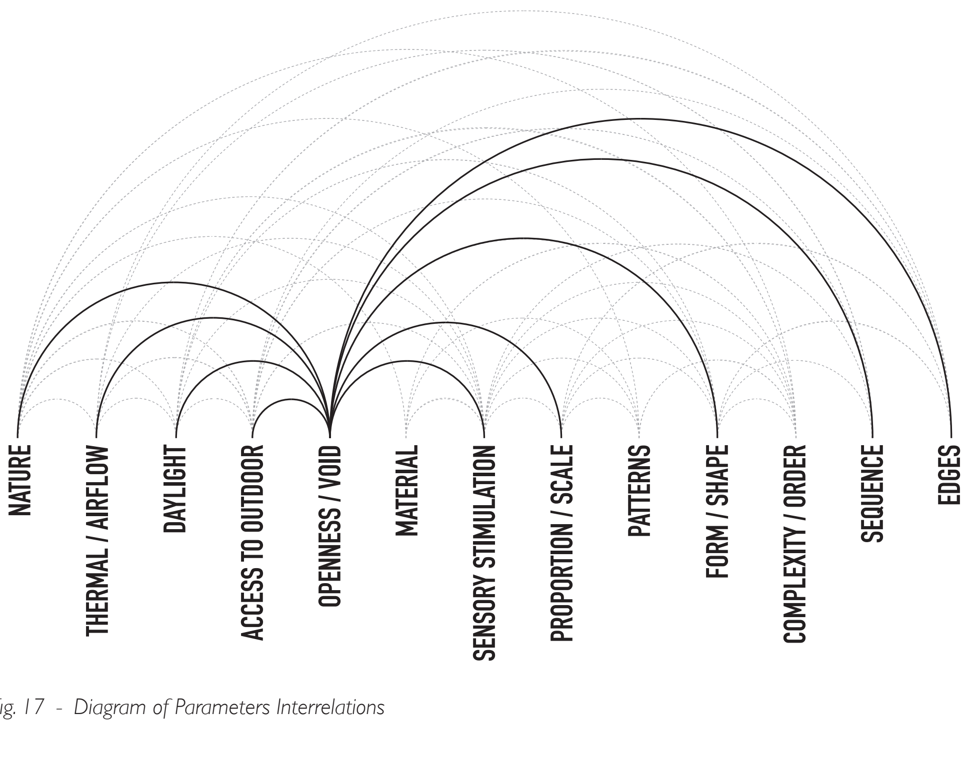

fig. 17 - Diagram of Parameters Interrelations

fig. 18 - Suzhou Chapel - Neri-amp-Hu Design and Research Office

5.1.2.2 MATERIAL

WHAT IT IS:

The Material parameter regards the sensorial experience promoted by materiality. Besides stimulating our five senses, material also promotes a sense of place, through local identity and geology relationship with the environment. The aspects of materials also imply different outcomes: the use of materials that can be identified as high-quality, like marbles, translates the notion of uniqueness and rarity; the use of materials that can be identified as natural, like wood, translates the notion of comfort; and the use of materials that can be identified as copies of natural materials, like synthetic wood, translates the notion of ordinary. Moreover, the parameter contributes to enhancing the relation of spatial details, especially by adding a sense of scale to the overall perception of the built space through its dimensions, features (color, texture, patterns) and type of surface finish (rough, gloss, polish).

OUTCOME:

Materials and its features have the ability to improve comfort, decreased blood pressure and improve creative performance.

THEORIES AND STUDIES:

Along with architectural history, many architects have advocated for the use of natural materials believing in their potential of promoting well-being, like Frank Lloyd Wright, and others focused on their aesthetic potential, like Mies Van der Rohe. In the cognitive and behavioral point of view, materials that can be identified as natural bring the most benefits for us. Their use has been linked to relief in stress, multiple sensory experiences, increase in creativity, imaginative and relaxation.[248] Wood, for example, has a strong potential to enhance a space. When applied in structures, finishings, and design elements, it provides a direct connection with nature. The overall impression spark on us positive feelings, such as comfort, besides its embedded symbolism of authenticity and sustainability. We also relate to it through our visual system (by its textural scale and color), through our olfactory system (by its smell), through our auditory system (by its sound or buffer effect), and through our haptic system (by its texture). The peculiar texture of wood can refract and diffuse sound, assisting in the balance ambience resonance. Wood also releases olfactory compounds that were demonstrated to help decrease stress hormones such as the concentration of adrenaline in urine, and enhance the activity of white blood cells which fight diseases.[249] Yet, a study suggests that in order to gain all its benefits, wood has to be used with moderation. An experiment revealed that wood materials provoke a significant decrease in blood pressure and increase of pulse rate in subjects, which

248 Chang, M., & Netzer, D. (2019). Exploring Natural Materials: Creative Stress-Reduction for Urban Working Adults. Journal of Creativity in Mental Health, 1–17.
249 Li, Q., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., Hirata, Y., … Miyazaki, Y. (2009). Effect of Phytoncide from Trees on Human Natural Killer Cell Function. International Journal of Immunopathology and Pharmacology, 22(4), 951–959.

also mentioned a "comfortable" feeling during the tests in a room composed of 45% wood. However, in a room composed of 90% wood, subjects' blood pressure declined and resulted in a fast reduction in brain activity.[250] Thus, although being a rich material for our senses, it cannot be overused since it can generate boredom and lose its essential attributes.

Nikos Salingaros wrote that materials with no natural properties don't cause any interesting response from the occupant. He theorizes that the only way to successfully use non-natural materials is through a scaling hierarchy and subdivision to generate contrast and in alternation between tones and colors.[251] This emphasizes that color is intrinsic to the Material parameter since it is a predominant feature of materials. Primary colors, secondary colors, collorations, tones, and hues can influence our cognition and behavior as demonstrated in countless studies. Jalil et al., for example, extracted evidence that color affects visual comfort, psychological and behavior activities, having a direct impact on focus, cognition, and wellbeing in learning spaces.[252] The color green, in particular, has been proved impact positively in creative spaces.[253]

Colors also stimulate memory by sparking attention and strengthening the memory location in our mental maps. Our ganglion cells are responsible for this process, which takes place by comparing light vs dark, red vs green and blue vs yellow as to provide the general information of environments to the brain. However, color processing changes with age, leading to consideration when applying certain tones to not wrongly evoke unnecessary stimulus.[254]

Materials also stimulate our haptic system, since we perceive their texture through touch and walking over them. These perceptions assist us to sustain our balance and trigger emotional and mental activity.[255]

PARAMETER APPLICATION:

The objective of application of the Material parameter focuses on the outcomes architects want to have for a certain environment, if it should be restorative, stimulative or contemplative. It also implies that the designer should explore materials' quantities, ratios, textures, tones, colors, and characteristics to optimize cognitive and psychological reactions. Furthermore, opting for natural/real materials in comparison to mimetic/synthetic ones is more appropriate, since the later are easily detected by our sensory receptors. Examples of natural/real materials are stones, woods, masonry, metals, paper, glass, among others; to be used in the structural systems, finishings, wall constructions, details, countertops and so on. Materials with natural tones, colorations and hues should also be considered.

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250 Tsunetsugu, Y., Y. Miyazaki, & H. Sato (2007). Physiological Effects in Humans Induced by the Visual Stimulation of Room Interiors with Different Wood Quantities. Journal of Wood Science, 53 (1), 11-16.

251 Nikos A. Salingaros, (1998). A Scientific Basis for Creating Architectural Forms. Journal of Architectural and Planning Research Vol. 15, No. 4, pp. 283-293

252 Jalil, N. A., Yunus, R. M., & Said, N. S. (2012). Environmental Colour Impact upon Human Behaviour: A Review. Procedia - Social and Behavioral Sciences, 35, 54–62.

253 Lichtenfeld, S., A.J. Elliot, M.A. Maier, & R. Pekrun (2012). Fertile Green: Green Facilitates Creative Performance. Personality and Social Psychology Bulletin, 38 (6), 784-797.

254 Bear ME, Connors BW, Paradiso MA (2001). Neuroscience: Exploring the Brain. Baltimore: Lippincott Williams & Wilkins.

255 Robinson, Sarah, and Juhani Pallasmaa. (2011). Nesting: Body, Dwelling, Mind. Richmond, CA: William Stout Publishers.

table 8 - Scientific Studies related to Material Parameter

effect	relevant studies	findings
•Health •Mental Health •Wellbeing	Chang, M., & Netzer, D. (2019). Exploring Natural Materials: Creative Stress-Reduction for Urban Working Adults. Journal of Creativity in Mental Health, 1–17.	the participants were inspired to be more playful, imaginative, and reflect on their lives outside of work through symbolic expression of reconnecting with nature.
	Negami, H. R., Mazumder, R., Reardon, M., & Ellard, C. G. (2019). Field analysis of psychological effects of urban design: a case study in Vancouver. Cities & Health, 1–10.	colorful crosswalks and greenery have positive effects on participants' mental well-being, sociability and feelings of environmental stewardship.
	Nikos A. Salingaros, (1998). Journal of Architectural and Planning Research Vol. 15, No. 4, pp. 283-293	natural materials triggers wellbeing.
	Robinson, Sarah, and Juhani Pallasmaa. (2011). Nesting: Body, Dwelling, Mind. Richmond, CA: William Stout Publishers.	Our sense of touch called haptic system, also add value to material pattern application since we also perceive texture through touching. It activates our perception organs by the touch receptors in the skin which assist us to sustain our balance and triggers emotional and mental activity.
	Sakuragawa, S., Miyazaki, Y., Kaneko, T. & Makita, T. (2005). Influence of wood wall panels on physiological and psychological responses. J Wood Sci, Vol.51, pp. 136-140, ISSN 0021-4795	visual stimulation from hinoki wall panels had an emotional and natural impression with a decreased in blood pressure. while steel wall panel made an unhealthy, stress and increase in blood pressure.
•Restorative •Stress Reduction	Li, Q., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., Hirata, Y., … Miyazaki, Y. (2009). Effect of Phytoncide from Trees on Human Natural Killer Cell Function. International Journal of Immunopathology and Pharmacology, 22(4), 951–959.	phytoncide exposure and decreased stress hormone levels and improve immunity
	Sakuragawa, S., Kaneko, T. &Miyazaki, Y. (2008). Effects of contact with wood on blood pressure and subjective evaluation. J.Wood Sci, Vol.54, No.2, pp. 107-113	It was therefore concluded that contact with wood, unlike artificial materials such as aluminum, induces no physiological stress
	Tsunetsugu, Y., Y. Miyazaki, & H. Sato (2007). Physiological Effects in Humans Induced by the Visual Stimulation of Room Interiors with Different Wood Quantities. *Journal of Wood Science, 53* (1), 11-16.	a difference in wood ratio in the interior caused different physiological responses, especially in the autonomic nervous activity. with the medium ratio a significant decrease in the diastolic blood pressure and a significant increase in pulse rate were observed.
•Cognition Improvement	Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning.	warm colors have a relation to improvement of the pupils' academic achievement.
	Bear ME, Connors BW, Paradiso MA (2001). Neuroscience: Exploring the Brain. Baltimore: Lippincott Williams & Wilkins.	Memory can be stimulated by colors, since the brightness sparks attention and which strengthen the location in the mental maps.
	Jalil, N. A., Yunus, R. M., & Said, N. S. (2012). Environmental Colour Impact upon Human Behaviour: A Review. Procedia - Social and Behavioral Sciences, 35, 54–62.	this paper highlights the potential scientific approach in finding colour effects on human behaviour, creative performance, stress reduction and wellbeing.
	Lichtenfeld, S., A.J. Elliot, M.A. Maier, & R. Pekrun (2012). Fertile Green: Green Facilitates Creative Performance. *Personality and Social Psychology Bulletin, 38* (6), 784-797.	a brief glimpse of green prior to a creativity task enhances creative performance. These findings indicate that green has implications beyond aesthetics and suggest the need for sustained empirical work on the functional meaning of green.

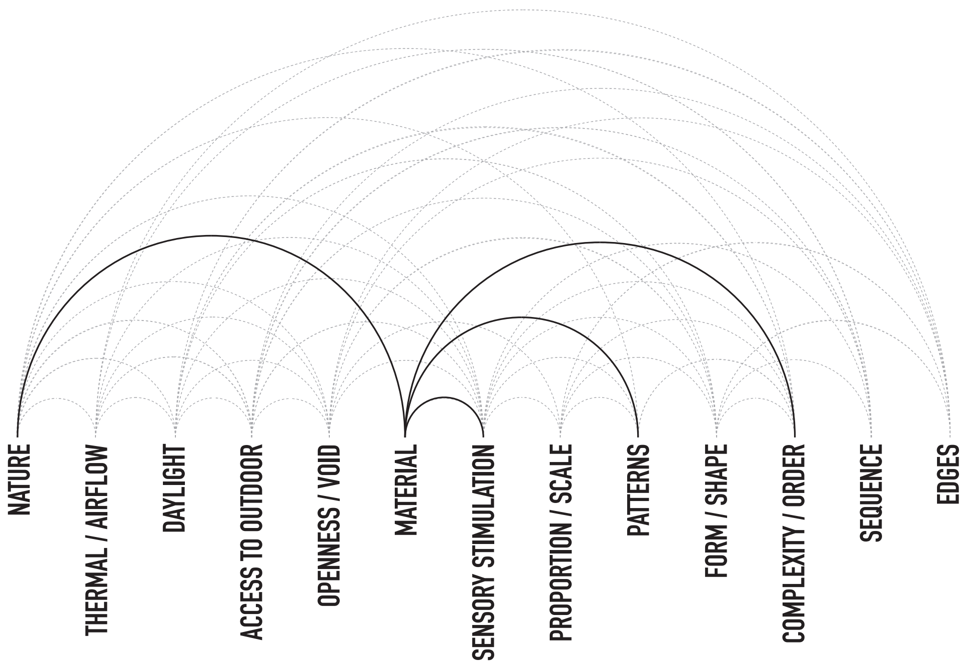

fig. 19 - Diagram of Parameters Interrelations

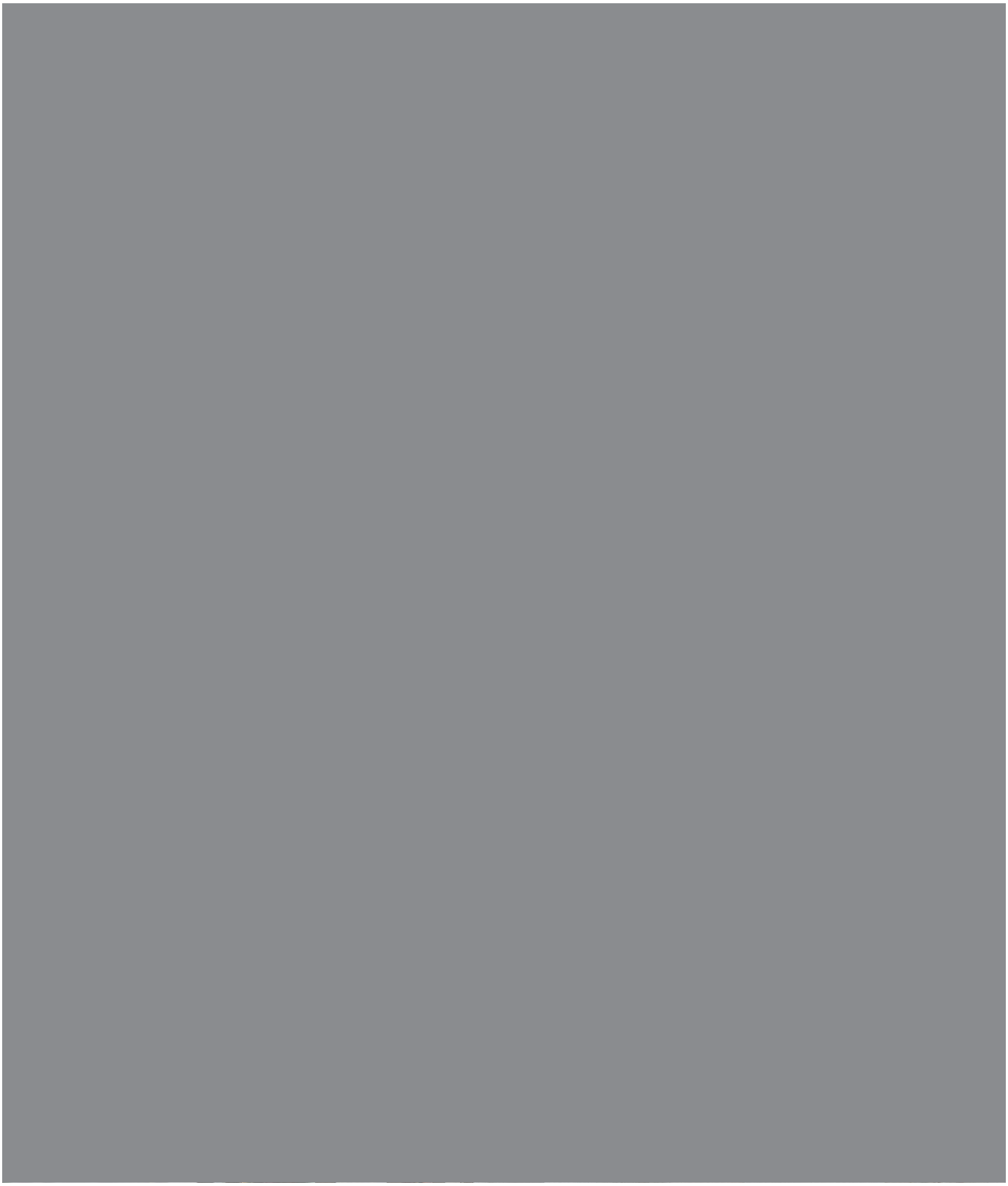

fig. 20 - Zaryadye Park / Diller Scofidio + Renfro

5.1.2.3 SENSORY STIMULATION

WHAT IS IT:

The Sensory Stimulation parameter entails environments that are not simply experienced by formal design elements that constitute a building. It concerns momentary experiences induced by a wide range of sensorial aspects to be processed by our brain. They are ephemeral connections with interesting and stimulating distractions, as a sense of being teased, which lead to physiological restoration. The parameter is promoted by momentary interaction of light variation, for example, sound, smell, temperature, connectivity to season and temporal changes.

OUTCOME:

The outcomes of the Sensory Stimulation parameter are momentary experiences such as surprise, mystery, attention, curiosity, and peculiarity. People enjoy the conscious exposure to controlled risk that can be promoted by different types of sensory stimulation, as well as gentle variations in the environment that incite curiosity. These may promote small doses of dopamine which activates motivation, memory, and problem-solving. However, long exposure to risk and threat results in overproduction of dopamine that may lead to mood disorders.[256]

THEORIES AND STUDIES:

Neuroscientific research demonstrates that we can have a great amount of different sensory experiences, with some of them being harmful, and others being therapeutically capable of improving our immune system.[257] Sound is one of the approaches to Sensory Stimulation pattern, vastly utilized in built environments to achieve certain outcomes. Sounds must vary in almost every building type, from library spaces, to museums, schools, offices, and residences. Design strategies to engage sound must be carefully analyzed by architects since it can influence in either stress levels, or promote positive feeling and general well being. Research on the biomedical foundations of music as therapy, for example, presents solid evidence linking sounds with positive neural impulses causing an improvement of cognition, anxiety reduction among many other injuries and disorders.[258] Being in front of water features, with their specific sounds, leads to pleasant distraction time.[259] And an experiment showed that participants who listened to river sounds after a task, have more energy and greater motivation compare to the participants who were in silent and with office sounds.[260]

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256 Kandel, E.R., J.H. Schwartz, T.M. Jessell, S.A. Siegelbaum, & A.J. Hudspeth (2013). Principles of Neural Science, Fifth Edition. New York: McGraw Hill.
257 Pope, D. S. (1995). Music, noise, and the human voice in the nurse-patient environment. IMAGE: Journal of Nursing Scholarship 27(4):291–296.
258 Taylor, D. B. (1997). Biomedical foundations of music as therapy. St. Louis, MO: MMB Music Inc.
259 Ulrich, R. (1991). Effects of interior design on wellness: Theory and recent scientific research. Journal of Healthcare Interior Design 3(1):97–109.
260 Jahncke, H., S. Hygge, N. Halin, A.M. Green, & K. Dimberg (2011). Open-Plan Office Noise: Cognitive Performance and Restoration. Journal of Environmental Psychology, 31, 373-382.

However, when distractions are not the intention, design strategies for sound mitigation have to be considered as to increase the acoustic quality of space. Acoustics is an important factor for building design when not appropriated applied since it can harm our health increasing blood pressure, headaches, sleep disorders, cognitive confusion, increasing in the stress hormones and decrease the general performance and wellbeing. Stress demand our nervous and endocrine system to overreact and pleasant sounds have a good effect to release endorphins.[261] Architects need to know the scientific knowledge behind a comfortable acoustic outcome to design a properly built environment. Hearing loss is related to prolonged exposure to high noise intensity, and low-frequency noises can affect sleep disruption and high blood pressure. Especially during the night which our cortical system arouse from low sound levels causing trouble for associative memory and wakefulness.[262]

In some built environments, the transition of spaces is perceived only through variations of sound, like an abrupt shift of sound pressure or a pleasant sequence that sometimes can be even considered as a melody. Our ears help us to be aware of such experiences, as well as of possible surrounded risks. Even during sleep, our ears are processing the surrounding sounds through sound pressures which vibrate the eardrum and results in nerves stimulus. Cycles of vibration, reverberance, frequency, pitch, and difference in pressure are detected. And built environments have a direct link with these attributes, sometimes because of the material, the room shape, height, transitions, sequence, openings and so on.

Another approach to sensory stimulation is through the olfactory system. It is the body's oldest perceptual system, capable of informing us about surrounded risks of the environment. It is based in the limbic structure, which is also responsible for intention, sense of time and sense of space.[263] Many environments entice our olfactory system with natural scents from plants, wood, organic materials and objects that stimulates the limbic system. As the limbic system is in charge of the emotional part of the brain, stimulating it appropriately results in a decrease of anxiety, dizziness, pain, blood pressure and so on. Essential oils used in aromatherapy can boost some of the effects of natural aroma and promote positive physical/psychological outcomes.[264]

Overall, wood has an impressive impact on the improvement of individuals wellbeing. One of the positive significance is the fragrance and ability to interact with the environment according to the humidity and dry levels, helping the improvement of the space. Not all wood has the same scent which varies according to each species. However, studies demonstrated that certain wood types have specific beneficial properties. Cedarwood and Sandalwood, for example, have been proved to stimulate sleep hormones.[265] The smell of a Japanese wood species called Hiba demonstrated

261 Taylor, D. B. (1997). Biomedical foundations of music as therapy. St. Louis, MO: MMB Music Inc.

262 Cedeño-Laurent, J., Williams, A., Macnaughton, P., Cao, X., Eitland, E., Spengler, J., & Allen, J. (2018). Building Evidence for Health: Green Buildings, Current Science, and Future Challenges. Annual Review of Public Health, 39(1), 291-308.

263 Freeman, Walter J. (2000). "Emotion Is Essential to All Intentional Behaviors." Emotion, Development, and Self-Organization, 209-35.

264 Ali, B., Al-Wabel, N. A., Shams, S., Ahamad, A., Khan, S. A., & Anwar, F. (2015). Essential oils used in aromatherapy: A systemic review. Asian Pacific Journal of Tropical Biomedicine, 5(8), 601–611.

265 Takeda, A., Watanuki, E., & Koyama, S. (2017). Effects of Inhalation Aromatherapy on Symptoms of Sleep Disturbance in the Elderly with Dementia. Evidence-Based Complementary and Alternative Medicine, 2017, 1–7.

to significantly decrease in depression and anxiety in chronic patients.[266] The smell of Japanese Cedar has also been proved to reduce anxiety and stress responses, and promote the general improvement of mental health.[267] The smell of Rosewood has analgesic properties.[268] And the smell of Sandalwood can also improve productivity and general comfort.[269]

Research has clearly stated that individuals appreciate the moderate variation of sensory stimulus from the environment.[270] [271] [272] [273] However, no stimulation at all is linked to boredom and depression.[274] [275] One approach that balances sensory stimulation is ephemeral distractions. Design strategies that promote these distractions are gardens and courtyards. The experience of being in nature promoted by: the ephemeral sounds effects of leaves rustling and birds chirping; the ephemeral olfactory effects of the flower and wood scents; the ephemeral visual effects of komorebi (the daylight effect permeating through the trees leaves) and cloud movements; and the ephemeral haptic effects of moisture and wind speed lead to physiological and psychological restoration. Also, the dopamine production encouraged by being in natural environments can encourage cognition, motivation and memory responses. For those reasons, it has been proved to be extremely important for a child's development to be exposed to nature experience, as described in the book "Saving our children from Nature-Deficit disorder".[276] Furthermore, nature is embedded with the dynamics of weather, season and day and night. The motions of these cycles create an overall unity which we humans are used to and suggest that architects must embrace these cycles with temporal and spatial relationships between artificial elements and natural beauty. [277]

The different effects of light exposure and environmental conditions also promote sensory stimulation. In a study to classify how individual perceive facades, it was demonstrated that individuals had different appraisals according to the time of the day and season. With the same house being welcoming on spring morning and

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266 Itai T, Amayasu H, Kuribayashi M, Kawamura N, Okada M, Momose A, Tateyama T, Narumi K, Uematsu W, Kaneko S (2000). Psychological effects of aromatherapy on chronic hemodialysis patients. Psychiatry Clinic Neuroscience; 54(4):393-7.

267 Matsubara, E., Tsunetsugu, Y., Ohira, T., & Sugiyama, M. (2017). Essential Oil of Japanese Cedar (Cryptomeria japonica) Wood Increases Salivary Dehydroepiandrosterone Sulfate Levels after Monotonous Work. International Journal of Environmental Research and Public Health, 14(1), 97.

268 De Cássia da Silveira e Sá, R., Lima, T., da Nóbrega, F., de Brito, A., & de Sousa, D. (2017). Analgesic-Like Activity of Essential Oil Constituents: An Update. International Journal of Molecular Sciences, 18(12), 2392.

269 Sowndhararajan, K., & Kim, S. (2016). Influence of Fragrances on Human Psychophysiological Activity: With Special Reference to Human Electroencephalographic Response. Scientia Pharmaceutica, 84(4), 724–751.

270 Platt, J.R. (1961). Beauty: Pattern and Change. In D.W. Fiske & S.R. Maddi (Eds.) Functions of Varied Experience. Homewood, IL: Dorsey Press. In: Heerwagen, J.H. (2006). Investing In People: The Social Benefits of Sustainable Design. Rethinking Sustainable Construction. Sarasota, FL. September 19-22, 2006.

271 Humphrey, N. (1980). Natural Aesthetics. In B. Mikellides (Ed.) Architecture for People. London: Studio Vista.

272 Heerwagen, J.H. (2006). Investing In People: The Social Benefits of Sustainable Design. Rethinking Sustainable Construction. Sarasota, FL. September 19-22, 2006.

273 Elzeyadi (2012). "Post-occupancy evaluation: A design, operations and performance assessment of a LEED Platinum building." World Health Design Journal. January 2012, pp. 60-69.

274 Cooper, R. (1968). The Psychology of Boredom. Science Journal 4 (2): 38-42.

275 Schooler, C. (1984). Psychological Effects of Complex Environments During the Life Span: A Review and Theory. Intelligence 8:259-281.

276 Louv, R. (2008). Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. New York: Algonquin Books. pp390.

277 Humphrey, N. (1980). Natural Aesthetics. In B. Mikellides (Ed.) Architecture for People. London: Studio Vista.

fringing on a freezing winter night.[278] Seasonal and daily weather conditions must be anticipated by the architects since buildings are inhabited during all the weather conditions. It is interesting to observe that many architectural rendering images illustrate the perfect sunny days of buildings located in the northern hemisphere.[279]

As light is an essential regulator of alertness and cognition, design strategies that promote it as a visual stimulus are endless. However, light can also be approached as a haptic stimulus as indicated in a study with blind people which was able to sense the presence of light, where activity in the cognitive brain areas as pulvinar, precuneus, anterior cingulate cortex, occipital cortex, and prefrontal cortex were noted. [280]

Controlled exposure to risk is also related to sensory stimulation and vastly proved to boost dopamine levels and pleasure responses with overall positive experiences.[281] Design elements such as cantilever walkway, which protects the user from harm while still allowing the peril experience. Mystery is also related to the exposure of risk since mystery activates our curiosity of confirmation of danger to be ready for quick reaction.[282] Design configurations such as sequential spaces that unfold gradually may promote this sense of mystery.

PARAMETER APPLICATION:

Ephemeral connections with interesting and stimulating distractions lead to physiological restoration. However, design strategies to approach the Sensory Stimulation parameter need to be carefully considered, since too much stimulation may have the contrary desired effect. Strategies for noise propagation with suitable materials, forms and elements should be considered when regarding olfactory stimulation. Visual stimulation can be approached with lighting transitions and indirect natural light. The olfactory stimulus can be approached with the use of materials, connections to natural elements. Haptic stimulation can be approached also by materials, mist, direct sunlight.

Sensory Stimulation can also be approached by design elements which promote different degrees of controlled risk, such as cantilevers, infinity edges, balconies, open staircases and elements that defy gravity forces.

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278 Ostwald, Michael, Kenny Hong, and Stephan Chalup. (2013). "Pareidolia Analysis of Architecture - ANFA."
279 Guggenheim Helsinki Design Competition. (2015). "Stage One Gallery." Stage One Gallery - Accessed April 10, 2019. http://designguggenheimhelsinki.org/stageonegallery/view/#
280 Vandewalle, G., Collignon, O., Hull, J. T., Daneault, V., Albouy, G., Lepore, F., … Carrier, J. (2013). Blue Light Stimulates Cognitive Brain Activity in Visually Blind Individuals. Journal of Cognitive Neuroscience, 25(12), 2072–2085.
281 van den Berg, A.E. & M. ter Heijne (2005). Fear Versus Fascination: An Exploration of Emotional Responses to Natural Threats. Journal of Environmental Psychology, 25, 26-272.
282 Herzog, T.R. & A.G. Bryce (2007). Mystery and Preference in Within-Forest Settings. Environment and Behavior, 39 (6), 779-796.

table 9 - Scientific Studies related to Sensory Stimulation Parameter

effect	relevant studies	findings
•**Health** •**Mental Health** •**Wellbeing**	Blood, A., & R.J. Zatorre (2001). Intensely Pleasurable Responses to Music Correlate with Activity in Brain Regions. *Proceedings from the National Academy of Sciences, 98* (20), 11818-11823.	This finding links music with biologically relevant, survival-related stimuli via their common recruitment of brain circuitry involved in pleasure and reward.
	Cedeño-Laurent, J., Williams, A., Macnaughton, P., Cao, X., Eitland, E., Spengler, J., & Allen, J. (2018). Building Evidence for Health: Green Buildings, Current Science, and Future Challenges. *Annual Review of Public Health, 39*(1), 291-308.	Architects need to know the scientific knowledge behind a comfortable acoustic outcome to design a proper built environment. Low-frequency noises can affect sleep disruption and high blood pressure.
	Cooper, R. (1968). The Psychology of Boredom. Science Journal 4(2): 38-42.	An environment devoid of sensory stimulation and variability can lead to boredom and passivity
	De Cássia da Silveira e Sá, R., Lima, T., da Nóbrega, F., de Brito, A., & de Sousa, D. (2017). Analgesic-Like Activity of Essential Oil Constituents: An Update. International Journal of Molecular Sciences, 18(12), 2392.	Rosewood type scent has analgesic chemechials.
	Elzeyadi (2012). "Post-occupancy evaluation: A design, operations and performance assessment of a LEED Platinum building." World Health Design Journal. January 2012, pp. 60-69.	individuals appreciate moderate variation of sensory stimulus from the environment.
	Freeman, Walter J. (2000). "Emotion Is Essential to All Intentional Behaviors." Emotion, Development, and Self-Organization, 209-35.	Olfactory system is based in the limbic structure, responsible for intention, sense of time and sense of space.
	Guggenheim Helsinki Design Competition. (2015). "Stage One Gallery." Stage One Gallery - Accessed April 10, 2019. http://designguggenheimhelsinki.org/stageonegallery/view/#	Seasonal changes impacts the wellbeing of the space.
	Heerwagen, J.H. (2006). Investing In People: The Social Benefits of Sustainable Design. Rethinking Sustainable Construction. Sarasota, FL. September 19-22, 2006.	Meaningful change and sensory variability result in general wellbeing with sensory experience in mind (touch, visual change, color, pleasant sounds and odors); spatial variability; change in lighting levels and use of highlights; moderate levels of visual complexity.
	Humphrey, N. (1980). Natural Aesthetics. In B. Mikellides (Ed.) *Architecture for People*. London: Studio Vista.	seasonal cycles and its dynamics create an overall unity of wellbeing, which can be explore by architects in the built space.
	Ikemi, M. (2005). The Effects of Mystery on Preference for Residential Facades. *Journal of Environmental Psychology, 25*, 167–173.	mystery induces strong pleasure response.
	Joseph, A. (2007). Sound control for improved outcomes in healthcare settings. Issue paper, Center for Health Design.	Sound control is critically important in healthcare settings, and different environmental design strategies have proven successful in mitigating negative effects of noise while allowing effective yet private verbal communication.
	Kahn, Jr. P.H. & S.R. Kellert (2002). Children and Nature: Psychological, Sociocultural, and Evolutionary Investigations. Cambridge: MIT Press.	Sensory stimulations play a role in developing risk assessment during childhood.
	Koga, K. & Y. Iwasaki (2013). Psychological and Physiological Effect in Humans of Touching Plant Foliage - Using the Semantic Differential Method and Cerebral Activity as Indicators. *Journal of Physiological Anthropology, 32* (1), 7.	people experience an unconscious calming reaction to touching a plant.
	Kohno, M., D.G. Ghahremani, A.M. Morales, C.L. Robertson, K. Ishibashi, A.T. Morgan, M.A. Mandelkern & E.D. London (2013) Risk-Taking Behavior: Dopamine D2/D3 Receptors, Feedback, and Frontolimbic Activity. Cerebral Cortex, bht218. First published online: August 21, 2013	dopaminergic neurotransmission may modulate risk-taking behavior through an interactive system of frontal and striatal activity.
	Lorenz, S. G. (2007). The potential of the patient room to promote healing and well-being in patients and nurses. *Holistic Nursing Practice, 21*(5), 263–277.	sense of environment sensorial control leads to positiveness and reduce negativeness distractions.
	Louv, R. (2008). Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. New York: Algonquin Books. pp390.	forest activate different sensory stimulation, such as sounds, contrast, smell, smell resulting in general wellbeing.
	Louv, R. (2009). Do our kids have nature-deficit disorder. *Health and Learning, 67* (4), 24-30.	Sensory stimulations play a role in developing risk assessment during childhood.
	Ostwald, Michael, Kenny Hong, and Stephan Chalup. (2013). "Pareidolia Analysis of Architecture - ANFA."	Seasonal changes impacts the wellbeing of the space.
	Pheasant, R. J., M. N. Fisher, G. R. Watts, D. J. Whitaker, & K.V. Horoshenkov (2010). The Importance of Auditory-Visual Interaction in the Construction of 'Tranquil Space'. *Journal of Environmental Psychology, 30,* 501-509.	acoustic information is an integral part of process to recover our sense of well being in the environment.
	Platt, J.R. (1961). Beauty: Pattern and Change. In D.W. Fiske & S.R. Maddi (Eds.) Functions of Varied Experience. Homewood, IL: Dorsey Press. In: Heerwagen, J.H. (2006). Investing In People: The Social Benefits of Sustainable Design. Rethinking Sustainable Construction. Sarasota, FL. September 19-22, 2006.	individuals appreciate moderate variation of sensory stimulus from the environment.

	Pope, D. S. (1995). Music, noise, and the human voice in the nurse-patient environment. IMAGE: Journal of Nursing Scholarship 27(4):291–296.	Nurses can explore sound's potential and demonstrate how music and the human voice contribute to healing and learning
	Salimpoor,V.N., M. Benovoy, K. Larcher, A. Dagher, & R. J. Zatorre (2011). Anatomically Distinct Dopamine Release During Anticipation and Experience of Peak Emotion to Music. *Nature Neuroscience, 14* (2), 257-264.	mystery induces strong pleasure response.
	Sato, J. (2017). Komorebi / 2D Spectrum Analysis : Naturalness, Comfortableness, Preference Composition of Morphogenetic Process.	the dappled light effect when sunlight shines in through trees, causing calmness, joy and comfort.
	Schofield, P., & Davis, B. (2000). Sensory stimulation (snoezelen) versus relaxation: A potential strategy for the management of chronic pain. Disability & Rehabilitation, 22(15), 675- 682.	sensory stimulation as a method to achieve wellbeing and decrease pain.
	Schooler, C. (1984). Psychological Effects of Complex Environments During the Life Span: A Review and Theory. Intelligence 8:259-281.	An environment devoid of sensory stimulation and variability can lead to boredom and passivity
	Smith R. Helmuth O. (2016) Therapeutic environments. http:www.wbdg. org/design/ therapeutic.php	sense of environment sensorial control leads to positiveness and reduce negativeness distractions.
	Standley, J. (1986). Music research in medical/dental treatment: Meta-analysis and clinical applications. *Journal of Music Therapy* 23(2): 58–122.	hospital environments with sound therapy improves the general wellbeing.
	Taylor, D. B. (2010). Biomedical foundations of music as therapy. Eau Claire, WI: Barton Publications.	sounds as a means of wellbeing therapy
	Tsunetsugu, Y., Park, B.J. & Miyazaki, Y. (2011). Physiological effects of visual, olfactory, auditory, and tactile factors in the forest environment. In : Forest Medicine, Q. Li, (Ed.), pp. 169-181, Nova Science Publishers, NY.	the five senses, providing sense stimulation of various kinds such leading to a positive effect on human physiology.
	Ulrich R, Quan X, Zimring C, Joseph A, Choudary R. (2004). The role of the physical environment in the hospital of the 21st century: a once in a lifetime opportunity.	control of sensory stimulation induce general wellbeing.
	Ulrich, R. (1991). Effects of interior design on wellness: Theory and recent scientific research. *Journal of Health Care Interior Design* 3(1):97–109.	sense of control results in general wellness with decrease on heart rate, systolic blood pressure and sympathetic nervous system activity.
	Van den Berg, A.E. & M. ter Heijne (2005). Fear Versus Fascination: An Exploration of Emotional Responses to Natural Threats. *Journal of Environmental Psychology, 25,* 26-272.	controlled threatening encounters with nature results to response with fascination and emerging of positive emotions.
	Zald, D.H., R.L. Cowan, P. Riccardi, R.M. Baldwin, M.S. Ansari, R. Li, E.S. Shelby, C.E. Smith, M. McHugo, & R.M. Kessler (2008). Midbrain Dopamine Receptor Availability Is Inversely Associated with Novelty-Seeking Traits in Humans. The Journal of Neuroscience, 31 December 2008, 28(53), 14372-14378.	controlled risk with a novelty experience lead to strong dopamine or pleasure reation
•Restorative **•Stress Reduction**	Ali, B., Al-Wabel, N. A., Shams, S., Ahamad, A., Khan, S. A., & Anwar, F. (2015). Essential oils used in aromatherapy: A systemic review. Asian Pacific Journal of Tropical Biomedicine, 5(8), 601–611.	natural olfactory has positive impact on treatment of central nervous system disorder.
	Alvarsson, J., S. Wiens & M. Nilsson (2010). Stress Recovery during Exposure to Nature Sound and Environmental Noise. *International Journal of Environmental Research and Public Health, 7* (3), 1036-1046.	nature sounds accelerates physiological and psychological restoration up to 37%
	Applebaum, D., Fowler, S., & Fiedler, N. (2010). The impact of environmental factors on nursing stress, job satisfaction & turnover intention. *The Journal of Nursing Administration, 40*(7-8), 323–328.	environmental factors of odor, noise, light, and color and influence stress, job satisfaction, and turnover intention.
	Baker, C. F. (1984). Sensory overload and noise in the ICU: Sources of environmental stress. Critical Care Quarterly, 6(4), 66-80.	noise and disturbance lead to stress
	Itai T, Amayasu H, Kuribayashi M, Kawamura N, Okada M, Momose A, Tateyama T, Narumi K, Uematsu W, Kaneko S (2000). Psychiatry Clinic Neuroscience; 54(4):393-7.	scent from japanese wood specie called Hiba demonstrated to significantly decrease depression and anxiety in chronic patients.
	Jahncke, H., S. Hygge, N. Halin, A.M. Green, & K. Dimberg (2011). Open-Plan Office Noise: Cognitive Performance and Restoration. *Journal of Environmental Psychology, 31,* 373-382.	nature sounds reduce cognitive fatigue and helps motivation.
	Matsubara, E., Tsunetsugu, Y., Ohira, T., & Sugiyama, M. (2017). Essential Oil of Japanese Cedar (Cryptomeria japonica) Wood Increases Salivary Dehydroepiandrosterone Sulfate Levels after Monotonous Work. International Journal of Environmental Research and Public Health, 14(1), 97.	Japanese Cedar also has the benefits of reduction anxiety and stress responses together with a general improvement of mental health.
	Takeda, A., Watanuki, E., & Koyama, S. (2017). Effects of Inhalation Aromatherapy on Symptoms of Sleep Disturbance in the Elderly with Dementia. Evidence-Based Complementary and Alternative Medicine, 2017, 1–7.	wood scent assist in the sleep hormones.
•Cognition Improvement	Herzog, T.R. & A.G. Bryce (2007). Mystery and Preference in Within-Forest Settings. Environment and Behavior, 39 (6), 779-796.	mystery activate our curiosity and improves cognition.
	Kandel, E.R., J.H. Schwartz, T.M. Jessell, S.A. Siegelbaum, & A.J. Hudspeth (2013). *Principles of Neural Science,* Fifth Edition. New York: McGraw Hill.	perception of the senses lead unconscious processing of information resulting in behavior improvement.
	Sowndhararajan, K., & Kim, S. (2016). Influence of Fragrances on Human Psychophysiological Activity: With Special Reference to Human Electroencephalographic Response. Scientia Pharmaceutica, 84(4), 724–751.	sandalwood scent improves productivity and comfortability.

	Vandewalle, G., Collignon, O., Hull, J.T., Daneault, V., Albouy, G., Lepore, F., … Carrier, J. (2013). Blue Light Stimulates Cognitive Brain Activity in Visually Blind Individuals. Journal of Cognitive Neuroscience, 25(12), 2072–2085.	despite the the lack of sight, activity in the cognitive brain were noted.
•**Healing** •**Immune Improvement**	Kim, J.T., C.J. Ren, G.A. Fielding, A. Pitti, T. Kasumi, M. Wajda, A. Lebovits, & A. Bekker (2007). Treatment with Lavender Aromatherapy in the Post-Anesthesia Care Unit Reduces Opioid Requirements of Morbidly Obese Patients Undergoing Laparoscopic Adjustable Gastric Banding. *Obesity Surgery, 17* (7), 920-925.	lavender aromatherapy can be used to reduce the demand for opioids in the immediate postoperative period.
	Kim, S.Y. & J.J. Kim (2007). Effect of fluctuating illuminance on visual sensation in a small office. *Indoor and Built Environment 16* (4): 331–343.	olfactory system process scent and triggers powerful memories.
	Li, Q., M. Kobayashi, H. Inagaki, Y. Wakayama, M. Katsumata, Y. Hirata, Y. Li, K. Hirata, T. Shimizu, A. Nakadai, & T. Kawada (2012). Effect of Phytoncides from Forest Environments on Immune Function. In Q. Li (Ed.). *Forest Medicine* (157-167). ebook: Nova Science Publishers.	olfactory exposure to herbs and oils from trees have positive effect on the healing process and human immune function.

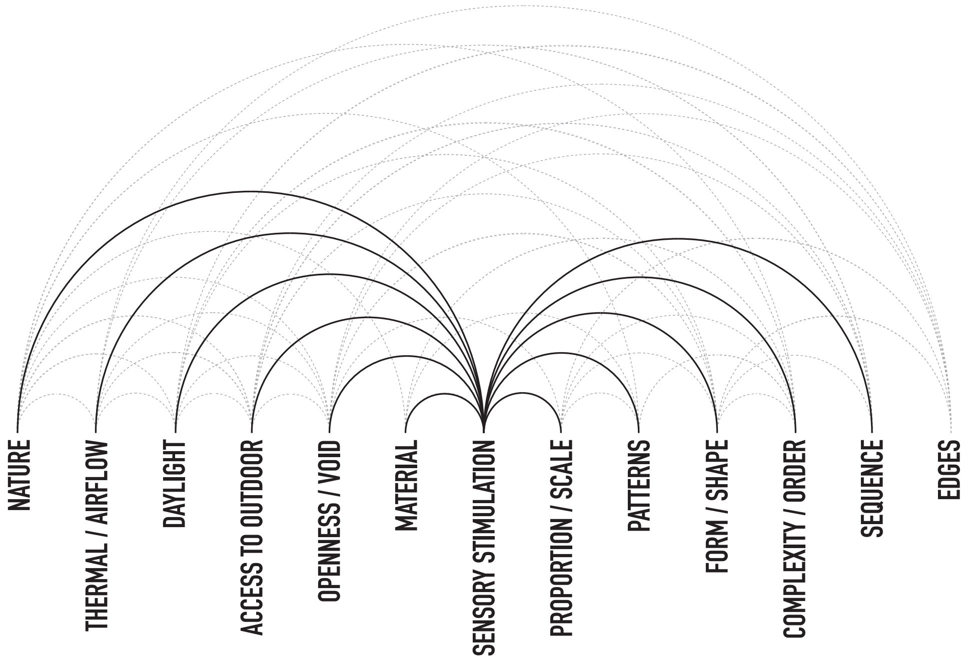

fig. 21 - Diagram of Parameters Interrelations

5.1.3 GROUP 3 – STRUCTURE

In the Structure group, four other parameters were identified: Proportion/Scale, Pattern, Form/Shape and Complexity/Order. Proportion/Scale parameter refers to the relations between ourselves and the design elements and spaces of built environments. Pattern parameter implies repetitions which add intricacy to the spatial experience. Form/Shape parameter entails the distinct spatial outline that facilitates the comprehension of a built environment. Complexity/Order parameter refers to the organization and arrangement of design elements.

fig. 22 - NASP Headquarters Dal Pian Arquitetos Associados

5.1.3.1 PROPORTION / SCALE

WHAT IT IS:

The Proportion/Scale parameter refers to the concept that our body has dimensions which impact how we perceive ourselves towards other individuals, objects and spaces. These relations compose our ideas of proportion and scale, where different levels of scale happen hierarchically to be combined in a harmonic balance. The point is to satisfy human needs and its relation to the environment and to the adequacy of building measurements to human scale and its functions. When considering each space separately within a building, they need to be optimized for specific purposes, and their individual parts - like rooms and circulation - can positively or negatively influence the user. For example, openings that are too difficult to open and close, stairs that are too narrow to be comfortably used, are functioning inappropriately. Considering the building as a whole, spaces need to be in proportion to each other.

OUTCOME:

The presence of essential mathematical harmonies, such as proportion and scale, has been proved to be perceived instinctively by people and to be emotionally fulfilling. Studies show that different ceiling heights interfere in the work performance of the occupant, and the proportion of buildings is suggested to represent different connotations such as authority and respect.[283]

THEORIES AND STUDIES:

Since Aristotle, there was a strong debate about our sixth sense, which refers to how we subconsciously perceive our environment, implying our innate skill to perceive relations such as proportion and scale. In the nineteenth century, however, scientific and behavioural evidence-backed its existence, being a sense which allows us to perceive the extent of our bodies and understand our physical place in the world.[284]

This sixth sense is justified through the activation of our proprioceptor neurons, which are responsible for our motion and body placement. In consequence, proprioception is acknowledged as a fundamental attribute to comprehend our body in space and time, relating to the cognitive perception of our body's position, its extension, as well as the position and movement of objects and other people's body in relation to ourselves. As a physiological sense, it is perceived through the positioning and movement of our organs and it is responsible for our sense of equilibrium and balance.[285] The resulting spatial cognition is conscious and unconsciously communicated through our reflexes, automatic responses, and muscle coordination.[286]

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283 Glenn, M. (n.d.). Architecture Demonstrates Power (Unpublished master's thesis). Bryn Mawr College.
284 Wade, N. J. (2003). The Search for a Sixth Sense: The Cases for Vestibular, Muscle, and Temperature Senses. Journal of the History of the Neurosciences, 12(2), 175–202.
285 Wolff, P., & Shepard, J. (2013). Causation, Touch, and the Perception of Force. Psychology of Learning and Motivation, 167–202.
286 Bergland, Christopher. (2016). We Are, Where We Are: Spatial Cognition Shapes Our Self-Hood. Psychology Today, Sussex Publishers, www.psychologytoday.com/us/blog/the-athletes-way/201605/we-are-where-we-are-spatial-cognition-shapes-our-self-hood.

A lot is discussed about the role of our sixth sense in the experience of space, but Juhani Pallasmaa presented it in an interesting way: "Our capacity to grasp qualitative atmospheric entities of complex environmental situations, without a detailed recording and evaluation of their parts and ingredients, could well be named our sixth sense, and it is likely to be our most important sense in terms, of our existence and survival."[287]

Throughout the history of architecture, many have approached this parameter. Vitruvius wrote in 26 BC about the importance of formal design elements, such as scale and proportion, in relation to the human body, and how these elements should be articulated in architecture by imitating of nature and its system.[288] Palladio, inspired by Vitruvius, came out with harmonious rules of proportion derived from simple mathematical ratios for his projects: he believed there must be symmetry, with a ratio of exact three, five or seven openings as windows on each side, never totaling even numbers. He also proposed a simple geometrical configuration for rooms, with three-fifths of the width in length and height for harmonious proportion and scale. He considered proportion the means of relating to divinity, an inspiration of love, harmony, and appreciation.

The Golden ratio is a system developed to achieve the ideal proportion. It is based on a number called phi, which can be found in many formations in nature. Considered by Plato as a system that unites all natural mathematical relationships, the ratio was identified in many historical buildings, such as the Egyptian pyramids, the Parthenon, Notre Dame, and Taj Mahal. But only in 1509, Luca Pacioli called it as "divine proportion" in his publishing "De Divina Proportione" with illustrations of Da Vinci's Vitruvian Man.[289] The Vitruvian Man summarized Da Vinci's approach to proportion and human scale, which relates to our proximity, capacity and interrelation of reach and touch details, textures and elements from eye-level, which give us the ability to comprehend the element and space towards ourselves. Centuries later, Le Corbusier's "The Modulor" was also a set of ideal architectural proportions formulated based on the human body and natural ratios as to emphasize human proportions in relation to architecture.[290]

More recently, mathematician Nikos Salingaros explains that levels of scale need to follow rules of coherence: a scale factor of 1.5 being too close to comprehend and 15 too confused to assimilate. He adds that mathematical distributions of scale by logarithmic constants together with the Fibonacci sequence, can help the design to satisfy the relation of human scale.[291] He also mentions the applications of the Golden Mean to Architecture as a system to investigate natural scales to enhance space and buildings proportions.[292]

Studies have evidenced that, in order to accommodate people within a humanized scale, room sizes, circulation, transitional spaces, and general building dimensions

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287 Pallasmaa, Juhani. (2014). "Space, Place, and Atmosphere: Peripheral Perception in Existential Experience." Architectural Atmospheres.

288 Vitruvius. (1914). Ten Books on Architecture. Massachusetts: Harvard University Press.

289 Hom, Elaine J. (24 June 2013). "What Is the Golden Ratio?" LiveScience, Purch, www.livescience.com/37704-phi-golden-ratio.html.

290 Corbusier, Le. (1954). The Modulor. Faber and Faber.

291 Salingaros, N.A. (2013). Unified Architectural Theory: Form, Language, Complexity. Portland: Sustasis Foundation.

292 Salingaros, N.A. (2012) "Applications of the Golden Mean to Architecture", Meandering Through Mathematics.

need to be designed for the maximal intention and purpose of inhabitant usability. Findings demonstrated that room proportion has a direct impact on our behavior. Ceiling heights, for example, have a notable effect on our cognition: while high ceilings are linked to freedom and broad thinking, low ceilings are associated to confinement and focus, since there is not enough room to distract the attention.[293] Another study, based on image data, demonstrated a relation between what is considered a beautiful space and ceiling height. Inhabitants tend to prefer rooms with higher ceilings because it allows for more areas of visual engagement, which activate our neuro structures related to visual motion, as well as brain regions related to emotion, pleasure, and reward. As for rooms with lower ceiling heights, they limit the possibilities of exploration and consequently evoke our objectivism in executing tasks by the activation of the cingulate cortex.[294] "Knowing that people's preference for rooms with higher ceilings might be driven by the ability of those spaces to promote visuospatial exploration helps partly explain why people opt to live in such spaces, despite the fact that they cost more to purchase and maintain."[295]

Studies show that different effects of heights can be used to strengthen the ability of concentration or encourage creativity in children. Children in healthcare exposed to medication and/or dealing with trauma usually experience difficulties in learning and lack of concentration. Spaces designed for learning, which have lower ceilings, help on concentration and attention. On the other hand, if to stimulate creativity is the goal, higher ceilings encourage broad thinking. [296]

Experiments comparing real spaces and virtual spaces using virtual reality technologies (VR), presented findings on the different aesthetic illusions in large spaces and narrow spaces based on self scale. It demonstrated that spatial continuity is perceived in the large spaces with and without the VR. The human body seems to point beyond the mere functionality of the metric size cue, with our embodiment enabling us to extend the experience of ourselves into space.[297]

PARAMETER APPLICATION:

The Proportion/Scale parameter can be approached locally or globally when designing a built environment. Locally, numerous design strategies can be used to create and/or divide spaces to help our perception of proportion and scale. Globally, architectural elements have to be designed in relation to us and also in relation to the context. A successful building incorporates both approaches simultaneously. Lighting effects can also influence this parameter. When lighting is properly used, it can create a sense of proportion and scale.

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293 Meyers-Levy, J., & Zhu, R. (2007). The Influence of Ceiling Height: The Effect of Priming on the Type of Processing That People Use. Journal of Consumer Research, 34(2), 174–186.
294 Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., … Skov, M. (2015). Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. Journal of Environmental Psychology, 41, 10–18.
295 Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., … Skov, M. (2015). Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. Journal of Environmental Psychology, 41, 10–18.
296 Meyers-Levy, J., & Zhu, R. (2007). The Influence of Ceiling Height: The Effect of Priming on the Type of Processing That People Use. Journal of Consumer Research, 34(2), 174–186.
297 Pasqualini I, Blefari ML, Tadi T, Serino A and Blanke O (2018) The Architectonic Experience of Body and Space in Augmented Interiors. Front. Psychol. 9:375.

table 10 - Scientific Studies related to Proportion / Scale Parameter

effect	relevant studies	findings
•Health •Mental Health •Wellbeing	Gehl, J. et al. (2006), Close encounters with buildings, Urban Design International 2006-11, p. 29-47	proportion and scale cause comfort and wellbeing when appropriated apply in the connection and encounter of buildings, store and pathways.
	Glenn, M. (n.d.). *Architecture Demonstrates Power* (Unpublished master's thesis). Bryn Mawr College.	the proportion of buildings is suggested to represent different connotations such as authority and respect.
	Hom, Elaine J. (24 June 2013). "What Is the Golden Ratio?" LiveScience, Purch, www.livescience.com/37704-phi-golden-ratio.html.	proportion system results in pleasant feelings.
	Livio, Mario (2003) The Golden Ratio: The Story of PHI, the World's Most Astonishing Number, Broadway Books, New York.	Golden ratio is a proportion system that results in a number called phi and can be found in many pleasant formation in nature.
	Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., … Skov, M. (2015). Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. Journal of Environmental Psychology, 41, 10–18.	Proved relation between beauty space and high ceiling, due to visual exploration.
•Cognition Improvement	Bergland, Christopher. (2016). We Are, Where We Are: Spatial Cognition Shapes Our Self-Hood. Psychology Today, Sussex Publishers, www.psychologytoday.com/us/blog/the-athletes-way/201605/we-are-where-we-are-spatial-cognition-shapes-our-self-hood.	our spatial cognition is related to proprioception, which conscious and unconscious communicate through several neural connections our reflex, automatic response, balance, muscle coordination and our spatial cognition of our body within space.
	Meyers-Levy, J., & Zhu, R. (2007). The Influence of Ceiling Height: The Effect of Priming on the Type of Processing That People Use. Journal of Consumer Research, 34(2), 174–186.	This article demonstrates that variations in ceiling height can prime concepts that, in turn, affect how consumers process information.
	Pasqualini I, Blefari ML, Tadi T, Serino A and Blanke O (2018) The Architectonic Experience of Body and Space in Augmented Interiors. Front. Psychol. 9:375.	Immediate space allows the extention of the body, increasing the embodiment.
	Salingaros, N.A. (2012) "Applications of the Golden Mean to Architecture", Meandering Through Mathematics.	natural scales in order to enhance space and buildings proportions.
	Salingaros, N.A. (2013). Unified Architectural Theory: Form, Language, Complexity. Portland: Sustasis Foundation.	The study adds a mathematical distribution of scales by logarithmic constant together with Fibonacci sequence that can help the design to satisfy human scales relation.
	Wade, N. J. (2003). The Search for a Sixth Sense: The Cases for Vestibular, Muscle, and Temperature Senses. Journal of the History of the Neurosciences, 12(2), 175–202.	We have a sixth sense which allows us to perceive the extent of our bodies and understand our physical place in the world.
	Wolff, P., & Shepard, J. (2013). Causation, Touch, and the Perception of Force. Psychology of Learning and Motivation, 167–202.	Proprioception is acknowledged to be a fundamental attribute of our body to comprehend our body position in space, and the position and movement of objects with other person's body and yourself to your body extensions.

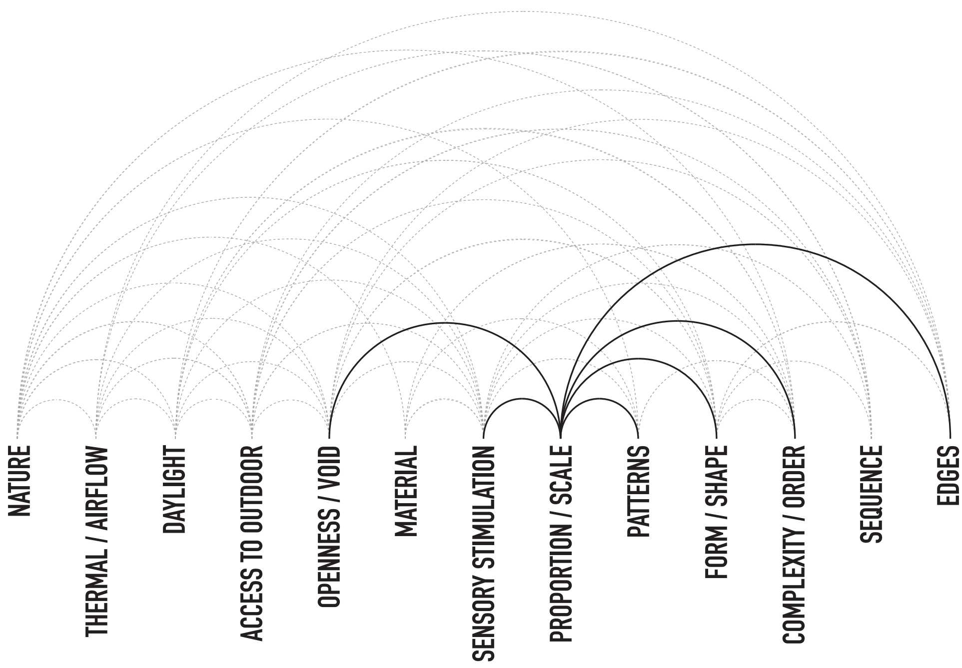

fig. 23 - Diagram of Parameters Interrelations

fig. 24 - Louvre Abu Dhabi - Ateliers Jean Nouvel

5.1.3.2 PATTERN

WHAT IT IS:

Pattern parameter can generally be defined as an approach to assemble complexity. As a design strategy it consists of random or regular repetitions which may change in scale, frequency and color, for example, or may even have a design transformation - as the case of woodcut print "Sky and Water I" from Dutch artist M. C. Esher.[298]. The concept of pattern should not be mistaken with a simple repetition of elements, which results in monotony and is the opposite connotation of patterns. Arrangements found in nature, such as fractals, are good examples of pattern for illustrating balanced repetitions, scaling, and variations. Fractals vary from large to small scale, in almost infinite multiplication, randomness, granulation, and in gradient variability. This is one of the reasons we appreciate and are intrinsically attracted to them. The forms generated by fractals have a wide range of systems and structures that interlock within each other in a growing/shrinking formation, which causes a calming effect on us.

OUTCOME:

The Pattern parameter gives us a contemplative sensation which attracts us without being overwhelming, generating pleasantness. It can be experienced in geometrical forms, outlines, contours, textures, and repetition which resemble the rules of natural patterns. The space with pattern parameter can provide interesting, comfortable, captivating, contemplative and/or fascinating experiences.

THEORIES AND STUDIES:

Humankind has always reproduced essential fractals in art, artifacts and in their construction. Some of them as a mimic of organic patterns, others as rational geometric. Along with architectural history, many professionals have explored patterns in their designs, especially those patterns related to nature. Examples of patterns being used in buildings can be identified throughout different architectural styles, like in Gothic cathedrals, and in many Art Nouveau buildings which carry different arrangements of patterns. However, studies observed that we prefer biomorphic forms and patterns found in nature, which includes the randomness and imperfections easily linked to natural systems. Still, not all fractals spike the same amount of positive cognition.

This theme has been explored by scientists who demonstrated our attraction for organic and biomorphic pattern designs as a metaphorical embodiment of nature and life.[299] Taylor et al. demonstrated through experiments with electroencephalogram that fractal patterns commonly found in nature can decrease stress hormones, resulting in improvement of positive feelings and enhancement of concentration.[300] which goes

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298 Locher, J. L. (2000). The Magic of M. C. Escher. Harry N. Abrams, Inc.
299 Vessel, Edward A. (2012). New York University Center for Brain Imaging. Personal communication with the authors.
300 Taylor, R.P., (2006). Reduction of Physiological Stress Using Fractal Art and Architecture. Leonardo, 39 (3), 245–251.

beyond the calming feeling and enjoyment. A study carried out by NASA showed that subjects respond positively to visual fractals in natural scenes and negatively to non-fractals shapes.[301] And within the natural scenes, we also have preferences: people tend to prefer more dense fractals, like the ones found in forests, than those found in the openness of the savanna.[302] In the same way, a study demonstrated that subjects who were exposed to savanna landscape images of the growing fractals of tree branches performed better when compared to counterparts who were exposed to geometrical/gray colored images.[303] The pieces of evidence linking pattern ratios and joy are so great that a study suggests that the fractal dimension can even be used to define and measure self serenity.[304] Another paper on how natural systems moderate psychological well-being illustrates that, once you are aware of nature, you have a propensity to strengthen your well-being when in contact with it.[305]

Grant Hildebrand wrote in his book Biophilic Design: "Order alone is monotony", and "complexity alone is chaos."[306] He investigated visual perception and the aesthetic aspect in the complexity of fractal, and concluded that individuals tend to prefer mid-range pattern scale regardless of the design. Nikos Salingaros also wrote on the theme. In "Why Monotonous Repetition is Unsatisfying" he explains that monotonous repetition cannot be found in natur, since there is no mechanical reproduction in a cellular scale. Even in examples that seem perfect, like hexagonal honeybee units, small dissimilarity occusr between the units.[307]

A study that validates pattern preferences is related to physiological responses to patterns in built spaces generated by the sunlight. The experiment exposed subjects to various types of patterns generated when the sunlight hit different shading screens. The irregular patterns generated by deviant shading screens were considered more interesting and exciting than the regular patterns generated by continuous shading screens.[308] This is a relevant finding for applications in architecture on how facade elements can influence occupants' subjective reactions. We can relate this study with the komorebi - japanese word to describe the daylight effect permeating through thelraveesof thl treves, resulting in a random effect of light in the space.

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301 James A. Wise, Erika Rosenberg (1986) "The Effects of Interior Treatments on Performance Stress in Three Types of Mental Tasks", Technical Report, Space Human Factors Office, NASA-ARC, Sunnyvale, California.
302 Stephen R. Kellert, Judith Heerwagen, Martin Mador, editors (2008) Biophilic Design: the Theory, Science and Practice of Bringing Buildings to Life (John Wiley, New York).
303 Heerwagen, J., Hase B & (2001). Building biophilia: connecting people to nature. Environmental Design and Construction, April 2001, 30-34.
304 Hagerhall C M, (2005) ``Fractal dimension as a tool for defining and measuring naturalness'', in Designing Social InnovationöPlanning, Building, Evaluating Eds B Martens, A G Keul (Cambridge, MA: Hogrefe & Huber) pp 75 ^ 82.
305 Zhang, J. W., Howell, R. T., & Iyer, R. (2014). Engagement with natural beauty moderates the positive relation between connectedness with nature and psychological well-being. Journal of Environmental Psychology, 38, 55–63.
306 Hildebrand, G. (2008). Chapter 16: Biophilic architectural space. In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), Biophilic Design: the theory, scienc,e and practice of bringing buildings to life (pp. 263-275). Hoboken: John Wiley & Sons.
307 Salingaros NA (2011) Why Monotonous Repetition is Unsatisfying. Meandering Through Mathematics, 2 September 2011.
308 Chamilothori, K., Chinazzo, G., Rodrigues, J., Dan-Glauser, E., Wienold, J., & Andersen, M. (2019). Subjective and physiological responses to façade and sunlight pattern geometry in virtual reality. Building and Environment.

PARAMETER APPLICATION:

Two general approaches can be taken into consideration when approaching the Pattern parameter. One approachiseapplying design strategies through the use of ornamentation, and the other approachise design strategies applied through the use of structural systems. Patterns can be applied in the micr- scale of construction details, and in the macro scale of a building structure, or in the urban system of a neighborhood or a city. Each design application has its peculiarities depending nf each desire, locatio,n and aspects. You can find Pattern application in the streets, with blocks and path designs, in building forms and elements, in the arrangement of building systems, through paneling, tiling, and texture.

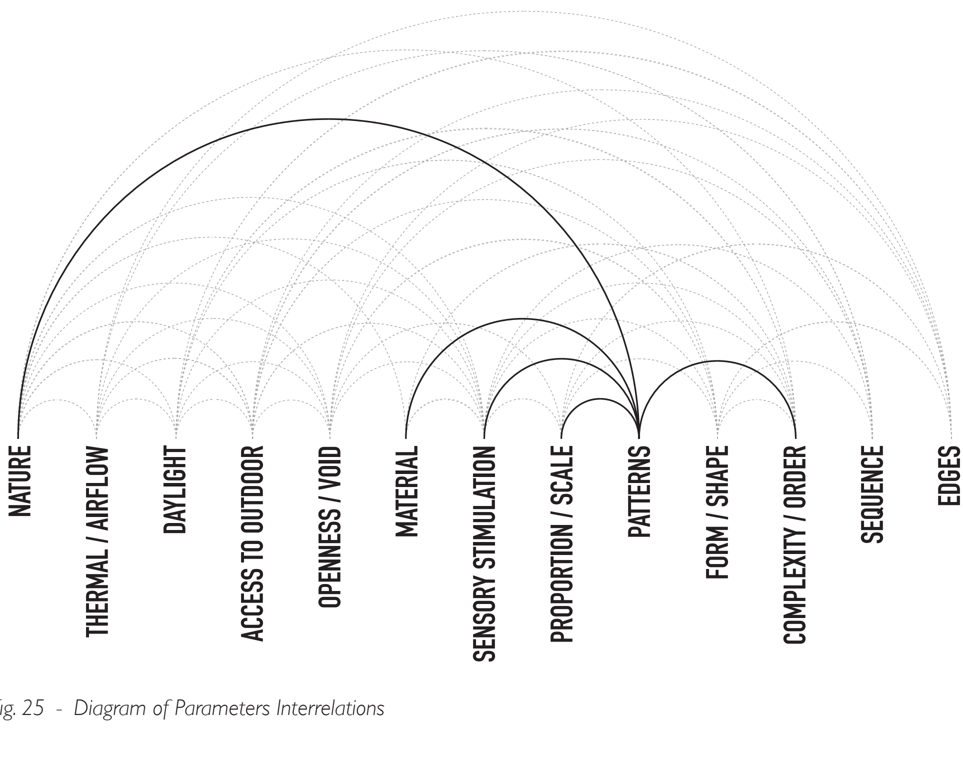

fig. 25 - Diagram of Parameters Interrelations

table 11 - Scientific Studies related to Pattern Parameter

effect	relevant studies	findings
•Health •Mental Health •Wellbeing	Chamilothori, Kynthia, et al. (2018) "Façade Design and Our Experience of Space: the Joint Impact of Architecture and Daylight on Human Perception and Physiological Responses." *Light Symposium 2018 - Light and Architecture: Multi-Sensory Experience.*	The results demonstrate the importance of façade and daylight characteristics, showing preference for irregularity.
	Daykin, N., Byrne E., Soteriou, T., & O'Connor, S. (2008). The impact of art, design and environment in mental health care: A systematic review of the literature. *Journal of the Royal Society for the Promotion of Health, 128*(2), 85–94.	artwork with patterns were preffered by the patients resulting in general wellbeing.
	Hagerhall C M, (2005) ``Fractal dimension as a tool for defining and measuring naturalness'', in Designing Social InnovationöPlanning, Building, Evaluating Eds B Martens, A G Keul (Cambridge, MA: Hogrefe & Huber) pp 75 ^ 82.	Great evidences linking pattern ratios and joy.
	Hägerhäll, C.M., T. Purcella, & R. Taylor (2004). Fractal Dimension of Landscape Silhouette Outlines as a Predictor of Landscape Preference. *Journal of Environmental Psychology. 24*, 247-255.	demonstrated connection to natural settings which lead to general weelbeing.
	Hildebrand, G. (2008). Chapter 16: Biophilic architectural space. In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), Biophilic Design: the theory, science and practice of bringing buildings to life (pp. 263-275). Hoboken: John Wiley & Sons.	"Order alone is monotony", and "complexity alone is chaos". Appropriated combination leads to positiviness.
	Hosey, L. (2012). The Shape of Green: Aesthetics, Ecology, and Design. Washington, DC: Island Press. pp216	Human attraction to natural aesthetics.
	James A. Wise, Erika Rosenberg (1986) "The Effects of Interior Treatments on Performance Stress in Three Types of Mental Tasks", Technical Report, Space Human Factors Office, NASA-ARC, Sunnyvale, California.	Fractals pattern produce positive feelings
	Joye, Y. (2007). Architectural Lessons From Environmental Psychology: The Case of Biophilic Architecture. *Review of General Psychology, 11* (4), 305-328.	natural patterns improve attention and wellbeing
	Joye, Y. (2007). Fractal Architecture Could Be Good for You. Nexus Network Journal, 9(2), 311–320.	fractal patterns induce general good sensation and wellbeing
	Michael Mehaffy & Nikos Salingaros (2012) "Scaling and Fractals", Metropolis, 28 May. Reprinted as Chapter 6 of Design for a Living Planet, Sustasis Press, Portland, Oregon (2015).	Ornament as a means to apply patterns.
	Salingaros NA (2011) Why Monotonous Repetition is Unsatisfying. Meandering Through Mathematics, 2 September 2011.	natural patterns follow rules which results in confort and wellbeing. while, monotonous repetition lead to boredom.
	Stephen R. Kellert, Judith Heerwagen, Martin Mador, editors (2008) Biophilic Design: the Theory, Science and Practice of Bringing Buildings to Life (John Wiley, New York).	dense patterns are preferred.
	Vessel, Edward A. (2012). New York University Center for Brain Imaging. Personal communication with the authors.	natural patterns induce wellbeing.
	Zhang, J. W., Howell, R. T., & Iyer, R. (2014). Engagement with natural beauty moderates the positive relation between connectedness with nature and psychological well-being. Journal of Environmental Psychology, 38, 55–63.	fractal patterns lead to natural connection with positive and wellbeing outcome.
•Restorative •Stress Reduction	Chamilothori, K., Chinazzo, G., Rodrigues, J., Dan-Glauser, E., Wienold, J., & Andersen, M. (2019). Subjective and physiological responses to façade and sunlight pattern geometry in virtual reality. Building and Environment. doi:10.1016/j.buildenv.2019.01.009	participants showed a larger decrease in heart rate while exposed to the Irregular condition compared to regular Blinds.
	Hägerhäll, C.M., T. Laike, R. P. Taylor, M. Küller, R. Küller, & T. P. Martin (2008). Investigations of Human EEG Response to Viewing Fractal Patterns. *Perception, 37,* 1488-1494.	EEG response demonstrated that fractals generated the maximal alpha response in the frontal region, consistent with the hypothesis that they are most restorative and relaxing.
	Salingaros, N.A. (2012). Fractal Art and Architecture Reduce Physiological Stress. *Journal of Biourbanism, 2* (2), 11-28.	positively decrease stress level with general wellbeing.
	Taylor, R.P., (2006). Reduction of Physiological Stress Using Fractal Art and Architecture. Leonardo, 39 (3), 245–251.	patterns decrease stress hormones
•Cognition Improvement	Heerwagen, J., Hase B & (2001). Building biophilia: connecting people to nature. Environmental Design and Construction, April 2001, 30-34.	Natural patterns improve cognition.

fig. 26 - JIKKA Issei Suma

5.1.3.3 FORM / SHAPE

WHAT IT IS:

Form/Shape parameter entails the predominant outline of an object and its limits, implying the interpretation/comprehension of a building as an object. Shapes can have pure or complex forms, some shapes can go through transformations which result in unique forms. In regards to this parameter, an ideal shape is when we easily understand its wholeness defined usually by its boundaries. Nonetheless, some complex forms might not have clear boundaries, but can still be perceivde as a whole. With this established, the importance of Form/Shape lays in our brain's clear process in recognizing it as n unit, while complicated forms demand more energy and may even induce anxiety and disturbance.

OUTCOME:

Studies have shown that people tend to feel more comfortable and welcomed in convex spaces, and uncomfortable and threatened from in spaces with sharp angles and sticking elements. Overall, harmonic and symmetrical spatial compositions transpire calmness and order, and opposing chaotic and challenging shapes requires more effort to understand,e specially those that defy gravityase big cantilever, can lead to people feeling disturbed. Also, we tend to identify with shapes and forms that we recognize more easily.

THEORIES AND STUDIES:

Research has shown that our brainsc no quickly process an object as a whole. In a study where individuals had their brain scanned while observing more than 200 objects of different shapes, researchers noted that when sharp-angle objects were shown, there was a significany activation in the amygdala, than compared to the curved ones. As the amygdala is linked to a part of the brain involved withthe processing of fear, it was concluded that people like shar- angled objects significantly less than they like objects with curved contours.[309] A studied from 1924, had already demonstrated that almost all of the 500 individuals invariably linked curves to calmness and angles to power and agitation, and implied that these responses are biologically intrinsic from the need to fast responsiveness to new encounters.[310] These findings were reinforced by advancements in neuroscience decades later, with studies that confirmed our preferences for curves also in built spaces. By using functional magnetic resonance imaging to analyze individuals while observing two hundred architectural environments, an experiment demonstrated that participants were more likely to judge spaces as beautiful if they were curvilinear than rectilinear. "Neuroanatomically, when contemplating beauty, curvilinear contour activated the anterior cingulate cortex

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309 Bar, M., & Neta, M. (2007). Visual elements of subjective preference modulate amygdala activation. Neuropsychologia, 45(10), 2191–2200.

310 Poffenberger, A. T., & Barrows, B. E. (1924). The Feeling Value of Lines. Journal of Applied Psychology, 8(2), 187-205.

exclusively, a region strongly responsive to the reward properties and emotional salience of objects."[311] Grant Hildebrand theorized that we prefer curves rather than sharp edges due to the enjoyment of perceiving the contours trajectories.[312] And in the study "Humans prefer curved objects", researchers reinforced that sharp contours, transitions and objects lead to a sense of threat and alertness[313], demonstrating that shape and form have a critical influence on our attitude toward a built space.

Features within shape and form also influence our attitude toward a built space. The cognitive process of quickly processing an object as a whole relates to our surviva, and is the reason we can easily see faces in many objects and even in simple lines as to be alert of dangerous situations. This phenomenon, called pareidolia, is related to the Shape and Form parameter because studies have shown that people can easily identify faces in buildings facades. An interesting study was developedatn the University of Newcastle related to our cognitive interpretation of building facades. Researchers developed a software capable of identifying face detection in buildings and link it to emotional expression while individuals perceived them. They used two distinct architectural style houses; one was Villa Savoye from Le Corbusier and the other was Robie House from Frank Lloyd Wright. Villa Savoye was built in 1929 and has no ornaments with a clean white geometry box-liked, with flat roof and terrace. And Robie House was built in 1909 and has a complexity of textures, materials and pitched roof. The software was able to find many face-like images in both houses, and both were read as being angry, with Robie House being a bit less angry than Villa Savoye. The findings prove the link between architectural form/shape and people's psychological responses.[314] Psychological responses unconsciously happen towards a built space, but through researc,h these connectionsc no be demonstrated: why we feel invited and welcomed by a space, while we feel sad, threatened and anxious by others. It was also scientifically proven in another study that people walk faster in front of blank facades in comparison to open/intricate facades, which they even make pauses to better understand what is happening.[315]Thesepi ces of eevidence emphasizs the strong impact architects have on the emotional lives of not only the inhabitants of their designs, but also the lives of everyone who passes in front it, and even of a whole neighbor and a city.

PARAMETER APPLICATION:

Design strategies to approach Form and Shape parameter should consider the volumetric compositional qualities of the building as a whole, as well as how its features contribute at composing this whole. Preference to curved shapes should be considered when aiming to design built spaces that promote the sense of serenity, and angular shapes to promote the sense of excitement.

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311 Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modrono, C., … Skov, M. (2013). Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. Proceedings of the National Academy of Sciences, 110(Supplement_2), 10446–10453.

312 Hildebrand, G. (2008). Chapter 16: Biophilic architectural space. In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), Biophilic Design: the theory, science and practice of bringing buildings to life (pp. 263-275). Hoboken: John Wiley & Sons.

313 Bar, M., & Neta, M. (2006). Humans Prefer Curved Visual Objects. Psychological Science, 17(8), 645–648

314 Ostwald, Michael, Kenny Hong, and Stephan Chalup. (2013). "Pareidolia Analysis of Architecture - ANFA."

315 Gehl, J. et al. (2006), Close encounters with buildings, Urban Design International 2006-11, p. 29-47

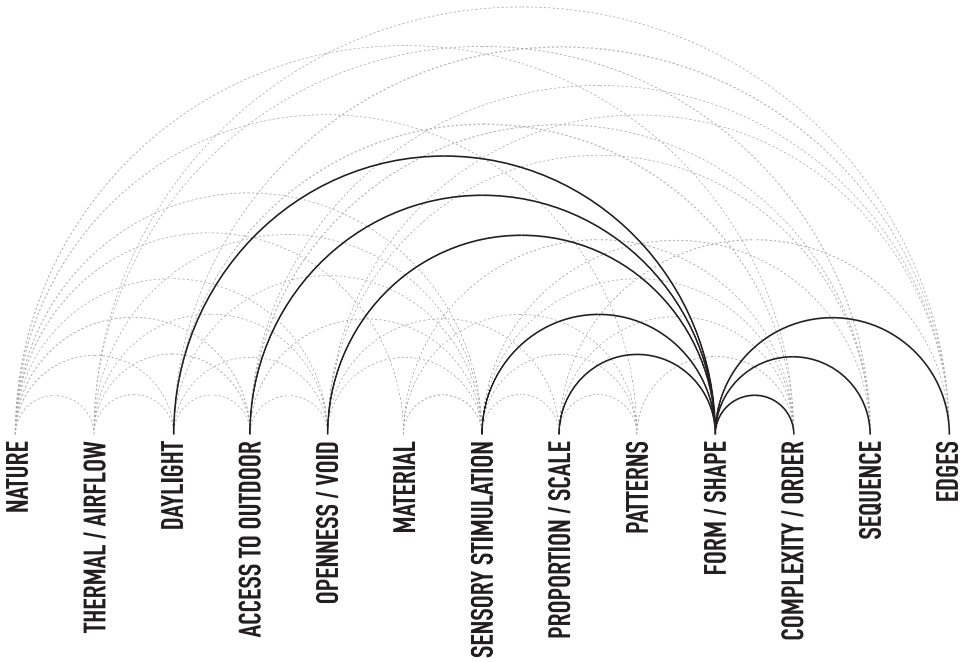

fig. 27 - Diagram of Parameters Interrelations

table 12 - Scientific Studies related to Form / Shape Parameter

effect	relevant studies	findings
•Wellbeing	Banaei M, Hatami J, Yazdanfar A and Gramann K (2017) Walking through Architectural Spaces: The Impact of Interior Forms on Human Brain Dynamics. Front. Hum. Neurosci. 11:477.	The results revealed a strong impact of curvature geometries on activity in the anterior cingulate cortex
	Bar, M., & Neta, M. (2006). Humans Prefer Curved Visual Objects. Psychological Science, 17(8), 645–648.	sharp transitions in contour might convey a sense of threat, and therefore trigger a negative bias. while angled or curved has a critical influence on people's attitude toward that object.
	Bar, M., & Neta, M. (2007). Visual elements of subjective preference modulate amygdala activation. Neuropsychologia, 45(10), 2191–2200.	Among 200 different shapes, researchers noted a significantly activation in the amygdala, which is a part of the brain involved with processing of fear, when sharp-angle objects were shown compared to the curved ones.
	Dazkır, S. S., (2010). "Emotional Effect of Curvilinear vs. Rectilinear Forms of Furniture in Interior", Oregon State University.	The settings with only curvilinear lines/forms would elicit more pleasant and arousal emotions than would the settings with only rectilinear lines.
	Gehl, J. et al. (2006), Close encounters with buildings, Urban Design International 2006-11, p. 29-47	People walk faster in front of monotonous, bored and unhappy spaces provided by the blank facades, compared to a lively, diverse, open and original facades, which they even make pauses to better understand what is happening.
	Hildebrand, G. (2008). Chapter 16: Biophilic architectural space. In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), Biophilic Design: the theory, science and practice of bringing buildings to life (pp. 263-275). Hoboken: John Wiley & Sons.	we prefer curves rather than sharp edges due to the enjoyment of perceiving the contours trajectories.
	Nejad, K. M. (2007). "Curvilinearity In Architecture: Emotional Effect Of Curvilinear Forms In Interior Design", Texas A&M University.	people described places with curvatures as pleasant, relaxed and friendly.
	Ostwald, Michael, Kenny Hong, and Stephan Chalup. (2013). "Pareidolia Analysis of Architecture - ANFA."	The findings prove the link between emotions and architecture.
	Poffenberger, A. T., & Barrows, B. E. (1924). The Feeling Value of Lines. Journal of Applied Psychology, 8(2), 187-205.	We fell calmer and empathy with curves while anxiety and threat with sharp angles.
	Shemesh A, Talmon R, Karp O, Amir I, Bar M & Grobman YJ (2016) Affective response to architecture – investigating human reaction to spaces with different geometry. Architectural Science Review,	square shape leads to efficiency and safetness, curvy to pretty, sharp to interesting, and round to interesting emotions.
	Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modrono, C., … Skov, M. (2013). Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. Proceedings of the National Academy of Sciences, 110(Supplement_2), 10446–10453.	Participants were more likely to judge spaces as beautiful if they were curvilinear than rectilinear.
•Cognition Improvement	Pasqualini I, Blefari ML, Tadi T, Serino A and Blanke O (2018) The Architectonic Experience of Body and Space in Augmented Interiors. Front. Psychol. 9:375.	Depth feelings emerge through different modulations, on the one hand through stimuli presented in peripersonal space of a physical or virtual body, or, somesthetic processes linked to the perception of a volume and continuity.

fig. 28 - Bloomberg's European HQ Foster + Partners

5.1.3.4 COMPLEXITY / ORDER

WHAT IT IS:

Complexity and Order parameter relates to our preference in views of fractals, our physiological reaction to fractals complexity and order that we can find with abundance in nature. Researches with fractals demonstrated that its structural design order, symmetry, sub symmetrie,s and hierarchy lead to behavior improvement through sensory stimulus, affecting neurologic and physiologic aspects. It results in an enriched environment with spatial hierarchy resembling what we experience in nature.

Our visual processing and interest in scenes, object,s and details rely on how our retina obtain them. In the built environment these aspects have importance on also, how focal, center and composition they are. The visual aspect is limited but it is intrinsically related to all the senses we use to experience the built environment. We are able to apprehend complexity and order and feel intensely pleasurable through our visual and neurological systems subdivided in symmetries, variations, systematization, hierarchy, alternation, repetition, rhythm, contrast, difference, gradient, similarity, simplicity, inner calm, interlock, ambiguity, grouping, organization, arrangement, uniformity, regularity, breaking down, decomposition and degeneration. However, when we experience disorder, confusion or monotony, the feeling of tedium, boredom and banality arise, causing unwell, repulsive and poorly outcome. As exemplified: "when we are unable to detect the horizon in a way that agrees with the balance systems in our inner ears, we get motion sickness, and we can become physically ill"[316]

OUTCOME:

Complexity and Order parameter transmit an experience of enrichment, happines,s and engagement when we appreciate it. It is an excitement condition without being monotonous or overwhelming. It is also a smart combination of hierarchy, scal,e and order to inspire deep knowledge of the space. Apparent structural elements, for example, help us to understand the built space by transmitting the idea that everything is in the right place, with each element performing their structural tasks. This parameter is related to the amount of information, diversit,y and unity; it gives a sense that everything is working simultaneously well, resultingin an entity of harmony within complexity.

THEORIES AND STUDIES:

Perhaps, Palladio had a sense about our neurological reactions when in 1570, he came out with harmonious rules of proportion derived from simple mathematical ratios for his projects; there must be symmetry, with ratio of exact three, five or seven openings on each side and not total of even number, simple geometrical configuration rooms;

316 Salingaros, Nikos Angelos, and Christopher Alexander. (2013). Unified Architectural Theory: Form, Language, Complexity: a Companion to Christopher Alexanders "The Phenomenon of Life: the Nature of Order, Book 1". Sustasis Foundation.

and three-fifths of the width in length and height. He considesr the proportion and its relation to the entity, na inspiration of love, harmon,y and appreciation even if the materials and place conditions were not ideal.

Hildebrand wrote in a chapter in Biophilic Design "Order alone is monotony", and "complexity alone is chaos"[317]. He investigated visual perception researches about the interesting aesthetic aspect fn the complexity of fractals. And concluded that individuals tend to prefer mid-range pattern scale regardlessof the design, also these patterns influencethe viewer`s cognitive aspect.[318] Salingaros demonstrated in his research that proportions vary from 1.3 to 1.8 according to the condition.[319]

Researchers have demonstrated that we feel calmer looking at symmetrical elements which trigger more smiling muscles if compared to random components and arrangements.[320] Hermann Weyl in his book "Symmetry"[321] explain from a historical, philosophical and biological outlook, how beauty is connected to symmetry and harmony with a straight link with natural word. Wolfflin in his extraordinary doctoral dissertation from 1886: "Prolegomena to a Psychology of Architecture" which was translated to a book, restate that order is a "basic condition of organic life".[322] And in the paper "The Science of Art, A Neurological theory of Aesthetic Experience" from the neuroscientist Ramachandran, he mentioned that "We have a built-in aesthetic preference for symmetry" [323].

First published in 1966, Robert Venturini wrote the awarded book "Complexity and Contradiction in Architecture"[324] which he manifested the uprising postmodern revolt averse purism of modern architecture, with hundreds of architectural photographs to support his opinion about how to have an enriched architecture.

In the 190's, psychologist Donald Hebb impacted the neuropsychology with his findings on neurons operations process. He claimed that an enriched environment with complexity and order not only improves intellectual capacity but it is also a demand for the development of animal intelligence. He found out that rats were notably mental greater when lived in enriched and stimulinged environments compared to the ones from inhospitable settings[325]. Posterior studies realized by psychologist Mark Rosenzweig in 1960 demonstrated the enriched rats were not only better in the probl-m solving tasks but they also had a bigger neocortex and advanced synaptic neurons connections.[326] Rosenzweig and his team proved that enriched environments

317 Hildebrand, G. (2008). Chapter 16: Biophilic architectural space. In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), Biophilic Design: the theory, scienc,e and practice of bringing buildings to life (pp. 263-275). Hoboken: John Wiley & Sons.

318 Taylor, R.P., (2006). Reduction of Physiological Stress Using Fractal Art and Architecture. Leonardo, 39 (3), 245–251

319 Salingaros, N.A. (2012). Fractal Art and Architecture Reduce Physiological Stress. Journal of Biourbanism, 2 (2), 11-28

320 Makin, T. R., Holmes, N., Brozzoli, C. and Farnè, A. (2012) Keeping the world at hand: rapid visuomotor processing for hand object interactions. Experimental Brain Research, 219 (4). 421428.

321 Weyl, Hermann. (1952). Symmetry. Princeton University Press.

322 Wölfflin Heinrich, and Michael Selzer. (2017). Prolegomena to a Psychology of Architecture. KeepAhead Books.

323 Ramachandran, V. S., & Hirstein, W. (1999). The science of art: A neurological theory of aesthetic experience. Journal of Consciousness Studies, 6(6-7), 15-51.

324 Venturi, Robert. (1977). Complexity and Contradiction in Architecture. Museum of Modern Art; Distributed by New York Graphic.

325 Hebb, D. O. (1947). The effects of early experience on problem-solving at maturity. Amer. Psychologist, 2, 306-307.

326 Renner, Michael J., and Mark R. Rosenzweig. (1988). Enriched and Impoverished Environments: Effects on Brain and Behavior. Springer.

leds to changes in the structures of the brain.[327] Concluding that our intelligence may have evolved from decoding the environment information.[328]

According to the scientist Nancy Kanwisher and her affiliates, when individuals look at complex scenes, the parahippocampal place area (PPA) - the region related to visual scenes, memory and retrieval; has intenfisier activity compared to simple and banal sight.[329] In another study developed by R. Kihsinger et al., it is showed that fishes raised in artificial minimalist tanks have smaller brain compared to the ones raised in a more complex and natural setting.[330] In a similar study, A. Sale e tal. verified that mies had an improved visual system in complex enhanced environments compared to minimalist settings.[331] And G. Kempermann et a., found more hippocampal neurons in mies living in an enriched environment.[332]

These theories validate the discoveries from the psychologist Donald Hebb, with Carnegie Task Force publishing in 1997 a report alerting that a poor environment causes permanent bad setbacks on the rearing of children, especially if compared to those whareis raised in enriched environments.[333]

Many other studies suggest that stimulating environments can improve our cognitive behaviour. This is something broadly studied with natural settings and cognition. However, this stimulus should be careful design for the user experience, by achieving the desbdle degree of excitement without being overwhelming and very challenging. Complexity / Order factors are essential to determine if space has the potential to provide such stimulation. However, environments which do not provide minimum positive incentive are prejudicial for your cognition and quality of life.

In 2006, Jan Gehl, who is a Danish urbanist who focused on improving the quality of urban life, studied people's behavior and reported that when walking in front of blank, unpleasant and monotony facade they tend to look for more interesting scene, walk faster, make less pause and look down compared to open and active facades, in which they try to understand if there is something interesting happening in the visual campus. This led to arousal and happiness in the individuals, compared to the boredom of the blank facade. That being the case, we tend to prefer interesting and intricacy locations, which make sense, since we evolved in different degrees of complty environments.[334]

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327 Rosenzweig MR, Krech D, Bennett EL (1960). A search for relations between brain chemistry and behavior Psychol Bull, 57, pp. 476-492

328 Rosenzweig, M. R., & Bennett, E. L. (1996). Psychobiology of plasticity: Effects of training and experience on brain and behavior. Behavioural Brain Research, 78(1), 57-65.

329 Kanwisher, N., et al., The Parahippocampal Place Area: Recognition, Navigation, or Encoding?, Neuron 23 (1999), pp. 115–125.

330 Kihslinger, R. L. (2006). Early rearing environment impacts cerebellar growth in juvenile salmon. Journal of Experimental Biology, 209(3), 504–509.

331 Sale, A., Putignano, E., Cancedda, L., Landi, S., Cirulli, F., Berardi, N., & Maffei, L. (2004). Enriched environment and acceleration of visual system development. Neuropharmacology, 47(5), 649–660.

332 Kempermann, G., Kuhn, H. G., & Gage, F. H. (1997). More hippocampal neurons in adult mice living in an enriched environment. Nature, 386(6624), 493–495.

333 Meeting the Needs of Our Youngest Children(Abridged Version ed., Starting Points, Rep.). (1994). New York: Carnegie Corporation.

334 Gehl, J. et al. (2006), Close encounters with buildings, Urban Design International 2006-11, p. 29-47

The environmental psychologist and neuroscientist Colin Ellard, reconducted the study in 2011 using biosensors which could measure biological information as skin conductivity - related to physiological arousal, excitement, interest, and levels of stress on pedestrians and questionnaires asking them how they feel when they passed in front of a market blank facade as well as a commercial lively strip with open doors and windows.[335] The results were unsurprising; people were bored, qitte, passive and unhappy, they also used the words bland, monotonous and passionless to describe the feelings while walking in front of the blank facade. However, at the livelier site, they were animated, chatty and enthusiastic, describing the place as sociable, explained by Colin.[336]

Boring sensation increase sadness, addicti,on and stress disorders according to Ellard. Negativity psychological and cognitive low arousal trigger boredom, which could lead to risky behavior as addictions, stre,ss and aggression, resulting in some way or another an impact on the mortality rates.[337] Many other studies reaffirm this conclusion, emphasizing the consequences of poorly and homogeneous design in our behavior. Owners usually justify their decisions through economic argument as excused of poorly and inadequate designe, specially in suburban developments. Nevertheless, we also can find recurrent design problems in large institutional buildings. Because perhaps the owners could not see the benefits and gains not only to benefits the public space community but the great impact on the productivity and wellbeing of the workers.

According to Colleen Merrifield and James Danckert's work on the psychophysiology of boredom[338], even a short boring episode can alter chemicals in the body leading to stress. Colin Ellard says: "It might seem extreme to say that a brief encounter with a boring building could be seriously hazardous to one's health, but what about the cumulative effects of immersion, day after day, in the same oppressively dull surroundings?"[339]

Since stress can be caused by boredom, according to Merrifield and Danckert`s study[340], and monotony can generate boredom, designers cannot overlook the potential harm their designs can cause. Boredom and monotony are linked to relevant health issues with cortisol and heart-rate increased levels, even compared to sadness. And it could be even worse if we accumulate the everyday influence built environments can produce on us, with monotonous city spaces, boring workplaces, and oppressive apartments.

"Boredom can also lead to risky behaviour. Surveys among people with addictions, including substance and gambling addictions, suggest that their levels of boredom

335 Ellard, Colin. (2015) "Streets with no game", Aeon; https://aeon.co/essays/why-boring-streets-make-pedestrians-stressed-and-unhappy
336 Ellard, Colin. (2015) Places of the HeartT the Psychogeography of Everyday Life. Bellevue Literary Press.
337 Danckert, James, and Colleen Merrifield. (2016) "Boredom, Sustained Attention and the Default Mode Network." Experimental Brain Research, vol. 236, no. 9, pp. 2507–2518.
338 Merrifield, Colleen, and James Danckert. (2013). "Characterizing the Psychophysiological Signature of Boredom." Experimental Brain Research, vol. 232, no. 2, pp. 481–491.
339 Ellard, Colin. (2015). Places of the HeartT the Psychogeography of Everyday Life. Bellevue Literary Press.
340 Merrifield, C. & Danckert, J. Exp Brain Res (2014) 232: 481.

are generally highr, and that episodes of boredom are one of the most common predictors of relapse or risky behaviour.” [341]

“Collectively, studies of both extreme and moderate forms of environmental deprivation provide compelling evidence that boring environments can generate stress, impulsivity, lowered levels of positive affect, and risky behaviour. At this point, we simply don’t know the extent to which such effects might be produced by simple daily exposure to poorly designed urban environments or building interiors because the studies have not yet been done. However, based on well-understood principles of neuroplasticity and on what is known of the effects of deprivation and enrichment in other more extreme settings, along with studies such as those conducted by Gehl and by my research group in several cities worldwide, there is every reason to believe that these sterile, homogeneous environments are exerting a measurable effect on our behaviour, and likely our brains as well. Given this, the prudent design of city streets and buildings is a matter of public health.”[342]

Salingaros describes the importance of repetition within alternation and symmetries together witthe h difference in hierarchy as a way to creatively approach complexity. The alternation promotes contrast which helps the translation of symmetries to s-ubsymmetries nested hierarchically and generating organized complex syste m.[343] With an overall coherence and order, complexity symmetries support each other in well-l balandce design, generating simplicity, uni,ty and inner calm. However, simple does not mean minimal. If we look in nature, simple is achieved with a very sophisticated intrinsic system with a deeply consistent order.[344]

Our enjoyment increases as the complexity of the system increases, and our ability to act and be alive turn us capable of having different aesthetics experiences in environments. “Aesthetic experiences do not just happen; they demand proficiency and effort, like those of a consummate storyteller or performing artist. Ultimately, aesthetics is about growth and mastery, about making one’s way in a world that is both dangerous and delightful—often at the sa metime.”[345]

We tend to enjoy symmetry together with complexity instead of only order, which is unexcited according to Hildebrand; “Order alone is monotony” and “complexity alone is chaos”[346] The fractals complexity are recurrent patterns in nature as in leaves, vegetables, snowflakes and so on. But contrast and equilibriuareis also important to help us distinguish between elements and outline the complexity structue, since the rigid contrasted sectors could also be strongly connected. Mild contrast results in a weaker comprehension of the structure, resulting in a poor design.

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341 Ellard, Colin. (2015). “Streets with no game”, Aeon; https://aeon.co/essays/why-boring-streets-make-pedestrians-stressed-and-unhappy
342 Ellard, Colin. (2015). “Streets with no game”, Aeon; https://aeon.co/essays/why-boring-streets-make-pedestrians-stressed-and-unhappy
343 Salingaros NA (2011) Why Monotonous Repetition is Unsatisfying. Meandering Through Mathematics, 2 September 2011.
344 Salingaros, N. A., et al. (2013). Unified Architectural Theory: Form, Language, Complexity: A Companion to Christopher Alexander’s “The Phenomenon of Life - The Nature of Order, Book 1”: Vajra Books.
345 Averill, J. R., Stanat, P., & More, T. A. (1998). Aesthetics and the environment. Review of General Psychology, 2(2), 153–174.
346 Hildebrand, G. (2008). Chapter 16: Biophilic architectural space. In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), Biophilic Design: the theory, scien,ce and practice of bringing buildings to life (pp. 263-275). Hoboken: John Wiley & Sons.

PARAMETER APPLICATION:

Scales, design qualities, details, surrounding environments, the approach, sequence, could be ways to apply the complexity towards cognitive environments. It can be applied as materials texture, tiling and contours; openings hierarchy; facade lines; building height; counterline and outlines; urban, landscape and building plans; exposed structure and mechanical systems; sequence and flow of people, resources and spaces; variation, combination and placement of plants, fragrances and materials; auditory stimuli; building and construction details; and all aspects of the design.

Visual balance is a principle related to symmetry and order within elements of composition, which also accounts for rhythm in a special rule of recurrence of elements. Symmetry is believed to be appreciated due to our symmetrical body, while rhythm is the organization of various elements.

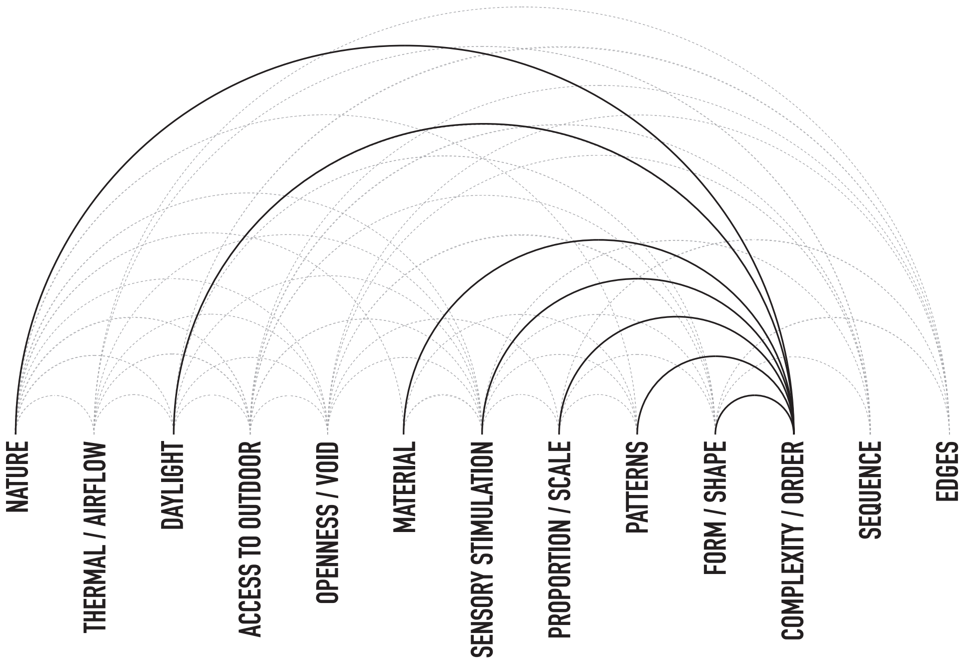

fig. 29 - Diagram of Parameters Interrelations

table 13 - Scientific Studies related to Complexity / Order Parameter

effect	relevant studies	findings
•Health •Mental Health •Wellbeing	Bejan, A. & J.P. Zane (2012). Design in Nature: How the Constructal Law Governs Evolution in *Biology, Physics, Technology, and Social Organization.* New York: Random House First Anchor Books, 304.	Law governs evolution and relates of the occurrence of design in nature.
	Danckert, James, and Colleen Merrifield. (2016) "Boredom, Sustained Attention and the Default Mode Network." Experimental Brain Research, vol. 236, no. 9,, pp. 2507–2518.	monotony leads to boredom.
	Ellard, Colin. (2015) "Streets with no game", Aeon.	Boring cityscapes increase sadness, addiction and disease-related stress.
	Ellard, Colin. (2015) "Streets with no game", Aeon.	people were bored, quite, passive, unhappy, bland, monotonous and passionless to describe the feelings while walking in front of the blank facade. However, at the livelier site, they were animated, chatty, and enthusiastic.
	Ellard, Colin. (2015) Places of the Heart: the Psychogeography of Everyday Life. Bellevue Literary Press.	complexity and order result in general wellbeing and excitement while monotonous cause boredom and sadness.
	Gehl, J. et al. (2006), Close encounters with buildings, Urban Design International 2006-11, p. 29-47	we tend to prefer interesting and intricacy locations, which make sense, since we evolved in different degrees of complexity environments.
	Hägerhäll, C.M., T. Laike, R. P. Taylor, M. Küller, R. Küller, & T. P. Martin (2008). Investigations of Human EEG Response to Viewing Fractal Patterns. Perception, 37, 1488-1494	EEG response demonstrated that fractals generated the maximal alpha response in the frontal region, consistent with the hypothesis that they are most restorative and relaxing.
	Hägerhäll, C.M., T. Purcella, & R. Taylor (2004). Fractal Dimension of Landscape Silhouette Outlines as a Predictor of Landscape Preference. *Journal of Environmental Psychology. 24*, 247-255.	demonstrated complexity connection to natural settings which lead to general weelbeing.
	Hildebrand, G. (2008). Chapter 16: Biophilic architectural space. In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), Biophilic Design: the theory, science and practice of bringing buildings to life (pp. 263-275). Hoboken: John Wiley & Sons.	"Order alone is monotony", and "complexity alone is chaos". Appropriated combination leads to positiviness.
	Makin, T. R., Holmes, N., Brozzoli, C. and Farnè, A. (2012) Keeping the world at hand: rapid visuomotor processing for hand object interactions. Experimental Brain Research, 219 (4). 421428.	We feel calmer looking at symmetrical elements which trigger more smiling muscles if compared to random components and arrangements.
	Merrifield, C. & Danckert, J. Exp Brain Res (2014) 232: 481.	Boredom and monotony are linked to relevant health issues with cortisol and heart-rate increased levels.
	Merrifield, Colleen, and James Danckert. (2013) "Characterizing the Psychophysiological Signature of Boredom." Experimental Brain Research, vol. 232, no. 2, pp. 481–491.	monotony causes boredom, sadness, difficulty to sustain attention and increase cortisol levels.
	Ramachandran, V. S., & Hirstein, W. (1999). The science of art: A neurological theory of aesthetic experience. Journal of Consciousness Studies, 6(6-7), 15-51.	"We have a built-in aesthetic preference for symmetry"
	Salingaros NA (2011) Why Monotonous Repetition is Unsatisfying. Meandering Through Mathematics, 2 September 2011.	complexity and rules result in confort and wellbeing. while, monotonous repetition lead to boredom.
	Salingaros, N.A. (2012). Fractal Art and Architecture Reduce Physiological Stress. *Journal of Biourbanism, 2* (2), 11-28.	complexity and rules result in confort and wellbeing. while, monotonous repetition lead to boredom and stress.
	Salingaros, Nikos Angelos, and Christopher Alexander. (2013). Unified Architectural Theory: Form, Language, Complexity: a Companion to Christopher Alexanders "The Phenomenon of Life: the Nature of Order, Book 1". Sustasis Foundation.	when we experience disorder, confusion or monotony, the feeling of tedium, boredom and banality arise, causing unwell, repulsive and poorly outcome.
	Shemesh A, Talmon R, Karp O, Amir I, Bar M & Grobman YJ (2016) Affective response to architecture – investigating human reaction to spaces with different geometry. Architectural Science Review,	complexity and order cause arousal.
	Weyl, Hermann. (1952). Symmetry. Princeton University Press.	Beauty is connected to symmetry and harmony with a straight link with natural word.
	Wölfflin Heinrich, and Michael Selzer. (2017). Prolegomena to a Psychology of Architecture. KeepAhead Books.	Order is a "basic condition of organic life".
•Restorative •Stress Reduction	Joye, Y. (2007). Architectural Lessons From Environmental Psychology: The Case of Biophilic Architecture. *Review of General Psychology, 11* (4), 305-328.	complexity and order were found to have positive effects on human functioning and can reduce stress.
	Taylor, R.P., (2006). Reduction of Physiological Stress Using Fractal Art and Architecture. Leonardo, 39 (3), 245–251.	cardiovascular, eye-tracking and pupillography responses proved the enourmous benefit in stress reduction.
•Cognition Improvement	Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning.	With regard to the display and decoration, classroom needs to be designed with a quiet visual environment, balanced with a certain level of complexity that relate to the improvement of the pupils' academic achievement

Cassarino M and Setti A (2016) Complexity As Key to Designing Cognitive-Friendly Environments for Older People. Front. Psychol. 7:1329.	complexity environments can benefit cognitive health in older age
Hebb DO (1947) The effects of early experience on problem solving at maturity. American Psychologist 2: 306–307.	environmental complexity and enriched environments improve brain cognition
Kanwisher, N., et al., The Parahippocampal Place Area: Recognition, Navigation, or Encoding?, Neuron 23 (1999), pp. 115–125.	Complex scenes have intensier activity compared to simple and banal sight.
Kaplan, S. (1988). Perception and Landscape: Conceptions and Misconceptions. In J. Nasar (Ed.), *Environmental Aesthetics: Theory, Research, and Applications* (pp. 45– 55). Cambridge, England: Cambridge University Press.	These four informational elements -- coherence, complexity, legibility, and mystery -- provide means of assessing landscape quality that are empirically based while at the same time intuitively meaningful.
Kempermann, G., Kuhn, H. G., & Gage, F. H. (1997). More hippocampal neurons in adult mice living in an enriched environment. Nature, 386(6624), 493–495.	more hippocampal neurons in mices living in an enriched environment.
Kihslinger, R. L. (2006). Early rearing environment impacts cerebellar growth in juvenile salmon. Journal of Experimental Biology, 209(3), 504–509.	fishes raised in artificial minimalist tanks have smaller brain compared to the ones raised in a more complex and natural setting.
Renner, Michael J., and Mark R. Rosenzweig. (1988) Enriched and Impoverished Environments: Effects on Brain and Behavior. Springer.	environmental complexity is one of the earliest methods utilized in the study of neural plasticity.
Rosenzweig MR, Krech D, Bennett EL (1960). A search for relations between brain chemistry and behavior Psychol Bull, 57, pp. 476-492	enriched environments leads to changes in the structures of the brain.
Rosenzweig, M. R., & Bennett, E. L. (1996). Psychobiology of plasticity: Effects of training and experience on brain and behavior. Behavioural Brain Research, 78(1), 57-65.	our intelligence may have evolved from decoding the environment information.
Sale, A., Putignano, E., Cancedda, L., Landi, S., Cirulli, F., Berardi, N., & Maffei, L. (2004). Enriched environment and acceleration of visual system development. Neuropharmacology, 47(5), 649–660.	mices had an improved visual system in complex enhanced environments compared to minimalist settings.
Schooler, C. (1984). Psychological Effects of Complex Environments During the Life Span: A Review and Theory. Intelligence 8:259-281.	environmental complexity leads to effective cognitive functioning across all stages of the life span.
Tsunetsugu, Y., Miyazaki, Y. & Sato, H. (2005b). Visual effects of interior design in actual- size living rooms on physiological responses. Building Environ, Vol.40, pp. 1341- 1346	complexity leads to excitement and improves cognition.

5.1.4. GROUP 4 - SPATIAL IDENTITY

Within Spatial Identity group, two other parameters were distinguished: Sequence and Edges. The Sequence parameter concerns interrelations as a means of connecting individuals and individuals with space. The Edges parameter relates to limits which generate spatial boundaries.

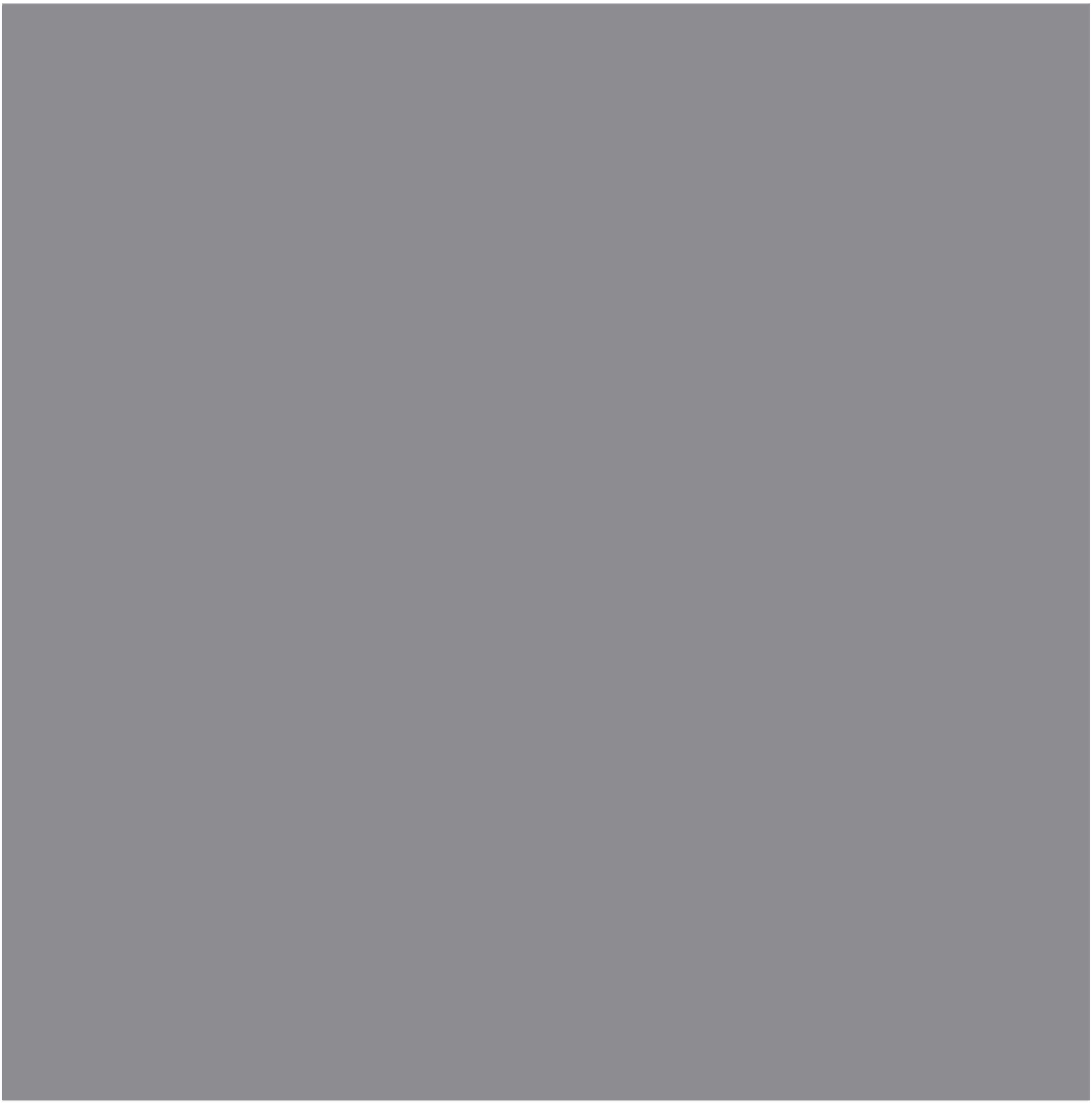

fig. 30 - Psychiatric Center - Vaillo - Irigaray Architects - Galar - Vélaz

5.1.4.1 SEQUENCE

WHAT IT IS:

The sequence parameter concerns two spatial concepts: storytelling and wayfinding. Storytelling entails the interrelations of decision, activity and uncertainty, within the spatial experience. And wayfinding entails means of connecting individual among themselves, and individuals with space. The sequential spatial flow that promoste storytelling and wayfinding within a built environment stimulates our retinal cells' and promote our sense of excitement, existence, connecti,on and survival.

OUTCOME:

To experience a built space gradually allows the experience of discovery, and is a strategy of storytelling which promotes curiosity and excitement in users ae space is slowly unveiled. The sequential experience of space also encourages decision making and se-f movement which improves perception and personality.

Studies demonstrated that simple design interventions leds to easier navigation and wayfinding, which promote positive psychological conditions, increase wellbeing and sociability. The hesitation feeling of being lost causes stress and lack of confidence, and coherent navigation routes in built environments improve accessibility and resuts in a sense of freedom. The possibility of diverse trajectories also stimulates active learning and cognitive map processing. Furthermore, appropriate encouragement oftilizationse of staircases for space connectivity promotes physical activity, mobility, overall heal,th and wellbeing, as well aan s opportunity for more social interactions.

THEORIES AND STUDIES:

People tend to understand space in relation to themselves. This relationship promotes spatial cognition, coordination and navigation, and the sense of connection to space.[347] The spatial experience can enhance this relationship through sequential flows.

Storytelling is one approach to sequential flw, and entails the interrelations of decision, activi,ty and uncertainty in the spatial experience. Consequently, different design approaches to this sequential flow results in different neuro reactions and body stimulation. Gradual exposure of built environments and gradual transition spaces can intentionally promote excitement and physical effects. A sequential flow of spaces generates a feeling of ambiguity for not understanding one's exact position in a built environment, but also generates excitement for the unknown. As boundaries dissolve and/or gradually overlap from one space to another, a feeling of security arises. This sequential flow is a strategy to make the body adapt to a new space and

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347 Proulx MJ, Todorov OS, Taylor Aiken A and de Sousa AA (2016) Where am I? Who am I? The Relation Between Spatial Cognition, Social Cognition and Individual Differences in the Built Environment. Front. Psychol. 7:64.

control, and consequent,lmanageol spikes of stress hormones in the body caused by sudden transitions of space or spatial divisions with uniform solid edges.

Effective environment navigation, or wayfinding, depends on two things: a clear spatial system but also different exploration opportunities. Smooth transitions and sequential spatial experience stimulate neuro reactions and embodiment through design. They are controlled strategies to make the body adapt ta new spaces and avoid spikes of stress hormones in the body, which cause alertness and vigilance. A study demonstrated that coherent spatial interrelation results in the desire of exploratin, since you don't want to get completely lost. The feeling of hesitation of being lost, when there is difficulty moving through space results in stress.[348] Spatial accessibility promotes self-confidence, and studies show that se-f movement and wayfinding improes perception and personality. This happsen if they have unrestricted movement to explore different paths over time to stimulating new perspectives and flexible navigation through trial and error which result in personal experiences.[349]

Wayfinding and clear mobility as to avoid the notion of being lost is important especially in places that requies easy access as in hospitals and schools since it avosid suffering, dela,ys and injuries. People neea clear circulation paths in these controlled environments in order to feel confident. Wayfinding becomes easier wite cognitety stimulation through space landmarks. Landmarks, which are features that stads out in space, stimulate the hippocampus by memorizing peculiar aspects and applying it to wayfinding. This process createahe spatial map through memory. However, the use of landmarks to facilitate navigation should be used with care, since overcrowding of landmarks inhibit the focus to recall memory and results in losing their function and generating confusion.[350]

Within sequential flow, spaces that promote a pause can also be an approach towards the improvement of spatial memory and cognitive mapping. Studies demonstrated direct implications between places that promote pause and navigability and memorable spatial experiences. This can also result in a beneficial relatishipon between user and environment by promoting spatial learning and cognitive refreshment.

Active Design is also a methoto d approach the sequence parameter. It encourages circulation, moveme,nt and activity of the users. One of their focus is on the potentiality of stairs in contemporary buildings to stimulate activity, encounte,rs and sequence. In many buildings, stairs are almost exclusively escingpe routes and even though difficult to find and access. Regulations codes have forced stairs to by enclosed and not appealing for everyday circulation. This is the opposite approach to that of ancient buildins, when staircases were placed in central spaces, and their

348 Cassarino M and Setti A (2016) Complexity As Key to Designing Cognitive-Friendly Environments for Older People. Front. Psychol.7:1329.
349 Craig, Michael, et al. (2015). "Wakeful Rest Promotes the Integration of Spatial Memories into Accurate Cognitive Maps." Hippocampus, vol. 26, no. 2, pp. 185–193.
350 Proulx MJ, Todorov OS, Taylor Aiken A and de Sousa AA (2016) Where am I? Who am I? The Relation Between Spatial Cognition, Social Cognition and Individual Differences in the Built Environment. Front. Psychol. 7:64.

designasre impressive and noble.[351] Even though fire regulations require sets of staircases to be enclosed as to be fireproof, the extensive relevance of stairs to enrich a built environment is leading to extra sets of apparent and accessible staircases in strategic building locations. Designers through the design decisions have to consider the great opportunity to influence healthy habits and human behavior for the users by encouraging activity, intuitive wayfinding and social interaction with places for encounters.[352] And stairs are a strategy to promote physical activity, interaction, mobility and health in built spaces. A study on how design choices influence physical activity proved that, whea good design is applied in staircase configuration, it promotes its utilization by building occupants. [353]

People and their daily patterns of routine, activities, experiences, explorati,on and encounters bring buildings to life. Different types of incentive to optimize these daily patterns are coherent floor plans, spatial configuration, spatial organizational, social dynamics and transitional spaces. Thus, we can say that building is the interface of the function happening within it. Specialists can predict how a space will be used prior to its existence through space syntax analysis, social network exploration, observational techniques, questionnaires, interviews, behaviour tracking technologies and tools which can assist the designers on how people navigate through spaces.[354]

PARAMETER APPLICATION:

Design strategies to approach the Sequence parameter includes placing buildings in strategic locations to allow the experience of discovery, where they seem hidden and are slowly unveedil. Al,so sequence within the built environment cabe n achieved by creating welcoming open spaces, places of rest, social staircases, places of socialization, restoration, prospe,ct and exploration in order to understand it.

351 Howard, Brian Clark. (2017). "5 Surprising Ways Buildings Can Improve Our Health." National Geographic, www.nationalgeographic.com/environment/urban-expeditions/green-buildings/surprising-ways-green-buildings-improve-health-sustainability/.

352 Active Design Guidelines Promoting Physical Activity and Health in Design. City of New York, 2010.

353 Baldwin, Alysia, and Derek Newby. (2018). "How Design Choices Influence Physical Activity." Innovation Incubator Project Report.

354 Ellard, Colin. (2009). You Are Here: Why We Can Find Our Way to the Moon but Get Lost in the Mall. DOUBLE DAY.

table 14 - Scientific Studies related to Sequence Parameter

effect	relevant studies	findings
•Health **•Mental Health** **•Wellbeing**	Active Design Guidelines Promoting Physical Activity and Health in Design. City of New York, 2010.	appropriate stair promote physical activity, interaction, mobility and health.
	Baldwin, Alysia, and Derek Newby. (2018) "How Design Choices Influence Physical Activity." perkins+will Innovation Incubator Project Report.	encouragement of staircase results in an overall health and wellbeing, with more physical activity and social interactions.
	Biederman, I. (2011). University of Southern California, Department of Psychology. Personal communication with the authors.	Mystery engenders a strong pleasure response within the brain that may be a similar mechanism to that of anticipation
	Brunec, I. K., Javadi, A.-H., Zisch, F. E. L., & Spiers, H. J. (2017). Contracted time and expanded space: The impact of circumnavigation on judgements of space and time. Cognition, 166, 425–432.	Understand routes navigation impact our better embodiment of the place and causes comfort and security.
	Cassarino M and Setti A (2016) Complexity As Key to Designing Cognitive-Friendly Environments for Older People. Front. Psychol.7:1329.	Easy environment navigation promote positive psychological conditions. And the feeling of hesitation of being lost in complicate sequence of spaces cause stress and lack of confidence.
	Herzog, T.R. & A.G. Bryce (2007). Mystery and Preference in Within-Forest Settings. *Environment and Behavior, 39* (6), 779-796.	conclude that when properly understood, mystery tends to be positively related to preference.
	Herzog, T.R. & L.S. Kropscott (2004). Legibility, Mystery, and Visual Access as Predictors of Preference and Perceived Danger in Forest Settings without Pathways. *Environment and Behavior, 36,* 659-677.	visual access and landmarks lead to legibility and positive preference in the sequence of the environment.
	Ikemi, M. (2005). The Effects of Mystery on Preference for Residential Facades. *Journal of Environmental Psychology, 25*, 167–173.	pleasure responses to anticipatory situations
	Negami, H. R., Mazumder, R., Reardon, M., & Ellard, C. G. (2019). Field analysis of psychological effects of urban design: a case study in Vancouver. Cities & Health, 1–10.	simple design interventions leading to easier navigation, increase wellbeing and sociability
	Salimpoor, V.N., M. Benovoy, K. Larcher, A. Dagher, & R. J. Zatorre (2011). Anatomically Distinct Dopamine Release During Anticipation and Experience of Peak Emotion to Music. *Nature Neuroscience, 14* (2), 257-264.	pleasure responses to anticipatory situations
•Cognition Improvement	Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning.	Wide corridor and The pathway has clear way-finding characteristics which can ease the movement and relate to the improvement of the pupils' academic achievement
	C. Kenneth Tanner, (2009) "Effects of school design on student outcomes", Journal of Educational Administration, Vol. 47 Issue: 3, pp.381-399.	The findings regarding movement and circulation in the school, show implications in the students performance.
	Craig M., Dewar M., Della Sala S., Wolbers T. (2015). Rest boosts the long-term retention of spatial associative and temporal order information. Hippocampus, 25(9):1017-27. Wiley.	rest allows superior consolidation/hippocampal replay of novel information pertaining to a recently learned route, thus boosting new memories over the long term.
	Craig M., Dewar M., Harris M.A., Della Sala S., Wolbers T. (2106). Wakeful rest promotes the integration of spatial memories into accurate cognitive maps. Hippocampus, 26:185–193. Wiley.	wakeful rest can improve the integration of new spatial memories in humans,
	Dzebic, V., Perdue, J. S., & Ellard, C. G. (2013). The influence of visual perception on responses towards real-world environments and application towards design. Intelligent Buildings International, 5(sup1), 29–47. doi:10.1080/17508975.2013.807766	Scene and environmental preference research suggests that particular visual features greatly influence one's response to their environment.
	Gupta, A. S., Meer, M. A. A. V. D., Touretzky, D. S., & Redish, A. D. (2010). Hippocampal Replay Is Not a Simple Function of Experience. Neuron, 65(5), 695-705. Elsevier Ltd.	possibility of sequence of trajectories play a potential role in active learning and maintenance of the cognitive map.
	Gutkowski, S., Ginath, Y., & Guttmann, F. (1992). Improving psychiatric environments through minimal architectural change. Hospital & Community Psychiatry, 43(9), 920–923.	additional entrances, improved accessibility led to increased the sense of freedom
	Martini, Markus, et al. (2019) "Brief Period of Post-Encoding Wakeful Rest Supports Verbal Memory Retention in Children Aged 10–13 Years." *Current Psychology*.	wakeful resting places improves retention of memories.
	Proulx MJ, Todorov OS, Taylor Aiken A and de Sousa AA (2016) Where am I? Who am I? The Relation Between Spatial Cognition, Social Cognition and Individual Differences in the Built Environment. Front. Psychol. 7:64.	environments impact in spatial and social cognition.
	Sun, H.-J., Campos, J. L., Young, M., Chan, G. S. W., & Ellard, C. G. (2004). The Contributions of Static Visual Cues, Nonvisual Cues, and Optic Flow in Distance Estimation. Perception, 33(1), 49–65.	availability of visual information during locomotion led to an 'under-perception' of movement
	Wiener, J.M., Franz, G., Rossmanith N., Reichelt A., Mallot H.A., & Bulthoff H.H. (2007). Isovist analysis captures properties of space relevant for locomotion and experience. Percep:on, 36(7), 1066–1083.	the outcomes suggest overall performance and navigation behavior in a coherent architecture environment.

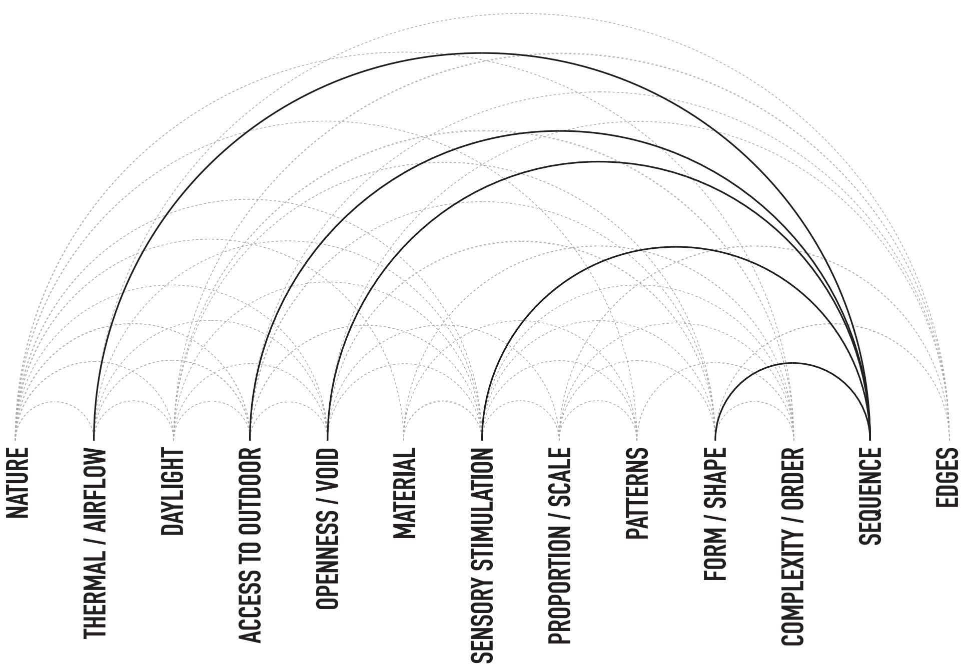

fig. 31 - Diagram of Parameters Interrelations

fig. 32 - DD16 - BIO-architects

5.1.4.2. EDGES

WHAT IT IS:

Edges parameter relates to spaces with defined boundaries that generate sheltered areas, and which promote a sense of relaxation, safe,ty and control. Since our bodies generate diverse biological responses that change our physical and psychological operation when our sense threatened is perceived,[355] Edges parameter is important when ensuring spatial experiences related to security.

OUTCOME:

Researchers observed that we appreciate buildings which form continuous lines around us and make us feel safe. People have a bias to avoid centers and seek safety by sticking to the edges of spaces. Clear edge conditions also releaes us from anxiety by enabling mental maps to form, as we have an inherent desire to be able to view the entirety of our surroundings and understand our whole context from a secityre perspective.

THEORIES AND STUDIES:

Edges parameter relates to spaces with defined boundaries, that generate sheltered areas which encourage a sense of relaxation, safe,ty and control. A way to promote this is through thick boundaries. Thick boundaries, as opposed to thin boundaries, entails design elements which are solid and rigid. Such type of boundaries inspire security and help in the construction of hierarchy in the building.[356] People tend to avoid being in central areas and exploring inner regions of unfamiliar spacs, since there is the notion that it might compromise their safety. The more insecure a person feels, the more time he/she will take refuge on boundary walls, while the mental spatial map is being generated.[357]This understanding comes from the concept of thigmotaxis: the motion or orientation of an organism in response to a touch stimulus. Where thigma means totouch and taxis accounts for arrangement. Thigmotaxis is an evolutionary adaptive behavior and has two functions in two distinct neuron structures; first is the learning and exploratory process - the thigmotaxis assists the person to define borders within a space and recognize escape routes. And it is also relades to the awareness of the surroundings while inputting enough informationnof the environment to situate oneself. According to researchers, thigmotaxis behavior is not difficult to measure. It is a survival strategy: animals with higher tghimoctatic levels are more likely to survivals, and as they become more familiarized with the space, the less edge-oriented they are.[358]

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355 Schneiderman N, Ironson G, Siegel SD. (2005). Stress and health: psychological, behavioral, and biological determinants. Annu. Rev. Clin. Psychol. 1:607–28

356 Botton, Alain (2006). De. The Architecture of Happiness. Vintage Books.

357 Kallai, J., Makany, T., Csatho, A., Karadi, K., Horvath, D., Kovacs-Labadi, B., … Jacobs, J. W. (2007). Cognitive and affective aspects of thigmotaxis strategy in humans. Behavioral Neuroscience, 121(1), 21–30.

358 Walz, N., Mühlberger, A., & Pauli, P. (2016). A Human Open Field Test Reveals Thigmotaxis Related to Agoraphobic Fear. Biological Psychiatry, 80(5), 390–397.

As for the cognitive and affective aspects of thigmotaxis strategy in humans, research in behavioral neuroscience evidenes that: "Although it seems to be plausible that thigmotaxis is a defensive strategy, it is less likely that thigmotaxis prevents the participant from learning the location of the target. Instead, we would argue that fear, related to an encounter with an enclosed spatial environment, triggers a specific exploratory strategy such as thigmotaxis, which plays an essential preparatory role in the first phase of spatial learning. The use of thigmotaxis helps the individual define the borders of an enclosed space and identify escape routes from that space. Thigmotaxis also provides the individual with the elements of an egocentric frame of reference. With the elements of that frame of reference in hand, the organism can begin to construct a cognitive map."[359] Therefore, defined boundaries in built spacecento promote confidence and avoid insecurity and anxiety.

As clear edge conditions facilitaes our mental maps, in urban settings, people prefer we-l defined street corridors and get inherently alert when the edgisre not well set.[360] Furthermore, open fields are linked to agoraphobia which accounts for fear of open spaces by triggering anxiety.[361] Anxiety and stre-s related hormones are adrenaline and cortisol, which cause intensified blood pressure and increased heart rate. The accumulation of these hormones for a long period generates significant consequences ie one's health, such as autoimmune diseases, inflammatory conditions, plaque formation, damage arteries, hypertensi,on and cardiovascular disease.[362] Edges parameter can help avoid these conditions by providina g feeling of refuge, prospect, boundaries, and protection.

PARAMETER APPLICATION:

Edges parameter can be achieved with design strategies such as thick boundaries and clear built spatial delimitations, which yet, enables the comprehension of the totality o space with unrestricted views over distance for surveillance and planning. A we-l defined space where the individual is protected from behind and overhead, and circulation that optimizes visual range. It can also be interpreted by space with an open free view from above achieved from an elevated position. A good example is a watchtower, which shelters while overviewing the surroundings.

Design strategies for edge parameter can also be considered in small interior conditions, through space delimitation using mid-height partitions, which allow for personal space and still enables visibility.

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359 Kallai, J., Makany, T., Csatho, A., Karadi, K., Horvath, D., Kovacs-Labadi, B., … Jacobs, J. W. (2007). Cognitive and affective aspects of thigmotaxis strategy in humans. Behavioral Neuroscience, 121(1), 21–30.
360 Jacobs, J. (1961). The Death and Life of Great American Cities. New York: Random House.
361 Walz, N., Mühlberger, A., & Pauli, P. (2016). A Human Open Field Test Reveals Thigmotaxis Related to Agoraphobic Fear. Biological Psychiatry, 80(5), 390–397.
362 Marsland A, Bachen E, Cohen S, Rabin B, Manuck S. (2002). Stress, immune reactivi,ty and susceptibility to infectious disease. Physiol. Behav. 77:711–16

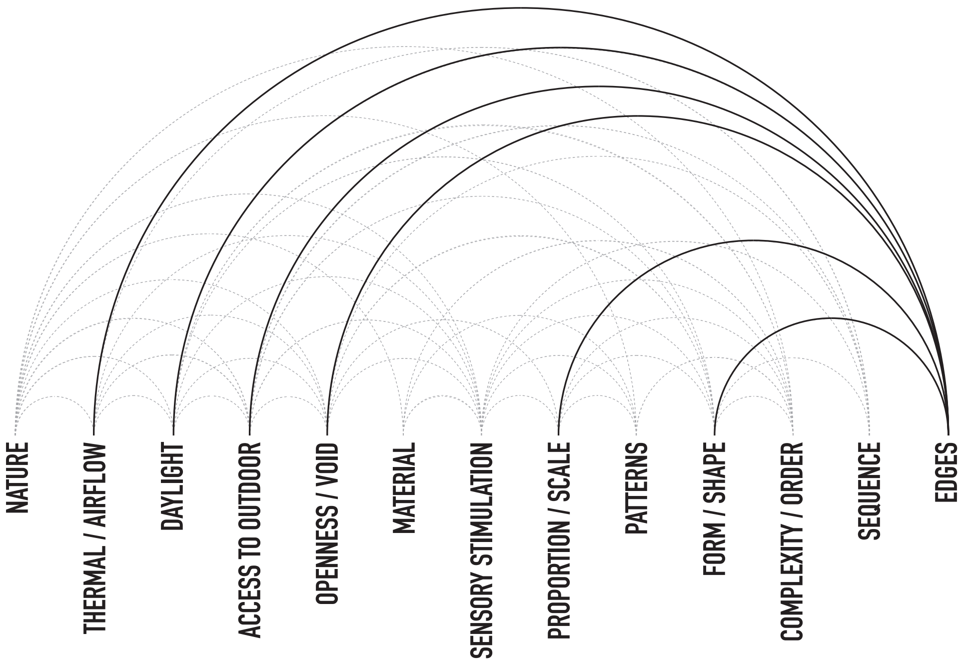

fig. 33 - Diagram of Parameters Interrelations

table 15 - Scientific Studies related to Edges Parameter

effect	relevant studies	findings
•Health •Mental Health •Wellbeing	Botton, Alain (2006). De. The Architecture of Happiness. Vintage Books.	thick boundaries, since it inspire security
	Clearwater, Y.A., & R.G. Coss (1991). Functional Esthetics to Enhance Wellbeing. In Harrison, Clearwater & McKay (Eds.). From Antarctica to Outer Space. New York: Springer-Verlag, pp410	reduced boredom, irritation, fatigue
	Heerwagen, J.H. & G.H. Orians (1993). Humans, Habitats and Aesthetics. In: S.R. Kellert & R.S. Wilson (Eds.). The Biophilia Hypothesis (138-172). Washington: Island Press. pp484.	Prospect leads to visual preference and calmness.
	Herzog, T.R. & A.G. Bryce (2007). Mystery and Preference in Within-Forest Settings. Environment and Behavior, 39 (6), 779-796.	conclude that when properly understood, mystery tends to be positively related to preference.
	Ikemi, M. (2005). The Effects of Mystery on Preference for Residential Facades. Journal of Environmental Psychology, 25, 167–173.	mystery induces strong pleasure response.
	Jacobs, J. (1961). The Death and Life of Great American Cities. New York: Random House.	Clear edge conditions facilitates our mental maps to shape and makes us feeling comfortable without being anxious.
	Kohno, M., D.G. Ghahremani, A.M. Morales, C.L. Robertson, K. Ishibashi, A.T. Morgan, M.A. Mandelkern & E.D. London (2013) Risk-Taking Behavior: Dopamine D2/D3 Receptors, Feedback, and Frontolimbic Activity. Cerebral Cortex, bht218. First published online: August 21, 2013	dopaminergic neurotransmission may modulate risk-taking behavior through an interactive system of frontal and striatal activity.
	Nasar, J.L. & B. Fisher (1993). 'Hot Spots' of Fear and Crime: A Multi-Method Investigation. Journal of Environmental Psychology, 13, 187-206.	The characteristics of the Mystery pattern are derived from visual preference and perceived danger.
	Petherick, N. (2000). Environmental Design and Fear: The Prospect-Refuge Model and the University College of the Cariboo Campus. Western Geography, 10 (1), 89-112.	refuge and prospect environment improves concentration, attention and comfort.
	Ruddlell, E.J., W.E. Hammitt (1987). Prospect Refuge Theory: A Psychological Orientation for Edge Effects in Recreation Environment. Journal of Leisure Research, 19 (4), 249-260.	The most preferred factors exhibited edge environment themes where a high degree of refuge was visually evident.
	Schneiderman N, Ironson G, Siegel SD. (2005). Stress and health: psychological, behavioral, and biological determinants. Annu. Rev. Clin. Psychol. 1:607–28	our bodies generate diverse biological responses that change our physical and psychological operation when our sense threatened is perceived.
	Ulrich, R.S. (1993). Biophilia, Biophobia and Natural Landscapes. In: S.R. Kellert & R.S. Wilson. The Biophilia Hypothesis (73-137). Washington: Island Press.	refuge environment improves concentration, attention and comfort.
	Wang, K. & R.B. Taylor (2006). Simulated Walks through Dangerous Alleys: Impacts of Features and Progress on Fear. Journal of Environmental Psychology, 26, 269-283.	refuge and prospect environment improves concentration, attention and comfort.
•Restorative •Stress Reduction	Amstadter AB, Acierno R, Richardson L, Kilpatrick DG, Gros DF, e tal. (2009). Post-typhoon prevalence of post-traumatic stress disorder, major depressive disorder, panic disorder and generalized anxiety disorder in a Vietnamese sample. J. Trauma. Stress 22:180–88	Built environment has also to entrust the security and safety of the users to not cause post-traumatic stress disorder, panic, anxiety and depression.
	Clearwater, Y.A., & R.G. Coss (1991). Functional Esthetics to Enhance Wellbeing. In Harrison, Clearwater & McKay (Eds.). From Antarctica to Outer Space. New York: Springer-Verlag, pp410.	prospect space reduce boredom, irritation and fatigue.
	Grahn, P. & U.K. Stigsdotter (2010). The Relation Between Perceived Sensory Dimensions of Urban Green Space and Stress Restoration. Landscape and Urban Planning 94, 264-275.	prospect space reduce stress
	Kallai, J., Makany, T., Csatho, A., Karadi, K., Horvath, D., Kovacs-Labadi, B., … Jacobs, J.W. (2007). Cognitive and affective aspects of thigmotaxis strategy in humans. Behavioral Neuroscience, 121(1), 21–30.	The results demonstrate that thigmotaxis plays a distinct role at different phases of spatial learning. greater thigmotaxis of spaces lead to a higher potential for fear response.
	Lorenz, S. G. (2007). The potential of the patient room to promote healing and well-being in patients and nurses. Holistic Nursing Practice, 21(5), 263–277.	appropiate prospect rooms promote, maintenance, or restoration of healing and well-being for patients.
	Walz, N., Mühlberger, A., & Pauli, P. (2016). A Human Open Field Test Reveals Thigmotaxis Related to Agoraphobic Fear. Biological Psychiatry, 80(5), 390–397.	increased movement lengths along the wall of the natural open field and fewer entries into the center which triggers thigmotaxis behavior leading to stress and anxiety.

5.2 CONCLUSION OF CHAPTER

The procedure was to first locate and analyze as many existing research related to human/space behavior - and the neuroscience/architecture relation - currently available. Then, identify within that body of knowledge findings which could lead to practical design strategies to be utilized for enhancing the human/space behavior relation in built environments. Consequently, clear patterns of stances were identified from the correlation of research results. From these patterns, an array of design parameters were able to be established in terms of the practical design strategies that determine them and the impact they may provide for the wellbeing of occupants in the built environment where they occur, structuring a framework to be used for designing human-centred environments towards spatial inhabitability.

Although the series of inhabitability parameters presented here could be used individually, most of them are complementary to each other. One of the intentions oe identifying them within four groups regards the encouragement to approach at least one of each group when designing built environments. Nevertheless, it is advocateto d apply all of them in a proper design approach, in order to obtain the maximum benefits, highest optimization and greatest outcome.

When the inhabitability parameters arcombineded with each other, their association tends to expand the benefits and satisfaction, producing a rich environment. This was evidenced by the overlapping of scientific findings. They demonstrated that our biological responses to the environment occur simultaneously within our bodies, and the parameters which promote it are at times intertwined. Therefore, combinations and applications of parameters are countless, flexible and replicable, with endless possibilities of implementation and under a wide range of circumstances.

The design strategy adopted to approach a parameter also can be the same or dependentnof a strategy of another. It will be the architect's responsibility to counterbalance the effects of each strategy he/she adopts. For example, to approach the daylight parameter, design strategies will differ in a house, in an office, in the hospital or in a library. All buildings need to make use of this parameter, howev,er the design should be based on particular needs, location and desired results.

However, the application of one inhabitability parameter adequately may be more effective than applying several effectively. Consequently, questions emerge on how much is enough, how long we should be exposed and how should be the proper application. Identifying a possible objective answer is difficult. Even so, some parameters outcomes present clues for the questions. As an example that students perform better with a view of trees compared to the restorative effect of a twenty-minute break in a proper garden during the work session.[363] Designers should take into consideration that students will benefit more from a window wita h view inside the classroom. And as for workers, they can feel can be relieved with a minimum of

363 Meyers-Levy, J., & Zhu, R. (2007). The Influence of Ceiling Height: The Effect of Priming on the Type of Processing That People Use. Journal of Consumer Research, 34(2), 174–186.

twenty minutes of immersion in nature,[364] so designers should consider designing courtyards or rooftops with gardens in office buildings.

Human perception must also be understood as a dynamic condition. Frequent exposure ton a inhabitability parameter within a building might be better than infrequent exposure to several other parameters. There is also the consideratio fto the different reactions to the built environment according to a specific age, gender, cultural background, social aspects, economical si,de and personalities. However, the majority of the studies presented in this chapter include a general approach, as most of the reactions are embedded in our existence as human beings which belong to the natural world. Also, the positive influence of these parameterisre generally related to overall wellbeing. Most also may contribute to economic benefits and sustainability, since the cycle turns around the user.

The proposed set of inhabitability parameters fundamentally enhance the human-centred approach to architectural design, by assisting the design decisions without considering style, aesthetics or personal. However, some parameters and its results may contribute to theories and hypotheses on concepts of beauty, transcenden,ce and sublime. Nonetheless, emerging research can reinforce some parameters with more findings, and they may also contributtoin the proposition of new or complementary parameters in the future.

The main consideration over the inhabitability parameters is always related to how the built environment affects its users. The final results will depend on the creativity of the architects that need to understand priorities and foresee the outcomes of design strategies to support the decisions of the design process. And with a supportive approach, those decisions could be refined and justified.

To conclude this chapter, the fundamental significance of the inhabitability parameters is to understand the profound impact an environment can make on the individual. Proper good design comes from a significant approach to optimize, inspire and restate, as well as promote health and wellbeing of the user. Locality, social and cultural standards, expectations, past experiences, actual health conditions, user perceptions, length and frequency of the involvement need to take into consideration during of the design process, besides the functionality and operation of the design itself and within a context. However, it is important to mention that the inhabitability parameters do not propose universal solutions, but an appropriate approach to consider. The consequences of design decisions should not be underestimated. This issue needs to be approached constantly by architects/designes, since our state of mind has a huge impact on our general health. And this is where the architect creativity plays a fundamental rolinto the contribution oa good design.

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364 Barton, J. & J. Pretty (2010). What Is the Best Dose of Nature and Green Exercise for Improving Mental Health. Environmental Science & Technology, 44, 3947–3955.

SUMMARY OF PARAMETERS OUTCOMES

Group	Parameter	Description
GROUP I **NATURE AND OUTDOOR**	NATURE -	General relation to natural elements, living systems and natural processes.
	THERMAL / AIRFLOW -	Temperature conditions, humidity and natural ventilation.
	DAYLIGHT -	Direct or indirect luminescence from the sun.
	ACCESS TO OUTDOOR -	Spatial interrelation between inside and outside.
GROUP II **COGNITIVE PERFORMANCE**	OPENNESS AND VOID -	The experience of unobstructed areas of space.
	MATERIAL -	Sensorial experience promoted by materiality.
	SENSORY STIMULATION -	Momentary experiences induced by a wide range of sensorial aspects.
GROUP III **STRUCTURE**	PROPORTION / SCALE -	The relations between ourselves and the design elements and spaces of built environments.
	PATTERN -	Repetitions which add intricacy to the spatial experience.
	FORM / SHAPE -	Entails the distinct spatial outline that facilitates the comprehension of a built environment.
	COMPLEXITY / ORDER -	The organization and arrangement of design elements.
GROUP IV **SPATIAL IDENTITY**	SEQUENCE -	Interrelations as a means of connecting individuals and individuals with space.
	EDGES -	Limits which generate spatial boundaries.

fig. 34 - Summary of Parameters Outcomes

table 16 - Interrelation of all Inhabitability Parameters

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Nature		■	■	■	■		■		■			■	■	8
Thermal / Airflow	■		■						■	■	■	■	■	7
Dauylight	■	■				■	■		■		■	■	■	8
Material	■				■		■					■		4
Patterns	■			■			■	■				■		5
Form / Shape			■				■	■	■	■	■	■	■	8
Complexity / Order	■		■	■	■	■		■				■		6
Proportion / Scale					■	■	■		■		■	■		6
Openess / Void	■	■	■			■		■		■	■	■	■	9
Sequence		■				■			■			■	■	5
Edges		■	■			■		■	■				■	6
Sensory Stimulation	■	■	■	■	■	■	■	■	■	■			■	11
Access to Outdoor	■	■	■			■			■	■	■	■		8
Total	8	7	8	4	5	8	6	6	9	5	6	11	8	**91**

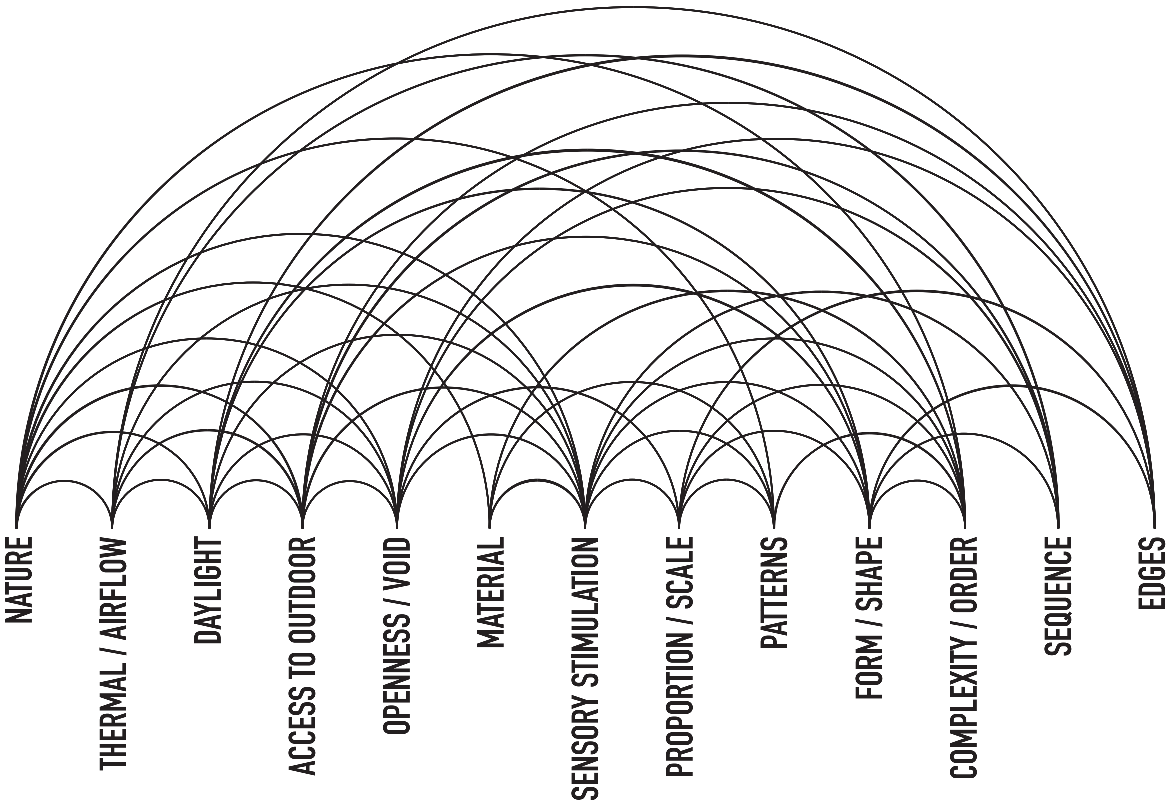


table 17 - Interrelation of all Inhabitability Parameters

PART III – ASSESSING INHABITABILITY

Part III presents a methodology to assess inhabitability. In Chapter 6, the proposed framework of design strategies based on human/space behavior relation is evaluated through case studies. Results and findings are analysed.

CHAPTER 6 – EVIDENCE OF INHABITABILITY IN ARCHITECTURE

After the proposal of parameters as a framework to approach inhabitability in architecture, an investigation on the relationship between the parameters and existing buildings was conducted to evidence the coherence of the framework for practical design outcomes. Two distinct case studies were conducted involving different types and scales of buildings and urban environments as to collect evidence based on real design strategies and to verify the hypothesis that the proposed inhabitability parameters could assist architects in achieving more human-centered design outcomes.

6.1 CASE STUDIES OF PUBLIC AWARD

The Case Study of Public Award was based on the material available on ArchDaily's website for finalists of "Building of the year" award 2018. It was proposed as a method of comparison between the website's 5 finalists of the 15 featured building categories and the inhabitability parameters. The idea was to correlate if the most voted buildings are also the buildings with the most evidence of the inhabitability parameters.

The criteria for choosing ArchDaily's website and award were: it is the largest architecture community website in the world; the fee to tender the award is free, which means any small architect in any part of the globe can submit a project; it is democratic in terms of voting, since everyone subscribed in the website can vote for only one project at a time and in each category; the submitted projects span different building types, locations, scales, and uses.

In the analysis, a total of 75 projects were evaluated against the 13 inhabitability parameters. It is important to state that the inhabitability parameters were only considered to occur in the building when they were clearly identified through the available material - photographs, and technical drawings - in the website, giving the analysis a subjective character. Nonetheless, to make the analysis equitable, the material used was entirely from ArchDaily's website, which is theoretically, the same material used by the voters to judge the building. Therefore, if any of the projects make use of design strategies that correspond to the inhabitability parameters but could not be evidenced by the available material in ArchDaily, it was not taken into consideration in this analysis.

6.1.1 APPLICATION

To verify the validation of the 13 inhabitability parameters against the most voted buildings in the ArchDaily's Building of the Year Award 2018, a case study analysis was carried out. The purpose was to use the parameters to evaluate built environments of different scales in order to collect evidence based on real design outcomes. The 15 building categories featured in the analysis were: Healthcare Architecture - including hospitals, clinics and health centers; Cultural Architecture - cultural centers and museums; Educational Architecture - universities and schools; Small Scale Architecture - pavilions and small buildings; Industrial Architecture - buildings related to industrial program; Commercial Architecture - retail projects; Offices - workplaces; Public Architecture - institutional buildings; Interior Architecture - refurbishments and interior design; Sports Architecture - sports centers and gymnasiums; Hospitality Architecture; Houses - private residential projects; Best Applied Products - innovative and creative ways materials were applied; Housing - apartment building; and Religious Architecture.

6.1.1.1 PRODUCTS CATEGORY

In the products category, the parameters Patterns, Sequence, and Sensory Stimulation were not identified in any of the five finalists projects. While Thermal/Airflow and Edges parameters were recognized in only one project and Daylight together with Material were found in four out of five projects. The category has the lowest number of parameters identified; 25 in total. 'CaixaForum Sevilla - Vázquez Consuegra' is the project with the highest number of parameters, 6 out of 13, followed by 'Canaletto Residential Tower - UNStudio', 'Kulm Eispavilion - Foster - Partners' and 'Skovbakke School - CEBRA' with 5 parameters each, besides the 'Flagship Building - Geodesic Design' project with 4 parameters.

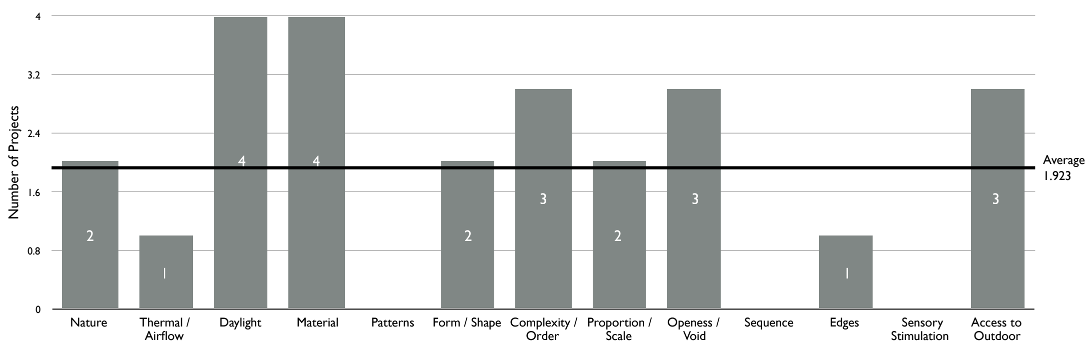


fig. 35 - Number of Projects in each Design Parameters - Products Category

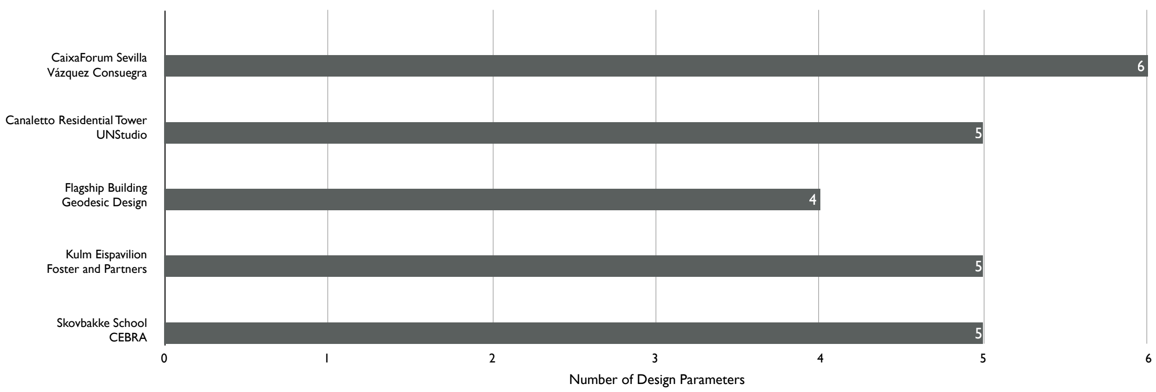


fig. 36 - Number of Design Parameters in each project of Products Category

table 18 - Inhabitability Parameters - Products Category

table 19 - Inhabitability Parameters - Products Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
CaixaForum Sevilla Vázquez Consuegra			■	■		■	■		■		■			6
Canaletto Residential Tower UNStudio	■			■		■		■					■	5
Flagship Building Geodesic Design	■	■	■						■					4
Kulm Eispavilion Foster and Partners			■	■			■	■					■	5
Skovbakke School CEBRA			■	■			■		■				■	5
Total	2	1	4	4	0	2	3	2	3	0	1	0	3	**25**

6.1.1.2 COMMERCIAL CATEGORY

35 parameters were found in the commercial category, with ThermalAirflow parameter not being identified in any of the projects. The parameters Nature, Patterns, and Sensory Stimulation occurred in only one project, while the Proportion/ Scale and Openness/Void was identified in all of them. The 'Apple Store Michigan Avenue, Chicago - Foster + Partners' has 9 out of 13 parameters, followed by 'CityLife Shopping District - Zaha Hadid Architects' with 8, 'PETRA. The Stone Atelier - Fran Silvestre Arquitectos' with 7, 'Malmö Saluhall - Wingårdh Arkitektkontor AB' with 6, and 'Common Ground - URBANTAINER' with 5.

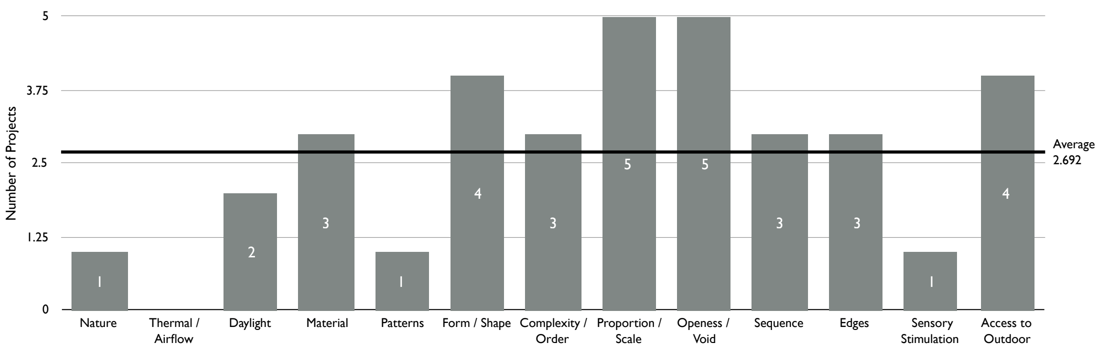


fig. 37 - Number of Projects in each Design Parameters - Commercial Category

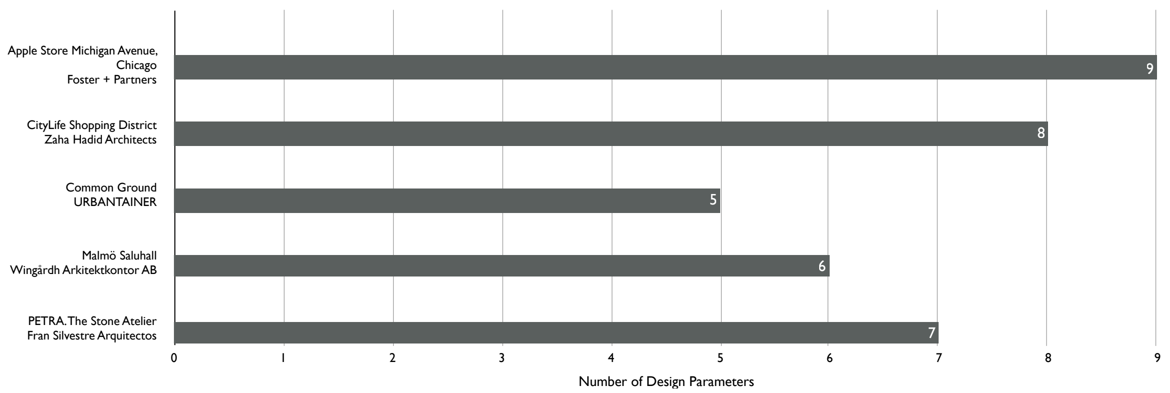


fig. 38 - Number of Design Parameters in each project of Commercial Category

table 20 - Inhabitability Parameters - Commercial Category

table 21 - Inhabitability Parameters - Commercial Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Apple Store Michigan Avenue, Chicago Foster + Partners	■		■			■	■	■	■	■	■		■	9
CityLife Shopping District Zaha Hadid Architects			■	■	■	■	■	■	■				■	8
Common Ground URBANTAINER							■	■	■	■			■	5
Malmö Saluhall Wingårdh Arkitektkontor AB				■		■		■	■		■		■	6
PETRA. The Stone Atelier Fran Silvestre Arquitectos				■		■		■	■	■	■	■		7
Total	1	0	2	3	1	4	3	5	5	3	3	1	4	**35**

6.1.1.3 CULTURAL CATEGORY

In the cultural category, Thermal/Airflow was not identified in any of the projects. The Edges parameter was identified in only one project, while Openness/Void occurred in all of the five projects. A total of 34 parameters were identified in this category. The project 'Louvre Abu Dhabi - Ateliers Jean Nouvel' and 'Zeitz Museum of Contemporary Art Africa / Heatherwick Studio' tied with the highest number of parameters; 9 out of 13 each. Followed by 'Tianjin Binhai Library - MVRDV - Tianjin Urban Planning and Design Institute' with 6, 'Foro Boca - Rojkind Arquitectos' and 'LEGO House - BIG' with 5 each.

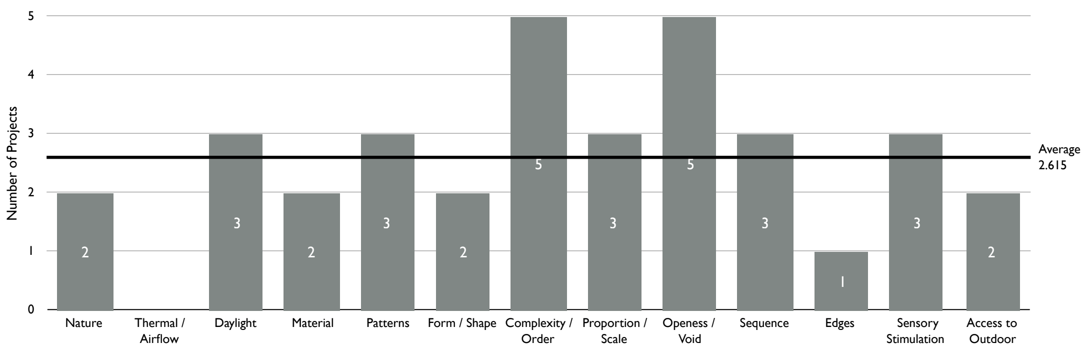


fig. 39 - Number of Projects in each Design Parameters - Cultural Category

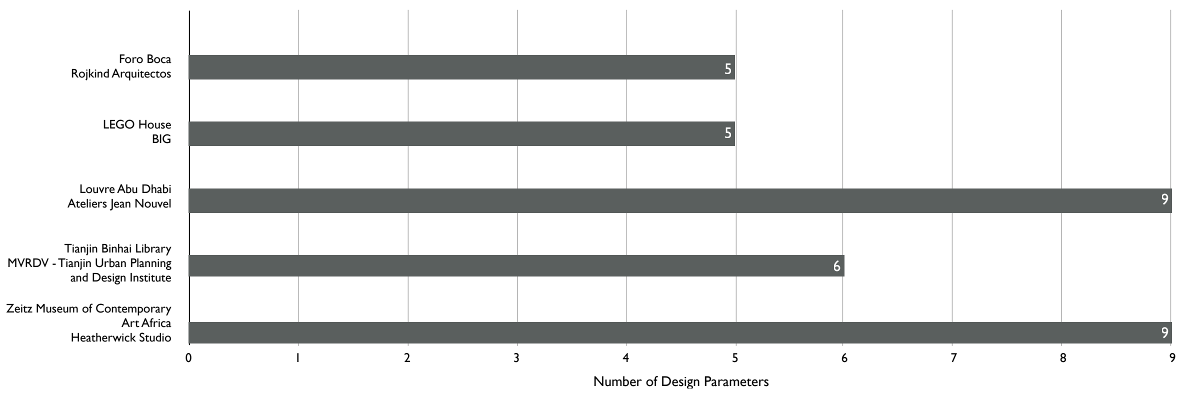


fig. 40 - Number of Design Parameters in each project of Cultural Category

table 22 - Inhabitability Parameters - Cultural Category

table 23 - Inhabitability Parameters - Cultural Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Foro Boca Rojkind Arquitectos				■	■		■		■		■			5
LEGO House BIG	■						■		■	■			■	5
Louvre Abu Dhabi Ateliers Jean Nouvel	■		■		■		■	■	■	■		■	■	9
Tianjin Binhai Library MVRDV - Tianjin Urban Planning and Design Institute			■			■	■	■	■			■		6
Zeitz Museum of Contemporary Art Africa Heatherwick Studio			■	■	■	■	■	■	■	■		■		9
Total	2	0	3	2	3	2	5	3	5	3	1	3	2	**34**

6.1.1.4 EDUCATIONAL CATEGORY

In the educational category, 38 parameters were identified in the buildings, with the Sequence and Edges parameters occurring only in one project, and Openness/ Void occurring in all of the five projects. The project 'Children Village - Rosenbaum + Aleph Zero' has 10 out of 13 parameters, followed by 'Lycee Schorge Secondary School - Kéré Architecture' with a total of 9 parameters. The 'King Abdullah Petroleum Studies and Research Centre - Zaha Hadid Architects' together with 'Maria Montessori Mazatlán School - EPArquitectos + Estudio Macías Peredo' have 8 parameters each. And in the project, 'Architecture Faculty in Tournai Aires Mateus' only 3 parameters were identified.

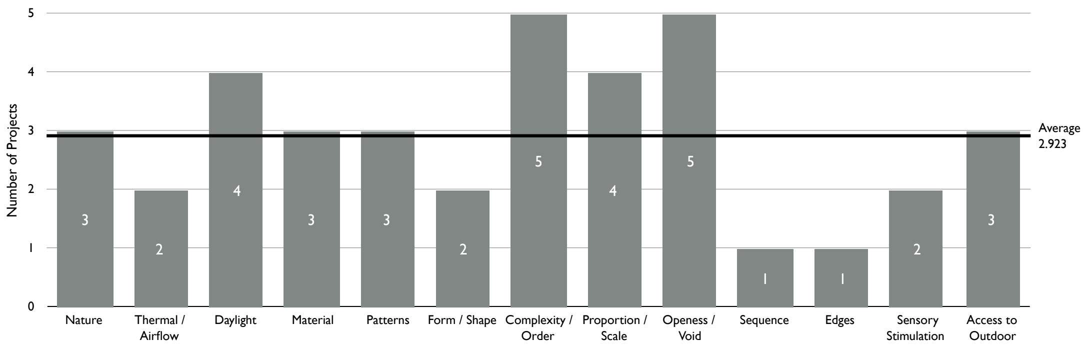


fig. 41 - Number of Projects in each Design Parameters - Educational Category

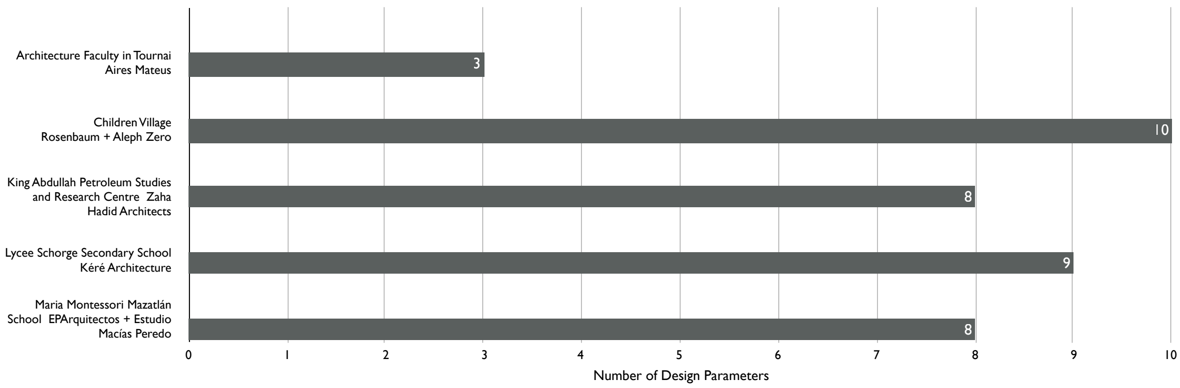


fig. 42 - Number of Design Parameters in each project of Educational Category

table 24 - Inhabitability Parameters - Educational Category

table 25 - Inhabitability Parameters - Educational Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Architecture Faculty in Tournai Aires Mateus														3
Children Village Rosenbaum + Aleph Zero														10
King Abdullah Petroleum Studies and Research Centre Zaha Hadid Architects														8
Lycee Schorge Secondary School Kéré Architecture														9
Maria Montessori Mazatlán School EPArquitectos + Estudio Macías Peredo														8
Total	3	2	4	3	3	2	5	4	5	1	1	2	3	**38**

6.1.1.5 HEALTHCARE CATEGORY

In the healthcare category, Thermal/Airflow parameter was not identified in any of the shortlisted projects, and the parameters Patterns and Edges were identified in only one of the five finalists. The parameters Daylight, Proportion/Scale, Openness/ Void and Access to Outdoor were found in 4 of 5 projects. In healthcare, a total of 33 parameters were identified within all the five projects, and the winner by the popularity is the same project with most parameters; the 'Santa Fe de Bogotá Foundation' from the 'El Equipo de Mazzanti' architects with 8 parameters out of 13. Followed by 'Urban Hospice - NORD Architects' and 'Maggie's Oldham - dRMM' with 7 parameters in total, 'Maggie--39-s Centre Barts - Steven Holl Architects' with 6 and 'Psychiatric Center - Vaillo - Irigaray Architects - Galar - Vélaz' with 5 parameters.

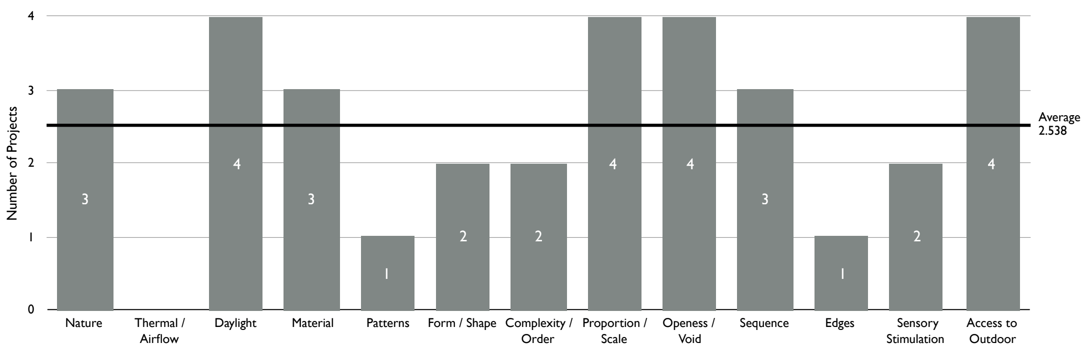


fig. 43 - Number of Projects in each Design Parameters - Healthcare Category

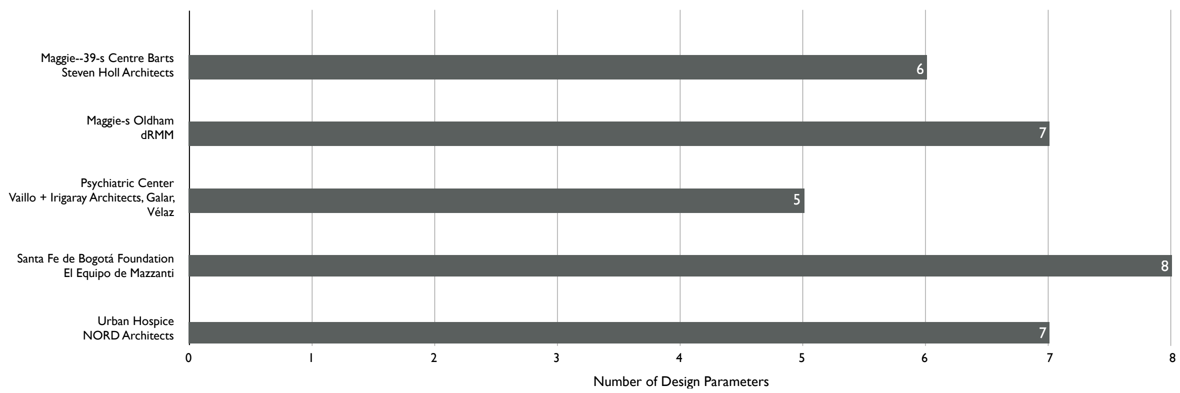


fig. 44 - Number of Design Parameters in each project of Healthcare Category

table 26 - Inhabitability Parameters - Healthcare Category

table 27 - Inhabitability Parameters - Healthcare Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Maggie--39-s Centre Barts Steven Holl Architects			■			■		■	■	■			■	6
Maggie-s Oldham dRMM	■		■	■				■	■	■			■	7
Psychiatric Center Vaillo + Irigaray Architects, Galar, Vélaz				■			■			■		■	■	5
Santa Fe de Bogotá Foundation El Equipo de Mazzanti	■		■	■	■		■	■	■			■		8
Urban Hospice NORD Architects	■		■			■		■	■				■	7
Total	3	0	4	3	1	2	2	4	4	3	1	2	4	**33**

6.1.1.6 HOSPITALITY CATEGORY

Hospitality category is the group with the highest number of parameters; a total of 41 were identified. However, Thermal/Airflow and Edges parameters were not identified in any of the five projects, and the Form/Shape parameter was identified in only two of them. The project with more parameters is 'KOI Cafe / Farming Architects' with 10 out of 13, followed by 'Ixi'im Restaurant - Jorge Bolio Arquitectura + Lavalle + Peniche Arquitectos + Mauricio Gallegos Arquitectos + Central de Proyectos SCP' and 'The Wine Ayutthaya Bangkok Project Studio' with 9, 'Oberholz Mountain Hut Peter Pichler Architecture + Pavol Mikolajcak' with 7 and 'JIKKA - Issei Suma' with 6 parameters.

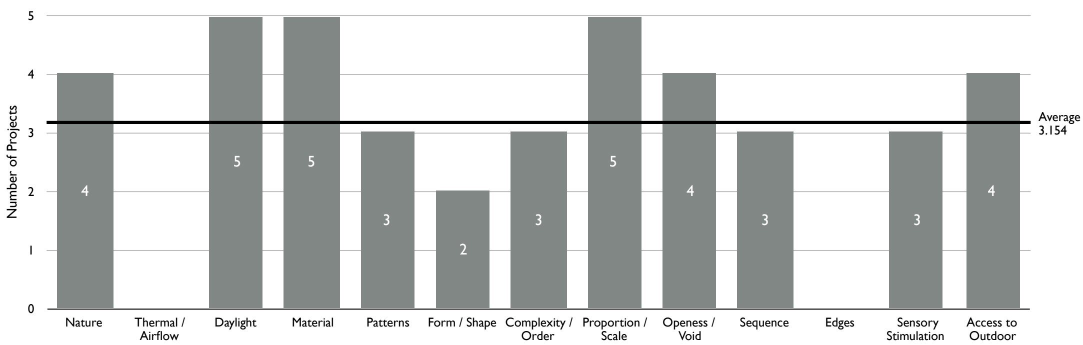


fig. 45 - Number of Projects in each Design Parameters - Hospitality Category

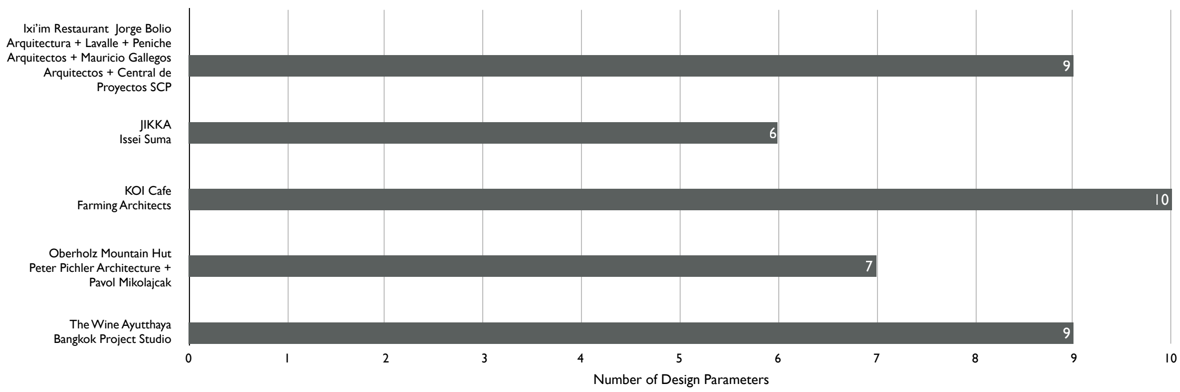


fig. 46 - Number of Design Parameters in each project of Hospitality Category

table 28 - Inhabitability Parameters - Hospitality Category

table 29 - Inhabitability Parameters - Hospitality Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Ixi'im Restaurant Jorge Bolio Arquitectura + Lavalle + Peniche Arquitectos + Mauricio Gallegos Arquitectos + Central de	■		■	■	■			■	■	■		■	■	9
JIKKA Issei Suma	■		■	■		■		■		■				6
KOI Cafe Farming Architects	■		■	■	■		■	■	■	■		■	■	10
Oberholz Mountain Hut Peter Pichler Architecture + Pavol Mikolajcak			■	■		■	■	■	■				■	7
The Wine Ayutthaya Bangkok Project Studio	■		■	■	■		■	■	■			■	■	9
Total	4	0	5	5	3	2	3	5	4	3	0	3	4	**41**

6.1.1.7 HOUSES CATEGORY

In the house category, Thermal/Airflow parameter was identified in only two projects, and the Edge parameter in only one. Daylight, Proportion/Scale, Sensory Stimulation and Access to Outdoor parameters were found in 4 of 5 projects. A total of 38 parameters were identified in all of the five house projects. In the 'Optical Glass House' - from 'Hiroshi Nakamura & NAP Architects - 11 parameters out of 13 were identified. Followed by 'Villa Ypsilon - LASSA architects' with 9 parameters, 'MeMo House - BAM! arquitectura' with 8, 'Primitive Future - GUMPHA House - Within N Without' with 6 and 'Carroll House - LOT-EK' with only 4.

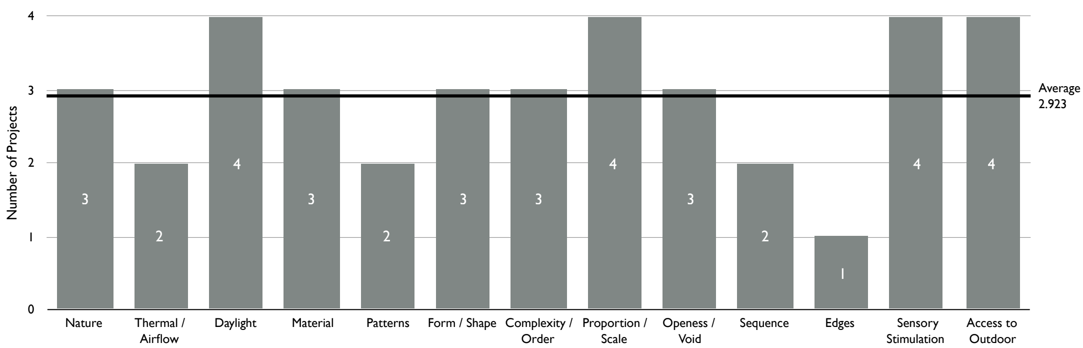


fig. 47 - Number of Projects in each Design Parameters - Houses Category

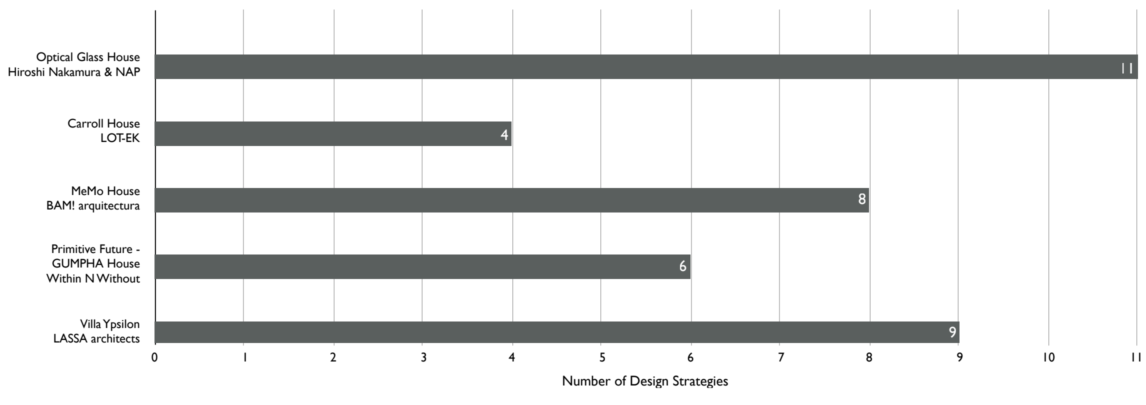


fig. 48 - Number of Design Parameters in each project of Houses Category

table 30 - Inhabitability Parameters - Houses Category

table 31 - Inhabitability Parameters - Houses Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Optical Glass House Hiroshi Nakamura & NAP	■	■	■	■	■		■	■	■	■		■	■	11
Carroll House LOT-EK			■			■				■			■	4
MeMo House BAM! arquitectura	■	■	■	■				■	■			■	■	8
Primitive Future - GUMPHA House Within N Without				■		■	■	■			■	■		6
Villa Ypsilon LASSA architects	■		■		■	■	■	■	■			■	■	9
Total	3	2	4	3	2	3	3	4	3	2	1	4	4	**38**

6.1.1.8 HOUSING CATEGORY

Housing category accounts for a total of 36 parameters identified, with thermal/ airflow, material and sequence parameters occurring only in one of the five projects, and none of the parameters happened in all of the projects. 'Huangshan Mountain Village - MAD Architects' is the project with the highest number of parameters, 9 in total, followed by three other projects with 7 parameters each; 'Folie Divine - Farshid Moussavi Architecture', '56 Leonard Street - Herzog & de Meuron', 'Tudor Apartments - Urko Sanchez Architects' and the 'POP XYZ - Triptyque' with 6 parameters.

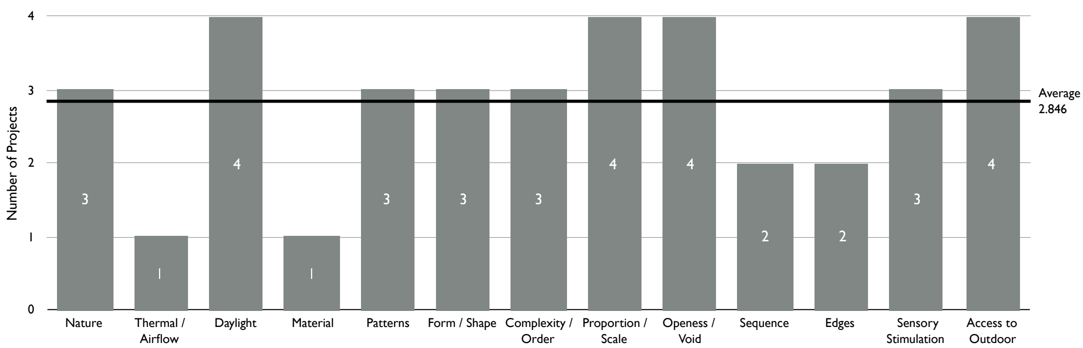


fig. 49 - Number of Projects in each Design Parameters - Housing Category

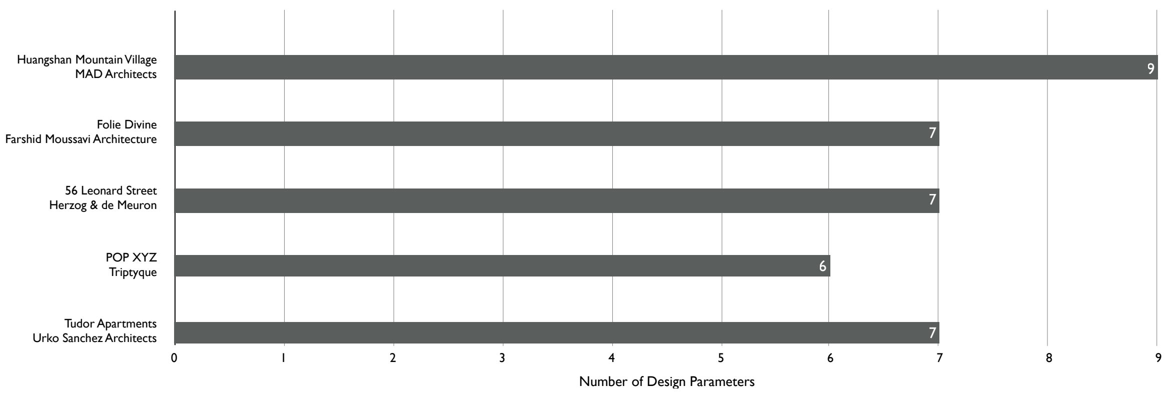


fig. 50 - Number of Design Parameters in each project of Housing Category

table 32 - Inhabitability Parameters - Housing Category

table 33 - Inhabitability Parameters - Housing Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Huangshan Mountain Village MAD Architects	■		■			■	■	■	■		■	■	■	9
Folie Divine Farshid Moussavi Architecture					■	■	■	■	■		■		■	7
56 Leonard Street Herzog & de Meuron			■	■		■	■		■			■	■	7
POP XYZ Triptyque	■		■		■			■		■		■		6
Tudor Apartments Urko Sanchez Architects	■	■	■		■			■	■				■	7
Total	3	1	4	1	3	3	3	4	4	2	2	3	4	**36**

6.1.1.9 INDUSTRIAL CATEGORY

In the industrial category, thermal/airflow and complexity parameters were identified only in one project each, and none of the parameters happened in all of the projects. The total of parameters found in this category was 31, being that 'Herdade Of Freixo Winery / Frederico Valsassina Arquitectos' is the project with the highest number, 9 out of 13, followed by 'DESINO Eco Manufactory Office - Ho Khue Architects' with 8, 'Lozy's Pharmaceuticals Factory / Vaillo + Irigaray Architects, Galar, Vélaz' with 6 and 'Abbey for the Production of Mustard- Pickles and Pickled Vegetables - Dhooge -amp- Meganck Architecture' together with 'The Victorian Desalination Project -amp- Ecological Reserve - AIA Architectes - ASPECT Studios' with 4 parameters each.

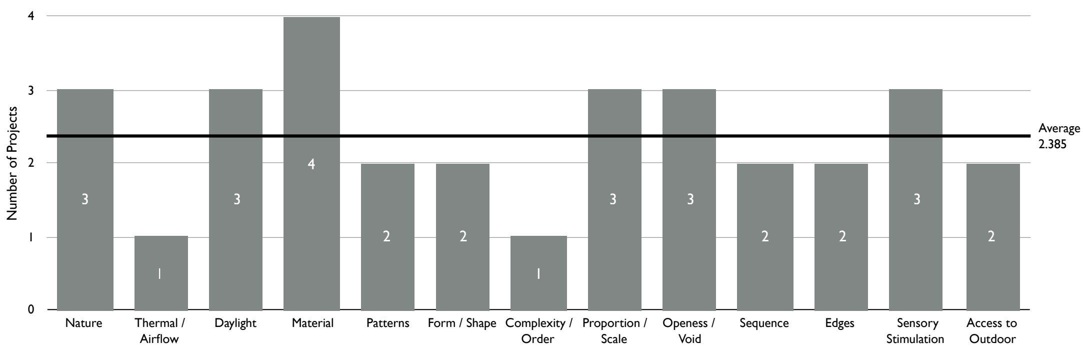


fig. 51 - Number of Projects in each Design Parameters - Industrial Category

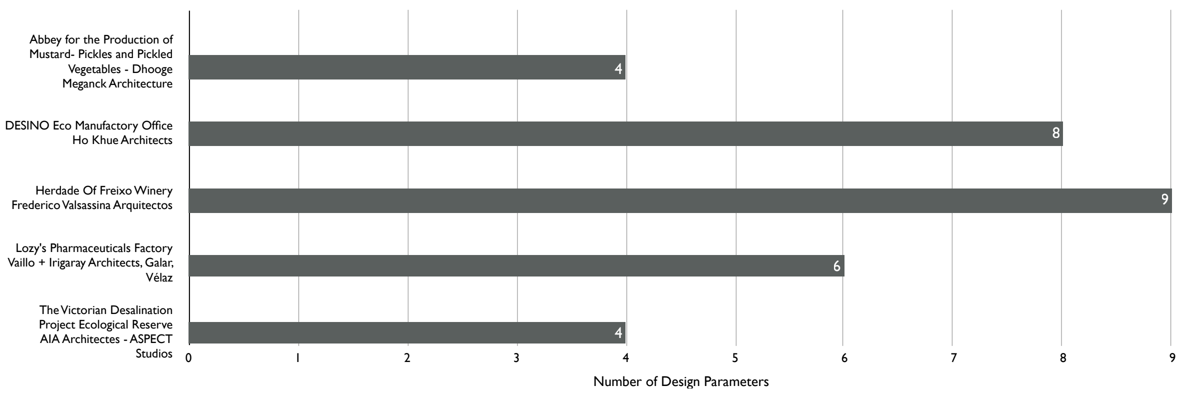


fig. 52 - Number of Design Parameters in each project of Industrial Category

table 34 - Inhabitability Parameters - Industrial Category

table 35 - Inhabitability Parameters - Industrial Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Abbey for the Production of Mustard- Pickles and Pickled Vegetables - Dhooge Meganck Architecture			■	■				■			■			4
DESINO Eco Manufactory Office Ho Khue Architects	■	■	■	■	■				■			■	■	8
Herdade Of Freixo Winery Frederico Valsassina Arquitectos	■		■	■		■	■	■	■	■		■		9
Lozy's Pharmaceuticals Factory Vaillo + Irigaray Architects, Galar, Vélaz				■		■		■	■		■		■	6
The Victorian Desalination Project Ecological Reserve AIA Architectes - ASPECT Studios	■				■					■		■		4
Total	3	1	3	4	2	2	1	3	3	2	2	3	2	**31**

6.1.1.10 INTERIOR CATEGORY

In the interior category, thermal/airflow and edges were not identified in any of the projects, besides sensory stimulation being identified in only one, which was the most voted building in the category. Nevertheless, a tie occurred between two of the projects in the inhabitability parameter framework. 'Nike New York Headquarters / WSDIA | WeShouldDoItAll + STUDIOS Architecture' and 'Airbnb Office - 999 Brannan - Airbnb Environments' have both 9 parameters each. Followed by 'Together Hostel - Cao Pu Studio' with 5, 'RÒMOLA - Andrés Jaque Architects' and 'Yojigen Poketto - elii' with 3.

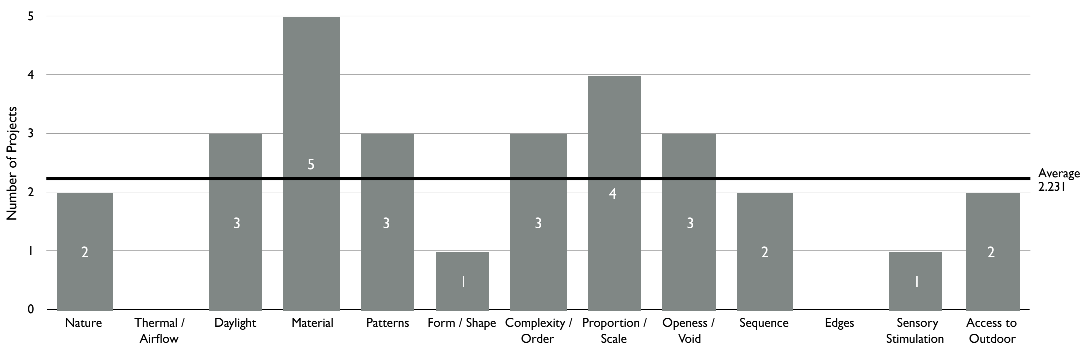


fig. 53 - Number of Projects in each Design Parameters - Interior Category

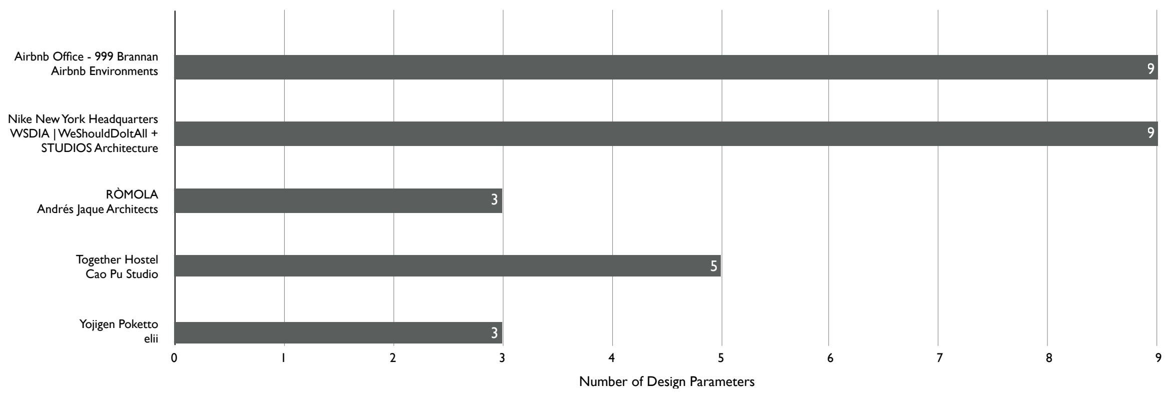


fig. 54 - Number of Design Parameters in each project of Interior Category

table 36 - Inhabitability Parameters - Interior Category

table 37 - Inhabitability Parameters - Interior Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Airbnb Office - 999 Brannan Airbnb Environments	■		■	■	■	■		■	■	■			■	9
Nike New York Headquarters WSDIA | WeShouldDoItAll + STUDIOS Architecture			■	■	■		■	■	■	■		■	■	9
RÒMOLA Andrés Jaque Architects	■			■	■									3
Together Hostel Cao Pu Studio			■	■			■	■	■					5
Yojigen Poketto elii				■			■	■						3
Total	2	0	3	5	3	1	3	4	3	2	0	1	2	**29**

6.1.1.11 OFFICES CATEGORY

In the office category, sensory stimulation was not identified in any of the projects. The category has a total of 37 parameters identified, with proportion/scale and openness/void parameter occurring in all of the five finalist projects, while sensory stimulation could not be identified in any of them. 'RIJNSTRAAT 8 / Ellen van Loon / OMA' was the project with the most parameters, a total of 9 out of 13, followed by 'NASP Headquarters - Dal Pian Arquitetos Associados' with 8, 'Bloomberg's European HQ Foster + Partners' and 'Shinsegae International Olson Kundig' with 7 parameters each, and 'GS1 Portugal PROMONTORIO' with 6.

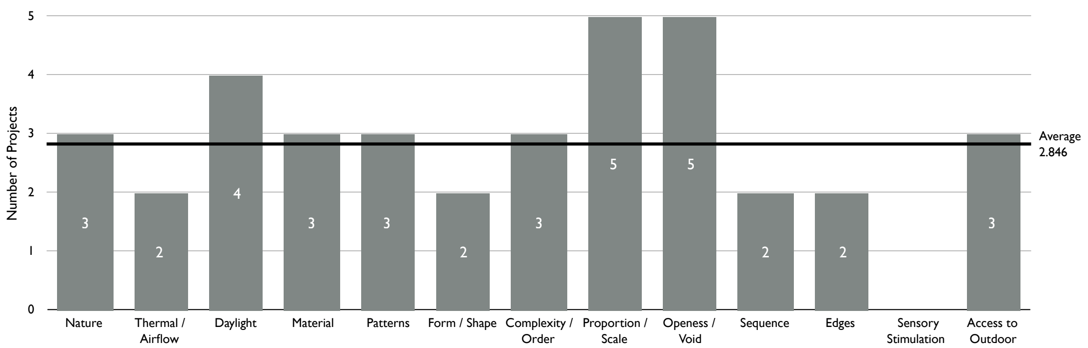


fig. 55 - Number of Projects in each Design Parameters - Offices Category

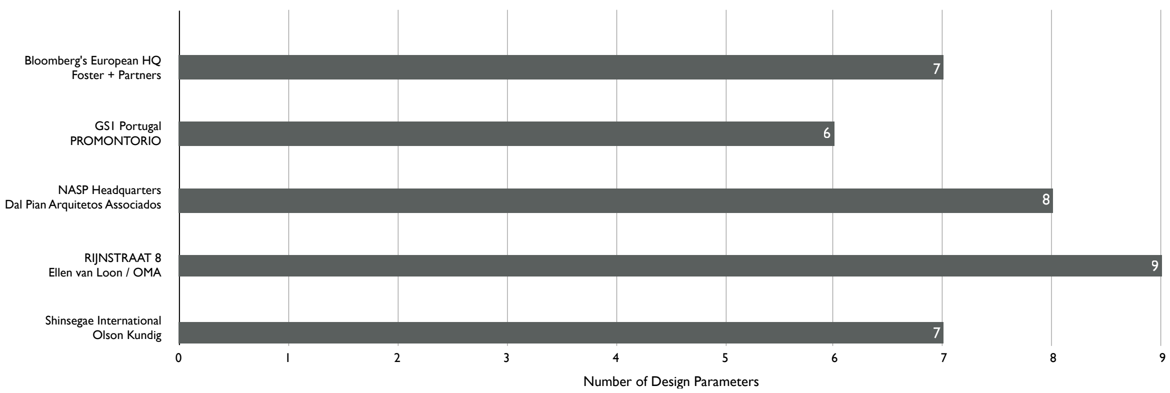


fig. 56 - Number of Design Parameters in each project of Offices Category

table 38 - Inhabitability Parameters - Offices Category

table 39 - Inhabitability Parameters - Offices Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Bloomberg's European HQ Foster + Partners			■	■	■	■	■	■	■					7
GS1 Portugal PROMONTORIO				■	■	■		■	■				■	6
NASP Headquarters Dal Pian Arquitetos Associados	■	■	■				■	■	■	■			■	8
RIJNSTRAAT 8 Ellen van Loon / OMA	■	■	■		■		■	■	■	■	■			9
Shinsegae International Olson Kundig	■		■	■				■	■		■		■	7
Total	3	2	4	3	3	2	3	5	5	2	2	0	3	**37**

6.1.1.12 PUBLIC CATEGORY

In the public category, it was not possible to identify a proper thermal/airflow strategy in any of the projects, since they are all open-air designs with obvious natural airflow scheme, but not with a proper approach to thermal conditions. Nature, daylight, proportion/scale, openness/void and access to outdoor parameter occurring in all of the five projects. The project 'Zaryadye Park - Diller Scofidio + Renfro' was the one with the highest number of parameters: 12 in total. Followed by three projects with 7 parameters; 'Park 'n' Play - JAJA Architects', 'Pedra Da Ra Lookout Point - Carlos Seoane', 'SEOULLO Skygarden - MVRDV'; and the last project 'Israels Plads Square - Sweco Architects - COBE' with 6 parameters. The total parameters verified in this category is 39.

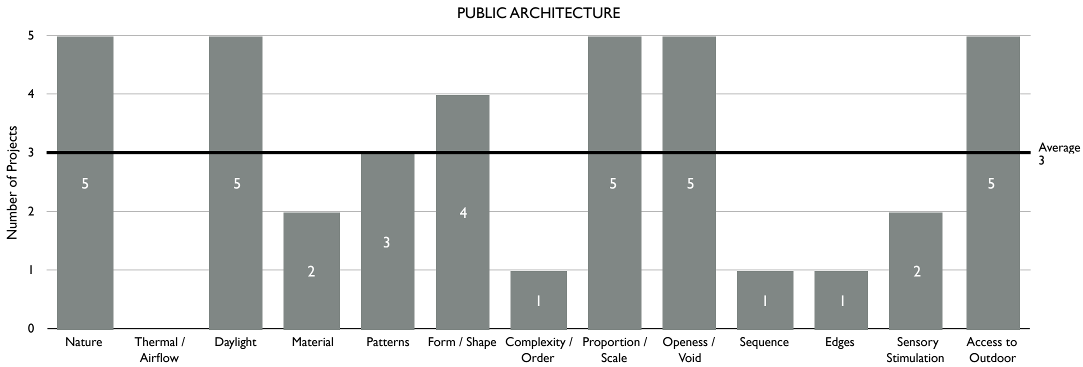


fig. 57 - Number of Projects in each Design Parameters - Public Category

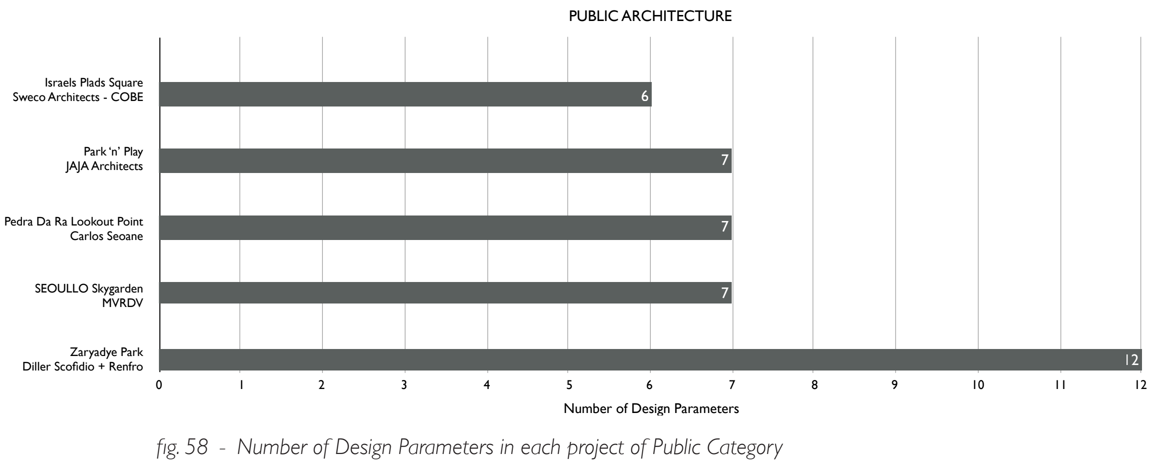


fig. 58 - Number of Design Parameters in each project of Public Category

table 40 - Inhabitability Parameters - Public Category

table 41 - Inhabitability Parameters - Public Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Israels Plads Square Sweco Architects - COBE	■		■			■		■	■				■	6
Park 'n' Play JAJA Architects	■		■		■	■		■	■				■	7
Pedra Da Ra Lookout Point Carlos Seoane	■		■	■	■			■	■				■	7
SEOULLO Skygarden MVRDV	■		■			■		■	■			■	■	7
Zaryadye Park Diller Scofidio + Renfro	■		■	■	■	■	■	■	■	■	■	■	■	12
Total	5	0	5	2	3	4	1	5	5	1	1	2	5	**39**

6.1.1.13 RELIGIOUS CATEGORY

In the Religious category, there is a building where all 13 parameters could be identified; 'Waterside Buddist Shrine - ARCHSTUDIO'. It is easy to observe the details, approach and design strategies of each parameter. The thermal/airflow was recognized in only one project, while daylight, material, patterns, proportion/scale, and openness/void parameters happening in almost all of the projects. Followed by 'Suzhou Chapel - Neri-amp-Hu Design and Research Office' with 9 parameters, 'Suvela Chapel - OOPEAA' with 6, and 'Kapelle Salgenreute - Bernardo Bader Architekten' together with 'Bosjes Chapel - Steyn Studio' with 5. The category accounts for 38 total parameters.

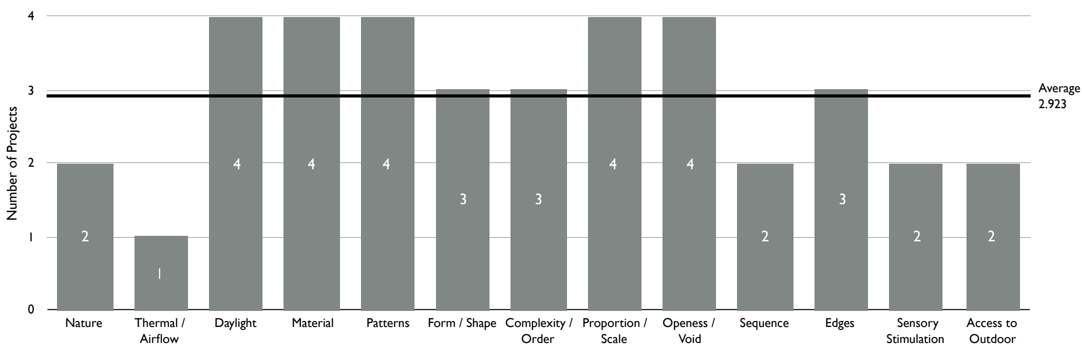


fig. 59 - Number of Projects in each Design Parameters - Religious Category

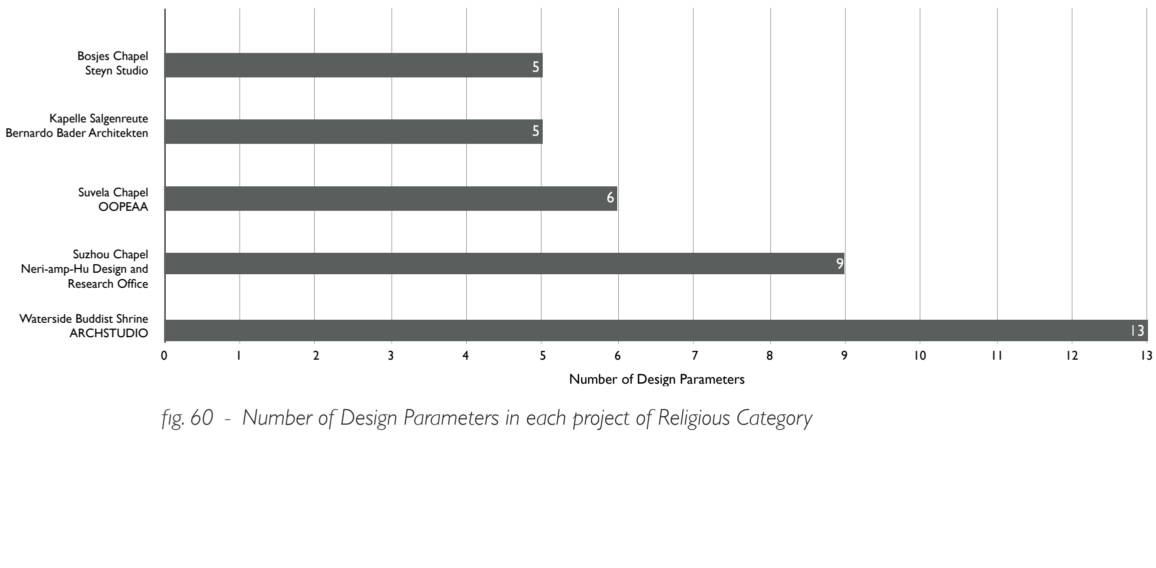


fig. 60 - Number of Design Parameters in each project of Religious Category

table 42 - Inhabitability Parameters - Religious Category

table 43 - Inhabitability Parameters - Religious Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Bosjes Chapel Steyn Studio	■		■			■		■	■					5
Kapelle Salgenreute Bernardo Bader Architekten				■	■	■		■			■			5
Suvela Chapel OOPEAA			■	■	■		■		■				■	6
Suzhou Chapel Neri-amp-Hu Design and Research Office			■	■	■		■	■	■	■	■	■		9
Waterside Buddist Shrine ARCHSTUDIO	■	■	■	■	■	■	■	■	■	■	■	■	■	13
Total	2	1	4	4	4	3	3	4	4	2	3	2	2	**38**

6.1.1.14 SMALL SPACES CATEGORY

In the small space category, a total of 36 parameters were identified. The Sequence parameter was not found in any of the projects and sensory/stimulation was identified in only one, while openness/void was identified in all of the five projects. The '100 Classrooms for Refugee Children / Emergency Architecture & Human Rights' is the project with the highest number of parameters identified: 9 out of 13. Followed by 'DD16 - BIO-architects', 'ICD-ITKE Research Pavilion 2016-17 - ICD-ITKE University of Stuttgart' together with 'MINI LIVING - Breathe - SO-IL' with 7 parameters; and the 'House of Switzerland Pavilion - Dellekamp Arquitectos' with 6.

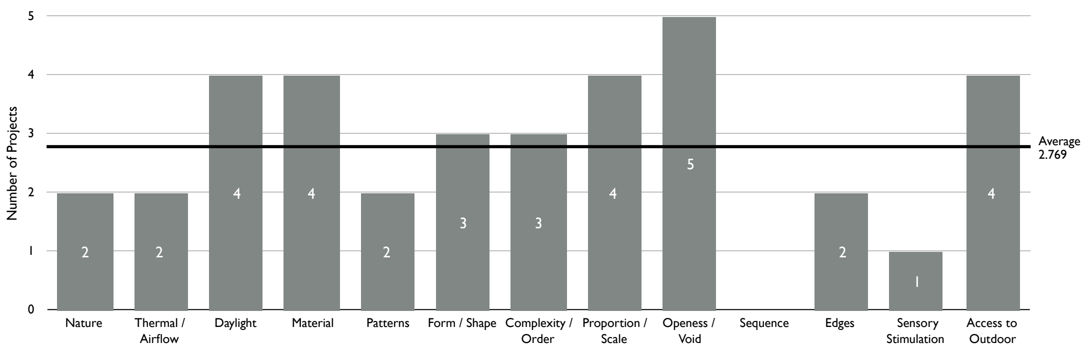


fig. 61 - Number of Projects in each Design Parameters - Small Spaces Category

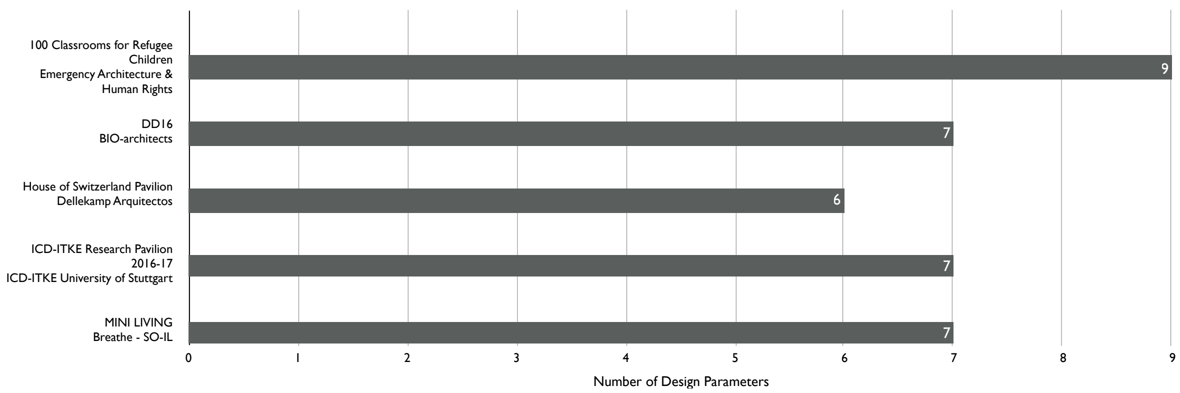


fig. 62 - Number of Design Parameters in each project of Small Spaces Category

table 44 - Inhabitability Parameters - Small Spaces Category

table 45 - Inhabitability Parameters - Small Spaces Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
100 Classrooms for Refugee Children Emergency Architecture & Human Rights		■		■	■	■	■	■	■		■	■		9
DD16 BIO-architects	■		■	■				■	■		■		■	7
House of Switzerland Pavilion Dellekamp Arquitectos			■	■			■	■	■				■	6
ICD-ITKE Research Pavilion 2016-17 ICD-ITKE University of Stuttgart			■	■	■	■		■	■				■	7
MINI LIVING Breathe - SO-IL	■	■	■			■	■		■				■	7
Total	2	2	4	4	2	3	3	4	5	0	2	1	4	**36**

6.1.1.15 SPORTS CATEGORY

Sports category accounts for a total of 35 parameters identified among the projects. Nature, edges and sensory stimulation occurred only once, while material, proportion/ scale, and openness/void happening in all of the five projects. The 'Gymnasium of New Campus of Tianjin University / Atelier Li Xinggang' with the highest number of 10, followed by; 'Rwanda Cricket Stadium - Light Earth Designs' with 9; 'Municipal Gym of Salamanca - Carreño Sartori Arquitectos' with 6; 'Pärnu Stadium - Kamp Arhitektid' and 'Topsportschool Antwerp - Compagnie O Architects' with 5.

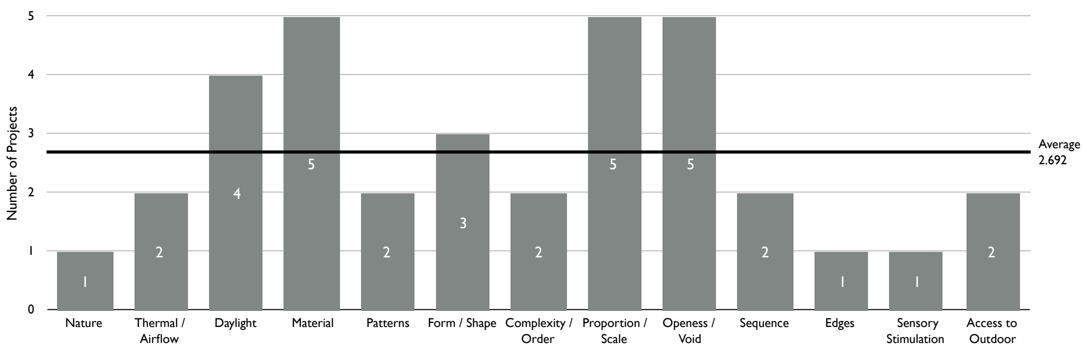


fig. 63 - Number of Projects in each Design Parameters - Sports Category

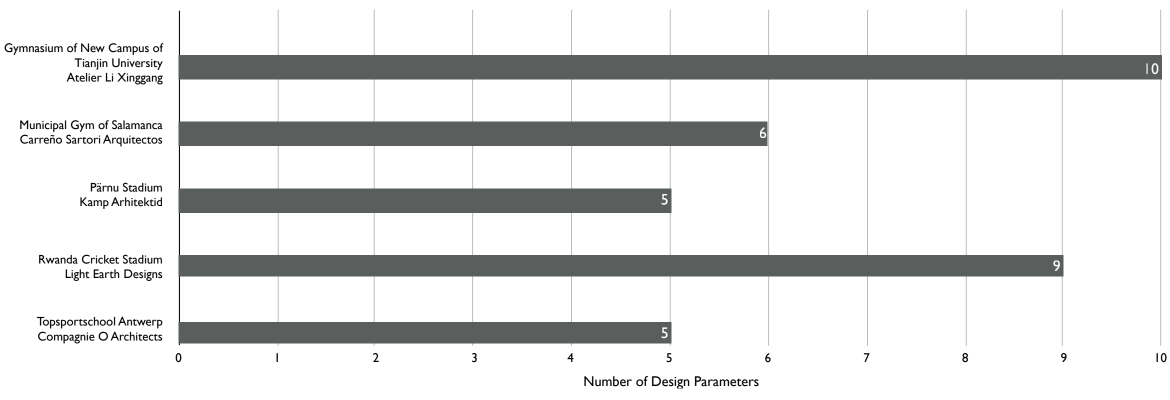


fig. 64 - Number of Design Parameters in each project of Sports Category

table 46 - Inhabitability Parameters - Sports Category

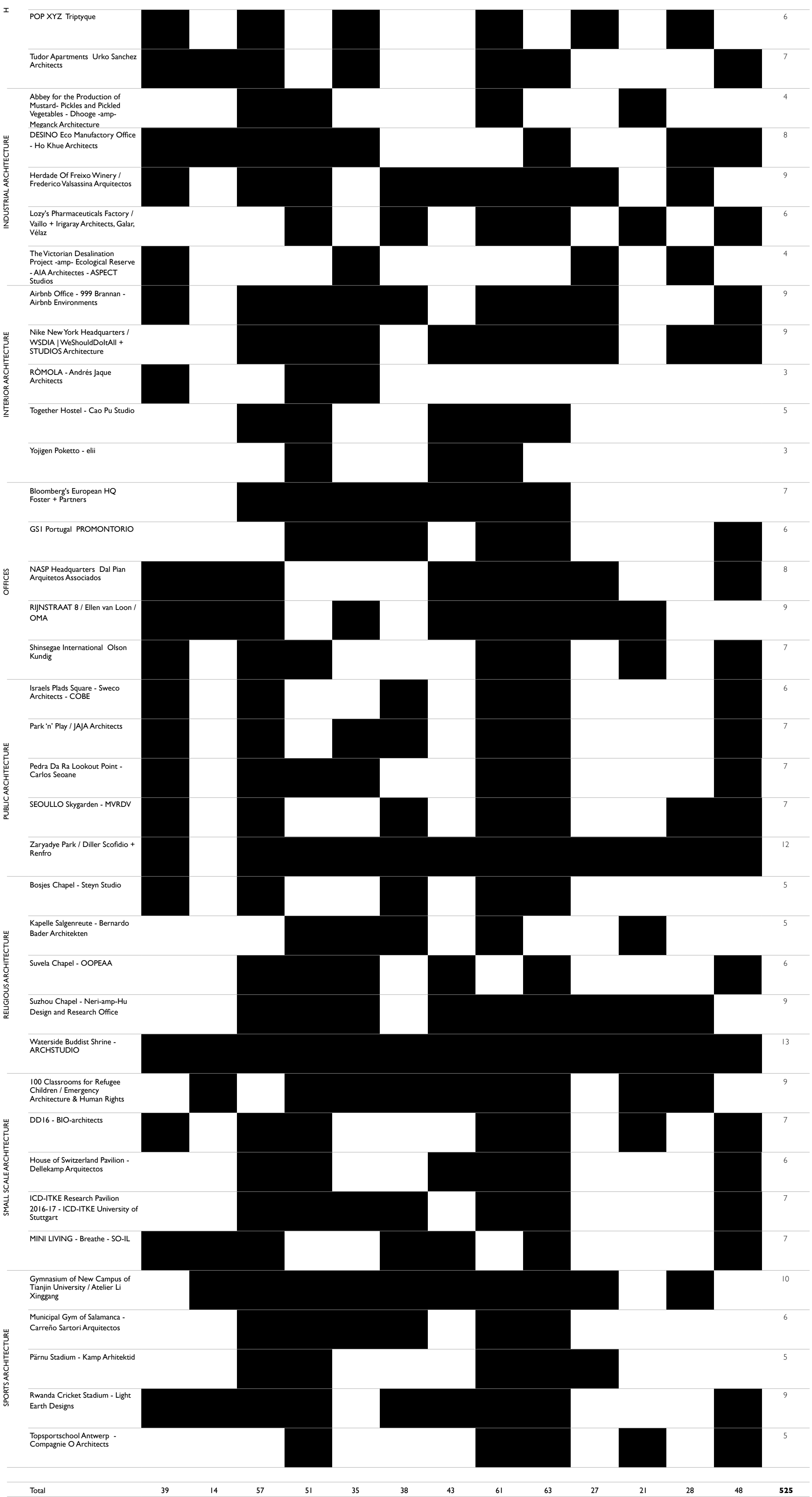
table 47 - Inhabitability Parameters - Sports Category

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Gymnasium of New Campus of Tianjin University Atelier Li Xinggang														10
Municipal Gym of Salamanca Carreño Sartori Arquitectos														6
Pärnu Stadium Kamp Arhitektid														5
Rwanda Cricket Stadium Light Earth Designs														9
Topsportschool Antwerp Compagnie O Architects														5
Total	1	2	4	5	2	3	2	5	5	2	1	1	2	**35**

table 48 - Total number o parameters identified in each project from the Case Study of Public Award

table 49 - Total number o parameters identified in each project from the Case Study of Public Award

	name	Nature	Thermal	Daylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
BEST APPLIED PRODUCTS	CaixaForum Sevilla / Vázquez Consuegra			■	■		■	■		■		■			6
	Canaletto Residential Tower - UNStudio	■			■		■		■					■	5
	Flagship Building - Geodesic Design	■	■	■						■					4
	Kulm Eispavilion - Foster - Partners			■	■			■	■					■	5
	Skovbakke School - CEBRA			■	■			■		■				■	5
COMMERCIAL ARCHITECTURE	Apple Store Michigan Avenue, Chicago / Foster + Partners	■		■			■	■	■	■	■	■		■	9
	CityLife Shopping District - Zaha Hadid Architects			■	■	■	■	■	■	■				■	8
	Common Ground - URBANTAINER							■	■	■	■			■	5
	Malmö Saluhall - Wingårdh Arkitektkontor AB				■		■		■	■		■		■	6
	PETRA. The Stone Atelier - Fran Silvestre Arquitectos				■		■		■	■	■	■	■		7
CULTURAL ARCHITECTURE	Foro Boca - Rojkind Arquitectos				■	■		■		■		■			5
	LEGO House - BIG	■						■		■	■			■	5
	Louvre Abu Dhabi - Ateliers Jean Nouvel	■		■		■		■	■	■	■		■	■	9
	Tianjin Binhai Library - MVRDV - Tianjin Urban Planning and Design Institute			■			■	■	■	■			■		6
	Zeitz Museum of Contemporary Art Africa / Heatherwick Studio			■	■	■	■	■	■	■	■		■		9
EDUCATIONAL ARCHITECTURE	Architecture Faculty in Tournai Aires Mateus							■	■	■					3
	Children Village	■	■	■	■	■		■		■		■	■	■	10
	King Abdullah Petroleum Studies and Research Centre Zaha Hadid Architects			■		■	■	■	■	■			■	■	8
	Lycee Schorge Secondary School Kéré Architecture	■	■	■	■	■		■	■	■				■	9
	Maria Montessori Mazatlán School EPArquitectos + Estudio Macías Peredo	■		■	■		■	■	■	■	■				8
HEALTHCARE ARCHITECTURE	Maggie--39-s Centre Barts - Steven Holl Architects			■			■		■	■	■			■	6
	Maggie-s Oldham - dRMM	■		■	■				■	■	■			■	7
	Psychiatric Center - Vaillo - Irigaray Architects - Galar - Vélaz				■			■			■		■	■	5
	Santa Fe de Bogotá Foundation / El Equipo de Mazzanti	■		■	■	■		■	■	■			■		8
	Urban Hospice - NORD Architects	■		■			■		■	■				■	7
HOSPITALITY	Ixi'im Restaurant Jorge Bolio Arquitectura + Lavalle + Peniche Arquitectos + Mauricio Gallegos Arquitectos + Central de	■		■	■	■			■	■	■		■	■	9
	JIKKA Issei Suma	■		■	■		■		■		■				6
	KOI Cafe / Farming Architects	■		■	■	■		■	■	■	■		■	■	10
	Oberholz Mountain Hut Peter Pichler Architecture + Pavol Mikolajcak			■	■		■	■	■	■				■	7
	The Wine Ayutthaya Bangkok Project Studio	■		■	■	■		■	■	■			■	■	9
HOUSES	Optical Glass House	■	■	■	■	■		■	■	■	■		■	■	11
	Carroll House LOT-EK			■			■				■			■	4
	MeMo House BAM! arquitectura	■	■	■	■				■	■			■	■	8
	Primitive Future - GUMPHA House Within N Without				■		■	■	■			■	■		6
	Villa Ypsilon LASSA architects	■		■		■	■	■	■	■			■	■	9
IOUSING	Huangshan Mountain Village / MAD Architects	■		■			■	■	■	■		■	■	■	9
	Folie Divine Farshid Moussavi Architecture					■	■	■	■	■		■		■	7
	56 Leonard Street Herzog & de Meuron			■	■		■	■		■			■	■	7


H
POP XYZ Triptyque 6
Tudor Apartments Urko Sanchez Architects 7
INDUSTRIAL ARCHITECTURE
Abbey for the Production of Mustard- Pickles and Pickled Vegetables - Dhooge -amp- Meganck Architecture 4
DESINO Eco Manufactory Office - Ho Khue Architects 8
Herdade Of Freixo Winery / Frederico Valsassina Arquitectos 9
Lozy's Pharmaceuticals Factory / Vaillo + Irigaray Architects, Galar, Vélaz 6
The Victorian Desalination Project -amp- Ecological Reserve - AIA Architectes - ASPECT Studios 4
INTERIOR ARCHITECTURE
Airbnb Office - 999 Brannan - Airbnb Environments 9
Nike New York Headquarters / WSDIA | WeShouldDoItAll + STUDIOS Architecture 9
RÒMOLA - Andrés Jaque Architects 3
Together Hostel - Cao Pu Studio 5
Yojigen Poketto - elii 3
OFFICES
Bloomberg's European HQ Foster + Partners 7
GS1 Portugal PROMONTORIO 6
NASP Headquarters Dal Pian Arquitetos Associados 8
RIJNSTRAAT 8 / Ellen van Loon / OMA 9
Shinsegae International Olson Kundig 7
PUBLIC ARCHITECTURE
Israels Plads Square - Sweco Architects - COBE 6
Park 'n' Play / JAJA Architects 7
Pedra Da Ra Lookout Point - Carlos Seoane 7
SEOULLO Skygarden - MVRDV 7
Zaryadye Park / Diller Scofidio + Renfro 12
RELIGIOUS ARCHITECTURE
Bosjes Chapel - Steyn Studio 5
Kapelle Salgenreute - Bernardo Bader Architekten 5
Suvela Chapel - OOPEAA 6
Suzhou Chapel - Neri-amp-Hu Design and Research Office 9
Waterside Buddist Shrine - ARCHSTUDIO 13
SMALL SCALE ARCHITECTURE
100 Classrooms for Refugee Children / Emergency Architecture & Human Rights 9
DD16 - BIO-architects 7
House of Switzerland Pavilion - Dellekamp Arquitectos 6
ICD-ITKE Research Pavilion 2016-17 - ICD-ITKE University of Stuttgart 7
MINI LIVING - Breathe - SO-IL 7
SPORTS ARCHITECTURE
Gymnasium of New Campus of Tianjin University / Atelier Li Xinggang 10
Municipal Gym of Salamanca - Carreño Sartori Arquitectos 6
Pärnu Stadium - Kamp Arhitektid 5
Rwanda Cricket Stadium - Light Earth Designs 9
Topsportschool Antwerp - Compagnie O Architects 5
Total 39 14 57 51 35 38 43 61 63 27 21 28 48 525

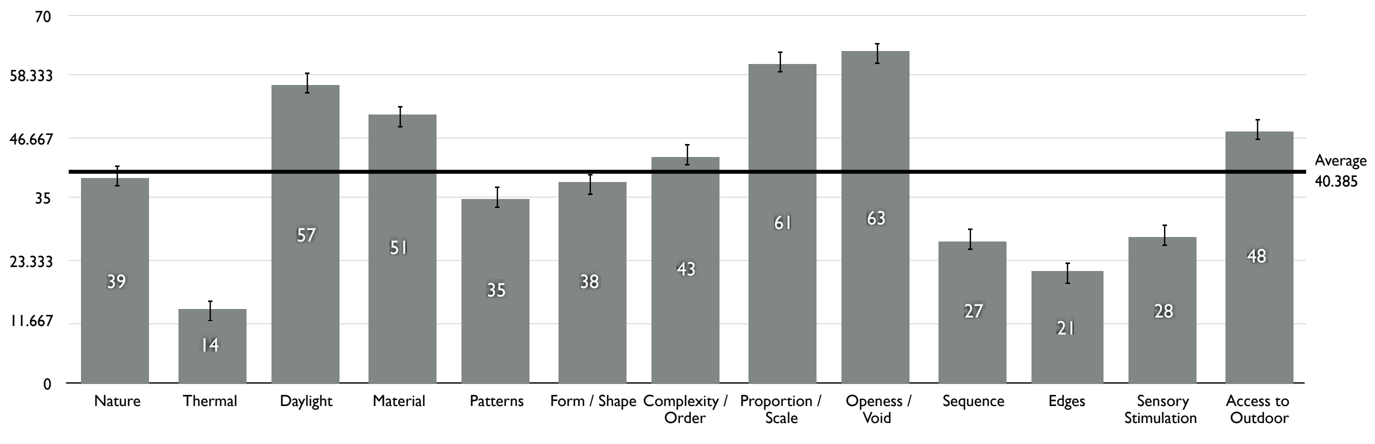


fig. 65 - Total number o parameters identified in each category from the Case Study of Public Award

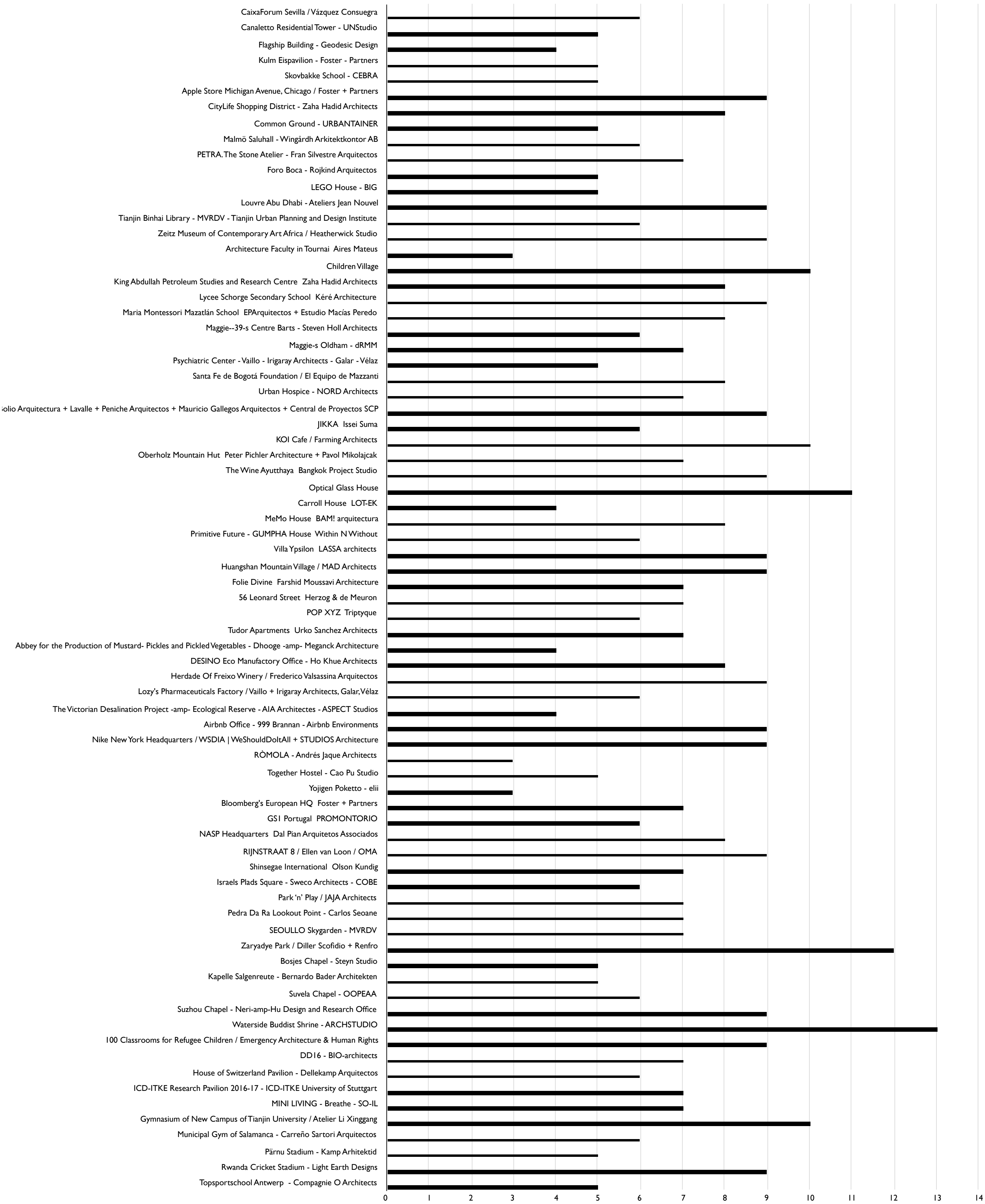


fig. 66 - Total number o parameters identified in each project from the Case Study of Public Award

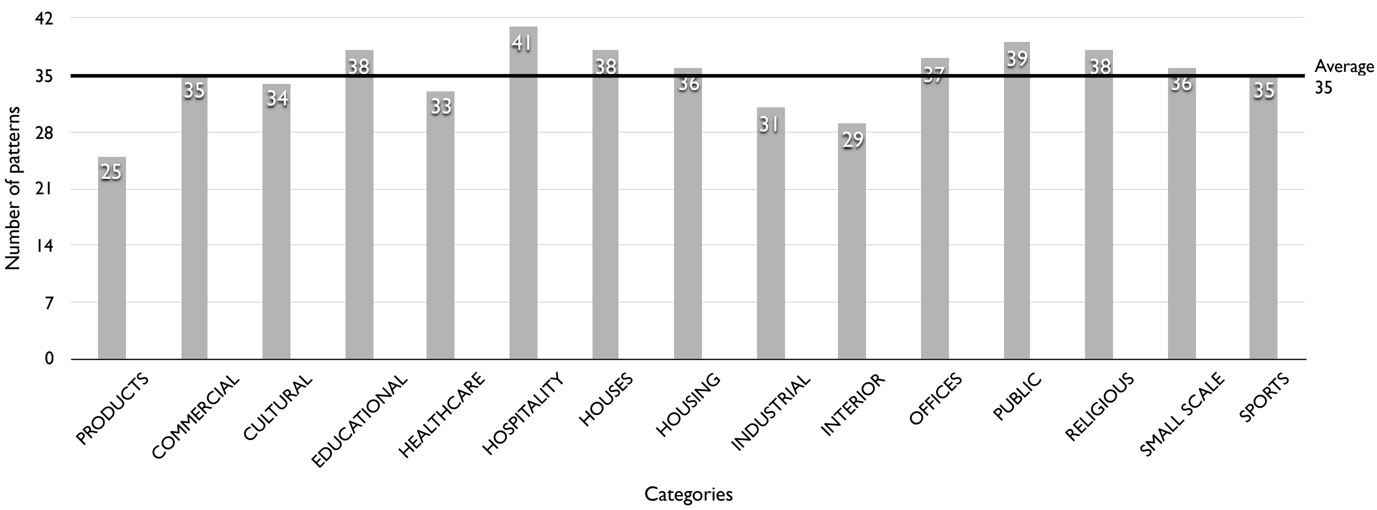


fig. 67 - Comparison of parameters utilized in each category

6.1.2 RESULTS

The proposed methodology successfully demonstrated the effectiveness of the inhabitability parameters framework by meeting the criteria of popular preferences, highlighting the parameters' practical implications. Consequently, it also demonstrated that the proposed inhabitability parameters objectively add qualities to the built environment as voters preferred buildings that have the most amount of parameters.

Subsequently, the research also presents a valuable dataset analysis of post-design evaluation, where the impact of the adopted design strategies could be observed, and improvements for each analyzed category were identified.

In the general analysis of the inhabitability parameters found in all building categories, it is possible to notice in table 63, the thermal/airflow as the smallest occurring parameter, in only 14 of 75 projects. Also, the parameter which was identified the most was openness/void, occurring in 63 projects out of the 75. In table 65, we can see that the building categories and the corresponding number of parameters. Hospitality was the category with the most parameters found.

6.2 CASE STUDIES OF BUILDINGS IN TOKYO

A second case study analysis was conducted on buildings around the Tokyo metropolitan area. The main idea was to be able to be present and have a holistic experience of the buildings, which is not always possible through photographs and drawings - like in the case study of Public Awards. The purpose again was to use the proposed inhabitability parameters to evaluate built environments of different scales in order to collect evidence based on real design outcomes. Therefore, five projects were chosen based on different size and program: the retail building 'Sunny Hills' designed by Kengo Kuma and Associates, located in Aoyama; the school 'Fuji Kindergarten' designed by Tezuka Architects, and located in Tachikawa; the museum 'National Art Center' designed by architect Kisho Kurokawa located in Roppongi; 'Yoyogi National Gymnasium' designed by architect Kenzo Tange located in Yoyogi; and the retail building 'Prada', located in Omotesando, and designed by architects Herzog and de Meuron.

6.2.1 APPLICATION

With the same method applied in the Case Studies of Public Award, an analysis was conducted on the buildings in Tokyo against the inhabitability parameters. However, as additional information and as a post method application, an Inhabitability Appraisal was proposed as an add-on method to understand one step further the occurrence of the design strategies that determine the inhabitability parameters. The appraisal was defined by a rating scale: one star means there is little evidence of the parameter in the project; two stars - when there is evidence of the parameter but it was not completely explored; and three stars - when the project fulfills the application strategies of the parameter clearly and completely.

6.2.1.1 SUNNY HILLS

The pineapple cake shop designed by Kengo Kuma and Associates was completed in December of 2013. It stands out for its intricate wooden structure based on a traditional Japanese joint system. The joint system produces a complex three-dimensional lattice with thin layers of wooden pieces, resulting in a compelling relation to the hexagonal skin of the pineapple. Which it was one of the requirements of the client: to reproduce in the building the preparation of its cake. The building has three floors and an additional rooftop with a total area of 297m2. Kuma words about this project: "Our aim was to create a forest in the busy city centre,"[365] "We studied how lighting states would change in a day in the woods, and came up with a shape like a basket."[366]

12 inhabitability parameters out of 13 were identified in the building, missing only the Form/Shape parameter, which is one of the main intentions Kuma has with his design approach: "I want to erase architecture"[367]. The total number of 12 parameters is an impressive achievement for such a small building, being a good example of how to approach a variety of design strategies. An important consideration to highlight is the scent of wood around all the spaces, and even outside when you are approaching the building - it happens especially in rainy days, and is a strategy linked to the Sensory Stimulation parameter. Thus, by utilizing wood - which is Kuma's material of choice - resulted in the occurrence of six parameters: Nature, Material, Patterns, Complexity/Order, Proportion/Scale, and Sensory Stimulation.

In the Inhabitability Appraisal, the project achieved 88% of its parameters, with a total of 32 stars out of 36. Edges parameter was evaluated with only one star; Openness/Void and Sequence with two stars and all the rest of the parameters with three stars.

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365 Frearson, A. (2014, February 25). SunnyHills cake shop by Kengo Kuma wrapped by intricate timber lattice. Retrieved from https://www.dezeen.com/2014/02/25/sunnyhills-at-minami-aoyama-by-kengo-kuma/

366 Ibid.

367 Kuma, K., & Bognár, B. (2009). Material immaterial: The new work of Kengo Kuma. New York: Princeton Architectural.

table 50 - Inhabitability Parameters and Inhabitability Appraisal - Sunny Hills

table 51 - Inhabitability Parameters and Inhabitability Appraisal - Sunny Hills

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Sunny Hills Kengo Kuma														12
Total	1	1	1	1	1	0	1	1	1	1	1	1	1	**12**
Inhabitability Appraisal	***	***	***	***	***		***	***	**	**	*	***	***	32

6.2.1.2 FUJI KINDERGARTEN

Tezuka Architects designed Fuji Kindergarten in 2007. The oval-shaped roof deck building with a perimeter of 183m accommodates more than 500 children, and its open plan allows pupils to explore all its spaces, and to run around the terrace in a never-ending loop. The roof deck preserved three large trees of 25m height each, enabling an interesting internal space with the trunks of the trees. Besides, they applied a strong net to connect the roof deck with the branches, which allows kids to play and trail on it. The roof deck is only 2.1m tall to facilitate the connection between the two levels. There are also several skylights built on the deck to transfer daylight into the interior spaces. Another curiosity is when it is raining, kids could also play with falling rainwater from the tubes since they are all facing the courtyard, generating an interesting natural ephemeral condition. The school was designed to give freedom to children by learning while exploring the space. The idea was to have the building as a playground with a continuous environment of learning and playing. All the classrooms have sliding doors and they are all facing the inward yard. This approach generates a fluidity and homogeneous integration of spaces, with a delimited center which provides democratic sense and of unity from being part of a group, since they are constantly seeing each other. The architects stated that the project was "...conceived as a single village."[368]

11 inhabitability parameters were identified in the building, only missing the Patterns and Edges parameters. There is no intentional design application of Patterns, and not having the Edges parameter, reinforce the design intent of the architects to have a fluidity and openness of the space. In the Inhabitability Appraisal, the project scored 28 stars out of 33, which means an achievement of 84%. The Material parameter was the only one evaluated with one star, while Complexity/Order, Sequence and Sensory Stimulation parameters have two stars each. The rest of the parameters all with three stars.

368 Tezuka, A. (2007). Fuji Kindergarten | Educational Buildings. Retrieved from http://www.tezuka-arch.com/english/works/education/fujiyochien/

table 52 - Inhabitability Parameters and Inhabitability Appraisal - Fuji Kindergarten

table 53 - Inhabitability Parameters and Inhabitability Appraisal - Fuji Kindergarten

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Fuji Kindergaten Tezuka Architects														11
Total	1	1	1	1	0	1	1	1	1	1	0	1	1	11
Inhabitability Appraisal	***	***	***	*		***	**	***	***	**		**	***	28

6.2.1.3 THE NATIONAL ART CENTER

One of the largest exhibition facilities in Tokyo, The National Art Center was designed by architect Kisho Kurokawa, and completed in 2007. An undulating curtain wall with glass louvers delimits the large interior atrium, and provides an impactful characteristic to the building. Besides the five large exhibition rooms, the Center also has a library, a restaurant, a cafe, an auditorium, a lecture room, a museum shop, and a rooftop garden. The rooftop garden is located on the third floor, between the library, auditorium and lecture spaces, with an interesting environment to be, while in the library or in the auditorium hall. Another outdoor space in the Center is the large terrace located behind the exhibition rooms.

Within the inhabitability parameters framework, 11 parameters were identified. No design strategy was identified for Thermal/Airflow and Edges parameters, since there is no option for natural ventilation, and not a protected, safeguard and retreated space. In the Inhabitability Appraisal, the project scored 24 stars out of 33, which means an achievement of 72%. The parameters Nature and Proportion/Scale were evaluated with only one star. Daylight, Material, Complexity/Order, Sequence and Access to Outdoor parameters with two stars each. And the rest of the parameters with three stars.

table 54 - *Inhabitability Parameters and Inhabitability Appraisal - The National Art Center*

table 55 - *Inhabitability Parameters and Inhabitability Appraisal - The National Art Center*

name	**Nature**	**Thermal / Airflow**	**Dauylight**	**Material**	**Patterns**	**Form / Shape**	**Complexity / Order**	**Proportion / Scale**	**Openess / Void**	**Sequence**	**Edges**	**Sensory Stimulation**	**Access to Outdoor**	**Total**
The National Art Center Kisho Kurokawa														11
Total	1	0	1	1	1	1	1	1	1	1	0	1	1	**11**
Inhabitability Appraisal	*		**	**	***	***	**	*	***	**		***	**	24

6.2.1.4 YOYOGI NATIONAL GYMNASIUM

The architect Kenzo Tange was in charge of designing the Yoyogi National Gymnasium for the 1964 Summer Olympic Games held in Tokyo. The gymnasium is an iconic building with a combination of traditional and modern architecture, and Japanese and Western aesthetics and technologies. Tange smartly utilized the green context of the site to blend his building with the landscape, in a way that the concrete curved structure seems to come out from the site. Tange explored the suspended prestressed cable structure in his design[369], inspired by the structural approach of Corbusier's Philips Pavilion and Saarinen's Yale Hockey Stadium. It is considered the largest suspended roof span in the world. The roof surfaces were so carefully designed and built that it transmits the idea of suspended fabrics.

11 parameters were identified in this project, missing the Nature and Access to Outdoor parameters. Nature is not observed as a design strategy in the building and Access to Outdoor was not present, perhaps due to a program which holds a great number of people. Therefore, considering the Inhabitability Appraisal, Daylight parameter was evaluated with one star; the parameters Thermal/Airflow and Material with two stars each; and the rest of the parameters with three stars. In a total of 29 stars out of 33 possibilities from its own parameters, giving the project a total achievement of 87%.

369 Kroll, A. (2011, February 15). AD Classics: Yoyogi National Gymnasium / Kenzo Tange. Retrieved from https://www.archdaily.com/109138/ad-classics-yoyogi-national-gymnasium-kenzo-tange *table 56 - Inhabitability Parameters and Inhabitability Appraisal - Yoyogi National Gymnasium*

table 57 - Inhabitability Parameters and Inhabitability Appraisal - Yoyogi National Gymnasium

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Yoyogi National Gymnasium Kenzo Tange		[redacted]												11
Total	0	1	1	1	1	1	1	1	1	1	1	1	0	11
Inhabitability Appraisal		**	*	**	***	***	***	***	***	***	***	***		29

6.2.1.5 PRADA AOYAMA

The cutting-edge building designed by Herzog & de Meuron and completed in 2003, and it is still a landmark on the Tokyo architecture. The building has a unique structure of diamond-shape grid pieces of steel with glass cladding panels as building system skin, that supports the six stories of retail, lounges and event space. The grid defines the shape of the opening and works as a mesh of structure to support the concrete slabs in a notable performance to protect the glass in case of earthquakes.

Despite the sharp angles of the form, there are plenty of smooth curves throughout the interior with a range of different materials. In addition, some pieces of the glass cladding panels are curved, due to the concave and convex approach, which results in a soft / bubble appearance. The navigation throughout the building is continuous and smooth, with the encouragement of fluid space. The building works as "an interactive optical device. Because some of the glass is curved, it seems to move as you walk around it. That creates awareness of both the merchandise and the city—there's an intense dialogue between actors. Also, the grid brings a human scale to the architecture, like display windows. It's almost old-fashioned." Jacques Herzog.[370]

The Prada Aoyama scored 10 parameters out of 13. Nature, Thermal/Airflow, and Access to Outdoor parameters were not identified. In the Inhabitability Appraisal, the project achieved a total of 26 stars out of 30, which means a use of 86% among its own parameters. Although there are several different materials in certain interior spaces, most of the store is white painted, resulting in only one star on the Material parameter. Edges and Sensory Stimulation accounts for two stars and the rest of the parameters with three stars each.

370 *Celant, G., & Prada, M. (2003). Prada Aoyama Tokyo: Herzog et de Meuron. Milan: Fondazione Prada.*

table 58 - Inhabitability Parameters and Inhabitability Appraisal - Prada Aoyama

table 59 - Inhabitability Parameters and Inhabitability Appraisal - Prada Aoyama

name	Nature	Thermal / Airflow	Dauylight	Material	Patterns	Form / Shape	Complexity / Order	Proportion / Scale	Openess / Void	Sequence	Edges	Sensory Stimulation	Access to Outdoor	Total
Prada Aoyama Herzog & de Meuron			[redacted]											10
Total	0	0	1	1	1	1	1	1	1	1	1	1	0	**10**
Inhabitability Appraisal			***	*	**	***	***	***	***	***	**	**		26

6.2.2 RESULTS OF CASE STUDY OF BUILDINGS IN TOKYO

The Case Study of Buildings in Tokyo validated the methodology of the previous Case Study of Public Awards, and was also able to confirm the legitimacy of the inhabitability parameters as a framework. It was evidenced that analysing projects only by printed material - as in the Case Study of Public Awards - does not translate the intensity of certain design strategies, which being physically in the building, facilitate the holistic experience. In the case of Sunny Hills, for example, the scent from the wood is a really important aspect of the building that stands out and which positively influences the users.

The Inhabitability Appraisal was also a relevant improvement to the previous method, since it enabled a more precise assessment of the characteristic of the Inhabitability Parameters Framework. It made possible to analyse the results, conclusions, and discussions from the general method. We can also observe the design integration between the parameters and the potentialities of development a specific parameter in a building category, besides comparing the weakness and potentialities in each project or other building types.

6.3 CONCLUSION

This research intended to present adequate scientific evidence associated with the built environment and human health as to reaffirm the potentialities of design decisions and the effect it has on buildings' users. As a result, thirteen parameters were developed based on scientific findings which are not specific to a rating system but objectify adequate approaches to the built environment. Designers can make use of the proposed parameters as a framework of considerations towards more human-centred architectural outcomes, and creatively address the challenges of the human/ space relation.

The case study of Public Award analysis conducted and outlined in this chapter was able to validate the legitimacy of the proposed inhabitability parameters by meeting the criteria of popular preferences, highlighting the parameters' practical implications. The proposed methodology, although subjective, successfully demonstrated that the proposed inhabitability parameters objectively add qualities to the built environment as voters preferred buildings that have the most amount of parameters.

The case study of Buildings in Tokyo analysis was able to further validate the legitimacy of the proposed inhabitability parameters. As the analysis was based on site visits, the spatial experience was intensified, evidencing the integration between parameters and how design strategies can be adopted to approach parameters simultaneously.

Subsequently, the results from both case study analysis present a valuable dataset analysis of post-occupancy evaluation, where the impact of the adopted design strategies could be observed, and improvements for each analyzed category could also be identified.

The presented framework to approach spatial inhabitability through practical design was demonstrated to be a valid resource for architects, designers, clients, contractors and stakeholders who seek human-centred qualities in architecture that support occupants' overall health and well-being. The analysis results also may encourage the discussion between professionals from different disciplines on subconscious perceptions, subjective preferences, and cognitive reactions as to promote a better understanding of environmental influences, and consequently inform designers how to creatively explore design strategies for optimal building outcomes.

The goal of this research is not only to identify every single aspect of spatial cognition but rather to provide an assertive explanation on how space behavior parameters could be positively applied to architectural design towards an evolution of the practice, the space, and the design methods. Discoveries like these can emphasize the importance of architecture as a habitable built space with a demonstration of scientific studies based on a review of the literature across health, behavior, space, and architecture but with the strong link on neuroscience and psychology which are the major disciplines that are going deep into the investigation on how environments affect human. In order to contribute to the architectural design process as well as other researchers and professionals in their quest to improve not only the built space but the general health outcome of the users by considering a crossover of architectural design and multidisciplinary collaboration as is evidenced by scientific studies.

CHAPTER 7 – FINAL CONCLUSION

Humankind has been benefiting for extraordinary innovations based on scientific knowledge. Technological developments, increased agricultural outputs, life expectancy, disease treatments, new energy sources, advancements in methods of communication and computational refinement, among others, brought revolutionary opportunities and challenges for new generations. As an evolving species, scientific knowledge is also based on evolution, with a constantly increasing body of knowledge.

Within these advancements, the importance of acknowledging findings and bringing them into practice is crucial. Unfortunately, the transition of information from academia into the professional realm is not always swift nor straightforward, leading to findings being relatively unknown to professionals and to the general public.

One of the main objectives of this dissertation was to bring scientific evidence into practical application. This was achieved by delving into an investigation of recent developments in the life sciences and in interdisciplinary fields with architecture that could improve the quality of buildings. Focusing on the qualities that make built environments more inhabitable, the investigation successfully revealed data that would have otherwise been overlooked by practitioners, and which have the potential to be utilized for more appropriate design outcomes. By correlating and integrating architectural concepts with scientific findings, a framework of practical design strategies towards spatial inhabitability was made possible.

It is important to note that the methodology of arriving at the 13 inhabitability parameters - through the analysis and interpretation of the 324 scientific studies - is categorised as a subjective procedure, since it was conducted in the format of a personal assessment. Nonetheless, this proposed methodology created a solid base for architects to reach their design goals, being capable of assuring the wellness and the enhancement of cognitive processes of the occupants of buildings they design. It should also inspire professionals to enrich their repertoire, reevaluate their responsibilities, and design more meaningful and sustainable environments. As Mallgrave appropriately puts it: "Do we really want yet another team of consultants on every large project to inform architects of their fundamental obligations as designers? Would it not be better to integrate these new insights into our curricula? For too many years now we have viewed architecture as a speculative exercise clothed in philosophical abstractions, as the creation of self-satisfying objects under the guise of aesthetic hypotheses that are, quite frankly, obsolete. It is time to reevaluate the matter, and perhaps employ the new tools at our disposal to explore other aspects of our beings..." [371]

7.1 GENERAL OVERVIEW

The human species has an innate biological connection with nature, its natural systems and the environment around us. Based on the implications of this relationship, numerous and significant areas of study emerged in order to comprehend and find answers to our behavior, influences, and responses towards the environment. Taking advantage of this newly acquired body of knowledge, this research placed the human-centred approach to architectural design within this context, along with that of architecture history and the varied architectural approaches existing today, as to propose a framework that might ensure spatial inhabitability. This dissertation's methodology assisted in that proposition.

371 Mallgrave, H. F. (2015). "'Know Thyself.' Or What Designers Can Learn from the Contemporary Biological Sciences," in Mind in Architecture: Neuroscience, Embodiment, and the Future of Design, eds S. Robinson and J. Pallasmaa. (Cambridge, MA: MIT Press), 9-31.

It was clear to detect the relevance of the theme of inhabitability throughout the history of architecture, and how many attempted to develop a framework to tackle it. The timeline of influential historical events for inhabitability developed in Chapter 2 evidenced the progression of approaches over the theme. In certain periods, history shows that inhabitability was not the focal point of architecture: other matters were more prominent, like stylistic representation, aesthetic, functionalism, rationality, among others. Nevertheless, the discourse would eventually return towards the human-centred approach. It was also demonstrated that architecture was always driven by larger intellectual contexts, employing interdisciplinary reasoning in a critical way. From Vitruvius to the Renaissance, architecture was tackled as an objective system which embodied art and mathematical reasoning, with the premise that architectural elements and structure should be based on nature. Eventually, during the eighteenth century, the architectural rationale began to shift from objective nature to the subjective mind influenced by the philosophical status quo. Later, led by the technological progress, modern architecture delved around systemization and architectural space.

The supporting role of the sciences to the human-centred approach to architectural design was also crucial to contextualize inhabitability. From a few decades ago until now, the escalating progress in a diversity of fields related to biology, physiology, psychology, and computer science are providing compelling research, with findings directly linked to human/space behavior. This implies that an interdisciplinary theoretical and methodological approach is the ultimate framework for the development of architecture and spatial inhabitability. Hence, the overview of the interdisciplinary approaches conducted in Chapter 3, demonstrated that architecture, together with other fields of study, are proposing coherent approaches to create optimized built environments and enhance the quality of life through design.

Since the 1990s, many attempts have been made to institute objective frameworks towards building performance. Chapter 4 presented the array of building assessment systems that exist today. Although targeting many different aspects of building performance, originally these initiatives mainly focused on sustainability, quality control and building efficiency towards healthier buildings. However, they have been harshly critiqued over time for not tackling the issue of the quality of space itself, considering its recognized influence on human well-being. It is undoubtedly that ventilation, temperature, lighting, noise, air quality and so on affect our health. But also proportions, scales, space configuration and sequence, complexity and order, view of nature, access to outdoor among others have been proved to also have a direct affect the human wellbeing. Indeed, many fail to consider the user experience, focusing essentially on technical requirements. In response, some building assessment systems have been implemented with requirements aimed at promoting human health, wellness, and positive experience. This has been an improvement. However, other methodologies and the inclusion of more parameters of evaluation need to be contemplated when considering the human experience in architecture.

The originality and purpose of this thesis are evidenced in Chapter 5. By investigating and gathering significant studies which delve on the subject of human/space behavior developed in the field of architecture and other disciplines, a framework consisting of 13 parameters were identified as practical design strategies for promoting spatial inhabitability. The work consisted firstly in assessing scientific journals and books which evidenced coherent findings to the theme. Among those, only findings which could be translated into practical design strategies systematically were endorsed. Hence that many isolated findings had to be combined, while others had to be disclosed in order to be considered into an outline which could result in a larger body of knowledge. Consequently, clear patterns of stances were identified from the correlation of research results. And from these patterns, an array of design parameters were able to be established in terms of the practical design strategies that determine them and the impact they may provide for the wellbeing of occupants in the built environment where they occur. The analysis arrived at 13 inhabitability parameters proposed as coherent constituents of a framework which could be used by architects who wish to arrive at effective results when designing environments focused on a human-centered approach. They were first categorized into four groups; Nature and Order, Cognitive Performance, Structure and Spatial identity. Then subdivided into 13 parameters: Nature and Order - 1)Nature, 2)Thermal/Airflow, 3) Daylight, 4)Access to Outdoor; Cognitive Performance - 5)Openness/Void, 6)Material, 7)Sensory Stimulation; Structure - 8)Proportion/Scale, 9)Patterns, 10)Form/Shape, 11) Complexity/ Order; Spatial Identity - 12)Sequence , 13)Edges.

As to verify the validity that the 13 inhabitability parameters could assist architects in arriving at more human-centered designs, case study analysis were described in Chapter 6. Based on real design outcomes, it was conducted on buildings and urban environments of different types, locations, scales, and uses featured in Archdaily's website for projects participating in its "Building of the year" award. The analysis was developed with a matrix-points based correlation of the design parameters. It successfully demonstrated the validity of the 13 inhabitability parameters by meeting the criteria of popular preferences in the website's poll results. Furthermore, it highlighted the parameters' practical implication intended to objectively add qualities to the built environment as design strategies. We could also observe the design integration between the parameters and the potentialities of development of each parameter depending on the function of buildings when comparing to other project types.

A subsequent case study analysis was conducted of Buildings in Tokyo as to further validate the legitimacy of the proposed inhabitability parameters. As the analysis was based on site visits, the spatial experience was intensified, evidencing the integration between parameters and how design strategies can be adopted to approach parameters simultaneously. Finally, the results from both case study analysis also presented a valuable dataset analysis of post-occupancy evaluation, where the impacts/benefits of the adopted design strategies were evidenced, and improvements for each analyzed category could also be identified.

This final conclusion complements the precedent analysis, with the following sub-chapters remarking variations and verification consistency in the use of the adopted method. Next, the discussion of possible causes of the lack of parameters in specific building function and implications of the results are discussed. It also attempts to encapsulate suggestions for integration of a guideline, extracted from precedent analysis. Conclusions are outlined in the findings of the dissertation as well as the future outlook research.

7.2 RELEVANT FINDINGS AND IMPLICATIONS

Given the extent of studies analysed in order to propose the framework of inhabitability parameters, its potential to unlock numerous positive benefits for the buildings' inhabitants is promising. The understanding on how different aspects of the built environment impact our health and wellbeing enables us to better comprehend the strength of design decisions. This increased insight on design consequences may help to better define and tune the outcome to clients' requests, or according to the priorities of each project. It also supports the definition of what type of information is needed to reach a specific project's result.

Once the literature was collated and parameters were identified, 4 major groups emerged from the review, and were later sub-divided into 13 parameters. Based on the analysis, the inhabitability parameters were developed to bring design research and practical application together by connecting findings from a vast array of reputable research to the design process. With the analysis of the scientific studies conducted in chapter 5, it was observed that some research topics have been extensively studied, while others have significantly less literature on. Therefore, it is possible to identify the lack of scientific studies in certain areas of interest, implying potential paths for future research as well as prospective new parameters, for example: Context, Unity, Novelty and Beauty.

The case study of Public Award analysis provided a direct confirmation of the parameters based on today's architecture production, with most popular preferences tending to have the most parameters. It might be questioned that such image-based analysis is limited, since it does not include the experience of being in the building. However, the inhabitability parameters are supported by design strategies to approach them. Therefore, the analysis was based on the evidence of these design strategies. Nonetheless, the case study of Buildings in Tokyo analyses conducted by site visits was able to validate the methodology of the previous case study, since the evidence of the parameters was identified through the use of the design strategies that accompany them.

The case study of Public Award analysis also provided information on the correlation between building category and parameters. It demonstrated the potential to improve certain categories of buildings by increasing the design strategies towards achieving the missing parameters. This is an important finding of the case studies, which demonstrated the potential design developments in specific architectural types.

The inhabitability appraisal applied to the case study of Buildings in Tokyo analyses also demonstrated that it might be possible to reach a parameters equilibrium. It implies that different design strategies towards a parameter could compensate for the lack of design strategies of another. For example, if you cannot provide access to outdoor, you can counteract with design strategies to ensure thermal/airflow. However, this issue needs to be further explored.

The research does not intend to compare the level of effectiveness of design strategies applied in each building featured in the case study analysis, not even the integration of the solutions. Each case depends on specific situations, requirements, circumstances, opportunities, and possibilities. This study also refrains from considering questions concerning material construction and specifications. It concentrates on integrating findings from different research areas as to assist the design process with an overall guideline with behavior parameters. It also contributes to the awareness and information on the subject by identifying studies and design parameters to intensify the competence and importance of responsibility in design. The proposed framework of inhabitability parameters is only one step towards achieving the desired human-centred outcome. Designers should take advantage of these findings, and creatively approach them with strategic design proposals.

The unprecedented set of analysis and interpretation of architectural design studies that was not previously correlated and studied together, proposes a unique way of analysing existing projects. Furthermore, it entails the exploration of more systematic methodologies in architectural design, which has been sought by many. The systematization of the analysis does not justify the lack of creativity and patronization in design. In fact, it is the opposite, designers can be benefited by an objective framework of what should be achieved and provide opportunities to focus on the development of originality towards a vision of innovation to solve design problems to enhance the user's health and cognitive performance.

The thesis confirms that the way places are perceived by our cognitive experience affects not only how we sense them but, as architects, also how we envision them. In many cases, there is a tendency to make design decisions based on a simplistic viewpoint or ignoring the complexity of a design problem. Although we are trained to deal with those complexities, we should also rely more on scientific data to back up our design decisions.

The thesis also clearly demonstrates that buildings have a crucial impact on human health, wellbeing, and performance. Some evidence also relates to economic assets in terms of value, efficiency, and profit. Therefore, there is no reason for not taking the findings into consideration, because all of this evidence cannot be ignored anymore. The indifference from professionals can not only lead to unhealthy and harmful environments but also to lack of efficiency and financial drawbacks. This is an opportunity for architectural professionals to enhance their design approach, with the appropriate justification of the design decisions.

It can be argued that much of the recent research is only acknowledging what people know intuitively, and some even say it is obvious and common sense. However, not even this common knowledge is being taken into consideration in many building designs. Furthermore, there are not many discussions about this topic occurring among professionals, society, and academia. We all know that connection to nature is important to our wellbeing, but the scientific evidence now provides an explanation on why and on how this connection occurs. This is valuable information which needs to be translated into practical design strategies to assist architects with their decisions.

7.3 LIMITATIONS OF THE STUDY

Although assertive, practical and significant contributions have been made throughout the research, basic limitations were observed in the analysis of the scientific studies related to inhabitability, as well as in the methodology proposed to interpret them.

This research-based itself in a numerous amount of studies to develop its inhabitability framework. The 382 studies that were analysed contributed towards defining the 13 parameters of the proposed framework. However, not all could be used for the correlation into practical design strategies. This was due to the fact that some studies either had findings that were too narrow or too broad to fit in different cases, scenarios or design circumstances. There was also the case of abundance of studies which support certain parameters, and fewer studies to support others, as shown in the diagram below:

Nature Parameters - supported by 63 studies
Thermal/Airflow Parameters - supported by 29 studies
Daylight Parameters - supported by 25 studies
Openness/Void Parameters - supported by 15 studies
Access to Outdoor Parameters - supported by 15 studies
Material Parameters - supported by 12 studies
Sensory Stimulation Parameters - supported by 48 studies
Proportion/Scale Parameters - supported by 12 studies
Patterns Parameters - supported by 19 studies
Form/Shape Parameters - supported by 12 studies
Complexity/ Order Parameters - supported by 34 studies
Sequence Parameters - supported by 21 studies
Edges Parameters - supported by 19 studies

Clearly, this research was not able to analyse all studies and findings available on the theme or which are related to it. However, the listing of studies which support each parameter revealed the potential of development of further studies on certain aspects of human/space behavior, and also fronts that could be further explored by the interdisciplinary fields of study. Nevertheless, the high quantity of studies and findings available also reaffirms the interest and importance of the theme. And, as the projection of research in the biological fields is ever in ascendence, findings that reveal additional parameters towards inhabitability will ultimately come to light as new discoveries and validations occur.

There is also the issue of the categorization of the parameters. It was found that many parameters relate to each other, and that the design strategies that accompany them may interact or even be the same. For example, the design strategy of designing an open garden in the middle of an enclosed space is related to nature parameter, thermal/airflow parameter, daylight parameter, and openness/void parameter. This categorization issue was solved in the best way possible to ensure their comprehensibility and practicality within the proposed framework towards inhabitability.

324 SCIENTIFIC STUDIES UTILISED FROM MORE THAN 800

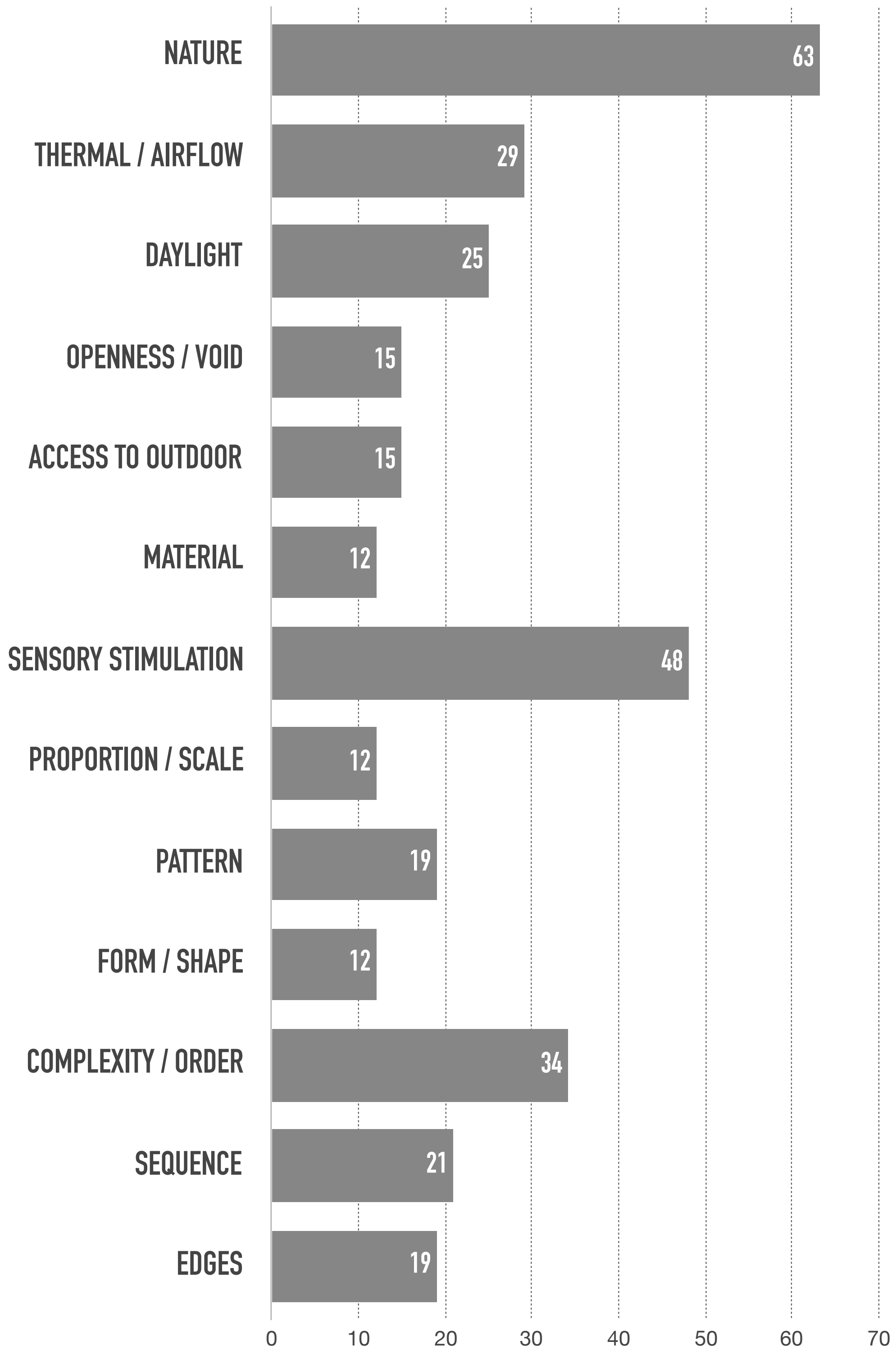

fig. 68 - Comparison bar chart of amount of scientific studies found in relation to Inhabitability.

Limitations were identified related to the adopted methodology for the case studies. For the case study of the Public Award, based on "Building of the Year 2018" from Archdaily website, the analysis was carried out by verifying the presence of the inhabitability parameters in building designs using photographs and blueprints available also on the website. For the case study of the Recognized Buildings, the analysis was carried out by verifying the presence of the inhabitability parameters in building designs using photographs and blueprints available on the internet, magazines, and books. Although it produced the intended results, this analysis through available material lacked the inputs that the experience of being in those building might infer. For that reason, the in loco analysis of 3 buildings in the city of Tokyo was carried out. It revealed that, although the physical experience of being in the buildings contextualized them better, it did not have a substantial effect on the objective identification of the inhabitability parameters.

The case studies were based on a public award and on a list of recognized buildings so that matters of taste and personal background/preference would not interfere in the analysis. In the case study of the public award, in particular, Archdaily's Building of the Year 2018 was considered because it is based on a limited number of projects - 75 projects in 15 categories - without concerning the country in which they are located nor their type of construction. Although it's award results are not meant to represent a specific group opinion, it is naturally based on independent evaluation. Therefore, the results from the cross-reference analysis with the inhabitability parameters were based on this restrained scope of projects. If time had allowed, it would have been beneficial to run the analysis of different awards. Furthermore, as the inhabitability parameters were cross-referenced with the design strategies used in the featured buildings, results showed that, consciously or unconsciously, the voters selected the most "inhabitable" projects. These results effectively demonstrated the human tendency towards environments that have the design qualities featured by the inhabitability parameters. However, it is important to mention that these results do not incorporate probable negative interrelation and trade-offs of stakeholders, green building rating systems, function suitability, and economical factors.

There is also the limitation of the quantitative vs qualitative outcome of the inhabitability parameters, once the case study analyses were not based on a quantitative evaluation of the occurrence of each parameter in the building designs. It would be important to further evaluate the occurrence of each parameter by a scoring system, as to provide evidence that a high occurrence of a parameter might compensate for the low occurrence of another. This could lead to demonstrate that in order to achieve the desired qualities of a built environment, design strategies to fulfill the inhabitability parameters could be applied at different rates.

A critic that may arise from the proposition of a framework towards inhabitability relates to its pragmatic and objective approach to architecture, since it does not concern an assessment of taste, aesthetics, creativity or intuition. That is exactly where the originality of this dissertation lies: to propose a framework purely based on scientific results and findings. Nonetheless, the cross-referential analysis of both Public Award and Buildings in Tokyo demonstrated the proposed inhabitability parameters correlate to people's preferences.

7.4 CONTRIBUTION OF THE THESIS

Humanities and Sciences are considered opposite areas of research. However, history has shown that architecture always attempted to be in common ground with them both. By presenting an integrative strategy for the development of a more human-centred architecture, this dissertation exemplifies an approach that bridges both areas. This integrative approach, besides promoting a more holistic design approach, also provided an objective framework towards inhabitability.

The suggested inhabitability framework has the potential to assist all stakeholders involved in the design process, construction and feasibility of the built environment. With the primary purpose of improving the quality of space and promote wellbeing, the proposed framework also has the potential to be used as a decision-tool to reaffirm design decisions to clients, other professionals and authorities.

It is also important to note that the inhabitability framework does not diminish internally-driven innovation and problem-solving capacity. Since it can be used to assist in most types of architectural projects, within diverse design teams, and in distinct locations, it only requires vision and creativity from designers in interpreting the parameters to ensure the uniqueness of each design outcome.

7.5 FUTURE PARADIGM

This research theme has the potential to be developed much further. As the projection of research in the biological fields is ever in ascendence, findings that reveal additional parameters towards inhabitability will ultimately come to light. New findings should also build a stronger foundation of the proposed parameters and presented arguments. Nonetheless, the methodology presented here can be further applied as is.

There is also the prospect of developing tools based on the inhabitability parameters. One prospect would be a digital score-based evaluation tool. The user would manually input the design characteristics of a building he wants to be evaluated, and the tool would score it against the inhabitability parameters. The results would identify the rating of inhabitability of the building in question. This would allow clients, investors, and designers to place their own project in relation to feasible requirements. By providing interactive visualization, the design characteristics which are suited or not could be identified in real-time. Furthermore, as the amount of evaluations increase so could the database, making the tool more efficient.

Another possibility is developing an open scientific studies database where researchers can submit the summary of their studies to be worldwide accessible by stakeholders. It would increase the knowledge of the current approaches, and be used as a reference to facilitate the search for individual parameters. It would also reinforce the importance of scientific research as a knowledge instrument to the design process and design outcomes. In practice, the idea would be to propose a free-access web-based platform which describes each parameter based on the latest scientific findings that support it. This format could: assist designers, clients, contractors, and stakeholders towards making better and more informed design decisions; facilitate the assessment to information on the theme; to group research related to the same topic under one platform; and potentially grow continuously as more research is developed on the theme. Furthermore, such a platform would bridge the gap between current research and practical implementation by assisting professionals who wish to propose human-centered designs in achieving better results.

Additionally, a printed version of the current scientific research which focuses on the inhabitability parameters could be published periodically. By publishing the latest research related to the subject, a periodical can work like an up-to-date reference guide to be easily accessible and used by professionals in their daily architecture practice, without the need to search through academic resources.

In addition, the inhabitability parameters framework may be envisioned as a complementary feature of building assessment systems. Since most assessment systems target building performance in terms of sustainability, quality control, and building efficiency, they would benefit from including a framework to assess the inhabitability of buildings. This would result in a holistic assessment towards healthier buildings and healthier inhabitants.

7.6 CLOSING STATEMENTS – A NEW APPROACH UNDER DEVELOPMENT

Architects, as professionals who shape and manipulate human habitats, must consider the limitations and aspirations of human nature. Today, the sciences have provided ample evidence to help us understand the ways in which the built environment can affect the building user's experience. Through this knowledge, architects should be able to become better designers, prioritizing the experience and well-being of those who will occupy the environments they design. With this newly acquired body of knowledge, a new approach in architecture is emerging.

As the life sciences and interdisciplinary fields expand their research, more results and new studies will continue to reaffirm the significance of this approach, as well as provide new evidence on how design can further impact its occupants. As progress continues, the more credibility these new findings, methods, and tools will attain, eventually gaining the awareness of the building industry.

A new approach in architecture, with a design method oriented towards human experience instead of concerns over style, form, and shape, has already emerged. Designers have responsibilities in their aesthetic design choices and artistic expression which could improve or damage the user's health and cognition. This statement is supported in this dissertation with the intention to demonstrate the greater level of responsibility of the professionals with their designs. And one of the most effective ways to demonstrate it, it is through informing and backing up the design decisions by scientific researches. Many architects are engaged in following methods and frameworks to achieve the desired design outcome. This research encourages methodological processes as a means to improve any design, and promote positive changes. It also reinforces the importance of the integration of scientific data into the design process, which contributes to the body of knowledge on how to approach new design challenges.

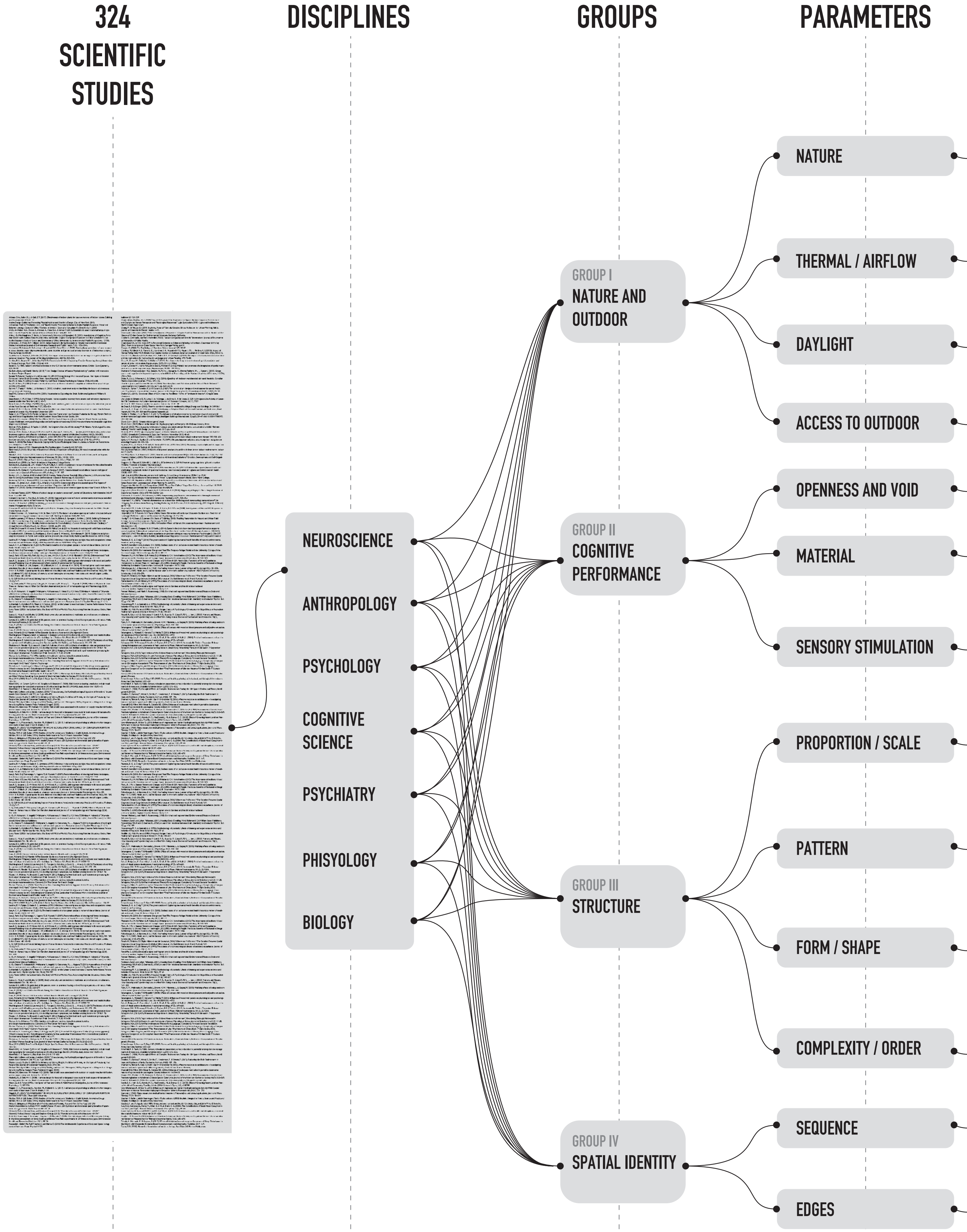

fig. 69 - Doagram of the Thesis Methodology and Framework

OCCURENCE	DESIGN STRATEGIES
GENERAL RELATION TO NATURAL ELEMENTS, LIVING SYSTEMS AND NATURAL PROCESSES	PHYSICAL AND/OR VISUAL CONNECTION TO NATURAL ELEMENTS, SUCH AS PRESENCE OF GREENERY, GARDENS, AND WATER
TEMPERATURE CONDITIONS, HUMIDITY AND NATURAL VENTILATION	NATURAL VENTILATION SYSTEMS, OPENABLE SPACES, PERSONAL CONTROL OF TEMPERATURE, HUMIDITY, AND AIRFLOW
DIRECT AND INDIRECT LUMINESCENCE FROM SUNLIGHT	MAXIMIZATION OF DAYLIGHT INCIDENCE AND USE OF SMART FACADE SYSTEMS SUCH AS LOUVERS
SPATIAL INTERRELATION BETWEEN INSIDE AND OUTSIDE	PHYSICAL ACCESS TO EXTERIOR SPACES SUCH AS ROOFTOPS, BALCONIES, VARANDAS, TERRACES, AND COURTYARDS
EXPERIENCE OF UNOBSTRUCTED AREAS OF SPACE	VISUALLY / PHYSICALLY PERMEABLE VOID SPACES
SENSORIAL EXPERIENCE PROMOTED BY MATERIALITY	USE OF NATURAL MATERIALS, AVOIDING MIMETIC AND SYNTHETIC MATERIALS
MOMENTARY EXPERIENCE INDUCED BY SENSORIAL ASPECTS	LIGHTING TRANSITIONS, NATURAL MATERIALS, AND DESIGN ELEMENTS WICH PROVIDE THE SENSE OF CONTROLLED RISK, SUCH AS CANTILEVERS, INFINITY EDGES, OPEN STAIRCASES
RELATION BETWEEN THE HUMAN BODY, DESIGN ELEMENTS AND BUILT SPACE	DESIGN ELEMENTS THAT CONSIDER THE PROPORTION TO THE HUMAN SCALE, SUCH AS CEILING HEIGHT, DOORS, OPENINGS, AND DISTANCE OF WALLS
INTRICATE REPETITIONS WITHIN BUILT SPACE	ORNAMENTATION, LOUVERS AND STRUCTURAL SYSTEMS ORGANIZED IN PATTERNS RANGING FROM MICRO TO MACRO SCALE
DISTINCT SPATIAL OUTLINE OF BUILT ENVIRONMENT	CONSIDERATION BETWEEN SHAPES ACCORDING TO INTENDED OUTCOME, SUCH AS CURVES FOR SERENITY AND SHARP ANGLES FOR EXCITEMENT
ORGANIZATION AND ARRANGEMENT OF DESIGN ELEMENTS	DESIGN ELEMENTS ORGANIZED IN SYMMETRY, RHYTHM, HIERARCHY, BALANCE, COMPLEXITY, AND ORDER WITHIN DIFFERENT DESIGN SCALES
INTERRELATED CONNECTIONS WITHIN SPACE	CLEAR SEQUENCE OF SPACES AND COHERENT CIRCULATION
ADJOINING SPATIAL BOUNDARIES	CLEAR BOUNDARIES AND SPATIAL DELIMITATIONS WHERE THE INDIVIDUAL FEELS PROTECTED WHILE OPTIMIZE VISUAL RANGE AND SURVEILLANCE.

DESIGN CAN:

- SPEED UP RECOVERY IN HOSPITALS
- IMPROVE LEARNING IN SCHOOLS
- INCREASE PRODUCTIVITY IN WORKPLACES
- MAKE HOMES MORE REINVIGORATING

INHABITABILITY FRAMEWORK:

- SUPPORTED BY SCIENTIFIC KNOWLEDGE
- ASSISTS IN SETTING DESIGN INTENTIONS
- HIGHLIGHTS STRENGTHS OF THE DESIGN
- IDENTIFIES OPPORTUNITIES FOR IMPROVEMENT
- FOCUSED ON DESIGN DECISION

SUMMARY

Throughout history, the relevance of the theme of inhabitability has pervaded the architectural discourse. Since Vitruvius (circa 15 BCE), many attempted to develop a framework to tackle it by involving the human perspective into the design process. Scholars repeatedly underlined the importance of formal design elements in relation to the human body - such as scale and proportion - articulating that the presence of essential mathematical harmonies is perceived instinctively by people, and is emotionally fulfilling. However, history also shows that this human-centered framework fluctuated in being the focal point of architectural design: other matters at times were more prominent, like stylistic representation, aesthetic, functionalism, rationality, among others.

At the beginning of the 20th century, in particular, distinguished architects engaged and theorized about the humanization of architecture. With an approach which drew on analytical observation in combination with scientific reasoning, they attempted to explain the links between nature, space and human biology. Frank Lloyd Wright, for example, introduced the word 'organic' to denominate an architecture that reinterpreted natural systems and principles to be in harmony with man, humanity and its environment. Geoffrey Scott examined the relation between built spaces and human biology, and the way we instinctively look into our surrounding environment for physical conditions that are related to our own. Alvar Aalto argued that, by covering all fields of human activities and considering humanitarian and psychological aspects, the goal of architectural design is to mediate man and nature. And Richard Neutra, whose alarmist discourse urged that man-made environments were becoming a threat to our vitality and soundness of mind and body, and that the relationship with nature needed to be reestablished.

Meanwhile, civilization witnessed surprising consequences from the interaction with the built environment. Significant outcomes happened at the end of the nineteenth century with the sanitation crisis,1 followed by the energy crisis and the outbreak of Sick Building Syndrome (SBS)2 in the 1970s. Over time, multitudes of studies evidenced the crucial effects the environment has over our physical and psychological health. Many of the public health disturbances, including obesity, diabetes, asthma, cardiovascular disease, injury, anxiety, depression, violence, and social inequities, among others, were linked to the built environment. Furthermore, overpopulated cities have caused an escalation of problems such as smaller enclosed spaces, lack of sufficient natural elements and real estate bubbles. This goes without mentioning the impact of climate change, greenhouse gas emissions and the decrease of earth's natural resources.

1 With increasing urbanization of the population in the nineteenth century, poor environmental conditions became common, and the spread of diseases spiked. However, advances in scientific knowledge on causes and prevention of diseases brought about unprecedented changes in public health and a sanitary revolution began to take place. Institute of Medicine (US) Committee for the Study of the Future of Public Health. The Future of Public Health. Washington (DC): National Academies Press (US); 1988.

2 Sick building syndrome is a medical condition where people in a building become symptomatic or feel unwell for no apparent reason. However, causes have been linked to flaws in the heating, ventilation, and air conditioning systems. The symptoms tend to increase as more time is spent in the building and disappear when they are away. The most common symptoms are headache, nausea, eye, nose, and throat sensitivity, lethargy, and vertigo. Sick building Syndrome; https://en.wikipedia.org/wiki/Sick_building_syndrome Acessed May 2nd 2019.

The green building rating systems that emerged in the 1990s were a response to the problems related to construction and sustainability. In general, they focus on evaluating the performance of buildings within a sustainability framework which evaluates indoor environmental quality, water and energy usage, and management of natural resources. Such building assessment systems have multiplied over the years, and, by promoting measures that were sometimes complex and costly to apply in the past, are responsible for transforming the construction industry. In consequence, they also managed to improve the general building standards and raised the status of buildings.

Yet, the green building movement brought about a backlash: it evidenced that besides sustainability, a framework which ensures the inhabitability of buildings is of utter importance and urgently needed. Hence that highly rated buildings in sustainability standards do not necessarily account for buildings which are good for its inhabitants. This issue has been raised by many, especially in consideration of the lack of knowledge over practical strategies to achieve more human-centred designs.

Parallelly, recent developments in the sciences are changing the entire body of human knowledge. It is correct to say that more has been learned about our biological selves in the past half-century than in all of human history.3 These developments, especially those determined by technological advancements, have forced major fields of study to go through a radical restructuring of agenda. And, within this scenario, many studies from different fields are contributing towards a human-centred framework for architectural design, either directly and indirectly. Experimental research in neuroscience, cognitive science, psychiatry, psychology, physiology, and anthropology, for example, are effectively producing unprecedented empirical evidence on how inhabitable space is according to the practical strategies used in a building's formal design. Through newly existing technologies, like brain imaging techniques, virtual reality programs, and specialized sensors, along with traditional analytical tools, researchers are able to measure behavioral, cognitive, and emotional reactions, as well as physiological markers and brain activity in relation to our surrounding environment.

This surrounding environment informs us about who and where we are, what we need, and if we are safe and well. It is not a coincidence that we prefer environments that impact us positively: we, as human beings, have a strong connection to the space around us. This connection - termed inhabitability in this thesis - happens especially in places that we are in for long hours. It involves our conscious and unconscious embodied cognition - our mental constructs and performance on various tasks - and has a direct effect on our physical and emotional wellbeing. The findings on the physical foundations of this connection are already being employed for decades in areas such as marketing and in the entertainment industry. In the field of architecture, practical findings have been generally applied to the design of specialized healthcare facilities.

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3 Harry Francis Mallgrave in Pallasmaa, J., & Robinson, S. (2015). Mind in architecture - neuroscience, embodiment, and the future of design. Mit Press. Pg. 18

Architects (in general) are far behind in the engagement to understand how a person's body and mind truly experiences and reacts to the spaces being designed by them. The reason for this delay might be that, despite established facts, many architects accept the romantic approach to the profession, believing it to be based on intuition and creativity, where artistry sensibilities should not be limited or controlled.4 There is also the economical excuse, which by contrast, has been discarded because increasing user wellbeing through building design was proved to economically benefit governments and companies in the long run.5 Adding that stakeholders have been increasingly requesting for employee, students and patients outcomes to be improved through the design of buildings, the question remains on the reasons why architects are still not embracing the scientific discoveries being made in parallel fields in the last decades.

Since there is still no appropriate theoretical and practical framework in architecture which objectively tackles the influence of design strategies on users, it is essential to explore and integrate the outcomes of the growing empirical knowledge from other influential fields of studies into architecture in order to improve/promote inhabitability. Studies in human health and cognition together with the theory of architecture may start to provide the foundations for involving such issues with design strategies towards a more human-centred approach to architecture. Unfortunately, results of research developed in scientific and academic settings are seldomly brought into the practical realm of the architecture profession, and it is not common for professionals to read scientific papers from other fields or search for answers in journals and databases.

There are many potential margins to tackle this setback. An integrative model, where relevant findings within this new body of knowledge are merged, could benefit architects in obtaining practical knowledge into more human-centred design practices. Additionally, it has the potential to guide future scientific research. To consider the substantial amount of existing data on human/space behavior and incorporate it in the design of the built space is an important step which will assist in our constant design challenges. With so many great achievements and developments taking place, and with all the available database and data-driven intelligence, we as professionals should not be intimidated to explore new ways of promoting inhabitability within our designs.

Inhabitability in architecture concerns not only spaces which are fit to be occupied/lived in, but spaces that are centered on humans and which positively affect what we think, feel and do. This thesis bases itself on the precedent that by acknowledging how the human brain assimilates the awareness and affection for environments, it is possible to intentionally design a more human-centred architecture. This human-centricity entails our conscious experience through our actions and uses of a built environment, like how well a building performs towards providing its occupants with

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4 Hart, Robert Lamb. "Reinvigorating Architecture With the Sciences: It's Time To Get On With It." Common Edge, commonedge.org/reinvigorating-architecture-with-the-sciences-its-time-get-on-with-it/

5 Macnaughton, Piers, et al. "Economic, Environmental and Health Implications of Enhanced Ventilation in Office Buildings." International Journal of Environmental Research and Public Health, vol. 12, no. 11, 2015, pp. 14709–14722.

physical well-being for everyday tasks such as working, studying, cooking, relaxing, sleeping, etc. And it also entails our subconscious experience, like how well a built environment performs towards promoting psychological well-being, e.g positive feelings.

The recent interdisciplinary studies developed in the fields of architecture and life sciences, which approach the human/space behavior relationship, are revealing important findings towards spatial inhabitability. Therefore, as to propose a method to tackle the issue of inhabitability in architecture, this research will engage in an investigation of studies in architecture and from relevant scientific research in various fields in order to identify, within this broader body of knowledge, relevant data that can be utilized for successful design outcomes. Based on available literature and in scientific data, the research intends to explore the correlation and integration of concepts and findings, and summarize them into an objective framework composed of practical strategies which could have a direct impact on the design process and building outcomes.

By encouraging the utilization of existing knowledge into the process, this methodology proposes to integrate diverse fields of study and to eliminate the disconnection among current scientific-based research and its practical application in architecture. Likewise, it aims to help inform, instigate and legitimize designers, planners, engineerings, policymakers, decision-makers, clients and all stakeholders involved in the design process into considering the effectiveness of built spaces.

The present research, therefore, set itself to explores the relationship between the design of the built environment and its effects on the human body and its physical/mental health. It is critical to understand the weight of design decisions on buildings' occupants. What kind of design strategies in schools enhance children's focus and the ability to learn? What kind of design strategies in workplaces can make workers more productive? What kind of design strategies in hospitals could lead patients to faster recovery time? These are questions that need to be addressed. This thesis does not intend to answer them categorically, but to provide a general framework for promoting overall well-being in built environments.

To determine the types of design strategies that ensures qualities to a built environment has the potential to assist architects in the proposal of more inhabitable spaces. Since inhabitability is defined by conscious and unconscious experiences in space, a thorough interdisciplinary research on the history and findings on the theme is necessary in order to identify what type of features an inhabitable space possesses. The resulting data should enable the establishment of a framework to promote inhabitability, aiming at providing a base for analysis and a model that contributes to the design process and assist architects in ensuring their design decisions.

Accordingly, a methodology was established to achieve this research objective. As to define and contextualize the concept of inhabitability, first, it was important to detect the occurrence and relevance of the theme throughout the history of architecture. Therefore, a literature review was conducted with the intention to gain information on the evolution of the theme along time, and insights on how architects have objectively approached the human/space behavior relation. This was carried out by identifying important theories/concepts/arguments on publications and events related to the theme which had a prominent impact in their current historical period and in the overall architectural discourse. Following in the contextualization of the theme, the supporting role of the sciences to the human-centred approach to architectural design was analyzed. The emergence of interdisciplinary fields linked to human/space behavior was investigated, and their role as providing evidence for a human-centred approach to architecture was established.

Subsequently, a method for approaching inhabitability within a design framework was proposed. First, a review was conducted on scientific studies developed in the field of architecture and in the sciences which identify relevant design strategies towards spatial inhabitability. Their analysis is crucial for understanding the recent and accelerated interest on the theme, which is mostly due to advancements in technology and neuroscience. The procedure was to first locate and analyze as many existing research related to human/space behavior - and the neuroscience/architecture relation - currently available. Then, identify within that body of knowledge findings which could lead to parameters based on practical design strategies to be utilized for enhancing the human/space behavior relation in built environments.

Finally, after parameters for inhabitability were established, there was a need to verify their validity. Two types of case study analysis were proposed to assist in the validation: one based on cross-examination of buildings submitted into popular voting against the inhabitability parameters, and another based on cross-examination of renowned buildings. Both analyses were developed by a matrix-points based correlation. The intention was for the results to demonstrate compatibility between the inhabitability parameters and the design strategies used in the featured buildings.

This proposed methodology created a solid base for architects to reach their design goals, being capable of assuring the wellness and the enhancement of cognitive processes of the occupants of buildings they design. It should also inspire professionals to enrich their repertoire, reevaluate their responsibilities, and design more meaningful and sustainable environments. As Harry Mallgrave appropriately puts it: "Do we really want yet another team of consultants on every large project to inform architects of their fundamental obligations as designers? Would it not be better to integrate these new insights into our curricula?" 6

Architects need to be reminded that people experience space through an ensemble of stimuli of their biological senses. Furthermore, architectural designs need to respond to new challenges and opportunities presented by a range of social, environmental, technological and economic motivators, architects are demanded to work across different scopes and scales, and to possess specialized expertise while maintaining a broad contextual grasp of the discipline. Furthermore, architecture cannot be judged

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6 Mallgrave, H. F. (2015). "'Know Thyself.' Or What Designers Can Learn from the Contemporary Biological Sciences," in Mind in Architecture: Neuroscience, Embodiment, and the Future of Design, eds S. Robinson and J. Pallasmaa. (Cambridge, MA: Mit Press), 9-31.

by its formal constructability, its accomplishment of programmatic requirements or its performance in terms of technical parameters, since these issues are fundamental. However, architects must strive to enrich their conceptualizations by understanding and articulating the experience built environments can provide to its occupants.

As a response to this prominent issue, the translation of scientific findings on human/space behaviour into a design framework aims at providing architects with practical strategies that support physical/mental health and wellbeing. The possibility to merge knowledge from different disciplines and explore it in new design approaches is a necessity for the development of architecture and an excitement prognosis for professionals. The more information about human/space behavior, the better the design can become. The objective is not to prescribe a solution or justify a style, but rather inform on the possibilities and outcomes, and put the emphasis on the experience of design. By drawing upon a range of sources, and emphasizing the far-reaching implications of new neuroscientific discoveries and models, this thesis intends to bring insights and clarity over findings that are fast becoming accepted in architecture.

Furthermore, this research entails the exploration of more systematic methodologies in architectural design, which has been sought by many. Systematization does not infer in lack of creativeness or standardization of design. In fact, it is the opposite: designers can benefit from an objective methodology which provides opportunities to focus on the development of original and innovative solutions within a reliable framework to enhance user's wellbeing. It also contributes to stimulate debates on approaches that may add to the discussion.

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MeMo House by BAM! Arquitectura ©Jeremias Thomas
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HOUSING

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Tudor Apartments by Urko Sanchez Architects ©Javier Callejas
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Municipal Gym of Salamanca by Carreño Sartori Arquitectos ©Marcos Mendizabal
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RELIGIOUS ARCHITECTURE

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The National Art Center by Kisho Kurokawa ©oji Kobayashi / SPIRAL
https://www.architonic.com/en/project/kisho-kurokawa-the-national-art-center/5100617
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APPENDIX I

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324 SCIENTIFIC STUDIES

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APPENDIX II

SYNTHESIS OF PARAMETERS

NATURE

OCCURRENCE:

GENERAL RELATION TO NATURAL ELEMENTS, LIVING SYSTEMS AND NATURAL PROCESSES.

BASED ON FINDINGS:

GREEN SPACES HAVE STRONG ASSOCIATION WITH MENTAL HEALTH IMPROVEMENTS, DECREASING STRESS AND PAIN.

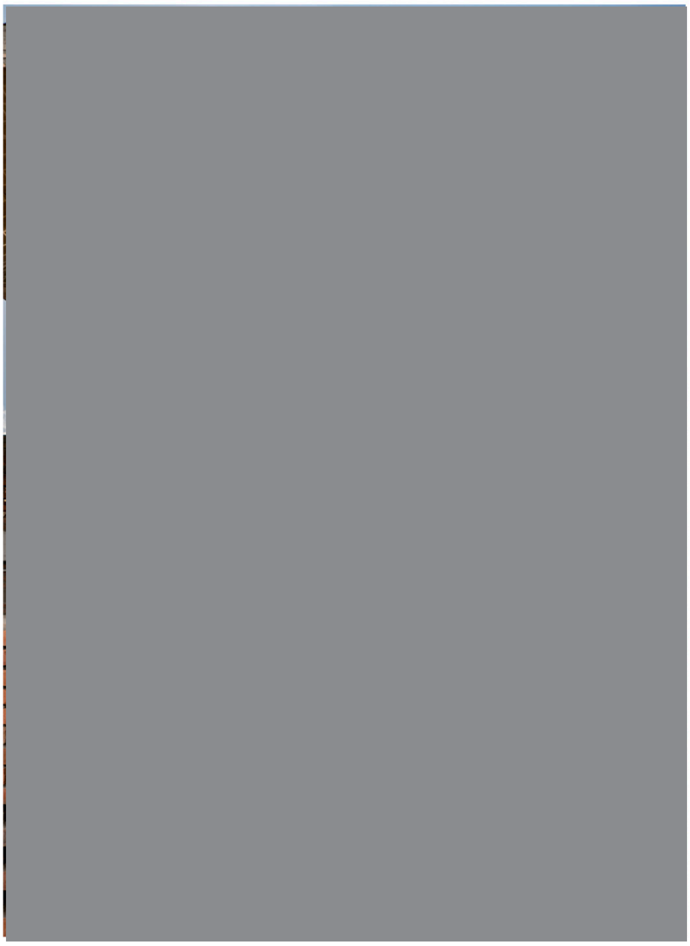
WORKERS, STUDENTS AND PATIENTS HAVE IMPROVED GENERAL COGNITION AND WELLBEING, WITH MORE PRODUCTIVITY, FEELING HAPPIER AND SATISFIED WHEN THEY HAVE VIEWS TO NATURE.

LACK OF NATURE DURING CHILDREN DEVELOPMENT LEADS 55% HIGHER CHANCES TO PSYCHIATRIC DISORDERS.

SCENTS FROM NATURE HAVE POSITIVE IMPACT ON TREATMENT OF CENTRAL NERVOUS SYSTEM DISORDERS.

DESIGN STRATEGIES:

PHYSICAL AND/OR VISUAL CONNECTION TO NATURAL ELEMENTS, SUCH AS PRESENCE OF GREENERY, GARDENS, AND WATER.



THERMAL / AIRFLOW

OCCURRENCE:

TEMPERATURE CONDITIONS, HUMIDITY AND NATURAL VENTILATION.

BASED ON FINDINGS:

AIR QUALITY IS ASSOCIATED TO PRODUCTIVITY, CONCENTRATION, GENERAL HEALTH, WELLBEING, COMFORT AND SATISFACTION.

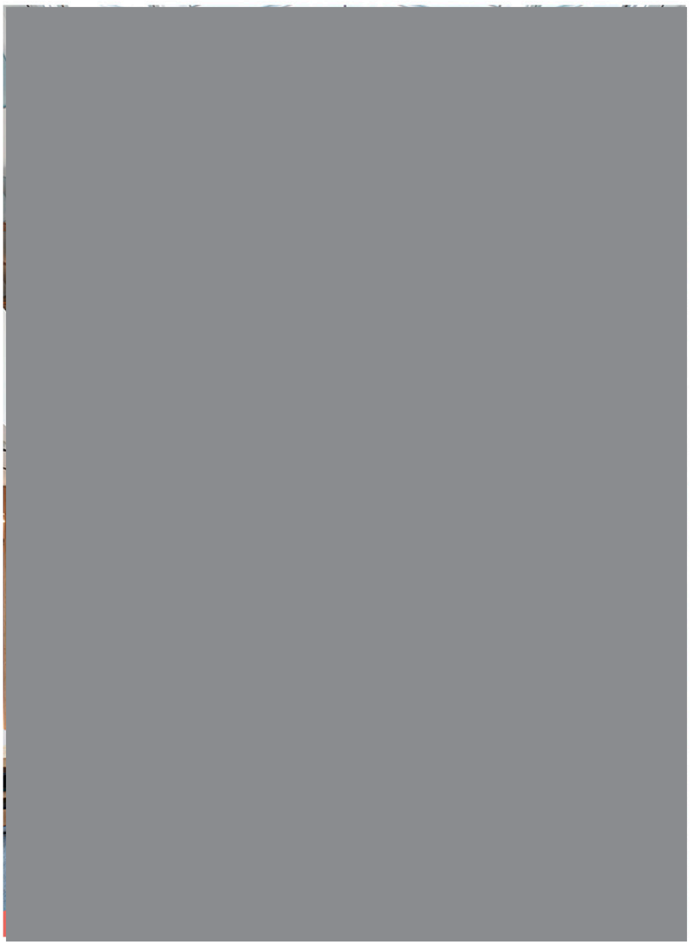
PERSONAL CONTROL OF AIRFLOW AND TEMPERATURE LEAD TO DIRECT COMFORT AND WELLBEING.

INADEQUATE AIR QUALITY IS RELATED TO HEALTH ISSUES SUCH AS ASTHMA, FATIGUE, ANNOYANCE, DISCOMFORT, HEADACHE, SINUS CONGESTION, COUGH, DIZZINESS, THROAT IRRITATION, DIFFERENT TYPE OF INFLAMMATION AND EVEN CANCER.

TRAPPED INDOOR POLLUTANTS ARE RESPONSIBLE FOR HEALTH CONDITIONS AND TRANSMISSION OF DISEASES.

DESIGN STRATEGIES:

NATURAL VENTILATION SYSTEMS, OPENABLE SPACES, PERSONAL CONTROL OF TEMPERATURE, HUMIDITY, AND AIRFLOW



DAYLIGHT

OCCURRENCE:

DIRECT AND INDIRECT LUMINESCENCE FROM SUNLIGHT.

BASED ON FINDINGS:

THE INCIDENCE OF APPROPRIATE DAYLIGHT INCREASES THE ACHIEVEMENTS AND PRODUCTIVITY OF WORKERS AND STUDENTS.

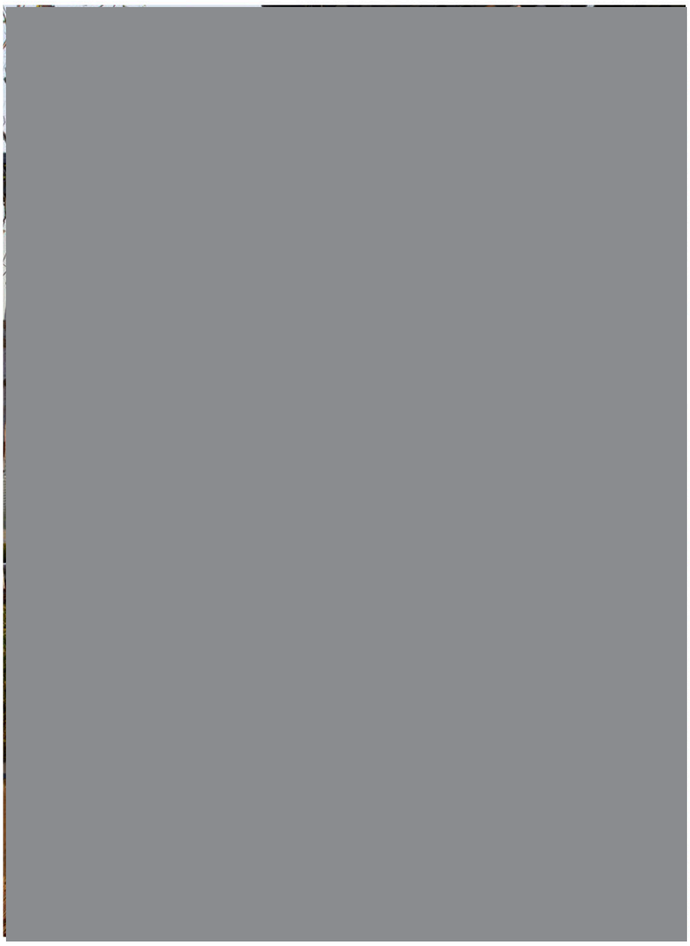
DAYLIGHT STIMULATES HIGHER COGNITIVE BRAIN ACTIVITY, EVEN IN INDIVIDUALS WHO LACK EYESIGHT.

DAYLIGHT IMPROVES MOOD, COMFORT, GENERAL HEALTH AND WELLBEING.

PLACES WITH SUPERIOR DAYLIGHT STIMULATE CONCENTRATION, AND IN CONSEQUENCE, HAVE LOWER NOISE LEVELS.

DESIGN STRATEGIES:

MAXIMIZATION OF DAYLIGHT INCIDENCE AND USE OF SMART FACADE SYSTEMS TO AVOID UNWANTED DIRECT SUN EXPOSURE



ACCESS TO OUTDOOR

OCCURRENCE:

SPATIAL INTERRELATION BETWEEN INSIDE AND OUTSIDE.

BASED ON FINDINGS:

BEING ABLE TO ACCESS OPEN AIR SPACES WITHIN A BUILDING SIGNIFICANTLY RESTORES MENTAL STATES AND OVERALL SATISFACTION.

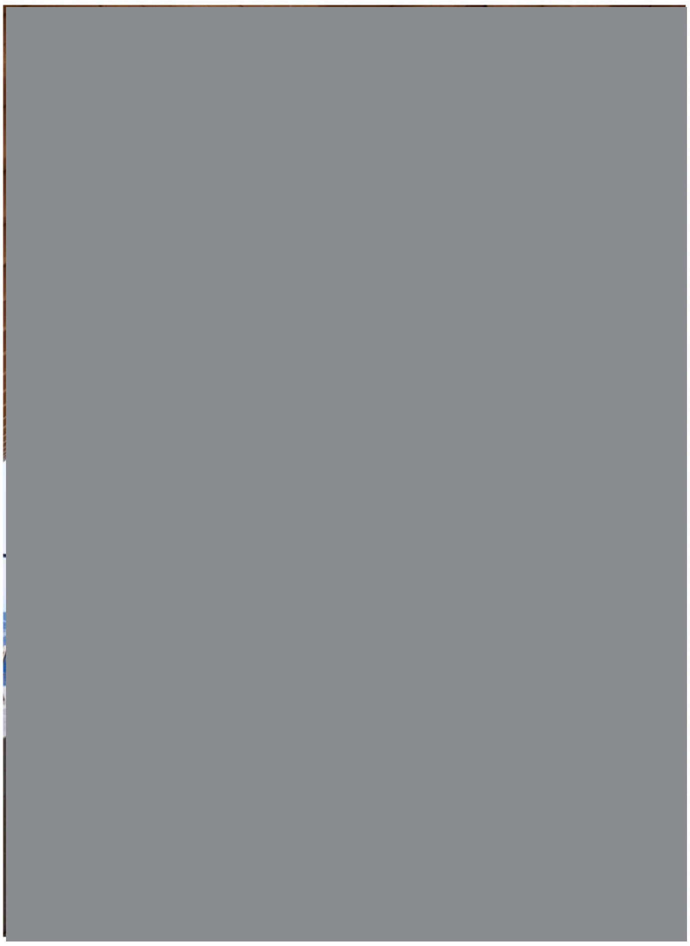
COGNITIVE FUNCTION DECREASES WITH THE DEPRIVATION OF ACCESSIBILITY TO OPEN AIR SPACES FOR SHORT MOMENTS.

BEING OUTDOOR INFLUENCES CHILDREN'S PHYSICAL AND MENTAL HEALTH, AS WELL AS THEIR DEVELOPMENT.

OUTDOOR ACCESSIBILITY FROM INSIDE THE BUILDING LEADS TO GENERAL COGNITIVE AND PHYSICAL RECOVERY.

DESIGN STRATEGIES:

URBAN ROOFTOPS, BALCONIES, VERANDAS, TERRACES AND COURTYARDS.



OPENNESS / VOID

OCCURRENCE:

UNOBSTRUCTED AREAS OF SPACE.

BASED ON FINDINGS:

ENCLOSED SPACES TRIGGER FEELINGS OF OPPRESSION AND CLAUSTROPHOBIA.

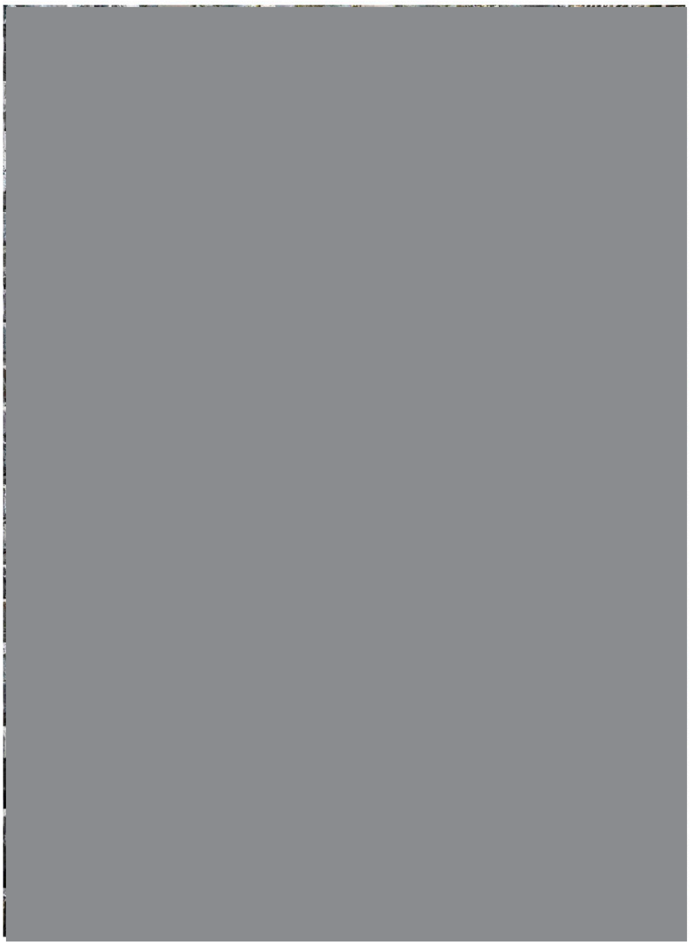
LACK OF PHYSICAL BOUNDARIES AMPLIFY THE FEELING OF EMBODIMENT OF SPACE.

SPATIAL PORTIONS OF VOID AND EMPTINESS ARE NECESSARY TO APPREHEND REGIONS OF INTENSE DETAIL AND COMPLEXITY.

OPEN SPACES IMPROVE LEARNING, BEHAVIOR AND GENERAL WELLBEING.

DESIGN STRATEGIES:

VISUALLY AND PHYSICALLY PERMEABLE VOID SPACES.



MATERIAL

OCCURRENCE:

SENSORIAL EXPERIENCE PROMOTED BY MATERIALITY.

BASED ON FINDINGS:

NATURAL MATERIALS TRIGGER WELLBEING AND EXPRESS SYMBOLIC RECONNECTION TO NATURE.

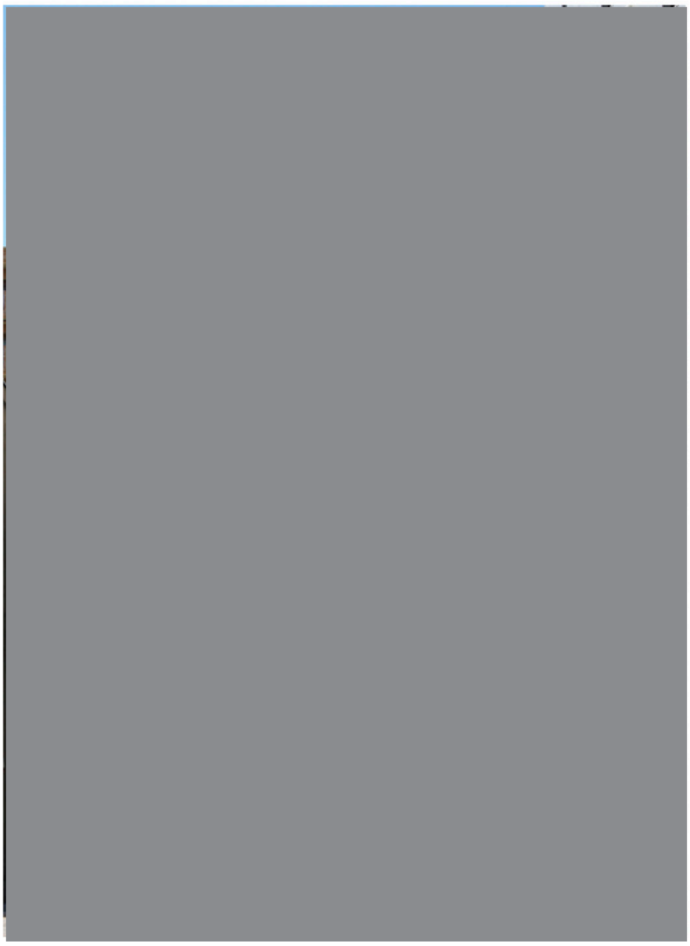
MATERIAL TEXTURES ACTIVATE BRAIN RECEPTORS WHICH TRIGGER EMOTIONAL AND MENTAL ACTIVITIES.

VISUAL STIMULATION BY NATURAL MATERIALS DECREASE BLOOD PRESSURE.

MATERIALS THAT ARE WARM AND/OR HAVE WARM COLORS, AND SOFT TEXTURES IMPROVE STUDENTS' ACHIEVEMENTS.

DESIGN STRATEGIES:

USE OF NATURAL MATERIALS, AVOIDING MIMETIC AND SYNTHETIC MATERIALS.



SENSORY STIMULATION

OCCURRENCE:

MOMENTARY EXPERIENCES INDUCED BY SENSORIAL ASPECTS.

BASED ON FINDINGS:

CONTROLLED RISK SPATIAL ELEMENTS INDUCE STRONG PLEASURE RESPONSE.

STIMULATION OF THE FIVE SENSES TRIGGER POSITIVENESS AND IMPROVES COGNITION.

INDIVIDUALS APPRECIATE MODERATE VARIATION OF SENSORY STIMULUS FROM THE ENVIRONMENT. AND SPACES WITHOUT SENSORY STIMULATION LEAD DO BOREDOM AND PASSIVITY.

LOW-FREQUENCY NOISE CAUSES SLEEP DISRUPTION AND HIGH BLOOD PRESSURE.

DESIGN STRATEGIES:

LIGHTNING TRANSITIONS, NATURAL MATERIALS, AND DESIGN ELEMENTS WHICH PROVIDE THE SENSE OF CONTROLLED RISK, SUCH AS CANTILEVERS, INFINITY EDGES, BALCONIES AND OPEN STAIRCASES.

PROPORTION / SCALE

OCCURRENCE:

RELATION BETWEEN HUMAN BODY, DESIGN ELEMENTS AND BUILT SPACE.

BASED ON FINDINGS:

HUMANS PERCEIVE THE EXTENT OF OUR BODIES AS A MEANS TO UNDERSTAND THE SURROUNDING PHYSICAL SPACE WITH AUTOMATIC AND SUBCONSCIOUS RESPONSES.

THE POSSIBILITY OF VISUAL EXPLORATION DUE TO PROPORTION AND SCALE, SUCH AS A DOUBLE HEIGHT CEILING, PROMOTES THE SENSE OF BEAUTY.

FEELINGS OF PLEASURE RESULT FROM THE RECOGNITION OF PROPORTION AND SCALE OF A SPACE IN RELATION TO OURSELVES.

OUR SPATIAL COGNITION PROMOTED BY THE SENSE OF PROPORTION AND SCALE AFFECTS OUR REFLEXES, BALANCE AND MUSCLE COORDINATION.

DESIGN STRATEGIES:

DESIGN ELEMENTS THAT CONSIDER THE PROPORTION TO THE HUMAN SCALE, SUCH AS CEILING HEIGHT, OPENINGS, AND DISTANCE BETWEEN BOUNDARIES AND OTHER ELEMENTS.

PATTERNS

OCCURRENCE:

INTRICATE REPETITIONS WITHIN BUILT SPACE.

BASED ON FINDINGS:

FRACTAL PATTERNS TRIGGER MAXIMAL ALPHA RESPONSES IN THE BRAIN'S FRONTAL REGION, RELATED TO RESTORATION, RELAXING AND GENERAL WELLBEING.

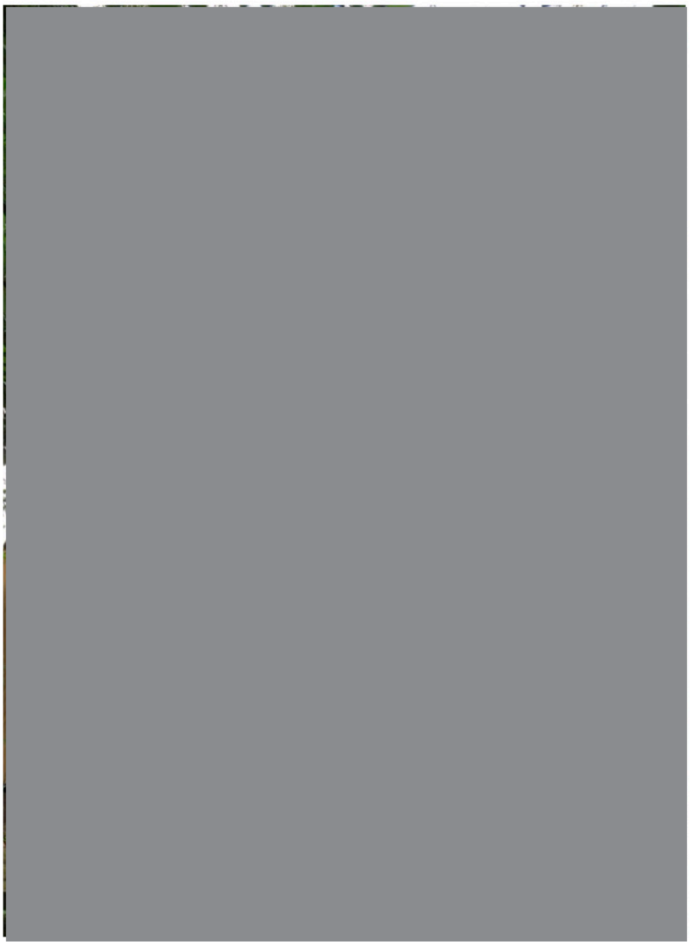
PATTERNS DECREASE STRESS HORMONES AND IMPROVE OVERALL COGNITION.

PATTERN RATIOS AND DENSITY ARE LINKED TO THE FEELING OF JOY.

PATTERNS FROM NATURE RESULT IN COMFORT AND WELLBEING, WHILE MONOTONOUS REPETITION LEAD TO BOREDOM.

DESIGN STRATEGIES:

ORNAMENTATION, LOUVERS AND STRUCTURAL SYSTEMS ORGANIZED IN PATTERNS RANGING FROM MICRO TO MACRO SCALE.



FORM / SHAPE

OCCURRENCE:

DISTINCT SPATIAL OUTLINE OF BUILT ENVIRONMENT

BASED ON FINDINGS:

STUDIES REVEALED STRONG IMPACT OF CURVED GEOMETRIES ON ACTIVITY IN THE ANTERIOR CINGULATE CORTEX, RESULTING IN FEELINGS OF PLEASURE, AROUSAL, AND ENGAGEMENT.

PARTICIPANTS WERE MORE LIKELY TO JUDGE SPACES AS BEAUTIFUL IF THEY WERE CURVILINEAR THAN RECTILINEAR.

SHARP ANGLES ACTIVATE THE AMYGDALA, WHICH PRODUCE FEELINGS OF FEAR AND THREAT, AS WELL AS OF INTEREST AND APPEAL.

SQUARED SHAPED SPACES INSPIRE FEELINGS OF EFFICIENCY AND SAFENESS, BUT ALSO BOREDOM.

DESIGN STRATEGIES:

CONSIDERATION BETWEEN SHAPES ACCORDING TO INTENDED OUTCOME, SUCH AS CURVES FOR SERENITY AND SHARP ANGLES FOR EXCITEMENT.

COMPLEXITY / ORDER

OCCURRENCE:

ORGANIZATION AND ARRANGEMENT OF DESIGN ELEMENTS.

BASED ON FINDINGS:

COMPLEX AND ORDERED BUILDING ELEMENTS HAVE POSITIVE EFFECTS ON BRAIN COGNITION, AND REDUCES STRESS.

COMPLEX AND ORDERED BUILDING ELEMENTS CAUSE EXCITEMENT, AROUSAL, AND GENERAL WELLBEING, WHILE MONOTONOUS REPETITION CAUSES BOREDOM, DIFFICULTY TO SUSTAIN ATTENTION, ADDICTION, STRESS AND SADNESS.

SPACES CONSIDERED BEAUTIFUL ARE CONNECTED TO NATURE'S COMPLEXITY AND ORDER, WITH SYMMETRY AND HARMONY.

ANIMALS RAISED IN MINIMALIST TANKS HAVE SMALLER BRAINS COMPARED TO THE ONES IN COMPLEX ENVIRONMENTS.

DESIGN STRATEGIES:

DESIGN ELEMENTS ORGANIZED IN SYMMETRY, RHYTHM, HIERARCHY, BALANCE, COMPLEXITY AND ORDER WITHIN DIFFERENT SCALES.

SEQUENCE

OCCURRENCE:

INTERRELATED CONNECTIONS WITHIN SPACES.

BASED ON FINDINGS:

EASY ENVIRONMENT NAVIGATION PROMOTES POSITIVE PSYCHOLOGICAL CONDITIONS, WHERE THE UNDERSTANDABLE ROUTES IMPACT OUR EMBODIMENT OF PLACE AND PROMOTES COMFORT AND SECURITY.

APPROPRIATE STAIRCASES PROMOTE PHYSICAL ACTIVITY, SOCIAL INTERACTION, MOBILITY, HEALTH AND WELLBEING.

STUDENTS AND WORKERS PERFORMANCE IS AFFECTED BY THE MOVEMENT AND CIRCULATION IN THE BUILDING, WHERE SEQUENCE OF TRAJECTORIES PLAY A POTENTIAL ROLE IN ACTIVE LEARNING AND IMPROVEMENT OF COGNITIVE MAPPING.

MULTIPLE BUILDING ENTRANCES IMPROVE THE SENSE OF FREEDOM.

DESIGN STRATEGIES:

CLEAR SEQUENCE OF SPACES AND COHERENT CIRCULATION

EDGES

OCCURRENCE:

LIMITS WHICH GENERATE SPATIAL BOUNDARIES.

BASED ON FINDINGS:

CLEAR SPATIAL BOUNDARIES FACILITATE THE CREATION OF MENTAL MAPS, RESULTING IN WELLBEING, COMFORT AND DECREASE OF STRESS.

SPACES WITH CLEAR SPATIAL BOUNDARIES GENERATE ENVIRONMENTS OF REFUGE AND PROSPECT, WHICH IMPROVE CONCENTRATION, ATTENTION, CALMNESS AND COMFORT, WHILE REDUCING IRRITATION AND FATIGUE.

THICK BOUNDARIES INSPIRE SECURITY, SPECIAL IN RESTORATIVE AND HEALING ROOMS.

UNCLEAR SPATIAL BOUNDARIES LEAD TO STRESS AND ANXIETY WHEN THE EDGES OF A SPACE CANNOT BE RECOGNISED.

DESIGN STRATEGIES:

CLEAR BOUNDARIES AND SPATIAL DELIMITATIONS WHERE THE INDIVIDUAL FEELS PROTECTED WHILE OPTIMISING VISUAL RANGE AND SURVEILLANCE.

For my precious wife;
Andrea Bagniewski