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The Interplay of Psychology, Physiology and Architectural Design: An Overview

Natalie M. Ricci

Savannah College of Art and Design, Savannah, GA, USA

Abstract. The relationship between design and psychology is both consequential and bidirectional. Successful design has been shown to have clear psychological and physiological benefits. The converse is equally true; psychology, human experience, and the function of our neurological systems all play a significant role in what we perceive to be successful design. Unfortunately, while the interplay between architectural design and human psychology is significant, it remains largely underappreciated or even ignored both within and outside the design industry. This paper endeavors to create a better understanding of how that complex relationship evolved and its implications in today's world by exploring how the human brain and nervous system are structured and function; how that structure and function benefited our human ancestors; and how modern society has impacted that function. With that background, the interrelationship between design, psychology and our nervous system is explored. Finally, the importance of incorporating nature into the built environment to benefit from its potential for positive psychological impact and restorative properties is considered.

Keywords: *architecture, design, psychology, biophilia, well-being*

Corresponding Author: *Natalie, Ricci, Savannah College of Art and Design, Savannah, USA*
e-mail: nricci141@gmail.com

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1. Introduction

Architectural and interior design have been societally classified as aesthetic bonuses to the "built environment" (defined as that environment comprised of man-made structures and settings within which human activities take place). This has not only damaged the legitimacy of the field but has also prevented it from receiving the necessary attention of the general public and funding that it deserves. Architecture started out as a means of creating protection or shelter from the surrounding environment. It gradually evolved into an art form within which subjectivity, creativity, and beauty were introduced. Today, we are seeing architecture evolve yet again, this time from an art form to a subject of psychological study and purposeful implementation focused on well-being. Because of that, studying the psychological effects of architectural and interior design is critically important to better understand their immense influence.

2. The Nervous System, Brain Structure and Function

The human central nervous system structurally consists of the brain, the spinal cord, and the peripheral nervous system. The brainstem, that portion of the brain which serves as the connection between the brain and spinal cord, is responsible for such involuntary functions as breathing, swallowing, heart rate, reflexes, etc. The brainstem also serves as a relay station, receiving information from the peripheral nervous system and distributing it to the corresponding parts of the brain to be evaluated and classified as pleasing or displeasing (Thau, 2020). Functionally, the central nervous system works in various interrelated units. The limbic and autonomic nervous systems are two such units with components of the limbic nervous system controlling various autonomic nervous system functions; both work together to control basic bodily functions like breathing and response to stress. The autonomic nervous system is further subdivided into sympathetic and parasympathetic nervous systems (Waxenbaum et al., 2020). When mammals experience danger, the sympathetic division of the autonomic nervous system jumps into action raising the heart rate and blood pressure, and opening lung airways to improve breathing. These changes, resulting from the release of adrenaline, norepinephrine and cortisol, also slow the bodily functions that are not immediately necessary (Waxenbaum et al., 2020). This fight or flight response to threats developed evolutionarily to increase our chances of survival when threatened. Once the threat has been neutralized through either fight or flight, the parasympathetic division of the autonomic nervous system kicks into action working to return the body to its resting state and reactivate various routine metabolic processes (McCorry, 2007).

The brain is also divided into different functional processing systems designated to perform different tasks. The cerebellum, or hindbrain, controls posture, balance, and coordination (Thau, 2020). The cerebrum, or forebrain, processes information from external stimuli, then triggers the proper reactions. The forebrain controls our crucial cognitive skills like memory, language, judgement, problem solving, sexual behavior, and emotions (Mai & Paxinos, 2012); in other words, it is responsible for both our rational and emotional thought. While the various functions of the cerebellum are all necessary for one's survival, it's the forebrain's role in cognition and experiencing emotion that is the most relevant as it pertains to the psychology of design.

3. The Evolution of the Mammalian Brain

During the course of evolution, human brains evolved in a more sophisticated manner than the brains of other mammals. The more primal portions of the human brain and brainstem retained their primary functional focus on survival and pleasure, similar to other mammals, while the human forebrain, the center of executive thinking, planning and emotion, developed to be disproportionately larger than those of other mammals. In its most simplistic form, the survival of our ancestors was predicated on the pursuit of shelter, food, and mating. In our modern world, where humans no longer have natural predators, survival has a less objective and more varied meaning across demographics, social class and geographical location. Pleasure, however, has retained the same meaning over the past 200,000 years; yet the ways in which this feeling can be achieved is quite subjective and has evolved in congruity with our human interests.

Evolutionarily, human brains have been encoded to associate a sense of pleasure with objects and places that increased our chances for survival (Moccia et al., 2018). For the earliest humans that consisted of food, water and shelter, all found within the savanna from which we originated. The appeal of the savanna was its advantageously spaced trees, the lush countryside, and the water and food it provided (Ruggles, 2017). Although most humans no longer live in such pure natural environments, the Savanna

Hypothesis suggests the characteristics of the savanna are encoded in our brains (Orians, 2016) thus influencing our preferences within today's built environment. As a result, modern humans still associate shelter with pleasure, but in a more subjective manner.

Modern humans experience stress very differently than did our ancestors and other mammals. For them, stress came primarily from threatening factors beyond their control like predators and inclement weather. The absence of modern-day predators coupled with readily available shelter has radically shifted our stressors. Stress today can come from virtually anything and differs greatly from person to person. Often times it comes from commonplace occurrences such as traffic, jobs, relationships, etc. Regardless of how trivial the stimuli may seem (at least compared to the stress felt by our ancestors when facing a predator), our bodies react in the same physiologic manner as did those of our ancestors: the sympathetic nervous system kicks in and all functions that are irrelevant to immediate survival are slowed. Modern stress also differs from the episodic stressors our ancestors faced in that many of our stressors never go away. Such chronic stress means our bodies spend too much time in a heightened "survival mode" at times when our survival is not even remotely at stake. Constant or chronic stress can lead to extremely detrimental, and even permanent, mental and physical health issues. It is known to be associated with the development of anxiety, insomnia, depression, a weakened immune system and muscle pain. It can also lead to development of heart disease, high blood pressure and other serious health issues (Yaribeygi, 2017).

Perhaps most significantly, chronic stress has actually been clinically proven to *directly* shorten life spans. Studies have shown that prolonged stress physically shortens the parts of chromosomes known as telomeres, a protective casing on the ends of our DNA. When cells divide, they often lose portions of those telomeres. Normally, they are restored by an enzyme known as telomerase. However, when a person is subjected to prolonged stress, the sympathetic nervous system constantly produces cortisol which in turn impairs the production of telomerase. The end result: the body is prevented from repairing the damaged telomeres resulting in premature cell death and acceleration of the aging process (Lu, 2014).

This then is where architectural and interior design focused on positive psychological effects and the creation of a sense of well-being have become extremely relevant.

4. Physiology, Psychology and Patterns in Successful Design

What separates successful architectural designs that last from those that do not? The ancient Roman architect Marcus Vitruvius Pollio, was the first to describe three elements that are essential for well-designed architecture: "firmitas" or physical strength; "utilitas", meaning utility or convenience; and, "venustas", a structure's aesthetic beauty or delight (Salama, 2007). Although these terms were coined many years ago, their definitions still hold true in their modern translation. Successful architecture is still contingent upon form, use, and beauty (Ruggles, 2017). Although the concept of "beauty" is fundamentally subjective, the feeling, and the physiological response associated with it is universal. Seeing something we define as beautiful causes us to feel a sense of pleasure; physiologically this results from the release of oxytocin, endorphins and DHEA in our brain (Estren & Potter, 2013). If the sole purpose of buildings is strength and utility, why then are they able to produce what Salingaros calls “visceral” responses (Salingaros, 2020). The answer has its basis in evolution. Buildings that provide us with a sense of pleasure are those that incorporate the architectural elements our brain recognizes as having similar characteristics or patterns to locations that helped our ancestors survive. Thus, it is important to identify which specific patterns our brain associates with those survival attributes and why.

Patterns have long been a subject of human curiosity and have been successfully adapted in our ability to plan ahead. In fact, there are several strategies our brain employs to recognize patterns. Feature matching occurs when incoming pattern information is broken down by the brain into parts which are then compared and contrasted one by one with parts of a previously stored pattern. In prototype matching, our brain attempts to link incoming information with certain characteristics of a known prototype (Pi et al., 2008). This would be equivalent to identifying an apple as a fruit, rather than an apple as an apple (the latter being an example of feature matching). Finally, template matching occurs when only certain aspects of the incoming pattern rather than the entire incoming pattern are matched to a template or prototype (Pi et al., 2008).

Patterns in life and in architecture represent consistency and organization, a lack of chaos. By identifying a pattern our ancestors were better able to predict what came next, thereby improving their chances of survival. Seeing similar advantageous patterns in our built environment today evokes a similar physiological reaction. It makes intuitive sense that chaos or unpredictability, the opposite of organized pattern, can negatively impact us physiologically. The human brain has used pattern recognition as a form of survival for so long, it has become something we subconsciously do daily. Although our conscious mind might not realize the feelings it is experiencing are due to a pattern, or lack thereof, our physiological system does, resulting in the same sympathetic or parasympathetic response our ancestors experienced.

The importance of pattern goes beyond our ability to recognize something literal like shelter or a house; in fact, patterns play an important role in the way our brains process information. Patterns are created through symmetry in which elements of a similar size and shape are aligned, rotated, or reflected (Salingaros, 2020). When observing an object, we subconsciously compare its intrinsic geometrical components to see if they match. This is our brains effort to analyze something in its holistic form as best as possible given our inability to scrutinize every detail individually; attempting to do so would result in cognitive overload (Salingaros, 2020). Our human “cognitive limit” is 7 components (Miller, 1956), after that it becomes stressful for our brain to try and remember more. Like objects presented in a pattern may be grouped together and cognitively accounted for as one object while dissimilar elements must be computed individually (Salingaros, 2020). Such ‘like object grouping’ to avoid cognitive overload, employed in nature and used by humans as a survival tactic, is also applicable to the built environment. Interestingly, just as cognitive overload induces stress, so too do environments devoid of information to process. As applied to the built environment, buildings that lack patterns and symmetries either don't register or actively repel us (Salingaros and Sussman, 2020; Sussman and Ward, 2017). As discussed earlier, such cognitive boredom can induce the same stress response as perceived danger.

Another way in which our brain groups like objects is through scaling symmetry in which magnified and reduced adaptions of the same object are accounted for as one (Salingaros, 2020). Scaling symmetry is an important aspect of Christopher Alexander's Fifteen Fundamental Properties. Alexander proposed that successful buildings are those perceived by humans to have "life", which he defines by his 15 fundamental properties: levels of scale, strong centers, thick boundaries, alternating repetition, positive space, good shape, local symmetries, deep interlock and ambiguity, contrast, gradients, roughness, echoes, the void, simplicity and inner calm, and not-separateness (Alexander, 2005). Importantly, each of those fundamental properties occurs in nature and are impossible without scaling symmetry. All are also necessary to incorporate into the built environment to both mimic nature and its restorative abilities and to prevent information overload.

We find buildings that incorporate these symmetries, patterns and fundamental properties to be more beautiful because our brains have been physiologically conditioned by evolution to associate those patterns with safety, security, well-being and survival. As noted previously, that perception results in the release of oxytocin, endorphins and DHEA, and throttles back the sympathetic nervous system, all resulting in a sense a pleasure. This in turn works to restore our body, our immune system, our telomeres, etc., all of which is beneficial for mental and physical health.

With that background, we can now understand the architectural success of many historical buildings. Many critically acclaimed buildings throughout time included patterns that mimic the natural environment from which we came. La Sagrada Familia, designed by Antoni Gaudí, is a beautifully extravagant cathedral located in Barcelona, Spain. The construction first began in 1882, but because the details are so intricate, it is projected the building will not be fully completed until 2026. Gaudí's inspiration for the cathedral came from the forest. Walking into the cathedral, one is greeted by hundreds of 78-foot-tall pillars that branch off at the top and converge into the ceiling and one another, like the intertwining branches of tree canopies (Figure 1). The Eden Project in Cornwall, England, consists of several transparent domes that house a wide variety of plants. The architect Nicholas Grimshaw found his inspiration in bubbles, making it easy for the translucent domes to effortlessly coexist with the natural surroundings (Douglass, 2016) (Figures 2 and 3).

Figure 1. A photo of the tree-like pillars that fill La Sagrada Familia. From Inside Sagrada Familia, by Trey Ratcliff, 2017, https://www.flickr.com/photos/stuckincustoms /34317112306/in/photostream/. © 2017 by Trey Ratcliff.

Figure 2. An inner view of the vegetation enclosed within The Eden Project. From The Eden Project, by Herry Lawford, 2009, https://www.flickr.com/photos/herry/3294823869 /in/photolist-629Qm6-cvye5y-dfnzYY-dfnvca-629Swn-dfnDzW-a5Bx27-cvyctL-62egCb-YgtxSP-CbzPLA-629RLk-YgtAaz-629R7D-62e3gy-62a4Cr-62e2RS-629Lcv-62e9t1-bkjoK-dfnvmP-2YBx3q-629Md6-ZeSVow-2WZM2n-dfnzWg-6PpSdx-ca4NF1-2WZJ9a-2YBuvQ-2YwZMF-629Lwa-a5Bt2j-CbzTmG-8AVE1u-a5yxLa-a5yBj8-2YwXVP-a5yGga-2Yx2N6-YgtxGi-a5yM4p-4EmYUE-a5yWip-CbMnj-2WZMvp-CbzWW7-2YBd87-YgtxqB-deg4fc. © 2009 by Herry Lawford.

Figure 3. The bubble-like domes of The Eden Project, shown here as part of an artistic installation, was inspired by the form of bubbles. Eden Project Has Giant Greenhouse Dome, by Solaripedia, 2009, http://www.solaripedia.com/13/64/580/eden_project_at_night.html. © 2008 by Mark Vallins.

One reason why many perceive those buildings to be architecturally successful is that our brains process the sensory information received from them and correlate it with patterns that had previously proven to be evolutionarily beneficial in nature. Yet, because this pattern recognition happens at a subconscious level, most viewers are unaware of the neuropsychological and physiological basis behind their perception. This same physiological reaction can happen even when the resemblance of the building to the natural environment is not as obvious as the aforementioned examples.

The ability of architecture and design to impact our emotions is more complicated than architecture simply simulating nature. The kinds of patterns used in design also play a significant role in our perception. "As architects and artists, we are in the profession of making patterns." (Ruggles, 2017). Ruggles had the good fortune to spend much of his young life traveling the world and observing everything from museums, to sculptures, to everyday homes. It was during these travels that he began to notice his preference for some buildings over others. Eventually he realized that the buildings he considered beautiful all exhibited variations of a 3 x 3 grid pattern (also known as the "Nine Square"). Ancient Asian cultures believed the pattern to have cosmological significance. In the Middle East, it was believed to represent primordial and perfect form. The pattern was also used extensively during the Renaissance and Neoclassical eras (Ruggles, 2017). In a time where global dissemination of ideas took years, or even decades, how did this same pattern make its way into so many different historical contexts in vastly different regions of the globe? The answer again has a neurological basis.

The root pattern of the 3 x 3 grid consists of a centralized space (the middle square) surrounded by an exterior zone (the outer 8 squares) (Figure 4a). However, because humans inherently see patterns in most things, there are many variations of the 3 x 3 grid that can produce the same effect. This is because the 3 x 3 grid pattern is less about the squares themselves and more about the symmetry and scaling hierarchy created in the division. As discussed above, symmetry of like objects allows for the brain to categorize these like objects (squares in this case) as one component, thus making the scene easier to read, preventing stress-inducing information overload (Salingaros, 2020). The four lines that define the grid can either be pushed closer together (Figure 4b), pulled farther apart (Figure 4c), broken apart so they are not continuous, or even removed fully. You can also create a 3 x 3 grid pattern within a square of a larger 3 x 3 grid pattern. All will maintain the original's effect.

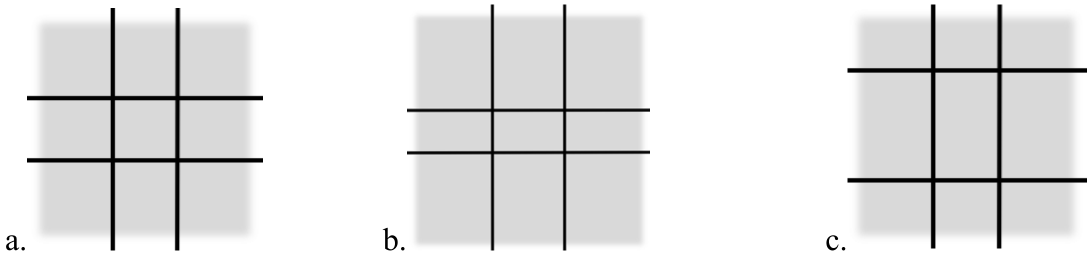


Figure 4. Various versions of the 3 x 3 grid pattern.

The pattern can be applied to everything from city plans, to building exteriors, and to floor plans. For example, the center of the 3 x 3 grid pattern has been utilized in Barcelona's block plan. The Basilica of St. Peter in Rome uses the center of the 3 x 3 grid pattern as well as the corner four squares. The Greek Parthenon, Roman Pantheon, and the Taj Mahal in India also utilize 3 x 3 grid patterns (Ruggles, 2017). These buildings are important architectural references due to their universally recognized beauty and their standing the test of time, both physically and metaphorically.

Believed to have been built between 447 and 432 B.C., the Parthenon in Athens, Greece was constructed to be viewed from the outside with only a glimpse of the inside caught through the outer pillars (Sakoulas, "The Parthenon"). The Pantheon in Rome, Italy believed to have been built around 120 A.D., consists of an identical 142 foot height and diameter giving it a naturally symmetric pattern. Utilizing the 3 x 3 grid pattern in both its entrance and main floor plan, the Pantheon remains one of the largest unsupported domes in the world (Ruggles, 2017). Lastly, the Taj Mahal, built between 1628 and 1658 and considered by some to be one of the world's Seven Wonders, incorporates two 3 x 3 grid patterns: one in the 9 arches in the front of the building and another inside the center front arch (Ruggles, 2017).

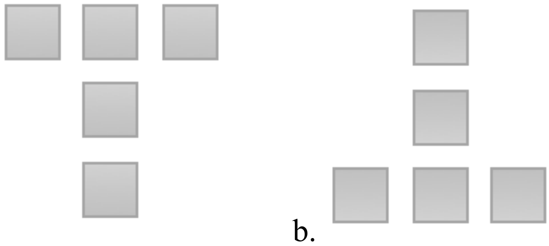
More recently, the 3 x 3 grid pattern has been used in buildings such as the Apple Store in New York City, the US Capitol Building, Frank Lloyd Wright's Falling Water house, and Richard Meier's 1965 Frederick J. Smith's Residence (Ruggles, 2017).

Both the historical and contemporary examples demonstrate how the 3 x 3 grid has been both a structurally sound pattern (satisfying Vitruvius's "firmitas" component) and an historically important architectural concept. Their universally accepted beauty also shows how psychologically impactful the 3 x 3 grid pattern, symmetry and scaling hierarchy are on the human brain. The vast distribution of the 3 x 3 grid pattern across time, geography, culture and religion, suggests it is highly unlikely that the continuous use of the 3 x 3 grid pattern in the built environment is simply the product of cultural integration. More likely, the frequency of its use is a result of the beneficial psychological impact of the pattern being encoded in the human brain, and therefore, in the minds of the architects who conceived those buildings.

On a more human level, the popularity and importance of the 3 x 3 grid pattern can be understood based on the similarity of the pattern to the structure of the human face. Facial recognition is one of the paramount survival adaptations of the human race. In fact, this is so critical that 65% of the brain's neuronal structure in a newborn child is devoted to facial recognition mechanisms (Ruggles, 2017). Evolutionarily, facial recognition allowed our ancestors to distinguish humans from animals, avoid predators, and recognize our parents from a very young age. In addition, facial recognition helps identify important social cues like identity, age, gender, and emotion that were once necessary for survival (Farah et al., 2000).

To recognize faces, humans employ several different strategies that process the following information: *featural information* which helps us to analyze the shape of individual facial features; *second-order configural information* which is used to evaluate the space between each facial feature (Maurer et al., 2002); and lastly, *holistic information* which allows us to consider the overall facial structure (Piepers & Robbins, 2012). In addition to those processing strategies, clinical studies of facial recognition have found that the brain recognizes certain patterns or features that make faces more easily distinguishable.

Two of these patterns are worth noting. The first, face inversion effect, is the idea that humans are less accurate at recognizing faces when the pattern is inverted as opposed to upright (Rossion & Gauthier 2002). This is due to our "face recognition cells" analyzing bilateral symmetry on a vertical axis. Our bodies also prefer verticality due to our inner ear mechanisms which control balance. When this axis is rotated or flipped (switching the mouth and eye height), it distorts these cells' ability to properly recognize a face (Salingaros, 2020). The second is known as the part-whole effect, which is simply that humans more accurately recognize the identity of a feature when it is presented on its respective face rather than alone (Maurer et al., 2002). Research conducted on infant preference has shown that they prefer certain facial hinting patterns to others. In one study, infants were presented with patterns, made up of various squares that vaguely resembled facial structures (the shape of a "T" for example) (Figure 5a).



a. b.

Figure 5. The shape of a T made up of various square to vaguely resemble facial structure. Inverting the T lessens its resemblance to facial structure.

The infants were shown these shapes in their upright form, as well as upside down, which obscured their resemblance to normal facial structure (Figure 5b). It was found that the infants were partial to the shapes when they were right side up and most resembled faces (Simion et al., 2002). It's also essential to note here that the upright "T" closely resembles the 3 x 3 grid pattern (Figure 6). The human face consists of two symmetrical eyes, a centered nose, and a centered mouth. When laying the 3 x 3 grid pattern over the face, the left eye lies in the top left square, the right eye in the top right square, the nose in the most center square, and the mouth in the bottom square (Figure 7).

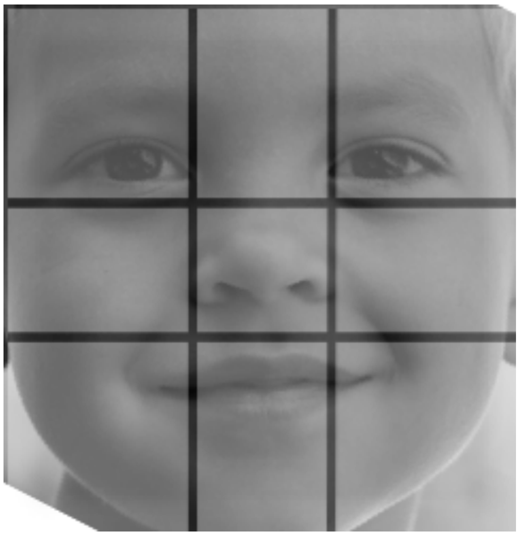


Figure 6 (left). The similarities between the basic facial structure and the 3 x 3 grid pattern. *Figure 7 (right).* Example of the human facial structure and the 3 x 3 grid pattern. Background Image from 2643525, by Tiluria, 2015, https://pixabay.com/en/portrait-child-face-boy-human-2643525/. © 2015 by Tiluria. Note: Reference lines for the 3 x 3 grid pattern in Figure 8 are not part of the original photograph. They were added to emphasize the similarity of the human face and the 3 x 3 grid pattern.

The close resemblance of the 3 x 3 grid pattern to the human face raises the distinct possibility that humans subconsciously see faces in certain architectural forms and patterns, stimulating the same physiological reactions demonstrated by Simion et al (2002).

5. The Negative Psychological Effects of Poorly Designed Architecture

Just as architecture has the ability to produce a positive psychological impact and promote healthy physiological responses, so too can poorly designed architecture produce a negative psychological impact. As Salingaros notes, "Our bodies signal the absence of natural geometries and structural balance with anxiety and illness" (Salingaros, 2015).

There was a time when the traditionally taught elements of architecture (strength, utility, and beauty), were exchanged for form, utility and function. The post World War II baby boom brought an increased demand for housing and commercial buildings that needed to be quickly constructed. This led to the proliferation of small, unstimulating houses (i.e., they lacked characteristics that activate our pleasure response) in the 1950's with a monotonously repetitive one floor 'box' design that was thoughtless in terms of floor plan, use of space, or aesthetics (Ruggles, 2017) (Figure 8). It was in this way that suburbia - neighborhoods with endless rows of indistinguishable houses situated as closely together as possible - was born (Figure 9).

Figure 8. Many post WWII houses traded beauty for utility. From Standard American Homes, by unknown, 2012, http://layered.typepad.com/antidote_to_burnout/2012/05/standard-american-houses.html. © 2012 by Mel Schenck.

Figure 9. The stressful, overcrowded, and repetitive neighborhoods that characterized the post WWII development of suburbia. From Image Levittown, Long Island, NY by unknown, 1948, https://www.flickr.com/photos/markgregory/8087087647. © 2011 by Mark Mathosian.

This trend of simple, architecturally unoriginal and uninteresting buildings was not unique to housing; it also greatly influenced the industrial and commercial side of the 1950's built environment. An increase in material production capabilities yielded cheap, new building products produced in the factories previously dedicated to the war effort. These materials set in motion the Modernism aesthetic that characterized many of the industrial buildings from the 1950s-1990s (Figure 10). Glass, concrete, aluminum, synthetics and steel were the primary materials utilized to create a boxy, futuristic, space-like style (Wagner, 2019). Monochromatic colors, poorly placed windows, an absence of architectural detail, and repetitive styles produced a unique form of sensory deprivation. Not only did this trend result in a lack of intellectual stimulation, it also effectively removed the positive aspects of human touch, creating a cold, unwelcoming environment that lacked the ability to produce a physiological or psychological a sense of well-being.

Figure 10. The overuse of cement in this building is representative of the color devoid, overly simplistic, boxy architecture that was frequently used in city landscapes during the post-war modern period. From Image George Square Theater, by Andy A., 2011, https://www.flickr.com/photos/kaputniq/6113408115. © 2011 by Andy A.

It comes as no surprise then that the style of the post-WWII period was soon replaced. A new desire for individualistic and creative architectural freedom emerged as the high demand for houses began to die down. Once again, Vitruvius's principles, including that of beauty, which had characterized successful Classical architecture began to re-emerge. There was a newfound emphasis on structure, geometry (patterns such as the 3 x 3 grid pattern), and the uniform grid. There was also a return of buildings raised on platforms, classically styled columns, entablature (Figures 11 and 12), and colonnade (Figure 12) ("Post-war modern architecture," 2019). In essence, the post-WWII design focus was replaced with a design ethos that employed patterns, symmetry and scale, concepts that had stood the test of time across centuries of changing styles and societal preferences due to their unanimously perceived beaty. In addition to reincorporating the solid structural elements and natural materials (travertine, marble and granite) used in the Classical period, this movement also introduced man-made products that mimicked the aforementioned materials. As a result, the houses produced during this time were larger in size and more thoughtful in design – which resulted in much greater expense ("Aluminum Finishes in Postwar Architecture," 2017).

Figure 11. An example of segment of entablature, a continuous horizontal lintel that is supported by columns; applied in the Parthenon and Pantheon as previously discussed. From Image Ionic capitals and entablature, Free Trade Hall, Manchester, by Orangeaurochs, 2011, https://www.flickr.com/photos/orangeaurochs/5763101886. © 2011 by Orangeaurochs.

Figure 12. An example of colonnade, a row of columns that support a roof, as demonstrated in this picture of the Parthenon. Their purpose is both structural and aesthetic. From Image Parthenon-Restoration-Nov-2005-a, by Barcex, 2005 https://commons.wikimedia.org/wiki/File%3AParthenon-Restoration-Nov-2005-a.jpg. © 2005 by Barcex.

Inadequately constructed buildings and poorly designed settings also have a significant negative societal impact. Public health has been at the forefront of governmental concern as far back as 1926, when the U.S. Supreme Court declared public health protection (defined initially as physical health) to be a fundamental responsibility of local governments. That declaration provided governments with legal authority to regulate land use. As time progressed, the World Health Organization (WHO) expanded the concept of public health to encompass mental and social well-being in addition to physical health and the absence of disease. Furthermore, the

WHO insisted that rather than just controlling disease (both mental and physical), we should act to prevent it (Jackson & Kochtitzky, 2002). While city planning is essential to the protection of public health, so too is the architecture of individual buildings that comprise the urban built environment.

Studies have shown that battered houses and neighborhoods with abandoned and dilapidated buildings make us feel unsafe and evoke a sense of fear and anxiety ("Could bad buildings damage your mental health?", 2016). We already know that these feelings activate our survival mechanisms and kick our sympathetic nervous system into action. In their book *Cognitive Architecture: Designing for How We Respond to the Built Environment,* Sussman and Hollander explore the negative psychological impact urban environments have on humans. They argue that humans are generally healthier when their built environment contains a variety of independent shops and unique spaces rather than cement buildings and repetitive chain stores (Sussman & Hollander, 2015).

Neuroscientist Colin Ellard went even further. By monitoring skin conductance and electrodermal responses to emotional excitement, he led a group of participants down two city streets. The first included a large, generic Whole Foods building; the other included a plethora of unique and lively restaurants whose buildings were made up of open doors and windows. He found that the former environment resulted in the lowest arousal level of the study, while the latter produced a high level of excitement (Ellard & Montgomery, 2011). The kind of disengagement Ellard and Montgomery found is undesirable from a psychological perspective; studies conducted by Merrifield and Danckert suggest that even small amounts of boredom can actually induce stress (Merrifield & Danckert, 2014). These results led Ellard to conclude: "The holy grail in urban design is to produce some kind of novelty or change every few seconds, otherwise, we become cognitively disengaged" (Ellard & Montgomery, 2011).

In summary, our built environment, good and bad, has a substantial psychological impact on humans. Well-designed buildings that use successful symmetry and patterns like the 3 x 3 grid pattern, or that evoke the sense of security our ancestors felt on the savanna cause the release of neurochemicals that make us feel a sense of pleasure and therefore have a positive psychological impact. Poorly maintained buildings and spaces make us nervous and fearful, while dull repetitive buildings bore us; both cause a physiologic stress response. Fortunately, the growing body of cognitive research regarding the positive and negative impacts of design make "bad design" both avoidable and correctable moving forward. Ideally, the construction of new buildings and urban areas should not simply avoid these negative attributes but should: 1) work to counteract them by incorporating the classical elements of beautiful design, and 2) test their effectiveness prior to using limited resources (Salingaros, 2020)

6. The Importance of Human Interaction with the Environment

There is another crucial element that, when absent, has the ability to completely derail the effectiveness of even good architectural design: nature and the environment. The field of environmental psychology studies the environment's impact on human behavior as well as the consequences of our behavior on that environment. Human behavior, to a significant extent, is determined by the environment in which it takes place and the resources that exist within that environment. Furthermore, a human's response to environmental stimuli has been shown to be dependent upon several factors including: a) the landscape and its complexity, novelty, and patterning; and b) the individual and their past environmental experiences, the amount of time they have spent in an environment, their ability to appoint structure on the environmental landscape, their personality traits, and their sensory associations with the environment (Bell, 2011).

In 1984, Edward O. Wilson published the book *Biophilia*, an in-depth exploration of a concept originally introduced by Erich Fromm and used to describe the necessity for modern humans to be in contact with nature. In *Biophilia*, Wilson proposed that this necessity was a vestige of the attraction experienced by our human ancestors for all living things; he also felt that we possessed a genetic predisposition to that attraction (Wilson, 1984). Wilson further believed this attraction remained intact during our evolution from our ancestors because it was beneficial to us in the process of reproduction. Eventually, as we became sufficiently cognitively aware to discern a difference between humans and other species, a more specific attraction to our own human species replaced the more generic attraction to all living organisms. None-the-less, remnants of that former attraction to all living organisms remains due to the positive psychological responses they invoke. This ingrained affinity for the natural environment and living things helps to explain, at least in part, our preference for architecture and designs that incorporate elements of nature like La Sagrada Familia and the Eden Project.

These positive effects from biophilia are made possible by two distinct factors: a) proximity and visual connection with plants, animals and people; and b) built environments that successfully mimic that natural environment through proper symmetries and patterns (Salingaros, 2019). Despite our human affinity for natural environments, too much nature can evoke a similar stress-type response seen with too much uniformity in buildings. Russell and Lanius developed a model to identify the preferred balance of built and natural environments using positive physiological responses to identify that preference. Their model breaks down the possible emotional reactions to environments into four categories: arousing versus not arousing, and pleasant versus unpleasant. Those categories were used to classify the various words subjects used to describe their emotions (Russell & Lanius, 1984). For example, active is an emotional descriptor associated with arousal on the pleasant side of the spectrum; while hectic, another descriptor for arousal, would be categorized as unpleasant.

When an environment is arousing but unpleasant, we feel panicked and tense, and our sympathetic nervous system is activated. Likewise, when the environment is unpleasant but not arousing, we feel unstimulated and bored; boredom, as we have already seen, is also a cause of stress. When environments are pleasant, they can either be arousing (making us feel excited and stimulated, causing chemicals like oxytocin to be released), or they can be not arousing (making us feel pleasantly relaxed and at peace, helping our autonomic nervous system to run smoothly). Regardless of which side of the arousal spectrum an environment falls, being too extreme on either side causes us to feel uncomfortable which generates a physiological response that causes us to seek either arousal reduction or sensory enhancement. Humans will for this reason seek out built environments that they find to be most pleasant and least stressful.

It is important to note that because each human being is unique, each person has different preferences and different reactions to environmental stimuli resulting from complexity, partiality and past experiences. Regardless of individual variations, human beings generally favor environments that are pleasant (whether arousing or unrousing) over environments that are unpleasant. One benefit of arousing and pleasant environments is the mental stimulation they provide. This turns out to be an important architectural and psychological consideration in our built environment. In fact, information processing is a separate environmental preference theory which suggests that because humans are natural information processors, we prefer environments that provide us with ample amounts of information to process (Bell, 2011). Applying that knowledge to the world of architecture, it's easy to understand why the simplistic and unimaginative designs of the immediate post-WWII era haven't lasted, while more ornate architecture using more classical columns, colonnades and entablature has lasted across millennia.

But just as too much nature can be overwhelming, too much non-reducible information tends to push the arousing environment away from pleasant and closer to unpleasant, as exhibited with like object grouping when the brain is presented with too much information. Kaplan and Kaplan took this environmental preference theory one step further in their preference model (Kaplan, 1987). The Kaplan model was created as a combination of native (Biophilia) and constructivist elements. Constructivism works in opposition to Biophilia and other native approaches in that it proposes that the process of perception is an active one in which we analyze incoming information and compare it to stored experiences (Bell, 2011). The categories defined in the model (coherence, legibility, complexity and mystery), are believed by Kaplan to increase an individual's preference for a specific environment. In Kaplan's view, the more of each of those components a certain environment has, the higher the individual's preference for it is (Kaplan, 1987). In other words, individuals are partial to environments that possess the attributes that they find most useful to their specific survival needs as defined by their stored experiences.

As noted in Section 4, good architectural design finds much of its influence in the symmetries and patterns of nature. The stress reducing capabilities of those designs are a direct result of our brain recognizing visual similarities to nature and to patterns that allow smooth information processing through like object grouping. The beneficial impact of natural design elements goes deeper than an improved sense of psychological well-being. Restorative environments are, as the name implies, those environments that foster restorative processes (Bell, 2011). Merely being in contact with nature and these environments is enough to set this process in motion. Such restorative effects were clinically proven in a number of studies conducted by Roger Ulrich. In one study, Ulrich demonstrated that simply viewing pictures of nature had the ability to lessen the effects of exam induced stress (Ulrich, 1979). In another, Ulrich demonstrated shortened post-surgical recovery times for patients in hospital rooms with a window overlooking a small stand of trees compared to patients recovering in a room with a brick wall in place of the window (Ulrich, 1984). A third study analyzed the physiological effects of a stress inducing 10-minute black and white video displaying industrial accidents on two groups of subjects. Following the initial video, one subject group viewed a 10-minute color video displaying everyday nature, while the second watched a 10-minute color video of urban areas. The participants exposed to the nature video experienced an increase in positive feelings and were found to have lower blood pressure, muscle tension, and skin conductance levels; the urban scenes failed to produce any of these positive physiologic effects (Ulrich et al., 1991).

Knowing the important restorative effects that come from human interaction with nature, it follows that architecture that incorporates the natural environment can facilitate similar restorative effects. Turning our personal shelter into a natural environmental provides us with *refuge* (a safe sheltered place) and *prospect* (an unobstructed view of the surrounding environment) (Appleton, 1996). Incorporating findings such as Ulrich's into the building process today is very simple. Of course, the degree to which this incorporation is possible will depend on space and available resources. In the most basic form, having windows with a view of nature is easily done. When this can't be done, in a city for example, simply adding pictures of nature to one's house can produce similar effects. When resources are bountiful, houses that have large windows or glass walls permitting an unobstructed view of nature (the closer the nature the better), or that have the space to place plants inside, will be the most beneficial at producing the desired psychological benefits. Adaption of such natural landscapes into our built environment is also an essential part of developing an attachment (defined as a sense of "rootedness" felt toward a certain location) to that space (Bell, 2011). Attaching sentimental value, a sense of safety, or a feeling of psychological well-being to a place provides us with an incentive or need to return.

Ulrich's findings are also applicable to the urban landscape. Unfortunately, most urban environments utterly fail from an architectural and design perspective if the goal is to produce a low stress, psychologically healthy environment. Urban architecture is often bland and featureless which we now know creates low level stress and results in insufficient mental stimulation. Urban areas are also frequently devoid of elements of the natural environment which not only creates further stress but also eliminates the potential for the important restorative benefits nature can provide.

7. Conclusion

There is now extensive research demonstrating that good architectural design has clear psychological and physiological benefits that transcend the mere sense of an aesthetically pleasing appearance. We also now understand there is a direct link between poor architectural design and execution and negative health and psychological issues. Finally, today we have a better understanding of the human evolutionary and physiologic basis for many of those psychological responses to design.

Utilizing that knowledge and the technological tools we now have available, we have an opportunity to create architecture that is not only aesthetically beautiful, but more importantly, psychologically beneficial. With health problems such as chronic stress induced heart attacks, obesity, high blood pressure, depression, anxiety, and more increasingly plaguing the modern world, employing architectural design that doesn't take advantage of elements known to produce psychological and restorative benefits is no longer an option.

It is also important that we reconsider the societally ingrained constructs that have wrongly labeled the field of architectural design as simply an art form, thereby stripping it of the meaningful legitimacy it deserves as a field that has the potential for real societal benefit. If the positive psychological and restorative impact of architecture is seen only by psychologists and some architects, and not the general public, then the psychological impacts of thoughtless architectural design will never be addressed, and the field will continue to lack the resources necessary to improve the world we live in.

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