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Reinventing the Relationship Between Architecture, Biology and Human Experience

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Abstract
The oblivious implementation of 'biology' or 'study of life' into architectural design has been shaping human experiences for centuries. The human body consciously or subconsciously accepts the constructed surroundings to design emotions, senses, behavior, and logical order of its own. Likewise, the identity of a group of individuals occupied by a built structure to a certain extent reflects the spatial experience outlined by the structure. The current gap in biological understanding in design often assists in resulting imbalance between the human body and the surrounding environment. With this in mind, the first phase involves an exploration of existing biological theories regarding user spatial experience. The second phase studies a complex range of human movements, sensory stimuli, and emotional and behavioral responses recommending probable approaches for assuring structural soundness, aesthetic pleasure, and functional accuracy of an architectural setting. This research finally opens an opportunity to re-evaluate design solutions based on the potential applications of bio-scientific research for future design development.
Keywords: Built Environment; Biology; Sensory Perception; Spatial Experience; Bio-adaptive design.

1. Introduction

The relationship between a man-made structure and the man himself is a complex one. The first representatives of *Homo Sapiens* appeared more than 300,000 years ago. Human survival instincts along with their inclination toward material culture resulted in the expansion of construction practice with time. People change their behavior to fit in the physical environment (Lawrence & Low, 1990). That means, humans, build defenses and shelters used for protecting themselves from biotic and abiotic conditions, which at the same time employ their very own behavior. Winston Churchill's statement, "We shape our buildings: thereafter they shape us", emphasizes this age-old correlation between the two. The survey data of 'The National Human Activity Pattern Survey (NHAPS), 2001,' states that people spend 90% of their time indoors. The UN predicts that 68% of the world population to live in urban settings by the year 2050. Though several studies have been conducted on POE (post-occupancy evaluation) in recent times, the majority emphasizes building performance, function, and durability. Despite the consistency of technological success in the field of architecture, there still exist several neglected areas. Design complexities encountered during the process of adaptation conventionally rely on technological solutions. Why and how man-made settings impact cognitive performance, psychological as well as physiological mechanisms can be hardly examined only through analysis and modernizations of the technological features.

The built structure not only hosts its inhabitants but experiences the performance of an occupant and gradually behaves like one. The process is vice versa and accordingly, a building assists in facilitating the functional, aesthetic, and physiological growth of the human body when designed sensibly. A thorough examination of innate impulses which are generated as the reaction to various stimuli produced by architectural elements is logically capable of determining how design models connect with modern-day users. The present paper reveals the significance of this very symbiosis between architecture, biology and human experience and the promising results of their integration for the future design of buildings.

2. Research Strategy

Formulation of the design principles considering biological aspects focuses on the investigation of three major areas in the study:

i. Human Biology;
ii. Biology derived design inspiration;
iii. Interconnectivity of i and ii.

The research firstly aims to explore the significance of the existing bio-inspired design and conduct a literature review leading to the argumentation of the study. Furthermore, it tends to investigate the present scenarios of the implementation and practice covering biological aspects in design, including the scope of discussion for future research.

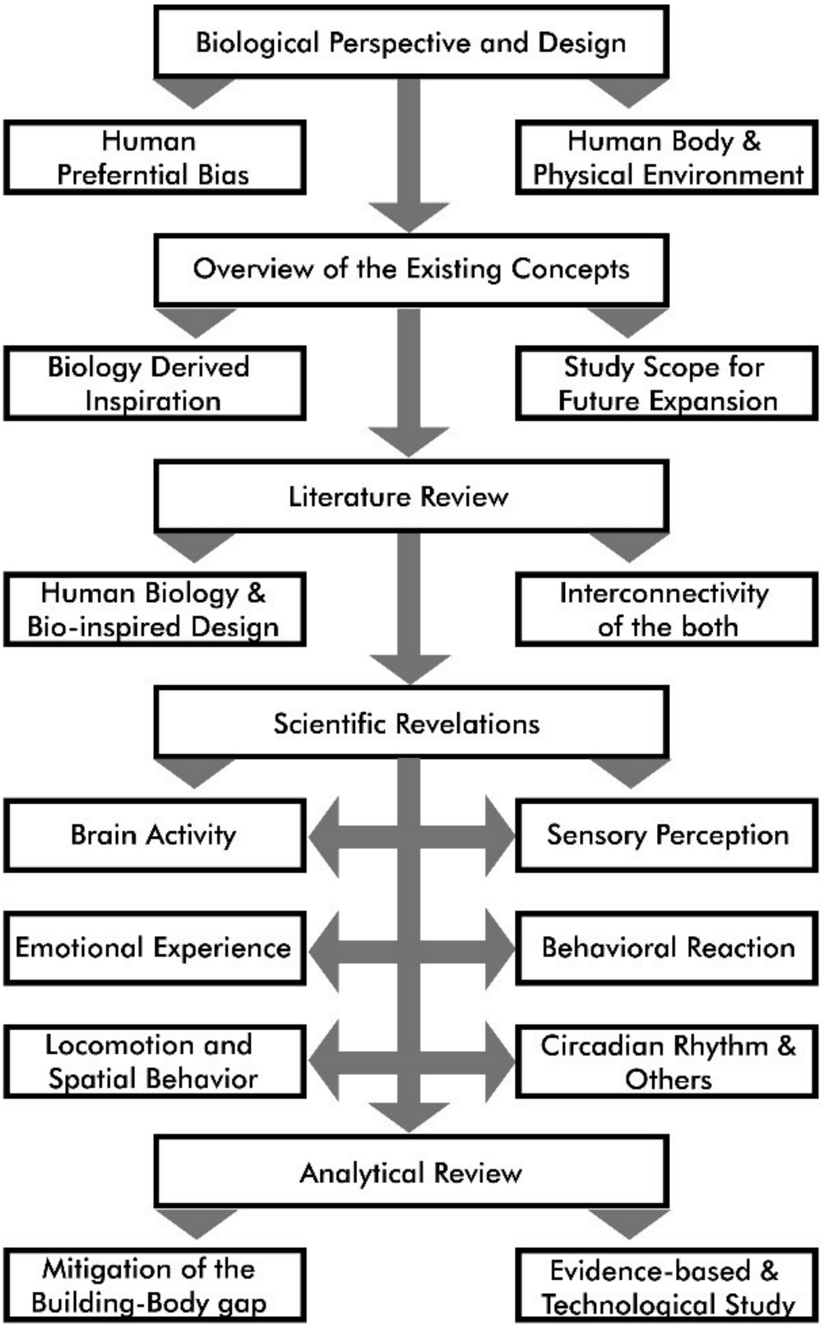

Figure 1. Structure of the Study (Developed by Author)

3. Biological Perspective and Design

Orians and Heerwagen's (1992) 'habitat theory' proposes that humans have a preference for certain visual landscapes, which later several studies have compared to the ancestral habitats. The savannah-like characteristics of open spaces with the availability of sufficient resources (water features, vegetative elements) and opportunities for protection, well-being, and productivity in which hominins evolved clarify the reason behind pre-existing biases. Preference of the involved participants in several empirical studies for such types of landscapes has been the subject matter regarding aesthetic judgment for centuries. Ricci (2018) insists that the process of pattern recognition in human beings that takes place at a subconscious level since the ancient period has been forming the mere sense of beauty and aesthetic perception. According to her study, modifications in this pattern generate unpredictability which occasionally deteriorates cognitive and physiological states.

Pallasma (1996) states that human bodies and movements constantly interact with the surrounding environment i.e. the environment and the individual inform and redefine each other constantly. He further expresses that buildings of this technological age intentionally encourage ageless perfection without including the dimension of time, or the inevitable processes of aging. Though human bodies possess the aptitude of adapting to a wide range of complex environmental features, the innate adaptive bias has been disfavored in numerous cases in the previous decades owing to the designer bias and technology-centric approach. The co-adaptation of the building/the immobile body and the living body regulates the quality of life. Our sense of balance relies largely on the external environment, and a slight disorder in each of the senses (vision, taste, smell, hearing, touch) results in the disruption of human behavior. A sensible design model to realize adaptation and functional needs thus necessitates a comprehensive assessment of the biologically inspired designs and a thorough understanding of the biological functions of humans.

4. Overview of the Existing Concepts

According to Ripley and Bhushan (2016), Bio architecture is a multiscale approach for utilizing the solutions and opportunities existing in nature to solve universal human problems. They also settled that bioarchitecture includes both direct bioinspiration and derived bioinspiration, and it is a practice yet to be achieved. Various bio-inspired design methods such as 'Biomimetic', 'Biophilic', 'Bionic', 'Biornametics' and 'Biomorphic' have become popular strategies and sources of inspiration for the designers over the last few decades.

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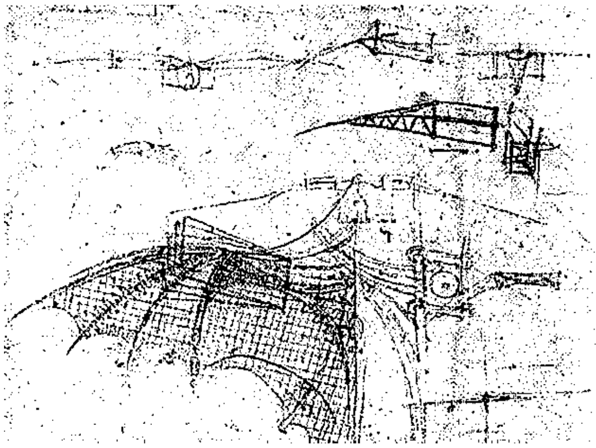

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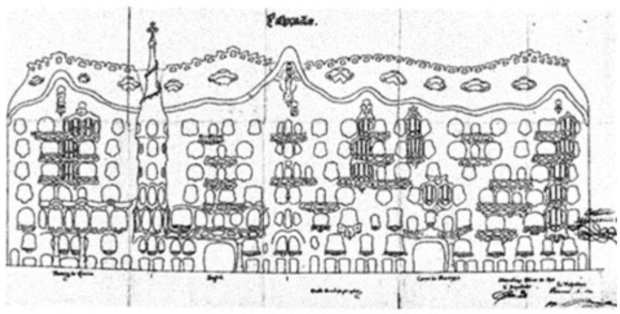

Figure 2. (a) Design for a Flying Machine, Leonardo Da Vinci, c. 1505 (Source: drawingsofleonardo.org); (b) Casa Milà, or La Pedrera, designed by Antoni Gaudí (Source: Gaudi: Introduction to his Architecture, Juan-Eduardo Cirlot, 2000.)

While the 'Biophilia Hypothesis' emphasizes the benefits of the human-nature relationship (Encyclopædia Britannica, 2014), 'biomimetics' or 'biomimicry' studies and mimics the nature-inspired solutions to answer complex human problems (Benyus, 1997). The idea and purpose of these approaches were explicated in the mid-19th-century (Steadman, 2008), although the biophilic movement began long before 600 BCE with the establishment of the Hanging Gardens of Babylon (Almusaed, 2011). Leonardo Da Vinci's sketches of flying machines and diving fins mimicking (Choi, et al., 2012) and observing the senses, behavior, and locomotion of living organisms like birds, fish, and bats in the 16th century to some extent instigated the movement of 'Biomimetics'. Likewise, Biornametics research studies the functionality of many natural patterns by examining the principles of nanotechnology research for the implementation purpose in an architectural design (Gebeshuber, Gruber and Imhof, 2015).

A closely related field to 'Biomimetics' is 'Bionics'. The term is a combination of the Greek word 'bios' meaning 'life' and the English word 'technics' indicating 'study' (Iouguina, et al. 2014). The Hungarian Etymological Dictionary of Foreign Words defines 'Bionics' as the 'scientific discipline researching the mechanism and functions of animal organisms, from the perspective of technical usability' (Sugár et al., 2017). The approach has been widely discussed and put into operation towards the end of the 18th century with Catalan architect Antoni Gaudi's bionic innovations e.g. 'La SagradaFamilia', 'Casa Mila', and so forth. A recent day example is the mechanical iris system on the building façade of Nouvel'sInstitut du Monde Arabe which simulates the real function of the iris of human eyes to achieve shading and ventilation of the built form (Megahed, 2012). Furthermore, other fields similar to Biomorphic, Zoomorphic, and Organic design, centering on biological forms and symbols have not been popular concepts in architecture only, but in other branches such as art, sculptures, and paintings as well. These branches of knowledge also remain as old as the times when the Greeks and Romans incorporated leaf and flower motifs into their built forms.

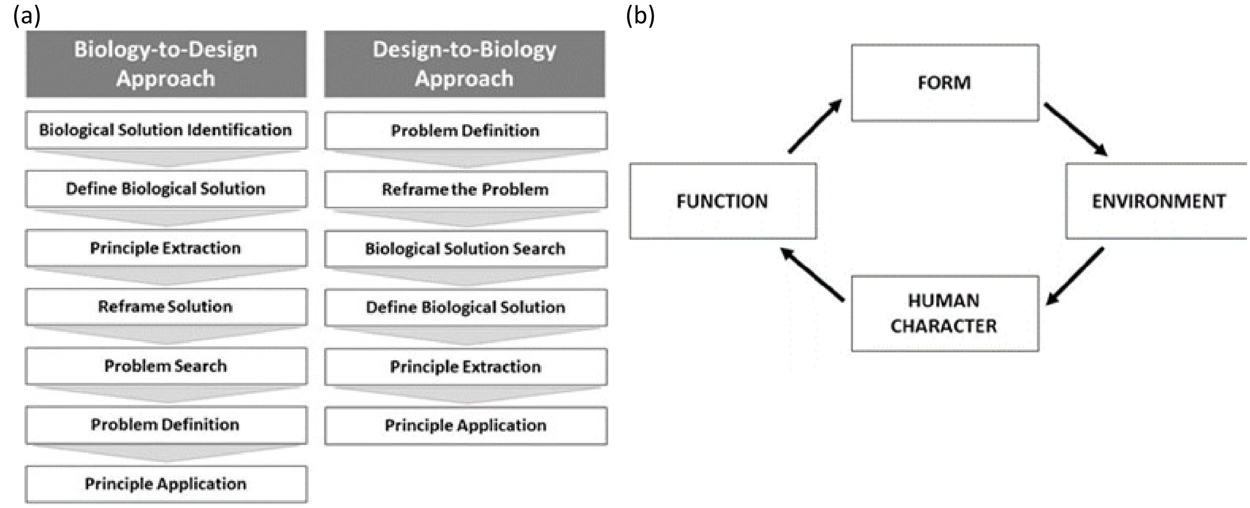

Figure 3. (a) Steps of design through Biomimicry, Image modified by Author (Source: Vattam, H et. al 2009, Sharif, S., 2010, Pandremenosa et. al, 2012, http://www.biomimicryinstitute.org/about-us/biomimicry-atool-for-innovation.html); (b) Building a Better World through architecture, By Arc. David 'Lola Majekodunmi, mnia, riba, aia (intl.assoc.).

However, to date, architecture and design have been limited mostly to direct imitation of natural shapes and ornamentation or inspired strategies that include one or another biological aspect (Ripley and Bhushan, 2016). There is undoubtedly room for this field to expand its scope. In this regard, how human spatial experience and biological response play a role in design remains a question. In recent times, assessment of the effects of environmental stress on cognitive performance led to a rise of several disciplines. For example, brain activity to external stimuli can be monitored and measured to formulate evidence-based design approaches for future intelligent buildings. The reevaluation of the influences of more of such growing ideas becomes essential to resolving existing challenges of architecture and future human survival.

5. Literature Review

Mathematician Luca Paccioli in 1498 through his mathematics book, De Divina Proportione expressed, "First we shall talk of the proportions of man because from the human body derive all measures and their denominations and in it is to be found all and every ratio and proportion by which God reveals the innermost secrets of nature." Similarly, the medical sciences emphasize the impact of human functional development, suggesting the necessity to rediscover the significance of 'place' for human health (Frumkin, 2003). On the other hand, Salingros and Masden (2006) established that biological systems and natural processes which are responsible to shape every living structure simultaneously rendered architecture and the built environment replete with life. However, whether the human response to the built environment to date has been considered in Bio-inspired design research, remains a question. Though humans are behaviorally flexible and can adjust to a wide range of environments and habitats (Smith, Borgerhoff Mulder, and Hill 2001), knowledge and understanding derived from human responses to the built environment can be utilized in design decisions to create a further harmonious relationship between humans and the built environment (Lang, 1987).

The post-industrial habitat design required to first and foremost consider human freedom (Demchak, 2000). Currently, the increase in designers' self-imposed separation from biological directives in design causes irrational construction habits. The negligence in considering bodily reactions to natural and artificial objects has become a habitual construction behavior and such a designer-based approach fails to connect to the reality of the existing physical environment. The long practice to use bodily reference by Vitruvius, through Alberti, Filarete, Francesco Di Georgio and Leonardo appears to be neglected in design (Vidler, 1990). The imposition of particular technical solutions or sets of ready-made variants is often considered standard causing 'the beginning of the process of erosion of the spatial differentiation, or the destruction of 'spatial identity of cities' (Lamprecht, 2016). The evolution of the modernist ideology following Le Corbusier's influential phrase 'The house is a machine for living in' shaped an uninvited trend leading to dehumanization and monotony in several aspects. Industrial and post-industrial architecture based on the mass-production of iron, concrete, and steel depicting "machine houses" lacked a human scale in major areas. Mitchell (1992) pointed out observations of industrial designer and theorist Christopher Jones of being 'frustrated with the superficiality of industrial design' in such a backdrop. Architectural culture accepted very limited industrial-minimalist typology which today benefits not the user, but the profession (Salingros, 2018).

Pinker (2002) criticizes modernist architects for uplifting boxy shapes of buildings made of industrial materials that effectively act like machines, however, eliminating ornamentation, traditional craftsmanship, and green corridors, interactive spaces that form the basic aesthetic and social needs. The practice of trained architects replacing the prevailing appearance of the real world with an abstract, formal set of computer-based images does not fully represent reality but expresses fictitious objects that don't exist (Salingaros, Masden II, 2015). The fabricated reality defines the homogeneity of the urban skylines, which in the long run represent merely collective rectangular boxes. The loss of such a sense of place leads to decreased social interaction, safety, and lack of identity increased social conflict, crime, and transgressions in towns (Nikoofam and Mobaraki, 2017). Thus, habitat arrangements lacking considerations of natural features and human preferential bias in cities become incapable to restore social, cultural, or ecological balance.

In every individual spatial condition of the post-modern world, the relationship between an object (both natural and artificial) and a subject modifies mood states, emotions, and productivity. Buildings, incompatible with their surroundings have been subject to criticism for the failure of function as well as unsatisfactory artistic qualities, alienating people that live in and around them (Farshchi, Fisher, 1997). Chandrasekar (2011) ascertained that a poor office environment does not negatively impact only productivity but health and the work-life balance of an employee. Palpitations, anxiety, sweating, higher adrenaline secretion, etc. may take place in any stressful spatial conditions. Stress, itself is the chief cause of 60% of all human diseases and illnesses (Farghaly, Hany & Moussa, 2021).

Human experience in the built environment refers to the human mindset influenced by external situations and revealed through human psychological, physiological, and emotional measures (Ergan et al., 2018). The elements of the built environment can directly impact physical health, at the same time being capable of both positively and negatively influencing behavior, habits, and feelings. (Lekić et al., 2018). For example, changing the built environment to increase children's physical activity for recreation and transportation can improve access to healthful foods and reduce access to harmful foods providing long-term results to the childhood obesity epidemic (Sallis & Glanz 2006). Moreover, appropriate space management can also have an important contribution to preventing spatial segregation of the elderly who prefer aging in place (Costa-Font et al., 2009). Another research points out that, the impact of the built environment may be a strong determinant in influencing behaviors regarding physical activity and diet as adolescents begin to explore the environment around them independently of parental influences (Papas., et al 2007). Researchers were successful to examine the relationship between the design of indoor environments and stress levels in health care, schools, and office buildings (Beukeboom et al. 2012; Rashid and Zimring 2008; Ulrich et al. 2008). Furthermore, in the last two decades, there have been few experimental studies in psychology and neuroscience that used Immersive Virtual Reality as a tool for observing human behavior and brain activity during natural contact with the external environment (Tarr and Warren, 2002). The evidence-based experiments on biological responses to spaces have been able to a degree to explain the symbiosis between humans and the built environment. The continuation of such research is a necessity at present. Therefore, architects responsible for designing the external environments for all humans should make the best effort to clarify the human-environment interface and environmental design by evaluating human needs and motivations as well as speculating their behaviors, actions, perceptual processes and emotional responses (Moneim, D. W. A., 2005).

6. Scientific Revelations Regarding Human Biological Response to Design

Modern humans experience the surrounding environment very differently than the ancient ones. Potential research studies in recent years observe the effects of natural and artificial objects on individuals in achieving preferable stimuli in various functional areas such as office environments, hospitals, schools, etc. Such outcomes depend largely on human physiological, physical, and psychological responses to design. For instance, it is proven that lighting and level of luminance influence our stress and anxiety levels. (Farbstein and Farling 2006; Sternberg and Wilson 2006). Additionally, researchers have found that during exposure to cognitive loads in a darker space, an individual's stress level increases. Developments in science and technology and interdisciplinary collaborations between fields such as bioinformatics, artificial intelligence, virtual realms, and neuroscience formed new perspectives and resulted in the progress of data-collecting devices, and measurement techniques, which helped to strengthen the knowledge of human-built environment interaction (Karakas and Yildiz, 2020). Such fields that now explore organism biological responses and structural adaptions to the physical environment through the investigation of the natural processes, biological forms, and living systems, intend toward human well-being and ecological restoration in the present context.

6.1 Brain Activity within Built Spaces

The neural responses to pleasant and unpleasant stimuli regulate decision making, learning, thinking, speaking, and the ability to solve the task in an architectural setting. According to William James, one of the founders of modern psychology, 'stimulation is the indispensable requisite for pleasure in an experience'. Various contemporary branches, for instance, NeuroeAsthetics, NeuroUrbanism, and NeuroArchitecture study brain activities around and within built spaces. From the formation of emotion to execution of an action, the readings of the frontal lobes dealing with cognitive functions, limbic system with its function to pay attention, cortex developing action tendency, amygdala's notification regarding fear or ventral striatum's about pleasure and activities of other related brain regions can be recorded through the application of scientific research. For example, the brain region amygdala associated with fear processing remains more active for sharp objects than curved contour counterparts (Bar and Neta 2007).

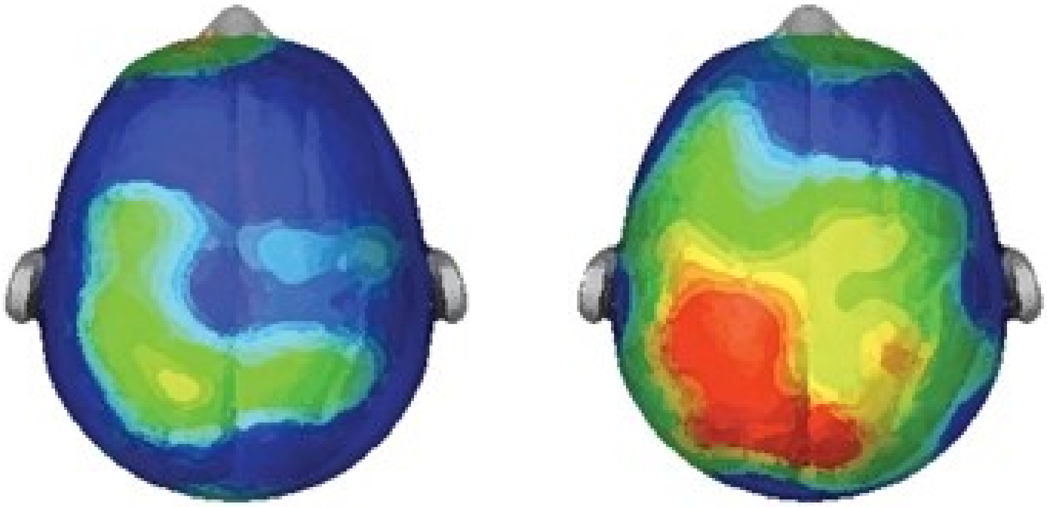

Figure 4. The left image shows brain activity for 20 minutes of quiet sitting in the classroom and the right image shows brain activity for 20 minutes of walking before the academic test of preadolescent children, indicating the increase in brain activity and better academic performance due to exercise. (Research by Dr. Charles Hillman, 2009)

Charles Hillman (2009) experimented with 5th-grade students and established that physical activity influences brain activity in due course affecting academic performance. Such scientific applications point toward the set of rules for design differentiating between the right and the wrong design decisions. Though the potential applications of scientific evidence to solve modern-day challenges such as promoting mental health and well-being are still at an experimental stage, the first studies using fMRI, EEG, PET, etc. display promising revelations. For instance, research shows that human beings' perception is highly sensitive to symmetry (Wagemans, 1995). Another study proves that perceivers have a positive aesthetic response when they can fluently process that object (Hekkert 2006). Geometry, light, texture, smell, air, and other factors contributing to the spatial complexities direct signal to the brain which is measured through the bodily responses. Researcher ItaiPalti with neuroscientist Dr. Moshe Bar has been engaged in evaluating the concept of "conscious cities" through human response based on the scientific evidence associated with cognitive sciences. The fact that design affects the brain is undeniable. Through neuroscience data, human response to functional complexity could therefore be assessed and reassessed to achieve better design outcomes.

6.2 Sensory Perception

Spatial perception evolves through human sensory exploration of objects and events in an environment. Though humans are considered visually dominant creatures (Levin, 1993), each sensory signal has a distinct influence on the relationship between the human body and its surroundings. Besides auditory, tactile, visual, gustatory, and olfactory aspects, various inherent yet recent-defined senses such as equilibrioception, kinaesthesia, thermoception, etc. in total have been constantly enhancing architectural experience since the beginning. According to the gestalt principle, the sensory input is not perceived as the sum of the individual components, but rather as a whole (Lin, 2004). All the environmental characteristics such as the existence of specific odors, colors, hues and shades, noise, acoustics, temperature, etc. generate sensory input to altogether produce specific reactions in an observer (Franz, 2006). Form and geometry, position and distance, surface and skin, material and texture, etc. of the surrounding objects in an architectural setting enable positive and negative sensations to develop as a reaction to the spatial experience. This may explain the reason behind human's preference for symmetric shapes, as they hold fewer complexities than asymmetric shapes (Garner, 1974). Also, evidence suggests circular surfaces and shapes to be more pleasing to common people than angular hexagons (Bar and Neta, 2008).

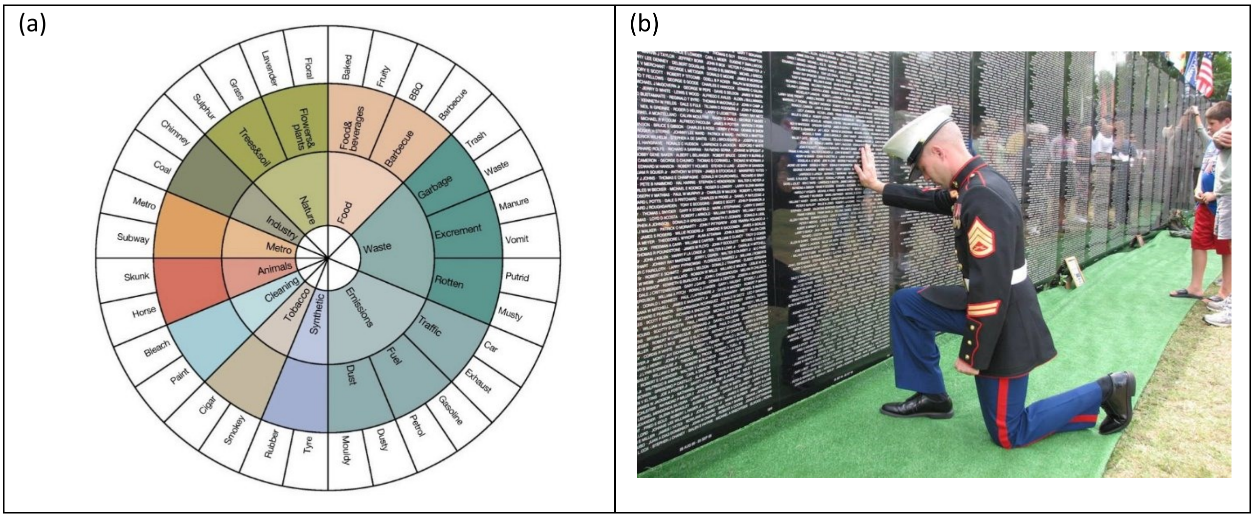

Figure 5. (a) Urban Smellscape Aroma Wheel (Aiello L, McLean K, Quercia D, Schifanella R. 2015), (b) Tactile Experience, Vietnam Veterans Memorial (Source: American Veteran Traveling Tribute & The Traveling Wall, AVTT, The Berkeley Observer, 2021).

In an ocular-centric contemporary world, several senses are habitually neglected and the process results in overlooking the effects of the designed environment on the cognition and emotional states of the individuals. Pallasma (1996) fairly quoted "Modernist design at large has housed the intellect and the eye, but it has left the body and the other senses, as well as our memories, imagination, and dreams, homeless." His further argument on the alarming effects of modern architecture on the human body owing to sensory deprivation portrays the increase of separation between the human body and the existing natural world in the present condition. Some research to observe the integrative sensory experiences in certain architectural arrangements experimenting with audio-visual or audio-olfaction, tactile-olfaction or tactile-visual, etc. stability signifies the impact of multisensory design in architecture. Such an experiment observing the effect of music and scent in an interior space of a gift shop has been conducted by Mattila and Wirtz (2001) where consumer satisfaction has been achieved as a result of the coalition, encouraging visit intentions and approach behavior with impulse buying rate. Likewise, tactile-visual aspects to cause composed sensory arousal in a spa have been experimented with to have established similar positive results (Kang, Boger, Back and Madera, 2011). However, the congruency effect between music and smell may produce a different result based on consumer mood and functional situation. This complex integration dictates human rejection or acceptance with respect to the hostility or hospitability of the space. For instance, 'Christmas music' and 'Christmas smell' together result in greater visit intentions and customer satisfaction than without any music or smell; nevertheless 'Christmas smell' with music dissimilar to Christmas melodies produces weaker visit intentions (Spangenberg, Grohmann, Sprott, 2006). Veterans Memorial of Vietnam and Civil Rights Memorial of Alabama, USA stands as a noteworthy example of a texture-rich experience for the human body. As such multisensory responses play an indispensable role to strengthen place identity along with self-identity, investigation of positive and negative olfactory, muscular, haptic, visual, auditory, or combined sensory aspects in every functional setting becomes a prerequisite for measuring the sensibility of the designed space.

6.3 Emotional Experience

Human emotional responses cannot be measured in one specific method. Humans react differently to certain stimuli and for determining the reactions, the experiential, physiological, and behavioral responses serve as three major components (Cho, Kim 2017). Among various response patterns, facial and vocal expressions have been considered the chief motor expressions for measurement (Desmet 2004). Charles Darwin's theories (1872) of discrete emotional entities have been focused on and extended by various psychologists in the later century. American psychologist Paul Ekman in early 1970 identified six universal or basic emotions (anger, surprise, disgust, enjoyment, fear, and sadness) through experimentation with human facial behavior. Plutchik R, in 1982 extended it and pointed at eight emotions as of primary and vital importance namely anger, fear, sadness, disgust, surprise, anticipation, trust, and joy. His proposed 'wheel of emotions' in 1980 centers around the relationships among the different emotional entities and the consequences and intensities of their mixture.

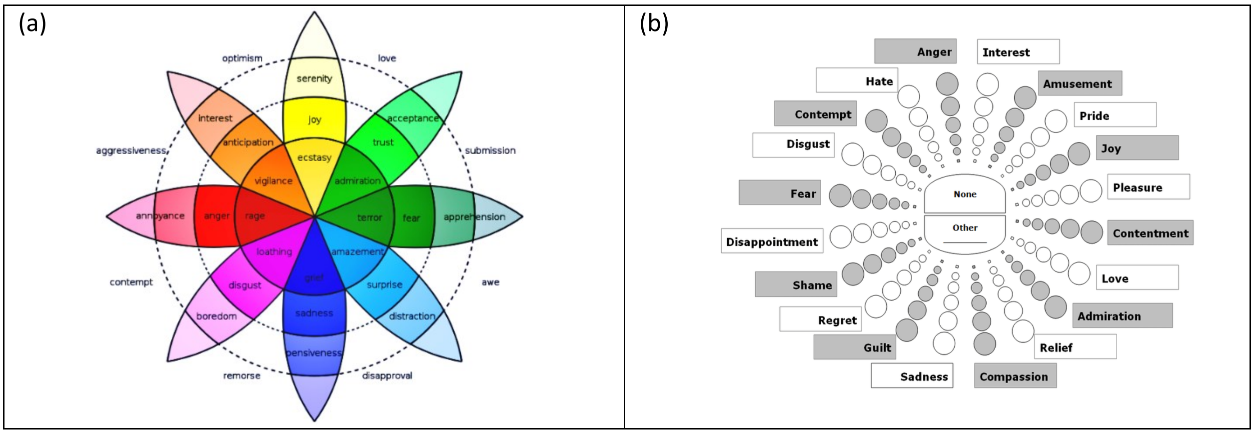

Figure 6. (a) Plutchik's Wheel of Emotions, 1980; (b) Geneva Emotion Wheel, 2013 (Source: Blaiech, H., Neji, M., Wali, A & Alimi, A.2013. Emotion recognition by analysis of EEG signals. 13th International Conference on Hybrid Intelligent Systems, HIS 2013.)

Facial behavior, vocal expressions, eye movements, bodily gestures, and other physiological responses to the built environment categorize emotional stimuli and prepare a human for a particular action. Judgments, choice, decision making, and behavior formulation take place throughout the process. For instance, frustration may arise and be depicted typically by the activation of various facial and vocal expressions as a result of behavioral attempts to overcome obstruction when an event interrupts an achievement of a human goal (Brosch et al.,2010). For this reason, a child's body with an impulse for physical movement in an inflexible spatial arrangement inside the traditional classroom model holds restricted choices of actions eventually losing motivation and interest in social interaction. According to a study by Liu and Jang (2009) in a restaurant setting, lighting, scent, music, and temperature have significant effects on both positive and negative emotions. However, an ignorant design approach develops negative emotion effortlessly as studies (Gelder et al., 2005, Pourtouis et al., 2005) show negative stimuli to be more spontaneously and speedily processed than positive ones. In such a case, the stimulation in the human 'bias for bigness' caused by the massive scale of monumental architecture portrays architecture's social function and role (Verpooten, Joye, 2014). An 'awe' is an emotional response caused by overwhelming vastness (Keltner and Haidt, 2003), and a study (Cappellen and Saroglou, 2012) shows such a response creates feelings of togetherness with each other and results in devoted relationships. Research shows that with greater forest cover possibility of 50% less depression and 43% less stress in neighborhoods remains (Cox, Shanahan, Hudson, 2017). Developed by the researchers of MIT's Computer Science and Artificial Intelligence Laboratory, the device "EQ-Radio," can currently detect a person's emotions using wireless signals by measuring breathing and heart rhythms and variations. Various new emotional mapping devices and on-body sensors help measure emotion in a natural or artificial setting. Designing architectural elements with emotional value complements the quality of experiential response. To recognize the human psychological cravings, and assure physical comfort and physiological well-being, the conscious and unconscious emotional experience of human beings in various architectural settings appeals to observation.

6.4 Behavioral Reaction

Architecture has been playing a remarkable role in shaping the behavior, perception, and intention of individuals and communities from the very beginning. Psychologist Kurt Lewin in 1936 formulated a heuristic equation to determine behavior that centers on the functional relationship between a person and the environmental situation. His equation "B=f(P, E)" expressing behavior (B) as the function (f) of both individual (P) and environment (E), grows into an influential formula. The behavior-shaping process is imperceptible and the slightest inattention of the bodily factors during the process may cause an unpredictable behavioral outcome. When individuals are compelled to show certain behavior in an unnatural approach through man-made design, they experience difficulties and expose disordered mental patterns during the process of adaptation (TavasoliAra&Bashiri 2015). Russell and Mehrabian (1978) emphasized the fact that emotional experience influence human behavior in an environment. Humans possess a tendency to approach or avoid an object assessing threat or opportunity with respect to the emotional response to finally lead to action tendencies as a component of behavioral response (Cho and Kim, 2018). Such bodily responses may be muscular or glandular, sensory or neural, etc.

ECG, fEMG, GSR, EEG, and PPG determine cognitive and physiological states including attention, memory, stress, emotional valence, fatigue, and so forth. Similarly, the whole-body behaviors in a built environment observed and analyzed through instinctive cortical arousal, bodily changes, eye movement, and facial expression promise to measure the soundness of the design. Behavior study through examining movement, rest and work, attitudes and actions, etc. measures the experiential quality of the functional space. Meyers-Levy (2007) experimented with such influence of architectural space on thinking style. He observed low-ceiling rooms to be assisting in concrete thinking as concentrating on the details of a particular subject or object while high-ceiling rooms assist in abstract thinking as creative activities, brainstorming, etc. Such role of architects in formulating behavioral intention in space has been overlooked for several years. The research in the field of 'Environmental Behavior' monitors environmental experience and consequences to measure the relationship between human behavior and his surroundings with an intention to promote human well-being. The importance of environmental behavior in architecture is undeniable as it ensures not only human health but predicts and studies pro-environmental behaviors. Habitual behavior patterns, place-attachment, and identity, automated cognitive process, etc. of humans in a man-made setting require thorough attention to gain an understanding of the methodology of behavior modification. Attainment of the preferred behavioral state through design thus requires evidence-based investigation of behavioral choices, judgments, and intentions based on the post-occupancy evaluation.

6.5 Locomotion and Spatial Behavior

As stated by architect Bernard Tschumi, "Bodies not only move in space but generate space produced by and through their movements." However, common techniques of architects to describe ideas through drawings, models, sketches, computer visualizations, etc. have been unsuccessful in the past to reveal the spatial quality of human movement (Vroman, Lagrange, 2017). Such spatial values being ignored, the lack of spatial sensibility manipulated people's spatial behavior for years. Many negative health consequences resulting from the lack of movement are caused by the bad structure of the built environment (Heath et al., 2012).

The psychology of motion plays an important role in evaluating architectural experiences. The design factors and elements in a space stimulate spatial continuity and direct the sequence of flow consciously or subconsciously. Humans have definite feelings for every particular shape within a built space (Shemesh, Bar, Grobman, 2015). The movements followed by the stimulation of the objects and the events are not necessarily physical, but often mental. The mental movements occur before the physical ones in maximum situations following the approach, direction, flow, and rhythm of the event and space. An explorer occupying a low degree of enclosure in a built space with a stimulating viewpoint towards a certain direction would habitually develop a sensual tendency to move towards that direction even before the physical action (Ahmadi, 2019). In such a stage where decisiveness of potential, imaginative, or future movement develops, the facial expression with eye movement as well as the shifting of muscular posture dictates the comfort and functionality delivered by the event or space. The research on spatiality at both building and urban scales deals with objects and the space between these objects, the shape, and characteristics of the void, and their mode of arrangement (De Aguiar, 2006). The role of the directional axis along with the surrounding air movement in characterizing human spatial action is immense. This is why Edward T. Hall's (1966) theory of interpersonal distance defines four zones (1969): intimate, personal, social, and public space, which remains a standard to measure stress and relaxation or flexibility and rigidity in a designed space.

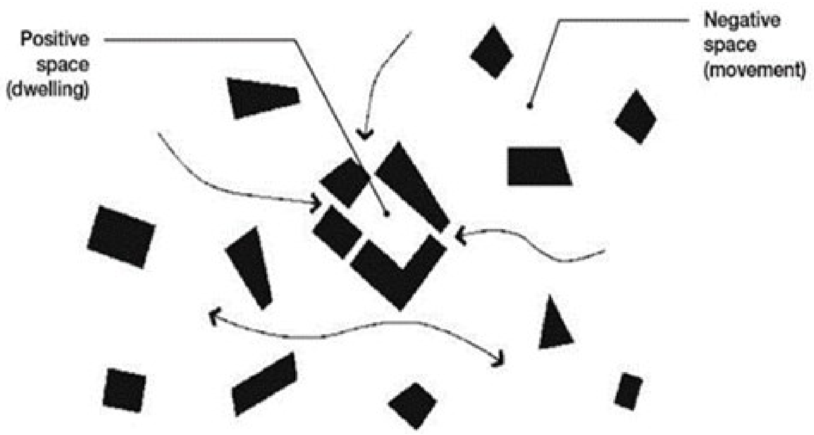

Figure 7. A college "quad" is usually the preferred space on campus for social interaction and hanging out, (Relation between ground and figures, Source: Ibrahim A, Mikhail R, 2016).

Though humans possess a variety of navigation abilities, certain behavior while navigating decides the usability of path design and integration. Mapping of everyday human activities is necessary to detect efficient or unused spaces to improve future urban performance through amended placement or design of furniture, lighting, navigation patterns, or other creative elements (Poulsen et al., 2011). These systematic observations could be carried out in areas of human gatherings and social interactions, or areas without activities. Human experiences both best and worst, eye-to-eye contact, speed of the movement, ignoring or interacting postures, etc. regulates the flow of experience in the urban areas. Experimentations of a diverse range of motion intensity in a public place from walking to with general people uniform remains a prerequisite for adaptable design. Professor of cognitive neuroscience, Collin Ellard in his lab experiments and studies human responses as fear and anxiety around the heavy traffic intersections and hiking paths to predict human urban behavior. According to Wunderlich (2008) “It is while walking that we sensorially and reflectively interact with the urban environment, firming up our relationship with urban places.” Eadweard Muybridge famous for his photographic studies of motion, since 1901 used cameras, stop-watches, time-lapse and electric lights (attached to the limbs) to capture sequential photos that represented the flow of the movement. Tracking the eye routes and observing the bodily postures with time and environment assist in predicting human behavior and action. How people move and adapt to space can currently be represented through various methodologies accompanied by the spatial analysis software. For instance, ‘Space Syntax’ is a visual perceiving system of movement patterns in the context of urban development and ‘Kinect’ is a data accumulator of people’s motion, voice, and facial expression in public spaces. Experiments to observe the lines of movement and spatial behavior require a detailed circulation diagram displaying obstacles and flexibility of the space. It is thus essential to design required performance through the allowance of spaces that enable human movement assisting him to adapt and change as per his wish.

6.6 Circadian Rhythm

Disruption of a human’s circadian rhythm cause desynchronization in metabolism, appetite, productivity, sleep-wake cycles, and emotional stability. Besides, change in melatonin levels, blood pressure, and blood sugar due to any disturbance of the rhythm are observed among people of different ages. Light, color, and texture have a significant influence on circadian rhythm. Actigraphy being the most common methodology, circadian rhythms in an architectural setting are generally measured by evaluating the core body temperature, melatonin levels, oxygen levels, etc. Though contemporary buildings and skyscrapers ignore the connectivity to the ground levels, physical contact with the earth’s ground regulates the human circadian rhythms. Such an experiment of walking barefoot on ground texture has been proved to achieve a similar affirmative result. However, there still exists a lack of detailed research in these areas. Measurement of visual comfort and circadian stimulus in the interiors through experimentation on light exposure has been a common method in recent years. The power of natural light being the utmost, following certain guidelines in the cases of designing artificial light is a precondition. Experiments reveal that the provision of cycled lighting (reduced light levels at night) in neonatal intensive-care units improves sleep and weight gain among preterm infants (Blackburn, Patteson, 1991). Another research shows that controlling the circadian system with natural and artificial lighting, depression, sleep, circadian rest-activity rhythms, as well as the length of stay of the patients or staff in the hospital can be influenced. (Joseph, 2006). Such human response is neglected very often and thus needs to be assessed and analyzed for future design accuracy.

6.7 Other Measurements

Various medical and therapeutic testing are capable of measuring human response to the environment. For instance, the measurement of heart rate predicts stress levels (Jovanov et al. 2003). An object is supposed to possess effective ‘value’ if it can impact a person’s breathing, heart rate, hormonal secretions, etc. (Barrett and Bar 2009). Psychophysiological parameters and measurements such as heart rate, respiration, blood pressure, and galvanic skin response (GSR) possess the capacity to predict human emotional experiences (Shemesh et al. 2017). The function of skin conductance to cause psychological or physiological arousal can be used to measure emotional and sympathetic responses (Carlson 2012).

Again, contact with natural landscapes or interrelated features, i.e. plants and animals, is found to be beneficial for child development, human physical and mental well-being, mood, disease, mortality and recovery from illness (Tost and Meyer-Lindenberg, 2015).

7. Analytical review

In most post-modern urban settings, the replacement of the naturalness of the landscapes with ‘concrete jungle’ in the process of stabilizing economic balance and efficiency consistently disregards the aesthetic and cognitive transformation of human beings. Today, there seems to be a huge gap between architects and building users that can be mitigated by current evidence-based research and advanced technology. Hence, bridging the gap between the two is necessary and one important way includes measuring and assessing human bodily responses and spatial experiences in a built space. Though industrial-modernist architects have segregated from the human need deducting the need for a healing environment for a long period by dropping adaptive design instructions, today's

professional practice should implement only tested design processes for health-promoting urban environments (Salingaros, 2018). A post-industrial civilization necessitates fresh design approaches than the industrial one. In such a case, Montana and Fiorentino (2016) suggest the expansion of bio-inspired and biophilic technologies as opportunities for freshness in post-industrial design. They also demanded that present transdisciplinary design practice and research must tackle challenges derived from the industrial revolution by exploring new technologies and design solutions for the betterment of mankind and their environment.
Post occupancy evaluations have been effective as a research methodology in the last decades. The practice of post-occupancy evaluations consists of using questionnaires, one-to-one interviews, field and photographic surveys, walkthroughs, group discussions, time-use recordings, as well as direct observation and evidence (Turpin-Brooks and Viccars 2006). Post-occupancy evaluation results can be implemented during the design process for future facility development, to ultimately devise a more solid theoretical framework directed at improving the process of forming a more responsive architectural environment (Horayangkura, 2012). Rob (2003) points out in his research the emergency for design to recognize and respond to the diversity of bodily needs in the built environment by allowing impulsiveness, overlooking restrictions and sensitizing to the corporealities of the body. As he stated, architects should identify the multiplicity of postural schemata of the body. According to research, the presence or absence of daylight, level of luminance in rooms, wall colors, circulation, spatial openness, accessibility to the built forms, outdoor landmarks, etc. can change people's perception of the space, and this perception is reflected in their bodily measurements (Ergan et al., 2018). The same research studying human experience concludes that one important challenge in quantifying the impact of architectural design features is to build controlled testing settings (Franz et al. 2005) in which design features can be changed and tested independently. Presently, building information modeling (BIM) and virtual reality (VR) tackle challenges by offering the flexibility to swiftly imitate and modify real-life environments under controlled settings with a high degree of practicality for users (Zou et al. 2017).
Architectural design features impact our experience in a space extensively and each design feature influences a specific human experience (Eberhard 2009). We have to understand that architecture and the human body are mutually constitutive (Imrie, 2003). Just as the bodily form is not independent of the architecture, architecture is not independent of the body. The key to a fresh design exists in the understanding of how physical/biological structure develops and embraces; knowledge of the design adaptability with the external and changing circumstances; information about multifaceted interacting systems and understanding of how our intellect links us with the real world (Salingaros and Kenneth, 2007). Hence, design should permit and consider the holistic approach of spanning and integrating the spheres of architecture, biology and human experience.

8. Conclusion

Biology and bio-architecture have offered architects a new framework to address the issues of healthy building design. However, bio-architecture is not only restricted to the existing fields. Through several kinds of research, it has been observed that architectural experience and human biology are two attributes that influence each other to a great degree. Current building practices result in an adverse effect on human biology as well as nature. As quoted by Pallasmaa (1996), "The inhumanity of contemporary architecture and cities can be understood as the consequence of the neglect of the body and the senses, and an imbalance in our sensory system." When humans perceive themselves as being isolated from the environment, it leads to unpredictability and mediation, ultimately directing towards extinction. Hence, it is high time to re-examine opportunities to learn from human biology and spatial experience to implement them in the development of design principles. Contemporary society must identify architectural misconducts and practices which today characterize built forms as isolated objects from the human body.
Bio-inspired design as a study dealing with nature, biological forms and processes should be also connected with the anatomy, biological functions and physical and mental states of humans in a built environment. Though mimicking and utilizing biological forms and the biological process in design bring new solutions to the table, a clear dialogue between the fields of biology and architecture cannot be obtained without analyzing human response and experience. Hence, architecture, biology and human spatial experience should be integrated to develop a separate approach or field to ensure quality design and human wellbeing in architecture.

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Conflict of Interests
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