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Niche Construction Theory, Cognitive Evolution and Evolution of Constructivity & Architecture

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Abstract

Since the beginning of human history, humans benefit from architectural settings to increase their survival chances. Thanks to its evolutionary primacy and precedence for life, architectural settings have shaped human biology, mind, behaviour, ecology, and socio-culture. The architectural environments have been shaped by these issues reciprocally. Niche construction is the process by which an organism alters its familiar environment. The alterations can be a physical alteration to the organism's environment. Alternatively, it may include an organism actively moving from one habitat to another to experience a unique environment. This article's primary motivation is to draw attention to the influential reciprocal profit and relationships between architectural environments and their users and designers by emphasizing the significant role in human life, from genetics to culture. This paper's contribution is to discuss some linking mechanisms to understand the significant value of architecture for human cognitive evolution and adaptation.

Key Words: Human and environment, architectural setting, niche construction theory, cognitive evolution

1. The background

From the beginning of human history, architectural design -as an activity to modify physical environments following human needs- have been entangled in other aspects of human life. The modified natural environments have become templates containing cognitive and socio-cultural traces. So, these settings modified human behaviours and maybe genetics to some degree. Due to the strong anthropocentrism in architecture, architectural settings have been examined under unidirectional perspectives. This approach has accepted that architectural settings as physical settings that are fulfilling human requirements. Their influence on our behaviours, phenotypes, genetics, cognitive and neural mechanisms, and socio-cultural traits have been ignored. Thanks to the phenomenological tradition and life philosophies drawing attention to human life's unique characteristics and experience and accepting objects and environments as the extension of existential being. Some approaches such as cybernetics, general and dynamic system theories, the influential roles of environments, objects, materials, body on human cognition, behaviour, socio-cultural traits have been begun to be examined. They have generated new models and terms approach based on examining complex phenomena such as life or cognition as a system and reciprocal relationships between these systems' elements (Jones et al., 1994; Laland & Galef, 2009).

One of the most comprehensive theories examining the influential reciprocal role of artefacts of the living on every aspect of their life from genetics to memes is ‘Niche Construction Theory’, coined in 1988 by Oxford biologist John Odling-Smee. Unlike standard evolution theories, Niche Construction Theory considers genetic inheritance and ecological inheritance; here, the livings are estimated as active agents when faced with environmental stress situations or natural selections. They challenge these selection pressures or stress conditions with their artefacts containing their sensorimotor and cognitive capabilities. Nests, burrows of animals, nitrification process of plants and clothes, architectural settings and other cultural traits of humans can be accepted as constructed niches against these pressures in the natural environment (Odling-Smee et al., 2013). However, differently from plants and animals, constructed niches of humans have evolved very dramatically. Another interesting fact about humans in niche construction is that humans

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can construct niches in different forms such as neural niche, cognitive niche, social niche and cultural niche, and ecological niche (McNair, 2016; Blute, 2010).

The cognitive niche can be defined as cognitive artefacts to challenge environmental pressures and neural niches. Neurogenesis increase brain functions for adaptation. The extended mind can extend the mind into the environment to increase the survival capacity via artefacts such as architecture. In this sense, architectural settings become cognitive extensions of the human mind. Moreover, this extension potential of architecture makes the nature of the architectural experience more complicated and stratified. In this view, designing architectural settings can be seen as a problem-solving activity against natural environments pressures, and aesthetical judgements can have some survival background.

2. Niche Construction Theory and Architecture

We were creating and using architectural settings that have priority and precedence compared with most other human activities. Thanks to these attributions, examining these settings on only physical levels will become superficial. They contain various aspects of human life and traces of human cognitive capabilities and socio-cultural traits. One of the other reasons beyond their complicated nature is the continuous interaction of us with them. As a result of the continuous reciprocal processes, architectural settings shape the living forms. One of the exciting and dramatic influences of architectural settings on human behaviour and cognition emerged in human history nearly 2,5 million years ago. According to evolution theory, Australopithecus species like primates were living on trees and constructing arboreal nests. After the emergence of the first *Homo* species, *Homo habilis* species such as *Homo gautengensis* and *Homo rudolfensis* began to construct terrestrial nests instead of arboreal nests. The main reason beyond this change was to increase the quality of sleep and comfort. The changing the ground of architectural setting on which they were built brought about dramatic changes in human bodily posture, behaviours and brain structure. In body posture, the human species became more terrestrial, and their backbone became more erected. They began to benefit from the advantages of bipedalism. Their hand evolved in order to manipulate materials instead of climbing trees. Due to the increasing environmental stress positions and natural selection pressures, cognitive capabilities and cranial capacity evolved. Because of the increased number of predators in terrestrial environments, their brain areas related to face recognition are developed. Increased group sizes and new primitive social norms for sharing and obtaining food and social cooperation against environmental pressures and complexity of the terrestrial environments triggered new functional areas in the brain and encephalization process. They contributed to the formation of the theory of mind. The increasing sleep quality and the emergence of daydreaming contributed to generating visuospatial simulations. For example, hunting and escaping from animals in imagination and contributed to encephalization and improving cranial capacity. Furthermore, exploring new areas on the terrestrial ground contributed to spatial cognition. These evolutions in human cognition and body posture begot the use of fire and making stone tools (Coolidge et al., 2014, p.177-204).

These reciprocal relationships between environmental pressures and human artefacts containing cognitive and socio-cultural relationships can be examined via Niche Construction Theory as aforementioned. Differently from Standard Evolution Theory, Niche Construction Theory emphasizes co-evolution of genes and cultures /development and examines phylogenetic evolution with ontogenetic development concurrently. The constructed niches of early *Homo* species contributed to the body posture and bipedalism to increase the survival chance and new artefacts. For example, fire and manipulating materials such as tools generating and nest constructing contributed to brain and body & phenotypic plasticity and consolidated adaptation. Reciprocal relationships between artefacts of living species and environmental pressures are among Niche Construction Theory's main issues. Moreover, constructing niches is very prevalent not only in humans but also in animals. One of the best examples of constructed niches is nests and burrows. Among animals, there are many species constructing niches. Kevin Laland and Kim Sterelny, in the articles entitled 'Perspective: Seven Reasons (not) to Neglect Niche Construction' classified some species displaying nest constructing behaviours (Laland & Sterelny, 2006). Another interesting fact that most of the species displaying nest-building behaviours are clustered in some families in their phylum or order. This causes us to consider whether genes drive the nest-building behaviour among animals or architectural design in humans. It mentions the existence of architectural genes. However, these issues are out of the scope of this study.

Differently from animals, constructed niches of humans are more diversified. In literature, there are some terms to define different forms of constructed niches by humans, such as neural niche, cognitive niche, social niche and cultural niche, and it can be extended. Also, the adaptation speeds of humans to each type of constructed niches are different from each other. Moreover, these gaps generate adaptive lags between created environments and changes in these

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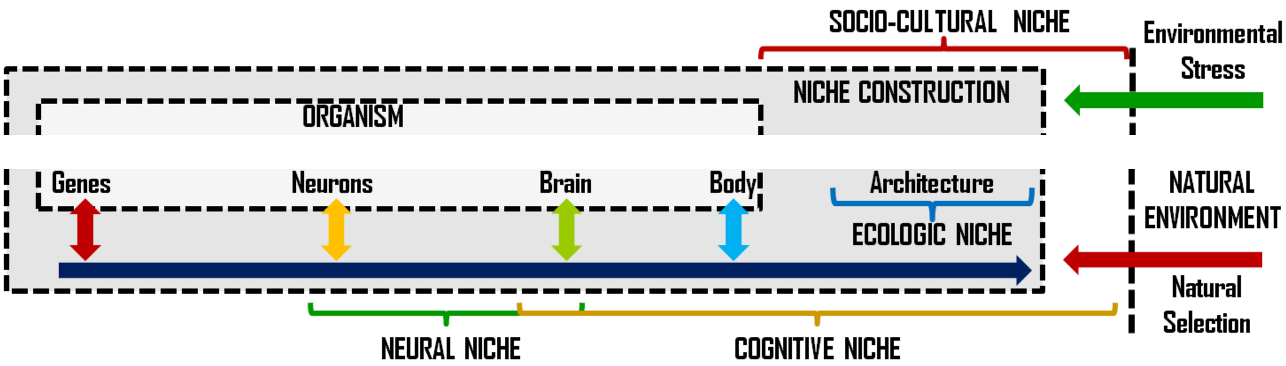
environments. Adaptive Lag Theory is one of the sub-theory of Niche Construction Theory and memetics, emphasizing the inconsistency between the rate of adaptation of organisms and environmental changes. One of the main reasons for

the adaptive lag in humans is that the speed of cultural niche construction is more than the pace of humans' adaptation to these niches. In modern culture, this lag is also valid for cognitive niche construction. There are some examples of these adaptive lags in humans. One of the most impressive examples is taking a person to one hunter-gatherer tribe from its environment and putting him into a very complicated metropolitan area like London or New York. There will be lags in his adaptation to these new environments. In this perspective, skeuomorphic design attitude can be assessed to increase cognitive adaptation to industrial design products as cultural niche construction elements via familiarity.

Figure 1: The graphic shows the forms of niche constructions of humans and architecture as ecologic, socio-cultural, and cognitive niche (Source: Author) developed by the ideas of (Odling-Smee et al., 2013).



We know there are also some different theories linking humans' biological basis with their cognition, artefacts such as Extended Phenotype, social and cultural traits. For instance, Extended Phenotype Theory examines artefacts of living beings as the extension of their phenotype and phenotypes as the extension of genes. Richard Dawkins coined the theory in 1982 via his book entitled 'The Extended Phenotype'. He constructed his theory on his concept of the selfish gene and his approach to gene-based evolution. According to him, selfish genes influence phenotypic effects and affect artefacts as extended phenotypes favouring their evolution. The owner's anatomy shapes the nests of animals and the architectural settings of humans. However, this theory ignores the role of nests and architectural settings on their owner's genes. It also ignores the relationships between genes and artefacts unidirectional, not reciprocal (Dawkins, 1982).

Another explanation linking organisms' biological basis to their artefacts, such as architecture and nests, burrows, was coined by physiologist Scott Turner as Extended Organism in 2001 through his book with the same title. According to his theory, architectural settings, nests, and burrows are not frozen agents, and their role is to assist their owners' physiological mechanisms. In his perspective, relationships between artefacts and their owners are active, and these artefacts are the indicators of their owners' cognitive capacity. In his view, he constructs some links between the physiological mechanisms of the cell to organism and colony level. He assesses artefacts such as architectural settings, nests, and burrows as the extension of the physiology of organisms regulating chemical matter and energy flow in favour of the organism. Although Turner's approach has similarities with niche construction theory, his main scope is on animals' built structures (Turner, 2000).

Thanks to the comprehensive nature of Niche Construction Theory dealing with artefacts of living beings and their links with natural selection and inherited niches, not only ecological niches but also different forms of niches (neural, cognitive, social and cultural) at the same environment make this theory more suitable to investigate the complicated and layered structure of architectural experience. This theory also suggests a framework for understanding humans'

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artefacts in a more inclusive perspective, including many aspects from genetics to cognition, from social behaviour to cultural traits. It can play a crucial role to link biological sciences to humanities and social sciences.

3. Neural and Cognitive Niche Construction and Parietal Cortex Evolution in *Homo sapiens*

Humans generate various niches differently from animals and plants—neural and cognitive niche construction associated with architectural environments—the elements of 'neural niche' based on the three concepts. The first is the production of neurons for increasing brain plasticity when an organism faced with selection pressures (neurogenesis), second is the axon, synapses and myelin production (axonogenesis and synaptogenesis and myelinization), third is the relationships between brain and body mass of an organism (brain expansion and encephalization). Expansion in brain functions and functional regions increase in the amount of white and grey matter. The main locomotives beyond neural niche construction are the polysemic, redundant and plastic structure of the brain. Neural niche construction can be assessed as the main locomotive of cognitive niche construction. Grammatical language and the ability to construct second-degree social relationships not based on kinship are humanity's most critical cognitive artefacts. However, the main problem under the scope of this study is to link architectural settings as ecological niches to cognitive and neural niches. So, cognitive niche construction can be expressed as total cognitive artefacts of organisms generated for challenging selection pressures.

One of the most contributing research was made by Atsushi Iriki and Miki Taoka about linking ecological niche construction to neural and cognitive niche construction. They conducted an experience examining Japanese macaques' tool-use behaviour and observed some parietal cortex extension in their brain after two weeks of training. As it is already known, the main two areas in the brain related to spatial orientation and navigation, bodily ownership and proprioception, which are the basis of architectural experience and understanding architectural spaces as ecological niches. In their study, it is examined the relationships between the posterior parietal cortex. The area corresponds to the superior parietal cortex in humans. It is responsible for spatial cognition in a conventional way and the inferior parietal cortex, which is coding body schema in monkeys. This fact is also responsible for understanding body schema and non-spatial cognition, such as the cognitive background of tool use and different cognitive abilities such as language, abstract and mathematical thinking. Their main idea beyond their experiment is that the inferior parietal cortex is evolved newly in humans compared to the superior parietal cortex thanks to the tool-using behaviour. They claimed the parietal cortex integrates the brain's cognitive background to create an ecological niche of architectural settings. This is associated with the superior parietal cortex responsible for spatial cognition- and neural & cognitive niches –associated with the inferior parietal cortex responsible for non-spatial cognition. They also associated spatial coordination and movement emerging tool-using to create different spatial thinking forms from concrete to abstract spaces. This situation linked the extension of inferior parietal cortex formation with working memory which is very active while using tools. The experiment allows us to investigate relationships between the cognitive basis of manipulating physical spaces as architectural activity and other forms of cognitive abilities (Iriki & Taoka, 2012).

However, tool-using as manipulating materials for defined purposes such as hunting can be associated with constructing behaviour and construction activity, including tool-generating and using. Since in construction activity, similarly tool production and use, organisms need to manipulate materials and integrate them in very complicated ways, especially among highly evolved vertebrates, especially Passeriformes in birds and Supraprimates (rodents and monkeys) in mammals. As aforementioned, even construction behaviour is more prevalent when compared with the tool using or producing tools. This perspective may be assessed as one indicator of the primacy of construction behaviour compared to tool-using or producing. Also, during architectural design, different cognitive abilities related to space emerge and the tool using or producing. When architects design architectural settings from the beginning of the conceptual level to the construction level, they manipulate spaces. They have integrated materials to the spaces in different layers; they have produced spaces such as conceptual spaces, spaces as objects, temporal or social spaces conceptually, inner and outer space discrimination.

The complicated nature of the architectural design process is prolific in terms of cognitive development compared to producing tools. Mike Hansell, the author of 'Animal Architecture and Building Behaviour' (Hansell, 2005) and 'Built by Animals' (Hansell, 2009), claims three differentiating human architecture points from animal architecture. One of the

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most exciting aspects among the others is scaffoldings as the borderline condition between tool using and construction. As it is known, scaffoldings are both tools for constructing and constructions in themselves. In research dealing with the animal tool, they can be assessed as associative tool-using. However, associative tool using is rare among animals. Moreover, the associative tools are not seen as construction functions. It can be assessed as one of the superior cognitive capacities of human beings, which emerges from cultural niche construction. Because scaffoldings have possibly not been used by hunter-gatherer societies, agrarian societies might have been used (Hansell, 2005).

4. Evolution of Constructivity, Architecture and Parietal Cortex-oriented Brain Evolution

Anthropologists made critical attempts to stress the significant role of construction behaviour in human evolution. Robert Yerkes, Jordi Sabater Pi, and Colin Groves have made outstanding contributions on this point. Differently from the central tendency based on relating cognitive evolution of hominids with tools producing and using, they stress the significant role of constructing human evolution. For instance, Comparative Psychologist and Primatologist Robert Yerkes examined the construction behaviours of apes and tried to construct some links between hominid construction behaviours in his book 'The Great Apes, a Study of Anthropoid Life' in 1929 and coined the term Evolution of Constructivity (Yerkes and Yerkes, 1929). Anthropologist Jordi Sabater Pi examined the relationships between the construction behaviours of apes and African Mbuti Pygmies. One of the pioneers of architectural anthropology Nold Egenter examined these ideas, and he generated a new model classifying the evolution of constructive behaviour and their manifested products. In his paper entitled 'The Deep Structure of Architecture: Constructivity and Human Evolution' (Egenter, 2001), he defined seven interactive processes involved in increasing brain size in his article. We can list them as;

- The transition from root to artificially stabilized buildings, which offered, first, the potential for site selection, combinations of materials and consequently a high potential for formal and functional variations with increasing complexity and stability
- The development of (topo-) semantic architecture (signs for migration, dwelling, food control)
- The potential of other derived artefacts (traps, baskets, storage, weapons, etc.)
- The development of domestic architecture from semantic architecture (access-place scheme)
- The development and implications of controlled fire derived from semantic architecture (symbolisms of fire).
- The development of polarity and the cognitive integration of natural forms into human perception; polarity can be considered the 'primary ontology' of hominids since the Middle Paleolithic may be related already to early *Homo sapiens*
- The development of language (relatively late) (Egenter, 2001).

The construction behaviours include using and producing special tools for construction and includes manipulating different spaces in different ontological levels from physical or concrete to semantic and conceptual spaces concurrently—this complicated nature of designing and constructing needs multi-sensorimotor and multi-cognitive integration. Also, using architectural entities requires the same cognitive processes. Because of this complexity, to understand the neural mechanisms beyond architectural design and using built environments, we need to examine the association areas responsible for multi-sensorimotor and cognitive integration in the cerebral cortex. These areas are in the integration regions of the parietal, occipital and temporal cortex. However, the frontal cortex's association area is different from the other three cerebral cortices in the prefrontal cortex. The parietal cortex is responsible for spatial cognition and proprioception; we need to focus on its association area. The inferior parietal lobule, which is thought lately, evolved when compared with the superior parietal cortex. This case must be in the area integrating information that comes from the occipital (responsible for visual perception) and temporal cortex (responsible for emotions and memory) and, to some degree, the limbic system (responsible for emotion, behaviour, motivation, long term memory, spatial memory). We can make inferences roughly near areas to each cortex responsible for supporting different architectural experience parts at the neuronal level. We can assume that regions of the inferior parietal cortex near to occipital lobe is responsible for visual perception during architectural design and user experience, and areas near to limbic system and temporal lobe is responsible for memory (working-short term memory, long term memory), emotions, motivations, and different sensations such as gustatory and auditory sensations. One interesting point is that the inferior parietal cortex is also related to language (linking Wernicke's area and Broca's area-two areas responsible

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for speech), abstract thinking, mathematical operations, and understanding body schema. Because of that, there must be some links between architectural experience and these cognitive skills. Before examining links between them, it will be helpful to briefly examine the parietal cortex's significant role in human evolution and the parietal cortex's functions (Laland & Sterelny, 2006; Odling-Smee et al., 2013; Turner, 2000).

The parietal cortex is responsible for heterogeneous cognitive activities from speaking to spatial encoding and spatial reasoning. We may mention them here from understanding body schema to mirror neuron activity-understanding others/ theory of mind, from object recognition to somatosensory integration, from haptic sense and grasping to spatial navigation with the help of hippocampus, from movement coordination to abstract reasoning and mathematical thinking and so on. Thanks to its complexity and diversity of functions and their significant role in survival in the natural environment and capacity for generating culture, this area must have a significant role in human evolution. Scott Elias made significant contributions examining the parietal chord capacities of *Homo erectus*, *Homo neanderthalensis* and *Homo sapiens* and their relationships between innovation and creativity. His book entitled 'Origins of Human Innovation and Creativity' represented a graph depicting their cerebral cortex lobules' comparisons. His graphs enlighten why *Homo neanderthalensis* were extinct even though they had bigger brains than *Homo sapiens* (Elias, 2012, p.1-15).

We know *Homo neanderthalensis* had a bigger frontal cortex, but *Homo sapiens* have a larger parietal cortex. Furthermore, according to the general view about their extinction, they cannot speak as much as *Homo sapiens*. We can extend this theory by benefitting from current findings of the functions of the parietal cortex. It can be said that *Homo neanderthalensis* were also incapable of the other parietal cortex functions compared with the Sapiens species. Diversity and heterogeneity of parietal cortex functions and its primacy for evolution and architecture give us a chance to examine the relationships between the other types of cognitive abilities such as language or social cognition or else mathematical/ abstract thinking and architectural cognition furthermore to search the complex nature of architectural experience and its uniqueness for human evolution (Akazawa et al., 2013).

Conclusion

Due to the continuous reciprocal interaction between built environments and their users, built environments become stratified, containing incoherent categories from the most concrete to the most abstract entities about human life and integrated into unified phenomena. The niche construction theory is discussed in this article to stress architectural settings' role on brain and mind activity. We understand that owing to architectural settings' inclusive structure and continuous interaction with them, examining architectural settings' role on human neural/mental activity is very important. We say the significant role of artefacts of organisms on evolution-from cognitive evolution to socio-cultural evolution- is assimilated in favour of genes. However, humans' architectural settings and animals' nests increase their survival chance and allow genetically-week individuals to survive.

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