

# The Phisiomimetics as the Main Principle of architectural Forming and Aesthetic Emotions

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**Abstract**— The value of a new evidence-based design approach to architectural forms is known. The paper then focuses on the essence of the interrelation between psychophysiology and geometric semantics as three-dimensional environment or stable patterns of architectural form as a semiotic structure. The architectural forming creativity is the process of generation of architectural form, the morphogenesis of "structural information". The search for principles, methods, and regularities of the forming process should be carried out from the psychophysiology of perception and cognition of architecture. It's an interdisciplinary study to understand the relations between the design of built-environments and associated human emotions. This interrelation represents the affective and reflex basis of the spatial imagination and the corresponding dominant activity of the neural network. It turns to be the basis of the study of psychophysiology of aesthetic emotions in the perception of form. The main subject of the paper is the discussion of proper theoretical base for revealing actual directions and methods for experimental work providing objective results in neuroscience, design research and developing the evidence-based design. A list of necessary experiments on personal emotional reactions on architecture objects is proposed. The conclusion gives the review of applying empirical scientific research knowledge to a creative design process.

**Keywords**- *Architecture; structural information, cognitive; spatial imagination; mode of imagination, neural network; perception; experimental, aesthetics, evidence-based design; creativity; design research; design means.*

## I. INTRODUCTION

There is an active scientific interest in the effects of architectural forms on the brain. Neuroscience and neuropsychology of perception of the architectural form and artificial spatial environments by humans is an actual scientific problem because of the content of the architectural theory. The study of it has become a special subject of the American Academy of Neuroscience for Architecture. There is a special direction of "healing architecture" in European projects for healthcare and "contemplative architecture" in American cognitive publications. While studying the influence of three-dimensional visual stimuli on the brain, Russian and European scientists may potentially need a multidisciplinary study of the processes related to cognition and perception. So, even experimental database

neuroscience, neuropsychology, biology, and psychophysiology are not enough now, because it does not create a complete map of what is happening in the human mind. Natural Sciences do not give a huge understanding of the processes of perception of the surrounding reality. I.e., in general the study needs to be completed by, anthropology, philosophy, art theory, the theory of architecture, sociology, even archeology and history. Only an analytic comparison of different sciences and disciplines can create a complete picture of perception processes and help to analyze necessary directions and compose the list of experimental work in order to reveal what design strategies are more human oriented.

The paper develops previous analysis of the author [1] and is organized as follows. Section II differentiates streams of aesthetic rating and cognition of recognizable pattern vs. archetype of perception [1]-[6]. Section III presents theoretical basis for the separation neural networks and physiology based modes of spatial imagination according to Duran [7] and gives the key for understanding of those modes [8]-[10]. In Section IV, there is a brief comparison of the neural networks base of Duran's [7] and Ukhtomsky's [11] concepts. Section V gives the review of the most important for the list of necessary contemporary anthropological, theoretical architectural and neuroscience issues for the important experimental work. Section VI gives a list of necessary experiments. The conclusion enlightens unresolved problems of the connection between formal characteristics of an architectural form as a visual stimulus and neural networks and physiology responses. At the end there are future perspectives of developing the phisiomimetics as the method of research based creative design process for architectural forming given.

## II. COGNITION OF REGORGNIZABLE PATTERN AND PERCEPTION OF ARCHETYPE

In order to compare the variety of scientific conceptions [1]-[6], we have to postulate[1] that cognitive and perception processes (see Table I) are the interaction of two informative horizons, i.e., the language of concepts and the visual formal language representing a three-dimensional lattice for composite design sliding. The experimental aesthetics of Fechner (Table I) discerns associative and

direct factors of the aesthetic impact of the form, similar to the concept of Shapoval [4] (see Fig. 1). There is a wide connection between the streams of aesthetic impact and combinatory levels of architectural form. The structure of architectural form is a kind of two-level grammar (see Table I).

TABLE I. COMBINATORIAL LEVELS OF THE ARCHITECTURAL FORM

Researcher	Combinatorial level of architectural forming	
	Signs, symbols, Pattern associations	formal geometric (archetypes), Abstract associations
Fechner [1]	associative factor	formal factor
Jenks [4]	signifier	signifying
Alexander[5]	pattern language	abstract
General	recognizable types of forming	geometry archetypes

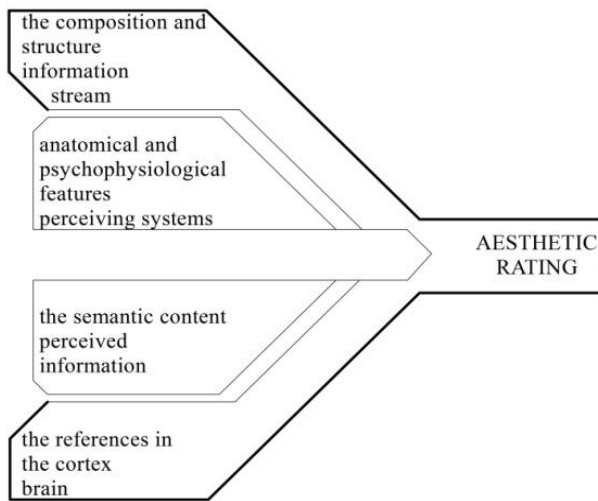


Figure 1. Two streams of aesthetic evaluation.

Primary geometrical elements give abstract associations because of connection with genetic archetypes of artificial perception. The problems of genetic archetypes (primary means of the architectural forming): rhythm, meter, space, metaphor, etc. equally belong to the problem area of the theory of architecture. The rhythm archetype has no clear foundation in the theory of architecture: there is a lack of general theory of composition at the formal and subject levels [1,2]. The fundamental archetypes of architectural forming are determined as geometrical manifestations of anthropological structures of the imagination [6]. This implies the reflexes based on archetypal groups of the spatial-imagination basic patterns [7].

Stable morphological artifacts of the architecture could be called "ARCHItypes" by analogy with recognizable

types in other fields of culture. The neuropsychological studies of the archaeologist and anthropologist David Lewis Williams [8] are interesting in this regard. His experimental work shows that the motor skills of the modern subjects at drawing geometric primitives are completely analogous to the cave ones [8]: metric linear grid, ornamental concentric and rhythmic motives, spiral forms, etc. (see Fig. 2).

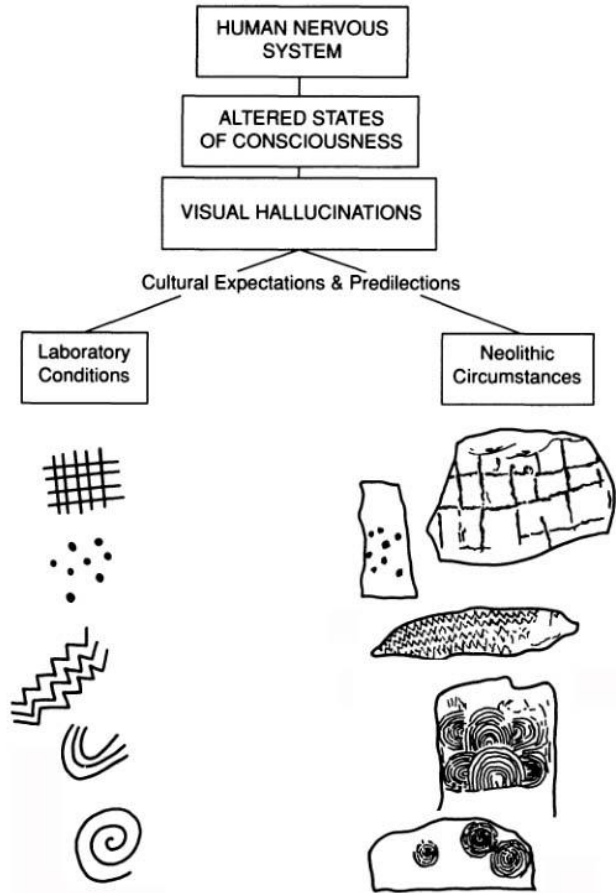


Figure 2. Comparison of the entopic forms depicted under laboratory conditions (after Siegel 1977) and in Neolithic art [8].

All these are currently used by the formal contemporary art and architecture. That is why ARCHItypes should be considered as stable and typologically recognizable elements of architectural forms and composite structures composed of them, bearing certain symbolic meanings and correlated with the epoch and style. Archetypes are geometrized manifestations of the spatial-imagination modes having a reflex nature, as it was shown in Williams' experiments and Picasso drawings (see Fig. 2 and Fig. 3). Figure 3 represents the drawing of Picasso (1924) included in the illustrated edition of "Unknown Masterpiece" [10] written by Honore de Balzac.

Let us recall that the primary art examples are more ancient than languages and architecture for more than 40 800 years BC [9]. From this viewpoint, the imagination

mechanisms for the mass, space, and rhythmic ratio represent the “archetypes” of architectural form [1, 2]. The primary elements of architecture and the rules for their connection are still the main problem in the theory of architectural composition, being not its specific subject.

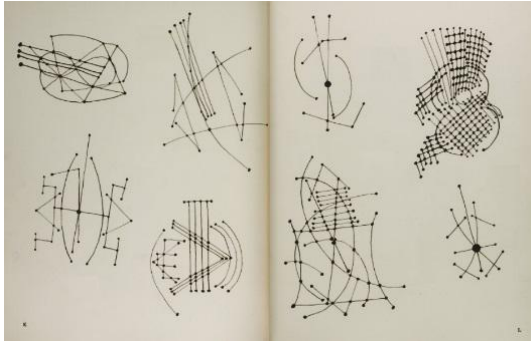


Figure 3. Drawings of Picasso (extracted from [10]).

### III. DURAND'S COGNITION CONCEPT

#### A. Durand's concept about archetypes of spatial imagination

An interesting research of the archetype revealing in art structures has been performed by Durand (1921-2012) in the middle of the XXth century [7]. This research was based on the reflexology of Bekhterev, Jung's psychotherapy statistics, and the seminars “Eranos” (see [7] and refs. therein). The Durand's concept is completely compatible with the systemic approach [4] currently used in the theory of architecture research. It refers to the triad of the thinking and modalities as the base. This triad involves the imagination process, the subject, and the object of imagination. Within the Durand's concept, this triad confronts the absolutely opposite (with respect to imagination) concept, i.e., “the time is death” [7]. An analysis of imagination modes leads to the inference that they are based on both, psychological as well as physiological mechanisms of perception and interpreting the physical laws and phenomena of the material world. From the viewpoint of Durand, anthropological structures of imagination, i.e., the process of architectural forming appears to be essentially the result of the mode geometrization. Neural networks and physiological basis of Durand's concept involves ancient archetypes of spatial imagination. It consists of three basic imagination modes. The first one is the postulated imagination mode corresponding to a social thinking [8]. The main physiological mechanisms of the postulated mode correspond to the instinct “toward the goal”, the extrapolation instinct, etc. Spatial geometrization of postulated mode is based on biomechanical functions of the skeletal musculature, vestibular apparatus, on the peculiarities of interaction between individuals. In the triad

of Vitruvius [11], the postulated corresponds to the “benefit”, as well as to the “function” (see Fig. 4). The form depends on its purpose. This concept includes the aggregate of social meanings of the form and its ideology as indirect function providing the social certainty of the form.

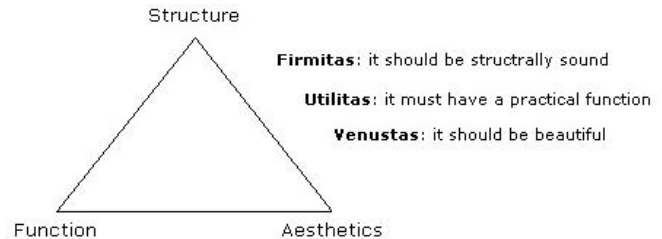


Figure 4. Vitruvian triad.

The scheme for geometrization of postulated imagination in architectural form becomes a structural frame for the dynamic and static axes. This mode is based on the geometrization of the uprightness instinct and the resistance to gravity (tectonics, in analogy to “gravitational forming”). Postulated basis underlies the parametric descriptions of the boundaries of objects and spaces, as a subject of social agreement. The same refers as well to movement representation in general, including the spatial element connection scheme, functional routes, etc.

The formal and semantic bases of the postulated mode of spatial imagination are linked with geometric metaphors of physical phenomena, such as configuration of force fields, momenta, trajectories, lines of forces, directions, points of force application, etc. Visual representation of these metaphors is very close to mathematical concepts in a symbolic graphic form used in natural sciences since Euclid's “Elements”. So, postulated elements of the spatial imagination are inspired by anatomic proprioceptive signals (receptors in the muscles, tendons, joints) and corresponding excitation in the neuron ensemble. This statement could be illustrated by the project of Toyo Ito [13] with the plan based on a math concept (Voronoi diagram, see Fig. 5). Implementation of the postulated imagination in the architectural form occurs in the structure static and dynamic (tonic) axes, manifests itself in a gradient distribution of visual masses along these axes. The digestive mode of imagination corresponds to the ontogenetic modality of thinking. The digestive mode is based on the physiological food instinct, i.e., the need for potential energy for building systems. This is similar to individual growth of a particular organism (the ontogenesis process).

The digestive metaphor in the architecture could be associated with the mass. In the triad of Vitruvius (Fig. 4) “Utilitas, Firmitas, Venustas” [12], it actually corresponds to the “structure”; the same is the “strength”.

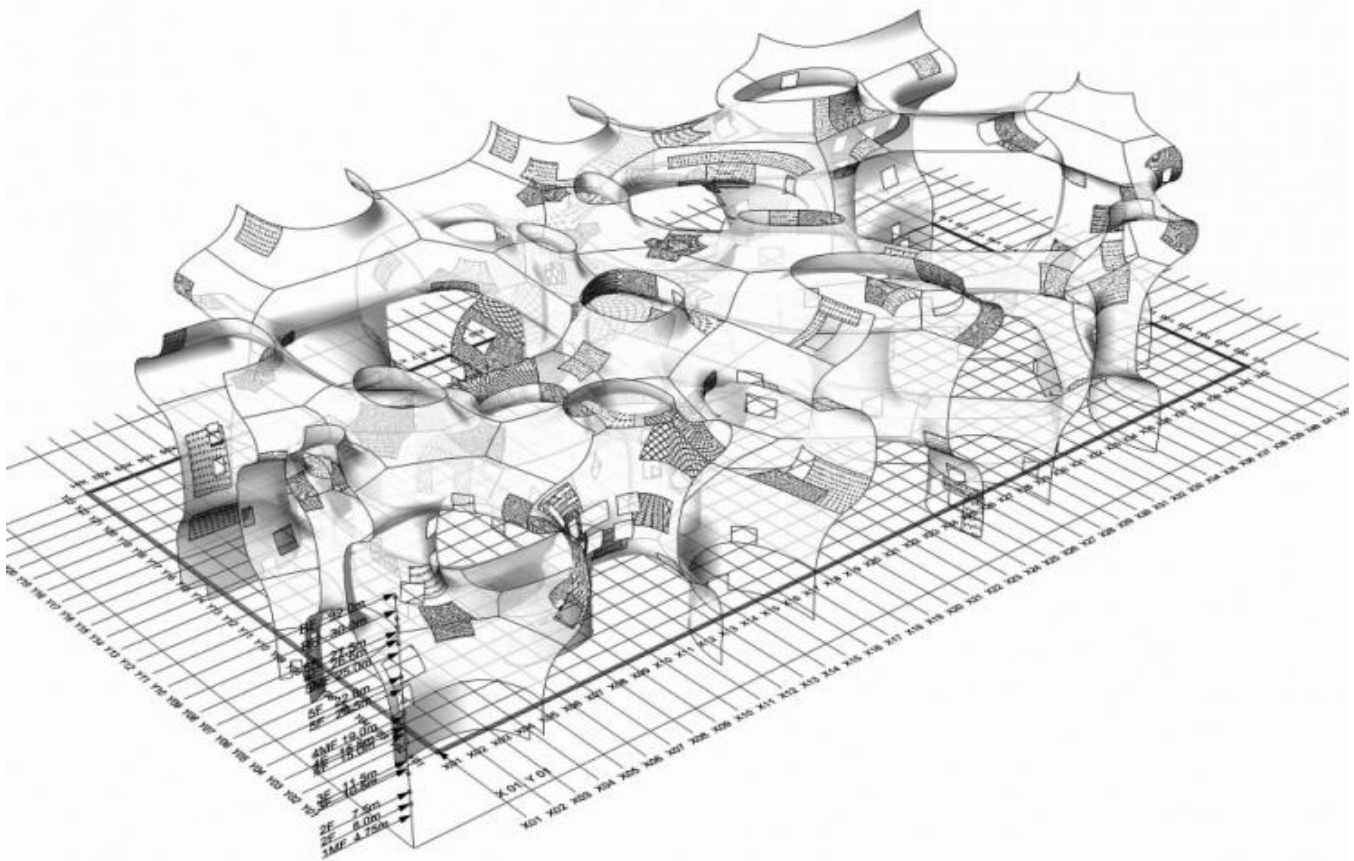


Figure 5. The Toyo Ito project of the National Taichung Theater [12].

The digestive mode represents the constructive definiteness of the form. The basis of the mental representations of the “mass” is a material body or, in a broader sense, matter in a condensed state. Anatomically, the digestive mode is controlled by the interceptive signals (from receptors of internal organs) to the Central Nervous System (CNS). Implementation of the digestive imagination mode is realized in the mass and space ratio of architectural forms. The copulative imagination mode should be interpreted more broadly as a regime of change, organizing rhythms, divisions, intervals, and fluctuations in the proportions of mass and space. Durand’s copulative mode implies that an imagination is inherent to the human physiological processes of higher nervous activity, biophysics, phylogenetics, i.e., anthropogenic modality of thinking. The semantic subtext of rhythm is a manifestation of the most important property of life, i.e., the changes. The copulative mode highlights the difference between psychological states (joy, sorrow, etc.) as functional transition from one process to another one, from one mode to the next one, and affects the psychophysiology.

General physical sense and the archetype of the copulative imagination mode is the wave, i.e., the oscillatory nature of the matter in general, including

biological and physiological processes (the electro genesis in CNS). In the triad of Vitruvius, the manifestation of copulative imagination mode is expressed by the term “aesthetics”. Physiologically, this mode is based on the signals from exteceptive receptors (coetaneous, visual, auditory, olfactory ones), subconscious internal perception of electro genesis (alternating currents) of the brain and CNS, and low energy electromagnetic fields of the body cells. The thesis “primary characteristic of architectural masterpiece is the space” [2] corresponds to the antithesis of the imagination triad as an objective source “the time is death”. The time (under the relativity) and the death (biological or cultural memory termination) exist in the physical sense only where any substance is presented, i.e., the substance in a condensed state, or the biological life. The imagination modes control the space as objective (i.e., existing regardless of imagination) reality. An artistic metaphor “time as death” is opposite to the notion of “Mass” as emptiness or vacuum, i.e., something that is opposite to the human beings.

A single natural-scientific source of discoveries and “white spots” of the theory of composition is called by the term “physiomimetics”. It was introduced by R. Soar and D. Andreen [14] for modeling the spatial structures for

buildings by analogy with the molecular lattices. But this term reflects the core of all methodological techniques of architectural forming, in line with the fundamental and applied physics (in math models), not only bionics (Fig.6).

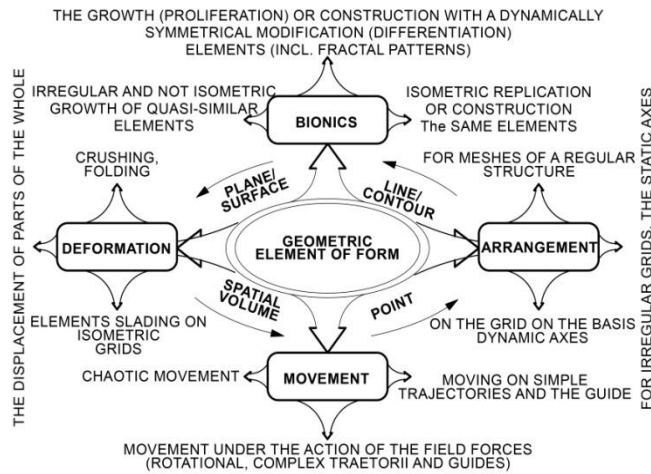


Figure 6. Interrelation and integration between phisiomimetical methods and the principles of architecture forming.

B. Durand's concept and Anokhin's "Cognitom"

Architectural forms represent the systemic encoded visual "information" in stereo-metric elements of the form/space, reflecting the multidimensional data from the highest physiological functions.

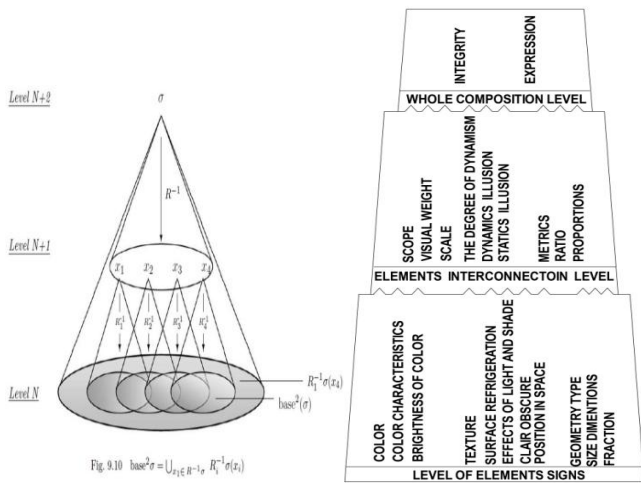


Figure 7. Comparison of the "cognitom" formalization according to Anokhin [15] and the hierarchy of formal composition properties.

At the same time, the functions work as filters and are included into the conversion mechanisms (see Figs. 6, 7, 8). The triad of imagination is a three-step statement, which corresponds to the graphs structure of "cognition", i.e. a hype network brain model proposed by K. Anokhin [15].

Similar interconnection exists between the "cognitom" formalization of the architecture of mind and the hierarchy of formal composition properties [16] (see Fig. 7). The highest level usually represents typical patterns, compositions (ARCHItypes), the lowest collects primary visual elements (extraception stimulus and arhetypes), and the middle one includes instruments of interconnection of elements (intraception archetypes).

IV. DURAND'S CONCEPT AND UKHTOMSKY'S DOMINANCE

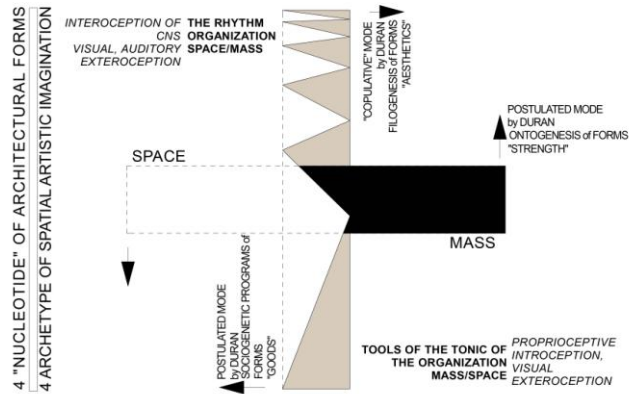


Figure 8. Complementary pairs of four "nucleotides" of architecture form and complementary pairs.

Interesting results come from the consideration of architecture history as the homological sets of various forms. The architectural form itself becomes a derivative of the four spatial operators, which are geometrical representations of abstract neural networks and physiological associations (see Fig. 9). The system of higher mental functions is controlled by a dynamic dominance. According to Ukhtomsky [11], the principle of dominance is applicable to the strategies of visual perception, which were studied by Arnheim [15]. The dominance might serve as the most determining factor integrating feelings in the process of visual perception into the whole picture-"gestalt".

The linguistic approach [6] to architecture is unable to explain, how a suite of primary geometric elements transform into the "enigmatic signifier" [5]. The way of transmission of multidimensional data of elements into the symbolic form of architecture is the actual problem of the architectural theory.

Any threedimensional form can be represented as a vector field model. The model's complexity depends on the forming paradigm. The change of paradigms is connected with revolutions of scientific knowledge, which implies that the science changes the ideology of art [17]. Consideration of the archetypical imagination modes in the light of physiology and the hypothesis on bi-similar basis of spatial imagination (see Fig. 1, Table I) leads to a natural-science concept of the geometrical imagination. This implies that

there is mutual reflection of the conscious- (ARCHItypes) and subconscious-level (archetypes) regularities, phenomena, principles of matter organization in living and nonliving nature (see Fig. 6). This concept explains the hypothesis of supra-modality of visual art and music according to Korsakova-Kreyn [18].

The dominance is also controlled by the experiences and beliefs, as well as by the physiology. According to Maslow [19], the pyramid of self-censorship reflects the "upward" sequence of dominances from the lowest to the highest level. Durand repeated Ukhtomsky regarding the concept of an art. Three functional modes of imagination, i.e., digestive, copulative, and postulated ones, could be called as the mass mode; the metro-rhythmic mode; and the tonic-axis mode of the architectural structure. The concept "the time is death" transforms into the mode of space-time. The proof of interrelation between the dominance principle and

the geometry forming could be provided by representation of the ontological categories of architecture (i.e., function, design, style, etc.) as a set of connected parameters.

Ancient Egyptian architecture describes the mass prevalence. The Gothic and Baroque architecture actualizes the vertical elements and also tonic curved elements with actual dynamic axis, which reveals the prevalence of the postulated mode. The analysis of actual for each style set of formal parameters gives the sequence of imagination modes in the history of architecture, which is equal to the structure of pyramid of self-censorship according to Maslow (see Fig. 9). The projection of this concept onto the forming process gives an understanding of the form scale as a consequence of interaction of copulative and digestive imagination modes (see Figs. 8, 9). The archetypes and manifestations of the anthropomorphic scale vs. socio scale (Neolithic community had about 30-40 people) emerged in the Neolithic period.

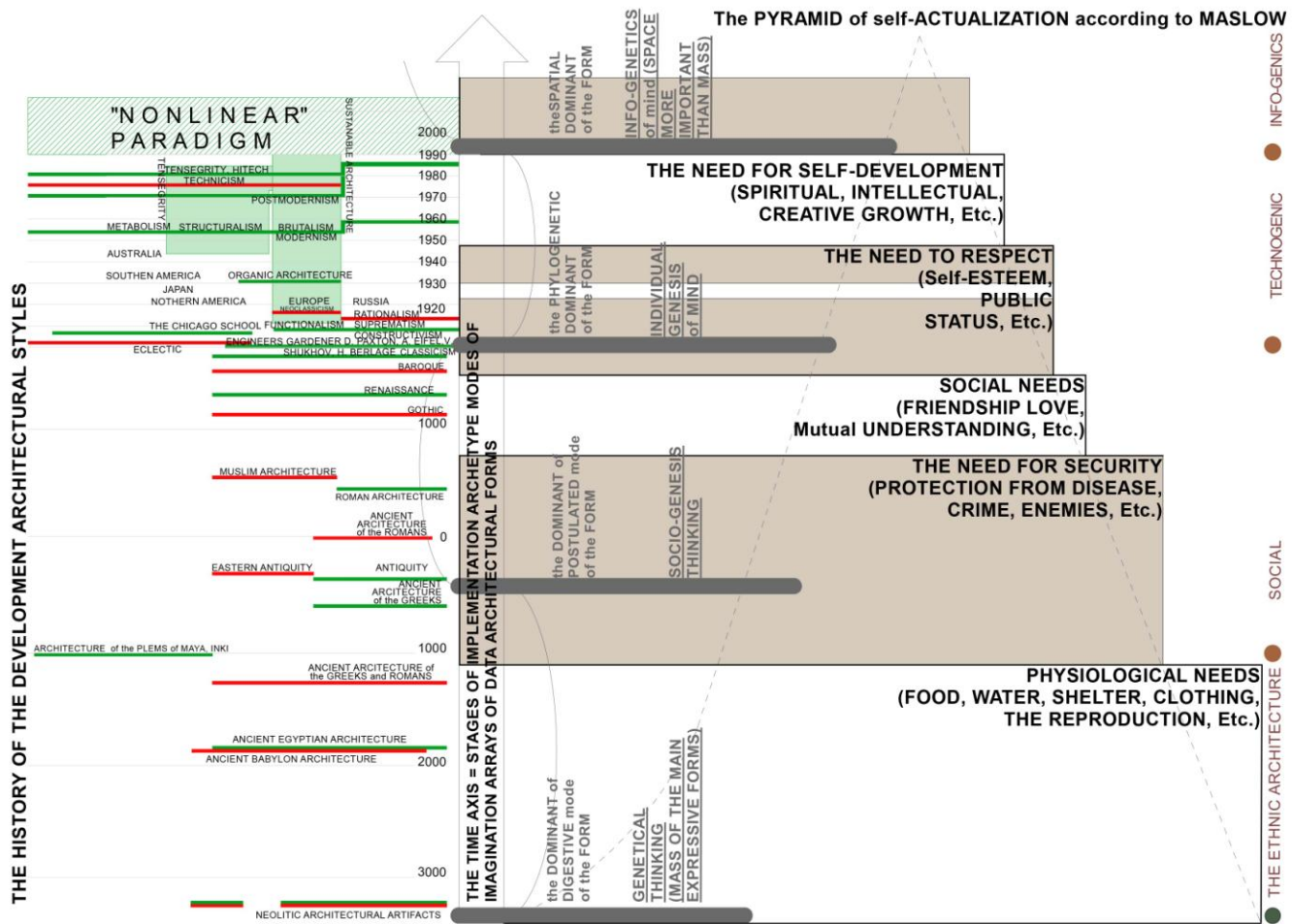


Figure 9. Comparison Preliminary graphical analysis of the actualization of imagination modes in the history of architecture.

## V. PATTERN SIGNIFICANCE AS THE DOMINANT MANIFESTATION AND THE REACTIONS OF THE CORE FOR THE ARCHITECTURAL FORM.

### A. *The Problem of Paradigms and new signifiers in Architecture. History of Architectural forms as the History of Emotions and Metaphors.*

We have met the fact of integration of design, architecture, visual arts and scientific progress that changed the whole concept of architectural forming into so-called nonlinear dynamics paradigm. It is a new kind of aesthetic metaphor. The metaphor principle according to Burke [20] is that makes the emotional experience socially shared. Starting from modern cognitive studies, the author shows that the metaphor in general is born from bodily experience. Schemes of space-time orientations, sensory and motor functions, and cardiovascular reactions to stimuli of the external world become metaphors. According to Burke, the body generates figurative languages of description, and is generated by them. "... Physiological facts are permeated with cultural signifiers. They become an integral part of the physiological system itself as value" [20, p. 70]. The natural meanings are inseparable here from the social, semiotic and historical ones. Proceeding from this mutual conditionality, the researcher identifies several successive discursive regimes, each of which has its own stock of metaphors. E.g., the humoral theory, which existed in European culture until the 19th century, presupposed a bodily unclosedness, the absence of clear boundaries between the zones of the material and mental, on the one hand, and between the individual body and the surrounding world, on the other. The language of "humors" is the language of tides, outflows and flows, that blur metric limits of personal space.

Metric radial limits for different perception types of spaces are stable: 1.5-2 meters for personal one, 6-15 meters for small group, 25-30 meters for large groups, 130-150 meters for public halls spaces. 200 meters lie over direct perception, 1200 m surpass individual perception.

The decline of the "humoral regime" brought new figurative descriptions, "more mechanistic and invasive," based on the notion of an "individualized" and "isolated" body. The architectural and spatial environment of the city is full of symbols and metaphors encoded in geometric forms and elements woven into the structure of the composition. How much a symbol can be perceived as a stimulus for neural and physiological reactions? Can the spatial environment cause stress reaction or reduce it and due to which factors or qualities of architectural form?

### B. *The geometric structure and planning of the city and stress reactions.*

The rigidity of a geometrically ordered spatial environment increases individual stress reaction. a certain number of factors in relation to urban fabric transport design, fatigue and number of accidents are not taken into account in the design.

An interesting example of such a study is the stress chart of the lower one made in 2014 by the results of work [21] by a research group led by Professor S. Parin [21], the head of the psychophysiology laboratory of the Nizhny Novgorod State University named after Lobachevsky. The research gives the answer for causes of accidents and driver's panics during a route, the map of stressful zones of the Nizhny Novgorod city. The main problem marker is the rhythm of the heart of motorists (see Fig. 10).



Figure 10. The map of stressful zones of the Nizhny Novgorod city developed by S. Parin's group of the Nizhny Novgorod State University [21,22], (extracted from [21]), available at: <http://stressmap.ru/>.

It is clear that without cooperation with architects scientists psycho physiologists can't produce even on the basis of the analysis of the most extensive database redevelopment of the spatial environment and the transport map of the city. This is a complex multidisciplinary task.

Architects, in turn, need to improve their skills and quality of design solutions within direct knowledge of stress factors discovered by psycho physiologists in the city area, which is rich in distances surpassing individual perception.

One of the important and universal factors of chronic stress in the city is the density of the population. We can convince ourselves that people around us do not affect us. But strangers' faces, crowding, smells, emotions strongly affect the hormonal system.

Standard stress reactions are triggered in most mammal populations with increasing density. The effect of the "population density factor" is the same in all studied, cases with different birds and mammals. It got a term so-called "overpopulation". Increasing density and increased frequency of contacts between individuals causes a stressful state that reduces fertility and increases mortality. The dependence of adrenal weight (producing cortisol and adrenaline) on the density of natural populations has been established for animals.

Similar facts are there in human society. E.g., the New York police gives an information that the number of crimes in skyscrapers increases almost in proportion to their height.

If in three-story houses are committed 8.8 crimes per thousand people. That ratio arises up to 20.2 in sixteen-storey houses. Also, citizens there often suffer from all sorts of mental disorders, such as anxious neurosis and affective disorder more than in three-story houses.

The connection between the activity of the adrenal weight and population density has been proven scientifically. The more a person lives in a larger settlement, the more the tonsil activates in response to stress. Note that it is more important not to live all the time, but to grow up in the village for a healthy psyche. Since the child's age is critical for neurogenesis. It is a simple way to reduce chronic stress and the proper development of the brain in children. Here it is necessary to establish experimentally whether the sense of stress is related to the density of urban development, its structure, the monotony of the city's visual grid fields.

Despite a great deal of talk about systems, we continue to organize cities as if they were a collection of isolated parts and not an integrated union of habitat, offices, plants, energy and transport routs, water, soils, land, forests, biota, and air: "Cities happen to be problems in organized complexity present situations in which a half-dozen or even several dozen quantities are all varying simultaneously and in subtly interconnected ways" [23]. The challenge is to reveal the research based opportunities how to transform urban complexity based on an industrial model for automobiles, sprawl, and economic growth into coherent, civil, and self-organizing human environments. In order to develop this human-oriented approach is necessary to find opportunities to enhance living conditions in cities, and research the relationship between humans and the formal geometry parameters of surrounding forms and environments, and the interaction between the two.

### C. *The geometruc structure as the humanity metaphor.*

A number of similar questions about the geometric structure as the humanity metaphor are discussed in the book written by C. Ellard "Habitat. How architecture affects our behavior and well-being." [23]: "Streets and buildings had been designed in accordance with universal and functional requirements and ignored the innate human need for sensory diversity were a tempting and economical solution".

But Ellard adds that a reasonable approach to the design of city streets and buildings according to the human nature is to use visual complexity as much as possible. So, this complexity needs to be natural and harmonious. But modern architects and their clients need objective measured parameters of this harmony.

The interaction of the disciplines would reduce the chances of repeating such architectural stories as the 1950s Pruitt-Igoe housing complex in St Louis, Missouri. 33 featureless apartment blocks by architect M. Yamasaki, responsible for the World Trade Center, became notorious for social dysfunction. Critics argued that the wide open

spaces between the blocks of modernist high-rises discouraged a sense of community as crime rates started to rise. Pruitt-Igoe housing complex was demolished in 1972 but wasn't an outlier. The lack of behavioral insight behind the modernist housing projects of that era, with their sense of isolation from the wider community and ill-conceived public spaces, made many of them feel as a factory not for humans.

Thanks to psychological studies, we have a much better idea of the kind of urban environments that people like or find stimulating. Some of these studies have attempted to measure subjects' physiological responses *in situ*, using wearable devices such as bracelets that monitor skin conductance (a marker of physiological arousal), smart phone apps that ask subjects about their emotional state, and electroencephalogram (EEG) headsets that measure brain activity relating to mental states and mood.

Signifier and signifying of architectural form has become a kind of fundamental problem now, a source of affordances, atmosphere and mood. On one hand there is stable permanent structural symbols and patterns, integrated into traditional architectural form, such as cross in the Christian temples [24]. On the other, there are changeable elements of non stable patterns, which cause mysterious signifiers and defense on geometrical parameters at the same time. These parameters during a long period of time depended on the main epoch style.

### D. *The neiral persepction of architectural forms: experiments and practice.*

To research the perception processes of different architectural geometry types neuroscience and anthropology integrates with eye tracking headsets, giving new research possibilities – test elements or environments themselves in virtual reality (VR) with a full suite of equipment, from eye tracking to GSR, EEG, ECG, (f)EMG, etc. It gives new opportunities of seamless real world testing – test inside the building, public spaces, in-car, on the street and many more real world scenarios with entirely new and immersive custom stimuli for the accurate instrumental detection of reactions to it.

Studies using fMRI showed that contemplation of architectural masterpieces of the brain causes changes similar to the same in meditation. It is proved that contemplation of architectural masterpieces reduces internal dialogue and improves attention, the functions of the prefrontal cortex, activates the occipital lobe, the precentral gyrus.

fMRI allows establishing that the brain response to conventional buildings and architectural masterpieces varies significantly. There are many ways in the diversity of research means with which they assess how comfortable a person feels in the city: to track the direction of his sight, palpitation, the state of the nervous system, gait and speed of movement, finally, his brain activity. All these data are then analyzed to reveal patterns and understand how



various elements of the environment affect one's health, mood and efficiency.

Dr. J. Bermudez [25] of Academy of Neuroscience for Architecture suggested that look at the buildings that were deliberately created for contemplation - museums, churches, libraries. Public spaces can have a measurable positive effect on the psychological state of a person. Bermudez leaded the study to determine the effect of architecture on the human brain. His team use fMRI and work to turn contemporary cultural manifestation of the city, i.e. the "phenomenology of urban architecture", into observations of neurology, the results of which can be used by designers and city builders. Bermudez focused on buildings and places designed for contemplation and put forward a theory that the presence of "contemplative architecture" can over time produce the positive effect on health as traditional meditation with fewer efforts on the part of the individual.

Contemplative architecture contains the same design solutions that were used in religious architecture. Bermudez noted that it is logical to use the connection between the created beauty and personal experiences for ritual purposes. This connection can be intentionally used in places intended for contemplation or research of any nature: mystical, personal and even scientific. During the experiment, 12 architects were shown pictures where were buildings themselves and their individual parts, from the facade to the interior. The buildings intended for contemplation and simple structures were demonstrated. As a result, researchers were able to observe the brain activity of people who imagined that they were in the places shown by scientists. All tested subjects were architects, white men, right-handers, who had no meditation practice before. A similar selection was made to ensure that the studies were uniform, as the Bermudez team wanted to be sure that the results of the scan would not be affected by any factors other than the pictures themselves, in particular: gender, race, education, and hand use for writing. E.g., scanning the brain of a right-hander and a left-hander performing an identical task gives different results.

The strict control over the suite of the experiment increases the chances of achieving the final result. Architects were the logical choice for experiment, because, their trained look and experience make them more sensitive to the details of architecture that the layman will overlook.

Problems began when scientists set out to measure only a few subjects. They conduct online studies in Spain and England in order to collect evidence of the unusual experience of contemplating architecture, or the facts of collision with places whose appearance radically changes the state of mind. It is especially important that most of the buildings and places mentioned in 2,982 cases were designed for contemplation: spiritual, aesthetic, religious or symbolic, which allows researchers to conclude that "buildings can cause deep, transformative states of

contemplation, and those buildings that were created for contemplation are the most successful" to a greater extent. In addition to churches, mosques and other religious buildings, some art galleries, monuments, houses and museums are examples of contemplative constructions: Guggenheim in Bilbao, the Louvre in Paris, Frank Lloyd Wright's Home at Fowlingwater are three of the top ten most mentioned objects in research. Dr. Bermúdez expanded their research using the results of neurobiological works, making significant amendments. His group of scientists attracted data on the mental states generated by the person himself, which are easily reproduced in the laboratory, and about the activity that occurs in the frontal cortex when test object makes a judgment about whether or not what is beautiful is in front of him.

The Bermudez team expected that the experience of "contemplating architecture" would be strong, and the extra-esthetic experience would reveal activity in those parts of the brain that are associated with emotion and pleasure, and not in the frontal cortex. The presence of external stimuli (pictures of buildings) also eliminates the tedious self-regulation that occurs in the frontal cortex during traditional meditation. A survey of 12 subjects showed that "weakening of attention dispersion, increasing concentration and deepening of experience appeared in all subjects; also common to all was the emergence of aesthetic judgments, apparently inevitable. Preliminary conclusions suggest that the brain behaves differently in the case of the contemplative and unreflective architecture. The state of contemplation caused by the "architectural aesthetics" in something similar to the state of traditional meditation, but with varies.

In general, the members of the American Academy of Neuroscience for Architecture also discuss ambitious design of architecture matters and details of the studies. That matters are the optimal height of interior spaces for various cognitive functions, the best design of the city to identify our research capabilities and simplify the search processes. The ways of solving problems has much in common with the base of the European "healing architecture" [1, 26].

In the native nature, which makes it so pleasant to look at, there are no straight lines. Non-natural city forms have straight lines, orthogonal outlines. So, the question arises, how different is the perception of visual series of rectilinear, orthogonal forms, arbitrary rectilinear contours or nature-like forms with curvilinear outlines?

It is very important to check the role and variety of psychophysiological impacts that proportions and fractals used in order of architectural forms give to the visual perception.

Fechner's test was static and flat, it didn't take into account three-dimensional forms and spaces. Visual perception is associated with a linear perspective and distortion of the properties. The application of the golden section affects the result in Fechner's experiment.

Proportions are found in nature, science, art, and architecture since the Ancient Greece epoch. The “golden” section accompanies all living things. Inanimate nature does not know what a “golden section” is, but undestroyed forms of inanimate nature are based on the Pythagorean Theorem, that is closely connected with the “silver” section.

There are mathematical fractal matrices, which got the name of “silver” section because of math connection with the famous “golden” section, which is known as the universal manifestation of natural structural harmony. This proportion mystically accompanies all living things. These proportions could be find in the bends of sea shells, and in the form of flowers, and in the guise of beetles, and in a beautiful human body.

It gives the variety of the mathematical fractal matrices based on the sequence of square roots of integers and integers. The “golden” and “silver” matrices have recurrence formulae. They are not arbitrary but have clear math order. So, we got another experiment task that is practical perception value of proportions.

Another important point in of visual perception research is the difference in the influence of the same proportional series that are used in structures of different types. I.e., is there a kind of the direct proportion psychophysiological impact? Does it depend on the ratio of proportions, and on the type of structure?

Arbitrary proportions of buildings and their parts also affect our perception. Is this affect negative or not? Is it better using the golden section and other proportions, the better it is perceived?

Different kinds of fractals are now popular in the architectural forming. They also give a kind of proportion ratio series.

Therefore, it is necessary to understand if the perception of the proportions of this mathematical series applied in different things and opposite areas of life and culture, in particular, in architectural forming is stable everywhere?

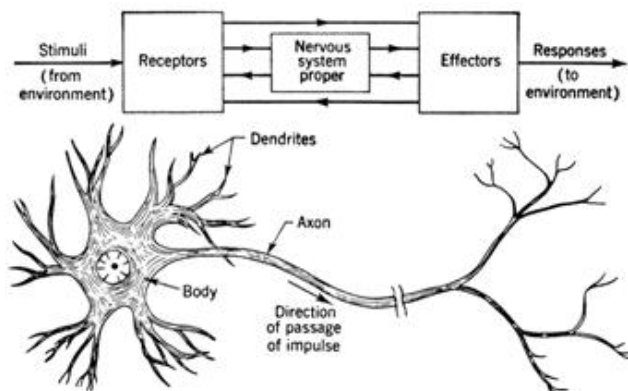


Figure 11. The scheme of perception and the structure of the neuron (extracted from [27,p.16]).

#### E. The brain mechanisms for visual perception analysis.

Professor M. Arbib [27] is researching brain mechanisms linking vision to action and language. He started from “What the Frog’s Eye Tells the Frog’s Brain” [27] via U. Pallasmaa’s “The Thinking Hand” [28] to get a new observe on how the brain links imagination to construction via sketching, whether by hand or on a computer [27, 28]. In recent years, this question has morphed into two major and connected with each other concerns about the conversation between neuroscience and architecture, and the conversation between computer science and neuroscience. This problem was discussed in the book “How the Brain Got Language” [28]. But we suppose that the basis of representation for any spatial structure in the mind is pattern, made of the frame containing abstract proprioceptive associations as a kind of geometrical canvas. Geometric elements often constitute the basis for the habitual patterns or construct new ones. And all the formal compositional means of geometric elements and their combinations influence the range of values of the new symbol or correct the semantics of traditional one. This is the two-level psychophysiological based language of architectural forming. But the base of this language is the one that M.Arbib leads in his book [27]: the stimulus, and the receptor signal transmitted to the central nervous system, the signal processing and the response to the environmental challenge in the form of an effectors’ work (see fig. 11) But the knowledge of the physiological mechanisms of the operation of CNS slightly reveals the curtain of the mystery of the cognitive processes of the brain, the work of the mind.

Therefore, the work of philosophers, anthropologists and the statistics collected by them, just like the empirical experience collected by the architects cannot be ignored when compiling a list of necessary experiments in the course of cognitive research for the purposes of architectural forming. Buildings and cities can affect our mood and well-being, and that specialised cells in the hippocampus region of the brain that are attuned to the geometry and arrangement of the inhabited spaces. Urban architects haven’t paid scant attention to the potential cognitive effects of the city’s inhabitants. The imperative to design something unique and individual or, on the contrary, cheap and affordable socially and economically tends to override considerations of how it might shape the behaviors of those who will live with it. It must be changed through the scientific way. R. Dalton [29] tells about both architecture and cognitive science: “There are some really good evidence-based guidelines out there how to design user-friendly buildings” [30].

J. Manpreet in his book “Designing mindspaces” [29] analyses the research method of G. Debord called psychogeography is an interdisciplinary study to understand the relationship between the design of environments and associated human emotions in detail, and further to

investigate the Philosophy of Heterotopia to apply its principles in curating positive experiences.

This interdisciplinary approach helps to theorize a framework which can help designers and architects to take advantages of the knowledge from the related fields and apply them in re-creating existing urban fabric. To understand the elements of this framework, Manpreet investigates the role of art, architecture, culture, media and technology in orchestrating urban experiences, not only to foster creativity and fresh thinking but also to inspire life in urban environments. Manpreet's approach is inspired by the Constructivist paradigm of learning. Manpreet has analyzed various examples to illustrate findings and understanding of experts and fellow researchers in related fields to arrive the methodology for final framework.

Methodology of Manpreet's research followed a human centered design process by keeping experience at the centre, and then applying system thinking to understand its core and periphery for the final framework. The proposed urban area in order to provide inputs for planning and policy making. Urban sociology should be used as a basis for creating a comprehensive programming for design of a new public space or architectural form.

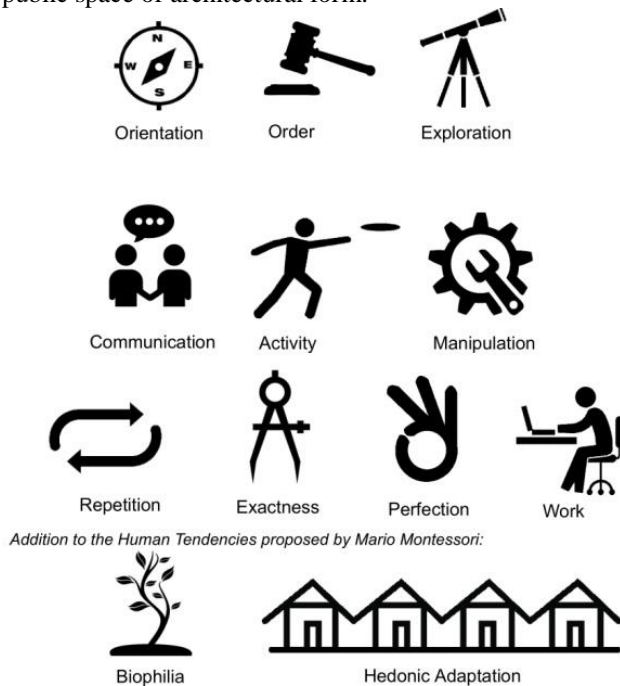


Figure 12. Visual representation for the Human tendencies is my contribution by adopting and recreating icons made by Freepik (extracted from [30, p.27])

Manfrid consider "programming" to be an important aspect of architectural design that architects and designers can use to reprogram and re-purpose any space, so as to enhance experience [29]. R. L. Hemmer programmed in 2005 a project named "Under Scan" in Lincoln, U. K., where the passersby were detected by a computerized

framework is essentially an end product of a literature review capturing the details and findings from the related fields of philosophy, cognitive architecture, and ontological design due to the architectural form of spaces.

Sussman and Hollander describe the reasons behind our attraction to edges, faces, symmetry, curves, and stories in the book about cognitive architecture [29]. Cognitive architecture is also an approach that focuses on research of the human response to the built environment. Buildings are intended to be viewed, traversed, and lived in by people. Only a handful of theoreticians and practitioners of architecture think deeply about human nature and, why and how it needs to be considered seriously during design process of buildings and urban area.

Urban sociology is the study of human interaction in metropolitan city areas and the development of society by means of urban space and design form. It is a normative discipline of sociology seeking to study the structures, processes, changes and problems of an tracking system, which activated video-portraits projected within their shadow. Virtual computer generated environments are slowly mixing our mental landscape through media architecture, test subjects were entering virtual spaces. Although real human environments have always had a layer of virtual elements in the form of printed media, paintings and art forms. The term "virtual environment" was coined with the advent of computers, and problem how to differ virtual from real had already arised.

The framework (see Fig. 13) proposed by Francis Ching in book "Form, Space and Order"[29] gives an overall idea to understand any physical or virtual environments (see Fig. 12). For the purpose of research the association of spaces or built environments and its elements with human emotions this framework is very useful, as it lays a foundation to get better understanding of the basics of architectural form.

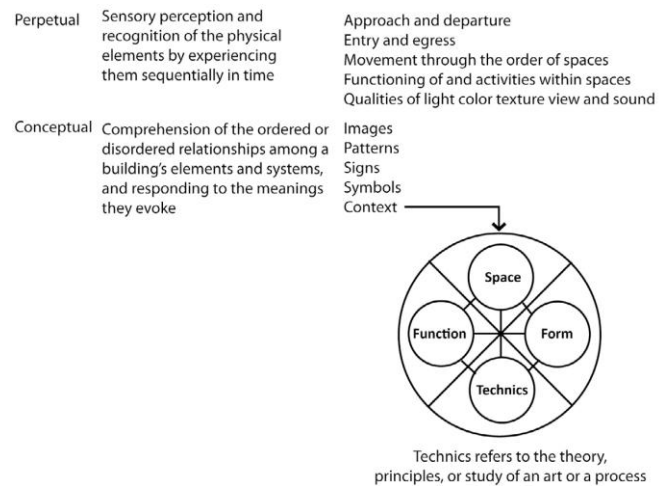


Figure 13. Illustration of the main for perception analysis part of framework for designing environments; proposed by F. Ching, "Form Space and Order" (extracted from [29, p.22]).

Manfred studies interiors of built environments in spite of the fact people disregard the type of ceiling above them and ignore the patterns on the floor, he supposes that man-made spaces around us without realization have some feeds back to shape one's behavior. So, Manfred supposes that human response to the built environment must be realised in detail with correlatoin with the time spended inside. E. g., somebody is sitting inside an office with a glass façade and his desk is positioned in a way that on a bright sunny day the sun directly shines upon his eyes through the glass wall, the uncomfortable glare one experiences may disrupt the work-plan for the day, and the same situation may get even more uncomfortable, if it is summer time and there is inadequate air-conditioning. The glass wall may be the reason of a whole day without productive work. It depends not only on lighting conditions and conditioning, but also on the boundaries and metrics of personal space, the configuration of the room, it's overall illumination, isolation, color, textures and materials.

## VI. CONSEQUENCES FOR THE FUTURE EXPERIMENTS.

### A. Finding Perception Meanings of the Structural information from the Architectural or Abstract Forms

So, the architectural form appears at the intersection of four imagination modes (see Fig. 8). The material of architectural sheaths is mass. But the primary material of artificial human environments inside the shells or between them is space. Architectural space is organized by function graphs within composition means based on axis frames and grids. They could be treated as "operators" of the three-dimensional form related to "structural information" (see Fig. 14) and semantic features.

The first aim of experiments is scientific evidence that the aesthetic quality of architecture expresses affects on human health and well-being by following means: structure and proportions of buildings, population density, and geometry or bionics character of designs for artificial environments.

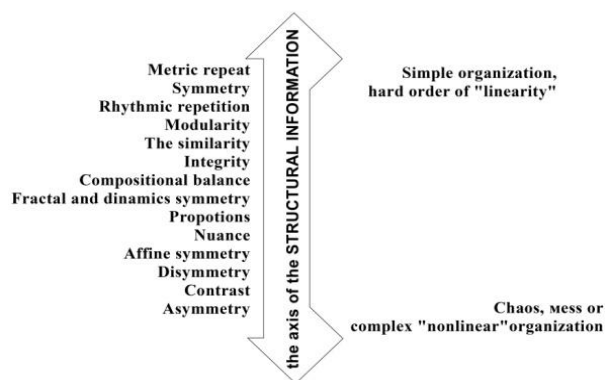


Figure 14. Structural information from the forming processes.

The second goal of experiments is to reveal a set of parameters for architectural environments or forms that influence directly test subjects groups.

The third goal of the experiment is to identify those characteristics and qualities of architectural forms and environments that have a beneficial effect on the test subjects and determine in what combinations this impact is positive. The forth additional aim is to reveal if architectural styles have some cognitive role in one's mind. It is rational to use the experience of such theorists of art and psychology and founders of the modern theory of formal composition, as G. Fechner, V. Kandinsky [30] and I. Itten [31] in experimental instrumental work.

### B. Equipment Requirements and Registration parameters

Analysis of the form as a set of parameters of archetype modes opened the way for researching dominances of emotional perception (see Fig.7). It is reasonable to combine the tracking of physiological processes (the frequency of respiration, palpitation, EEG parameters, etc.) with purely cognitive tasks associated with individual perception and spatial thinking of test subjects. Test subjects have to be logically divided into groups according to the occupation, sex, age, dominance of right-handedness or left-handedness.

### C. The List of experiments

A suite of experiments according to the previous analyses of publications must include the following groups of studies with the fixation of the physiological systems work and the objects of tested one's personal concentration:

1. Experiments based on the V. Kandinsky book "The Point and The Line on The Plane", fixing the physiological answers and the trajectories of the glance movement in response to images of abstract structures similar to those given in Kandinsky's book. The first stage is the repetition of images through the same pause or cyclicity. The second stage is a repetition through an unsystematic different duration.
2. Experiments for testing the physiological changes during the observation of the tested subject the rotation of figures (spatial and impossible) without changing the proportions. In this case, the analysis of the results should take into account the different character of the silhouette, the discrete or specific configuration of the forms.
3. Experiments on the mental rotation of the similar figures (spatial or impossible) with difference between proportions, color, texture, etc.
4. Testing the physiological changes when displaying video with different scenarios of perception of the same architectural form, as well as groups of architectural forms of different styles, groups of architectural objects that are topologically equivalent (homologous series of architectural forms).
5. Video rotation of detailed or generalized models of architectural forms with the study of fixation of tested subject's attention on structure, comparison of little changes in similar structures. The first option is to show different

images with proportions of the golden section through the same pause. The second option is to show the same structures with arbitrary proportions and different time intervals along the golden section. The third option is the display of the same structures with arbitrary proportions and different temporary arbitrary time intervals.

6. Perception of monotonous visual media and architectural fields (short and long surfaces, facades) with two stages: the repetition of images with a certain frequency and the repetition of an unsystematic and with different duration.

7. Cognitive tasks before and after the experiment. The study of the role of the part and whole symbol; dependence between the signifying of the symbol and formal characteristics; the relationship between detail and the whole; a group of experiments on the perception of generalized models of well known architectural objects.

8. The comparison of the perception of artificial three-dimensional objects with the perception of natural prototypes. It is necessary also to account the possibility of cognitive dissonance and other stress factors in the subjects' reaction, comparison of results for different age and other categories of subjects.

9. An experiment of subjective division of structural and composite forms into provocative and harmonizing, stimulating with fixing a stable effects that these forms have on neuropsychological status of the person.

10. Structural and architectural design analysis of stress map project for redevelopment of the Nizhny Novgorod city area and agglomeration.

For diagnostics of the physiological reactions, not so expensive equipment is needed, such as fMRI, the thermal imager, ECG, EEG, and the eye-tracker (to account for the attention-fixing points of the testing subjects).

## VII. CONCLUSIONS

The actual set of experimental work can give the key to the main problem of architectural theory: an understanding division of structural and composite forms into provocative and harmonizing, stimulating and tiring. And give the answer to the question if the phisiomimetics is the future of architectural forming or a kind of the neotrabalizm phenomenon.

The experiment with instrumental diagnostic care can give objective answers, unlike H. Fechner's studies, how harmful are arbitrary proportions in architectural forming. Whether arbitrary proportions affect human perception and means of forming what architects should learn from natural forms really negatively.

Experiments set by A. Shapoval answered the question of perception of contours and the silhouette of industrial design forms.

In addition, there is not highlighted in the experimental work of A. Shapoval [4] difference in the perception of bent and broken rectilinear or folded forms. The question about the effect of the curvature of the shape and the nature of the

influence of this curvature on the subject's well-being remains open.

Only empirical architectural experiments stay numerous: "I am attracted by curves, free and sensual. Those curves that we can see in mountain silhouettes, in the form of sea waves, on the body of a beloved woman"- wrote in his memoirs Oscar Niemeyer - an outstanding architect of Brazil [32]. This was a core of Niemeyer's approach to design, thanks to which all his projects amaze until our days. Simplification of the means spent for the achievement of a certain goal leads to a detachment from architectural form creative principles and to the extinction of architecture as art in general.

Only neuroscience-based research may resolve the dispute of radical functionalists and artists, because the constructions of Niemeyer remained unclaimed. Architect can add the terrain, details, such as portico, columns, bay window, decor, and coloring environment in order to get rid of the aggressive and tedious homogeneous visual fields in the city. But architect needs objective criteria to evaluate visual environments as aggressive or friendly to humanity, and to make a comparison with the research of the influence of coloring on physiology.

Another way to avoid homogeneous visual fields is the complete change of the paradigm for future architectural forms. But it also requires human oriented cognitive research.

Obviously, one main trend is already clear. The transition of mankind to urbanized environments and separation from nature requires an ecological new approach to urban design, and no new visual "ecology" of the spatial man-made environment of cities, the likening of nature, geometric balance, measure and a certain ratio of rectilinear and geomorphic surfaces in architectural forms.

That is why architectural forming is now already connected with phisiomimetics. And, also we need to develop the phisiomimetics research, as the fundamental principle of architectural forming. A series of experiments have to be connected with the phisiomimetics research because of physiological benefits of nature based aesthetics.

Harmony of the architectural form and space means not only similarity to natural forms. It's not the only way of generating forms and spaces. Similarity to nature only exaggerates and compensates the prevalence of rigid geometry in contemporary architecture and city environments. Nature teaches new ways and methods of architectural forming.

It is necessary to mark that a structure of an architectural form can be taken as a system of neural and physiologically encoded visual stimulus information. The systemic relationship between psycho physiological concepts and the theory of formal composition promises an effective experimental study. The list of experimental study proposed in this paper is not completed because it should be supplemented by wide graphic and video series of visual stimuli. A convincing chain of relations between the formal

characteristics of the architectural form as visual stimuli and neural responses is not complete.

However, the developed theoretical base guarantees not only the right direction of the experimental strategy, but also its reliability. The main aim of this study is to find clear interrelations between the geometry of architectural form and the way of emotional perception. The second aim is to establish an interrelation between emotional reactions and phisiomimetical patterns of forming to reveal possible new ways in architecture forming. The third goal is to clarify possible new directions in architectural education, methods, strategies, necessary new disciplines, etc. However, the greatest difficulty of the forthcoming work will be precisely the analysis of the experimental data. An interesting perspective is the connection of parametric modeling of an architectural form and neuroscience-based strategies for its design, but is such a connection possible? This question will be answered only by further research.

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