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Epistemological gaps in studying design, design ability and the phenomenology of architecture, Neuroanatomical basis –mind and body– of the design cognition and action

Introduction

This study finds its place in a much large research project, which aims to furnish some new, more empirical and scientific explanations to the problematic articulation and the relation between the deliberate –cognitive- control and the spontaneous generation of designs in creative designing process.¹ These accounts concern the methods of the process of implicit and explicit space experiments and the “phenomenons” lived by the designers, which enter in the new designing experiments through sketching.

Secondly, in the meta disciplinary level, this general research approach postulates and tends to demonstrate that the findings in the scientific disciplines can (*and must*) be applied to the design research. And doing this, it claims the necessity and the feasibility of the cross and interdisciplinary approach in the study of the design and the architectural design.

Thirdly, it postulates in fine as an epistemological level hypothesis that the design activities such as architectural design, urban design activities involving space, because of their foundational epistemological difference (*the phenomenological aspects in the involvement of space in the cognitive functions*), must be separated from other types of so named “design” activities.

Then briefly, we can say that this study has two main goals. First of all it outlines a framework of design process as space creativity based on a totally new perspective of functional cognitive neurosciences.

And secondly it tries to place within this new theoretical framework a certain amount of those issues evoked in the established design research -in general and the architectural research in particular-, issues such as the phenomenology of architectural design (*Pallasmaa, 2009, 2005, 2006*) in one hand, and the issues like “designerly ways of knowing”, “the nature and nurture of design ability”, “design thinking and design sketching” (*Cross, 1982, 1984, 1990, 1995, 1999, B.I.R.D. 2007, Dorst, 2006*) “how designers think, design in mind, what designers know” (*Lawson 1979, 1980, 2004*).

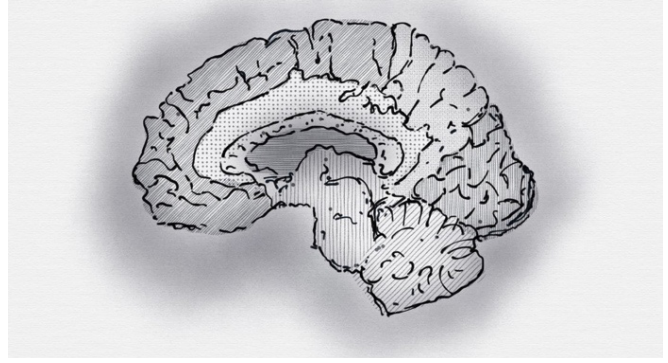
First Part

Main epistemological issues

This research program is based on some major postulates and working hypothesis:

In the contemporary design research fields developed after the Second World War, the

¹ We make a radical difference between industrial/organisational and other type of designing process and space and human scaled designs. This account constitutes our metatheoretical basement.

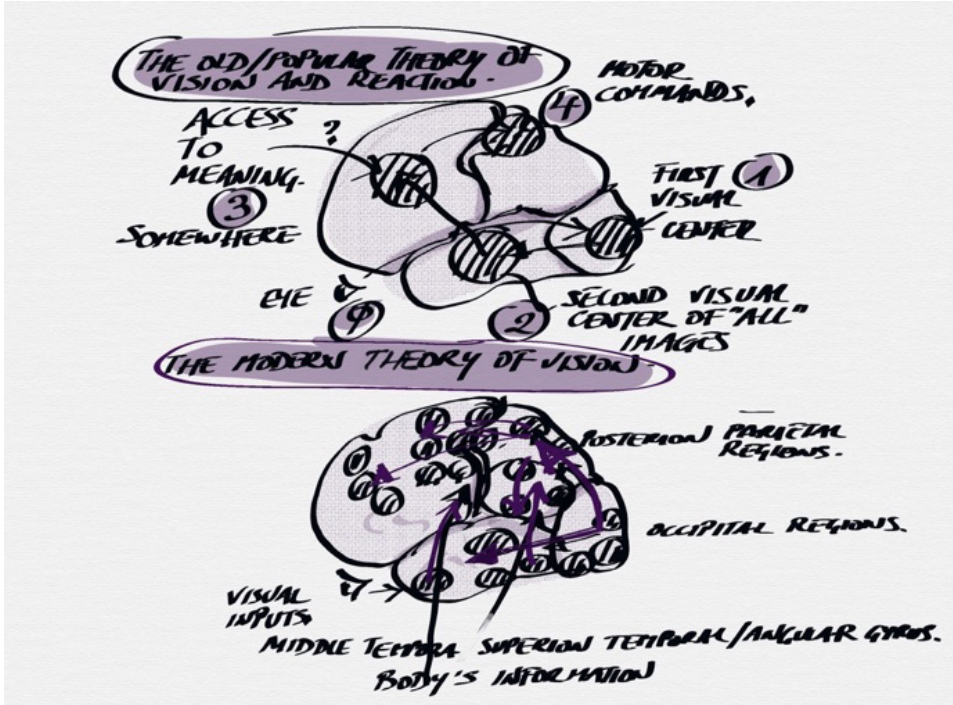


isolationism is the main characteristics of the must of the design research programs. The main claim used to be proposed at the time was the following:

“all disciplines have a major goal and the design research must have its proper one”²...

“and the design research isn't "the application field" of other scientific disciplines”.

“they have their relevant "goals" and design research must have its own, demarcated and delimited orientations.



In this paper it is argued that this isolationist orientation is false by trying to demonstrate the insufficient results obtained through the most of the design research programs based on the intra methodological accounts. Thus the main claim consists to declare that the complexity of the design process and the multi dimensionality of the components couldn't be theoritised in the only specific intra-disciplinary framework.

This isolationist posture doesn't allow to explain not even the really basic issues. Effectively it can be affirmed that even in the thematics like the vision, the perception, the images, the mental images, the nature of mental images, the egocentric disciplinary approaches, don't have relevant and productive “theories”.

² Ex. Work of Philippe Boudon, Architecturologie et Epistémologie.

Following the hypothesis that this study tries to assert, issues related to the modelling of the design process and its teaching, and other derivative issues such as the role of the sketching, the technical assistance to design etc. are based on very weak epistemological foundations that can be called "gaps".

Among the reasons of the “weaknesses”, the first and principal issue concerns the “real” human capacities of space perception linked to the very nature of human vision system. The second concerns more generally the human cognition.

To illustrate this, let us quote a famous scholar of “perception” in architectural and art fields, Rudolph Arnheim. (*V. Margolin & R. Buchanan, 1995, 70*)³.

...“The architect's moves produce the drawings and they supply essential new food for the arguments. The drawings are tangible visual percepts, and it is their relation to the arguments that is the principle concern of the present discussion. Mental images derive from optical percepts, but they are not identical copies of them. Mach (1886) describes them as necessary completions and elaborations of percepts. They differ from the optical percepts recorded by the eyes by their reduced intensity. They are fugitive, easily wiped off the slate of memory and, therefore, they offer a freedom not granted to optical percepts, especially in their dealings with space. Mental images can handle visual objects though they were weightless..”⁴

As seen on the above example, we have no assumptions and theories, but we act as if we have in the most important and foundational issues such as vision and perception, not to mention more complex problems such as cognition, action or drawing.

And generally we take then speculative accounts as genuine scientific accounts, or the partial intuitions as methodological solid concepts... (*i.e. gestalt psychology...*)

We often refer to obsolete or outdated accounts (*as Arnheim did, with referring to this account of the end of the 19th century to Mach, even if Mach is a major scientific figure.*) or to some fallacious accounts as genuine theories which concern more general sense the human cognition.

In fact, particularly in the fundamental level of the cognitive architectural design cognition and the architectural design abilities, we have neither good theories nor structured frameworks.

Generally, as a primitive cognitive explanation we refer to some classical cognitive psychology accounts on the one hand and the folk psychology intuitions and “beliefs” non justified but broadly accepted on the other.

According to these “cartesian like” mechanistic, deterministic, linear, cognitivist accounts, the sketching, drawing as the main design abilities (*as the other higher cognitive abilities*) are ordinary problem solving activities: the design idea is formed in the “mind” before its “motor expression”. In this methodological construction between the perceptual dimension of the cognition and the expression of the new ideas are the computational processes in the mind.

The contemporary design research programs are mainly based on this weak epistemological foundations and the particular theoretical expressions of functionalist cognitivist account of H. A. Simon's “problem solving” framework.

From this point of view, the brain which is the main location of the image perception (*“cartesian theater”*) and the memory (*images accumulation*), analyses and synthesises, solves the design problem, and transmits the computational resolution to the body (*the hands*) which executes: the mind and body are two different “things”.

That is the reason why we call this approach “behaviourist”. Because in the last instances we look only at the results, that is to say, we continue to believe that the “architectural design is the result of the computing processes which occur in the so called ‘black box’”.

When we design to look at other disciplines, we borrow our frameworks from theories outwardly mastered, copy and paste conceptual frameworks opportunistically and we mix and fix and tinker bits of theories (*certainly with “honest” educational intentions*).

³ Arnheim R. *Visual Thinking* (Berkeley. U. of California Press; 1969).

Arnheim R. *Art and visual perception* (Berkeley. U. of California Press, 1974)

⁴ Arnheim R. in. *The idea of design*. ed. V. Margolin & R. Buchanan, MIT Press 1995, p.70

Frequently we put philosophy behind the ideas to display and make-up for our misleading accounts, invent theories with unverifiable para-philosophical speculations, if we don't go as far as marketing of authentic philosophical insights and debates as genuine architectural theories.

The beginning of "dialogical" relations with the neurosciences

1- The first claim we propose is that the design research program is a cross-disciplinary account and must be constructed on the frame of the main disciplines essentially concerned with this goal. Many disciplines are involved in this program: psychology, ergonomics, neurosciences, cognitive and ergonomic psychology, educational sciences...

But, to modelize design process in this perspective and to choose any cross-disciplinary frame, one must then have a teleological research orientation. The account proposed is essentially oriented towards an educational perspective, and have preferred users such as design educators, and researchers.

Another teleological orientation must also be designed: the methodological choices must be justified in a broad sense of the term, and then, be in one hand established on philosophical and scientific ground, and in the other, be empirically sustainable and plausible. It is clear that some main design research programs are based on weak theoretical foundations even though empirically they sound justified.

Conversely this research program claims that the design research must and be obliged to construct useful links with the established scientific disciplines. It is indeed, a *sine qua non* condition of its legitimacy.

2- One of the main issues of the design process is to clarify intuitive and traditional explanations of some foundational "evidences". The first one of this auto-justified "evidences" is designing and drawing for and in the design processing. These actions and processes empirically studied constitute a main research field of design research. But again the formulation of the hypothesis which frames this mainstream of research is not sufficiently close to the design "reality" and to the intuitional claim of professionals and educators which is the ability to draw and express and form design ideas and living actual and creative design experiences.

Some classical cognitive psychology accounts in the one hand and the folk psychology intuitions and beliefs broadly accepted on the other hand have created on these issues a primitive cognitive explanation.

According to these "Cartesian like" accounts, sketching and drawing as the main design abilities are -as the other higher cognitive abilities- ordinary problem solving activities, even if they are "ill-defined"⁵: the design idea is formed in the "mind" before its "motor expression".

In this methodological construction, between the perception dimension of the cognition and the expression of the new ideas, there is a computational process in the mind.

In this linear cognitivist approach, in the brain, everything begins with the observation of the images coming from outside. This is followed by their analysis and storage. At the heart of intense philosophical debate, this approach to the process of "perception" implies the existence of a "center" for observation, then an observer (*or observer function*) in the brain. However, both philosophically and neurologically what Dan Dennett calls the Cartesian Theater is not and cannot "logically" exist (*the observer of the observer of the observer*).

Then the brain, solves the design problem, and transmit the computational resolution to the body (*the hands*) who executes. The mind and body are two different "things". The contemporary design research programs are mainly based on this weak epistemological foundations and its particular theoretical expression of functionalist cognitivist account of H. A. Simon's "problem solving" framework.

⁵ Referring to the Simonians cognitivist account.

But, the professional designers practices and the main classical (*Vitruve, Alberti*) and modern (*le Corbusier*) design theorists have noticed that the sketching and drawing are atypical processes and sketching is another type of experience than a cognitive and conscious phenomenon.

These are complex phenomena in which occur and intersect multiple cognitive corporal and emotional processes.

Understanding the creative process can not be possible by simply linear and simplistic theories.

This should and could start by a theoretical adjustment of the matter of perception. As is said earlier, this is the first objective of this paper. And it will be seen, challenging older approaches while suggesting a new theory of perception - indeed more complex and more integrated with other problems - which will form the basis of theoretical frame more "fair" explaining more phenomena.

In the neuroscientific fields, to explain the creativity phenomenon, a secondary research program occurred: creativity research program. But as Arne Dietrich⁶ explains, "much has been written about creativity from social, psychological, developmental, cognitive and historical perspectives and a number of theories have been proposed from those view-points (*Amabile, 1983; Csikszentmihalyi, 1996; Eysenck, 1993; Gardner, 1993; Gruber, 1981; Guilford, 1950; Martindale, 1995; Mednick, 1962; Simonton, 1988; Sternberg & Lubart, 1995; Ward, Smith, & Finke, 1999; Wertheimer, 1982*). (...) "However, little is known about the brain mechanisms that underlie creative thinking". (*Arne Dietrich, 2004, p. 1011*)

This is also main claim of this article. To study the design process, studying the brain and body mechanism that underlie perception, mental imagery, design drawing and sketching is essential. To study this phenomenon the dualist and functionalist/computationalist approaches have failed.

In fact in this present discussion, as defined below it is proposed to shift from a functionalist paradigm to construct a new one based on two foundations: one by taking the designers' intuitions of the "autonomous like" process of sketching as legitimate claim, and the other by looking into the contemporary neuroscientific and psychological issues on the brain mechanisms which can be involved in designing and particularly in the perception, mental imagination, sketching and drawing actions and experiences.

This study constructs a general framework to study the design, based on the accounts issued from some principles disciplines like cognitive psychology, ergonomics and cognitive psychology, (*French approach of "psychologie du travail"*), educational training theories of didactics of adult training, and semiotics (*applied to design, architecture and music*).

In this study we are completing our framework with a complementary dimension of the theoretical foundations of the design cognition and experience: functional neuroscientific accounts.

In the following part, it will be briefly exposed the main "rationale", the "whys and wherefores" of this theoretical proposition. This construction is a synthesis of several distinct accounts and proposes to assemble them in order to display a unified explanation of the perception process as a theoretical base to study the sketching and designing process. The study claims an innovative synthesis by reinterpreting some major discoveries.

Second Part

Vision and perception state of art

In this second part, it is proposed to describe this first essential facet of this thesis on new theoretical framework announced earlier: the vision and perception issues.

It is initially designed to present theories about perception as well as vision and the philosophical and scientific debates that took place in the last 40 years.

⁶ Arne Dietrich, *Introduction to consciousness*, Palgrave Macmillan, New York, 2007

As it is said at the very beginning, the problem has two interrelated dimensions, the problem of perception and vision on one hand, and cognition on the other. The theory proposed to treat one of these dimensions necessarily determines the methodology and the explanation that covers other dimensions.

So the idea put forward consists to say that the functionalist theory of cognition and computationalism necessarily implies a mechanistic approach, and therefore shows the limits of the “symbolic and informational” features assigned to the perception.

This approach widespread in the 1960s, 70s and 80s is now seriously opposed, although some disciplines and research schools, continue to refer to it, which is probably due to – the presupposed- lack of alternative.

Within this approach, perception and vision can be understood through a general and unified visual system.

The alternative thesis to these cognitive and functionalist theories of cognition, suggests more complex approaches generally incorporating the body, the emotions and the more complex vision and visual cognition systems.

In the next section, we will first discuss the historical debates, and then expose one of the most important aspects of the visual system: "natural" rights.

As this thesis is concerned by the implications of this approach in analyzing the design process, it can draw some conclusions in this field.

These discussions mainly concern the first period of establishment of cognitive sciences in the early 60s up to the late twentieth century. Behind important theoretical rivalries, they adhere to a set of metatheoretical unity that is concerned with the status of the vision in the perception and the central role of perception in mental processes. This concept of vision and perception can also be characterized by passive vision (*the attribute of the vision*) or passive explanation (*the attribute of the theory*):

"According to what may be called passive explanation, the physical stimulus induces a change in the state of sensory neurons related to cortical areas of which activation causes the perception and creation of a sensation"(41). But as Pierre Jacob said, "the study of neuroscience of vision challenges the double persistent prejudice that' (i) seeing is knowing' and'(ii) the world is revealed immediately by the vision' ".

Vision and perception

Below are some benchmarks that represent the vision-centric theories:

A first seminal case was formed by the approach called "ecological" formulated in the 60s by J. J. Gibson (*Gibson, 1979*) and then completed in the course of 70's (*Gibson 1979*).

The Gibson model proposed to insert the vision system in a functional balance of the human subject with its natural contextual needs. The gibsonian vision of vision is still the closest to the concepts that speaks of the perception to action. His model is based on the description of the balance of possibilities and abilities. This balance is modelised by the concept of “affordance”. It symbolizes the state of “equilibrium” which represents the limits of the exchanges between the environment and objects present in it and the animals. Gibson re-examines the real and relative role of the direct vision within this ecological framework and introduces the concept of perception of "proper motions" of the body as a constitutional element of “ecological system” of perception.

As part of the debate about the mental images issue, one of the above mentioned studies, the cognitivist (*Kosslyn, 1994*) school have been endorsed and reinforced with the development of functional neuroimaging techniques and have resulted in significant discoveries.

The opposing (*A.I, Fodor, Pylyshyn, Gero...*) pole was more represented by the contributions of contemporary artificial intelligence, the current and the operational cognitive psychol-

ogy, the functional and computational cognitivism.

These studies were finally freed of the initial (*simulation/human like vision or intelligence*) restrictive framework of and have established a proper way of thinking.

Architectural research and vision: theories from general cognitive accounts to the neurological frameworks

However, the question of the articulation of architectural research with scientific developments remained stalled. As this linkage did not part from "intentions" and from prevailing attitudes, architectural research remained entangled in its patterns of previous debates and discussions.

Moreover, epistemologically speaking, none of these objects of research and theories could be linked directly to the architectural research without an effort that the study named "dialogic".

For this, as said initially, a theoretical effort and a prior epistemological framework were needed. What's called the dialogic approach was to examine the field, for instance, of architectural design while observing "external" scientific developments and to seek to bring them closer, to first build bridges and then find cross reformulations.

As part of a previous work, the prior assumptions that were made to develop the theory for the process of modeling the design, has led to identify issues that current theories do not allow to grasp in a satisfactory manner.

This observation was valid in one hand for the paradigms used in research on the architectural design, and on the other, for the paradigms of the computational cognitive psychology.

So, as it has already been noted, any unified theory that could describe adequately the issues of the design process was not developed: description of perception processes, involvement of the whole body in perception, experience and phenomenology of space, the spatial experience, the mental imagery process, "mystery" of drawing and design sketches, etc.

Note that this dissatisfaction is a "scientific" dissatisfaction. It is different and not similar to "pragmatic" dissatisfaction expressed by the architecture design teachers. The dissatisfaction of architectural design teachers concerns the limitations of the design issues, theories and models of design that they "find" essentially too rigid with regard to the complexities that make up the architectural "object" and which enter into its design.

It is known that these "research objects" which the theories of design and design patterns do not capture in their entirety, are intuitively seized by teachers and are often and partially expressed, without the utilization of meta-languages.

The contemporary psychology and neurosciences made some revolutionary discoveries in this issues. From these issues, next eight points, seems -as expressed in this article- to be supporting groundbreaking explanation potentials to the design issues.

These are:

1. The new dual model of vision and perception and visual cognition,
2. The perception and action theories, multimodal body perception (*interoceptive body information*) accounts
3. The visuomotor account of the perception
4. Some aspects of mirror neuron theory
5. The perception and mental (*visual*) imagery
6. The motor imagination theory
7. The new accounts on the consciousness

8. New approaches to the creativity (*dualistic model*)
9. A new global conception of the unity of the body and the mind, and scientific and philosophical naturalization of the phenomenology

The core idea of this new theoretical approach is: putting the vision and motricity in parallel.

Main architectural issues and neurosciences accounts on these issues: a synthesis proposition

In this section it will be exposed only one of these principal accounts, particularly the first one, even though only the holistic comprehension can provide an overall framework for our 'architectural' questions: the architectonics (*the very nature of*) human perception of space, the human action on space and human scale.

In this research we refer mainly to the work of Marc Jeannerod and his colleagues, who, in the late 1980's introduce to the general human perception and vision framework, the idea of the combination of the vision with action and motricity. This line of research has become today -despite some controversy and doubts about its generalization-, "the theory" of the main feature of perception and human cognition.

In the following section will be described the main components of this approach. It will expose the components which participate to the understanding of the two main issues of the vision and the motricity in parallel: "On the one hand, seeing is connected to thinking about the world, on the other, seeing is connected to acting upon the world(...)".

"Astonishing situation": our vision of the vision is wrong

As Milner and Goodale⁷ (*Sight Unseen*, Oxford University Press, 2006) say, folk psychological vision of vision is wrong. Generalized "folk psychological" and functionalist approach is wrong because it considers the visual system and its products the "mental images" as "photographical" and passive one. In this vision our visual system is a "unitary and general purpose" system.

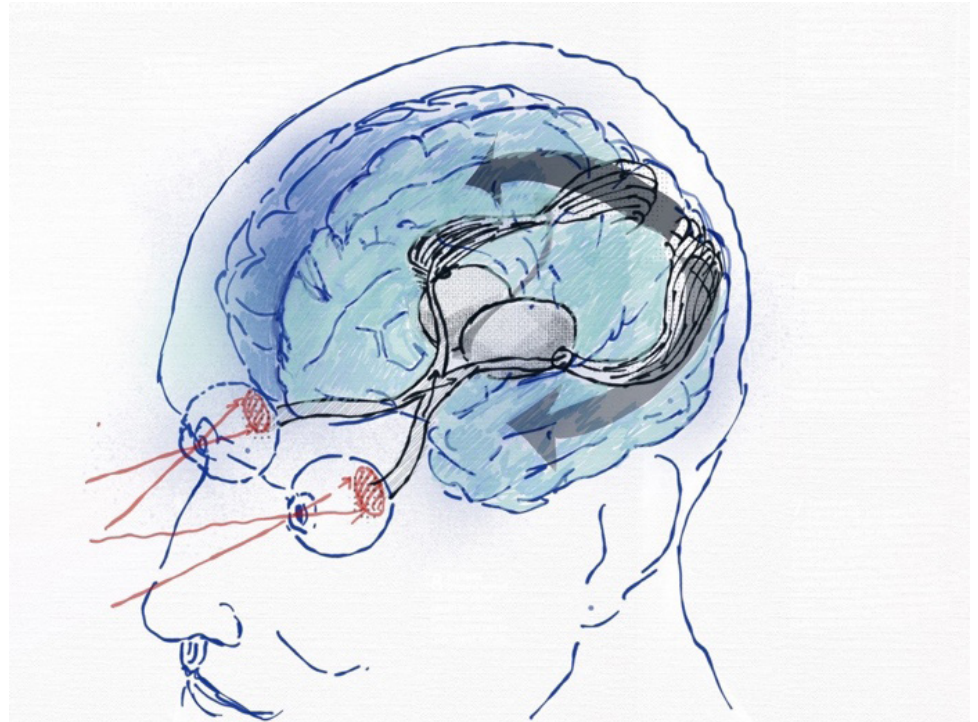
"Vision, more than any other sense, dominates our mental life. Our visual experience is so rich and detailed that we can hardly distinguish that experience from the world itself. Even when we are just thinking about the world and not looking at it directly, we cannot help imagining what it looks like (...) But where does that rich visual experience come from? Most of us have the strong impression that we are simply looking out at the world and registering what we see as if we were nothing more than a rather sophisticated camera that delivers a faithful reproduction of the world on some kind of television screen inside our heads. This idea that we have an internal picture of the world is compelling, yet it turns out to be not only misleading but fundamentally wrong..." (p.1)

Neuroscience and contemporary psychological studies made interesting discoveries that led to new theories of vision and perception. These findings based on clinical observations of impairments and the extraordinary advances in neuroimaging techniques have revealed a strong duality in our visual system.

This system can be summarized as differential treatment of the same object by the visual system. It is also called the dual system.

This differentiation seems mainly due to the characteristics and objectives of the act of vision. The human vision system (*but as also seen in other primate's visual systems*) has two types of processes revealing by the two different neural networks underlying them.

⁷ D. Milner and M. Goodale, *Sight Unseen*, Oxford University Press, 2006



What distinguishes them is essentially linked to the action and control actions on those objects observed.

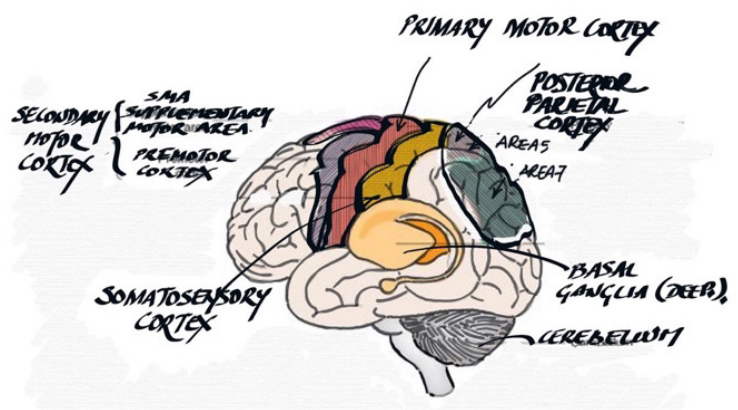
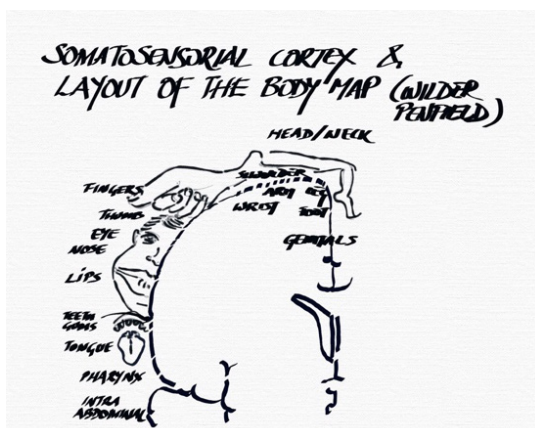
If we want to summarize we can say that in the dual system of vision, the same object (*stimulus*) gives rise to two types of representations defined according to the nature of the efficient action that can be taken on this object.

1- a perceptual visual representation -a visual percept for short-

2- and what is called 'visuomotor representations' "which are visual representations of those visual aspects of a target that are relevant to the action to be performed, resulting from "the" pragmatic processing of objects".

This second type of representation is essentially spatial and involves the neural mechanism of action. As Jeannerod says "in normal human beings, visual perception and the visual control of actions work in tandem".

Prior to going further in describing this new dual visual system hypothesis, let us go back a little to evoke the history of its discovery.



Historical background of the dual model of the human visual processing of objects

The hypothesis of the existence of two types of vision and two modes of representation in humans was first expressed in the early 20th century by the Hungarian neurologist Balint. Despite the relevance of the findings on the symptoms and illnesses he reported, his thesis did not have enough feedback in the early European ophthalmological studies which was dominated until the late 70's by a unitary visual system theory.

The contemporary discoveries have begun with the work of pioneers like Ungerleider and Mishkin who followed the path traced by Ingle (1973, 1980) on experiments on frogs in the early 1970's.

Indeed, Ingle has discovered the existence of two neural pathways in frogs and identified the existence of the path of action in the space. Later, confirmed in experiments on mice, this work was pursued by Mishkin and Ungerleider on the primates. These researchers are the first to describe these two brain pathways distinguished by their functionality: the path of "where" and the path of "what".

For the clarity of the presentation it can be said at once that, the "electro chemical impulses" which start from the retina lead first to the primary visual area on the opposite side (*occipital lobe*) and then "depart" in two different directions, one toward the temporal lobe (*called ventral pathway*) and the other above to the parietal lobe (*called dorsal pathway*). Following observations of the functionalities, the two channels give rise to two different perceptual modes of perception.

These studies have identified the anatomical nature of these two pathways. If the track of the path of so called "what", seems to belong to neural phylogenetically more recent networks (*i.e. cortical networks*), the dorsal pathway called "where" which serves to identify spatial relations, uses also some more primitive, subcortical networks.

We must recall that these two pathways and systems are neither completely independent nor conflicting but highly interdependent and interconnected. Everything seems to indicate the formation of a new set of cortical structures built on older subcortical parts.

Basically, the networks share at the beginning of the retina the same channels (*lateral geniculate body*) to reach the posterior part of the brain that houses the V1 area of vision then to separate into two streams.

For the first generation of theories (Ingle, Mishkin and Ungerleider), in view of their functions the ventral stream furnishes the features of the observed objects. This vision is called the vision for the percept (*what?*). The dorsal pathway gives to the observer the spatial representations and dimension of the objects and called for that the (*where?*) stream.

Three approaches to the dual system

The work of pioneers such as Mishkin and Ungerleider, are echoed by several research teams. This study builds on the works of two of the most important teams: The first team consists of two researchers, the Canadian Melvyn A. Goodale and Scottish A. David Milner. The second is formed by a team formed around the French neurologist Marc Jeannerod.

Within the context of this research, for theoretical reasons, the findings of the team Goodale & Milner are put between the pioneers Mishkin and Ungerleider and those Jeannerod.

To summarize it can be said that the dual system of vision is described as three different polarities these three works;

- In Mishkin & Ungerleider: "what" and "where"
- In Milner & Goodale: "vision for perception", "vision for action"
- In Jeannerod "representation for the perception", "visuomotor representations".

In the rest of this presentation of the arguments of the thesis of Jeannerod will be a little more explicit. For transition and in a first approximation we can say that it seems that the dual system of the vision proposed by Milner and Goodale limit the problematic issues to the perception, while the framework proposed by Jeannerod opens to other functions and permits the integration of the problem to other human functions.

Within the context of a broader approach of the problems that this work studies the theoretical framework which allows such articulations seem much more fruitful and useful as that proposed by Milner and Goodale.

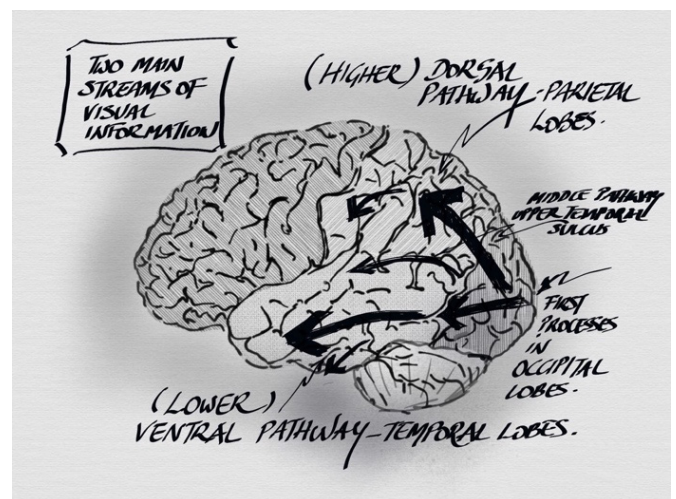
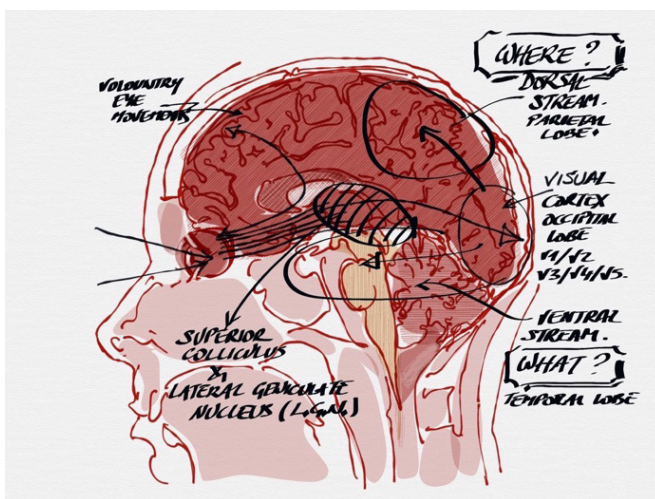
The dual system and human relationships to space and objects

For architectural research in general and the design research in particular, the interest of the theory of the dual system seems to be of primary importance. Therefore we propose an analysis of the key elements in this account - which became the dominant-. Its formed by two major neuroanatomic channels which give rise to two “different” kinds of perception. The first channel represented by the anatomical and functional features of the ventral stream, and the second by the dorsal stream realized in the parietal cortex.

The first channel and the first type of abilities: perceiving the intrinsic qualities of objects

According to the dual visual cognition system theories, the first type of vision, one that is realized in neural networks of the ventral (*temporal lobe*), gives the human subject information on the intrinsic qualities of objects (*color, texture, nature etc.*). But even if it seems astonishing, it cannot provide information about the size, spatial relationships and the environment, particularly in the view of the observer (*distance, mode of grasp, grip, seize, apprehension, usage etc.*). That is the first lesson we must take for the architectural research. The stream reaches the inferotemporal area (*TE*) and informs the human subject (*and primates*) about more complex visual properties of the observed objects.

Conversely, the second stream which uses the dorsal pathway and reach “the anterior intraparietal area (*AIP*)” of the cortex only, respond to the geometrical and spatial features of objects. We will return to its description later.



Ventral stream

The ventral stream permits the object recognition and form the percepts in pictorial like representations. “It has strong connections to the medial temporal lobe (*which stores long-term memories*), the limbic system (*which controls emotions*), and the dorsal stream (*which deals with object locations and motion*)”.

The dorsal stream

Unlike the so-called ventral pathway, the dorsal pathway that occurs in the parietal lobe, informs the human subject on the spatial coordinates, dimensions and the distance between the subject and the observer. But the observation on the deficiencies that affect this second pathway neural projections showed that the “representations” that are formed in this second type of vision are poor in intrinsic informations, specific to the object.

The first generation researchers gives to this stream two attributions by calling metaphorically “where” and “how” system. Indeed this second type of visual cognition concerns informations and their transformed representations. These transformations are about in one hand the spatial relations between the object and the subject and in the second hand and synchronically create a spatial awareness which essentially serves to the guidance of actions like reaching preparation. But unlike the perceptual sensations which occurs in the ventral stream and the phenomenological knowledges that we have (*humans*) and the natural language terms we have in our communities, to speak about them, we are not able to communicate the “sensations” and phenomenological first person experiences about this second type of “dorsal” perception phenomenon.

These transformed representations “contains a detailed map of the visual field”. They allow “detecting and analyzing movements”, they are essential for “the perception and interpretation of spatial relationships, accurate body image, and the learning of tasks involving coordination of the body in space”. The concepts “visuomotor representation” or “visuomotor transformations” introduced by Jeannerod seem theoretically the more adapted concepts to this type of “perception”.

Such informations didn’t get formed and were ignored by the ventral pathway functions. Deficiencies in the dorsal pathway do not alter the subjects’ “seeing capacities” of objects to describe them, but at the same time, also, do not allow them to seize, to obtain precise information on the dimensions of objects. They appear unable to reach or manipulate them.

Clinical observation of cases of deficiencies in the ventral stream (*which have been important discoveries such as those of Milner and Goodale*) show that, while subjects said they did not “see” the objects presented, they were able to seize them properly and to use them, avoiding obstacles, and moving in space with little difficulty.

Phenomenological issues, conscious vision versus unconscious vision

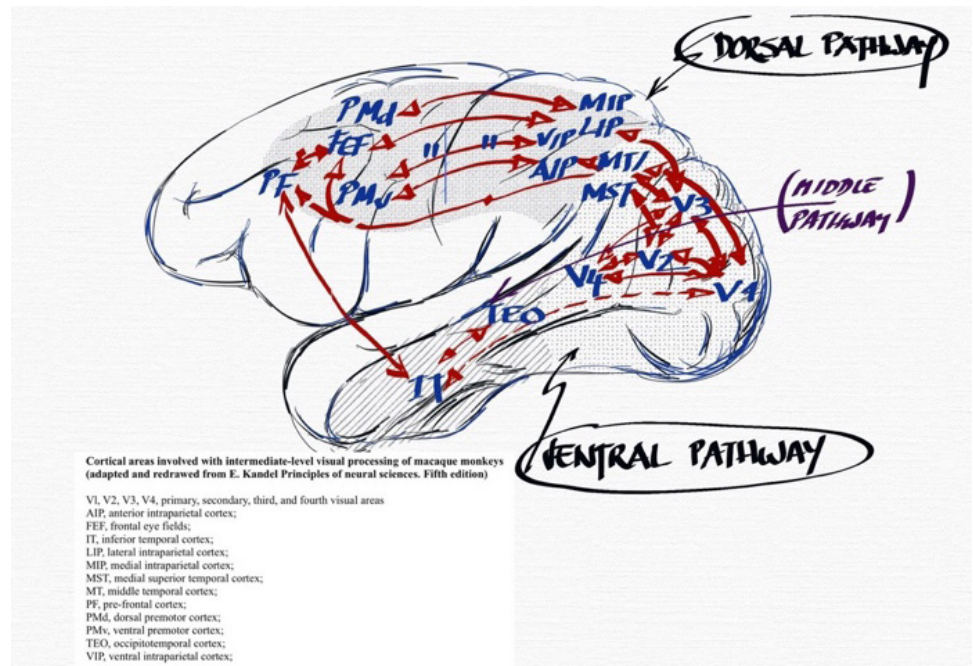
It seems important to note that both pathways and different types of representations that formed on them, are “perceived” by human subjects in radically different ways. If we can “express” on first performances using natural language terms such as “I see”, “I perceive”, it is impossible to “feel”, to be aware of the latter types of visuomotor representations, and hence name the object. They are realized internally by mobilizing internal networks that are preparing a possible action, simulate without going in action, and waiting action. The mirror neurons theory and the new type of human (*and primates*) capacities to represent external world by imitating it, especially the human movements, furnishes some comprehension elements of this type of “vision” by imitation. As Milner & Goodale say the dorsal pathway serve to “doing without seeing”.

The role of subcortical circuits (the quasi-third stream)

The problem posed by the inability to “feel” phenomenologically and “define” the visuomotor representations can be explained also by the existence of a third way. This third path traverses very different anatomical networks which use the cortical primary visual pathways (*i.e. from the retina - via the thalamus structures -to the occipital lobe (V1)*).

Instead of using this projection to the primary visual cortex (*V1*) it takes the faster path and form some short circuits through the thalamus (*pulvinar* ⁹) to finish in the parietal areas/ the dorsal circuit.

8 “The pulvinar is the largest nucleus in the thalamus, occupying two-fifths of the thalamic volume. The pulvinar plays a crucial role in attention, by contributing to the activation of neurons for the object which is at the center of visual attention, and by contributing to the deactivation of other neurons”.



Jeannerod cite to explain the existence of this stream Girard (Girard et al. 1992)

"However, the contribution of V1 to the two streams is not equivalent. Destruction or temporary inactivation of V1 completely deprives 'ventral' neurons from visual input, while 'dorsal' neurons still remain responsive. This difference can be explained by a contribution of subcortical visual pathways to the dorsal stream, not to the ventral stream (see below). Bidirectional interconnections exist between nearly all areas of the two streams. However, as stressed by Young (1992) areas in a given stream are more connected with each other than with areas outside their stream". (Jeannerod & Jacob 2003, 54)

These subcortical structures include the striatum, superior colliculus, and basal ganglia. They are phylogenetically more ancient and primitive cerebral formations. We can say that they correspond essentially to the basic anatomical structures. Thus they are destined to the immediate vital and survival needs (*environmental adaptation needs, action/reaction, emotion/fear, reaction, hunting etc.*). These anatomical structures "have created such reactive linking sensors between the inputs in the reticular formation and the projections toward premotor and motor centers of the parietal lobes".

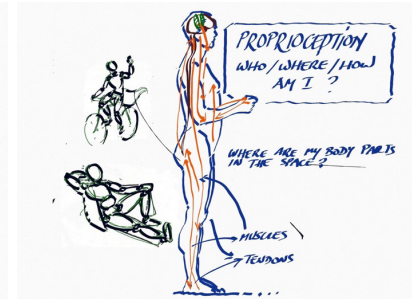
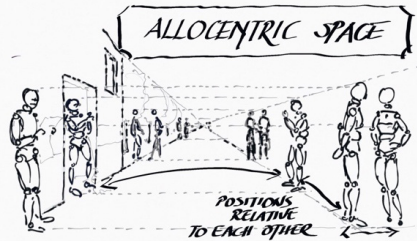
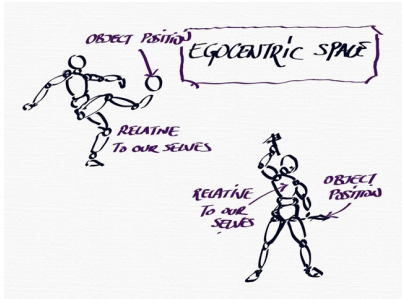
From an evolutionary point of view, -and in the time scale of the phylogenetic development- to this kind of primary structures, other subcortical and cortical layers are added successively. And now all this structure the ancient (*subcortical visual circuits*) and the new one (*cortical visual structures*) cohabits and interacts. Jeannerod says "Already at this elementary level of visual cognition, one encounters a primitive version of the opposition between visually guided actions and visual perception". (Jeannerod & Jacob 2003, 52)

The complexity of the dorsal stream some consequences and perspectives

As we have seen, the dorsal pathway appears to be more complex both on the anatomical and on the functional level than the the ventral pathway. The first of the consequences of this complexity is theoretical. It concerns the evolution of various theories of visual cognition suggesting the duality of human vision.

We found that in continuity of the work of Ingle, Ungerleider and Mishkin, the assumption of duality has reached a certain maturity in the ideas of Milner and Goodale. This account has resulted in an explanatory framework that distinguishes the vision-for-perception from the vision-for-action.

Always located in the same theoretical lineage, the work of M. Jeannerod, however, proposes an interpretation and a new framework that should be more open and less restrictive than a dual polarity. This approach starting from the same observation about the existence of two streams (*ventral and dorsal*), provides a better account which (*we believe*) permits to consider the complexity of the dorsal stream and thus the parietal lobe towards it leads and vice versa.



This approach is based on the complexity of functions that are realized in the parietal lobes. The physical limits of this paper do not allow to better develop this complexity. However if the approach of Jeannerod can be summerized, this can evoke a strong first element which is to propose a dual characteristics of dorsal stream, which opens the duality theory to a form of ternary.

The complexity of the dorsal stream: space and action

As we have noted, the various contemporary theories of dualistic vision, agree broadly on the role of the ventral (*occipito-temporal*). On the contrary, there remain gray areas and differences in the conceptualization of roles or functions that emerged from the dorsal pathway. Note that this is mainly due to the dual functions and capacity induced by the dorsal pathway passing through a portion of the parietal lobe.

If closely examined, it can be seen that the dual theories maintain a certain ambiguity on this internal complexity of features emerging in the dorsal pathway. The theses of Milner & Goodale illustrate some duality of functions that the term "vision for action" cannot express adequately.

After a closer examination, it can be seen, as pointed by Jeannerod, this second pathway called dorsal way brings out the properties and capabilities of differents natures. One concerns the spatial relationships of objects and the proximal space. The second is the transformation experienced by "inputs" to become visual representations for action. These transformations also include multiple facets. These are some of the features of objects (*dimensions, relationships, distance, etc.*), their potential use, the access problems, and reaching, etc.

Three questions raise serious problems about the the dual model formulated by Milner and Goodale:

The first concerns the "objects" of life and nature for which it is considered to be impossible to perceive through the sense of "vision for action". Jeannerod and Jacob cites as an example objects like rivers, clouds, vapors etc., which are not concerned by the second type of vision (*for action*).

The second issue raised in the work of M. Jeannerod, is the perception of "others' actions". Indeed, several studies including the discovery of mirror neurons - in the last twenty years - represent serious problems to the simplified dual model. We will have the opportunity to develop in other studies the contribution of the hypothesis of mirror neurons for a better understanding of the problem of visual cognition.

We know now that another set of parietal structures contributes specifically to the perception of biological movements and the recognition of some particular actions. "The

anatomical regions concerned with these additional properties undergo a much wider development in the human brain than in the monkey brain, due to the extension of the associative cortex in the posterior ventral part of the human parietal cortex”.

The hemispheric specialization is another important issue. For the reasons of clarity of the presentation, the issue of lateralization and hemispheric specialization has not been discussed until now. However, the problem of the complexity of the dorsal pathway is also seen in the case of lateralization of the parietal lobes and their emerging functions.

For instance, “human right parietal lobe allows new abilities in the visual perception and the representation of spatial relationships...”, and “allows for the development of new abilities in the visual perception and the representation of spatial relationships between objects as well as between the agent and the external world (...), the extension of the left parietal lobe underlies the development of new abilities for representing and imagining actions”. (Jeannerod & Jacob 2003, 104)

The third issue that seems to be the most important is also raised by the approach of Jeannerod. The question seems very relevant: The two visual functions emerging from the dorsal pathway, namely the perception of spatial relations and the visuomotor transformations are they single and superimposed or are they different mechanisms realized in the diverse anatomical sites?

The answer seems clear for Jeannerod: they are realized in different cortical modules and they seem to be two functions (*admittedly related*) but differentiated. Jeannerod says “[...] Neuro-imaging data obtained from normal subjects tend to confirm the view that the visuomotor transformation and visuospatial processing is subserved by separate mechanisms. Using experimental paradigms specifically designed for isolating visuomotor processing from the perception of spatial relationships, we can start to map the functional anatomy of the parietal lobes relevant to each processing.” (Jeannerod & Jacob 2003, 103)

"Thus neuroimaging findings are generally consistent with the clinical data, which emphasize the role of the right hemisphere in space perception and the separation between visuomotor and visuospatial processes. This is not to say that there are no functional links between the two kinds of processes. Parietal lobes play a critical role, both in the visuomotor transformation and in the perception of spatial relationships. Arguably, both the visuomotor transformation and the perception of spatial relationships between objects involve the selection and the localization of objects in space. An object can be located in space relative to other visual stimuli or relative to the agent. Thus, the parietal lobes must contribute to the process of selection and localization of objects in the workspace in both perceptual tasks and in goal-directed actions... Thus in the context of a visually guided action towards an object, the use of egocentric coordinates is central to the visuomotor transformation. The crucial point is that the transformation of coordinates is effected in the parietal areas, where not only visual, but also somatosensory cues and eye movement cues are available." (*ibidem*)

Perceiving space, objects in space... it is not what we believed... and now? ***Some temporary conclusions***

Throughout this first part of our thesis, we tried to demonstrate - by building on new knowledge allowed by neuroscience, psychology and functional brain imaging techniques - that our beliefs about the perception of space were completely inaccurate.

The multiple modes of perception, modularity of the dimensions by which the vision is realized, the distinction between "pictorial" vision and vision of the spatial relations and of the space, are of a nature to completely change our basic views on these topics, so central in the architectural design and its teaching.

We wanted to demonstrate that -as an architect and lecturer in architecture-, on basic topics our "approximations" do not allow us to base our training approaches on scientific

accounts. Although it seems strange at first, we wanted to show that even in some basic human features such as the vision and the perception of objects and space, the human functioning was not what the common sense really imagined.

As a result, it seems surprising now that we could build good training programs for architectural design on such false beliefs.

However, it seems that in the absence of a good theory of perception of space, many architects/teachers have rather listened to their intimate convictions about the corporeality of the perception of space. Thus we have seen that the perception of space was not a process of accumulation of "photographs" quasi faithful to the external world. We also saw that the perception of other people's actions and the preparation of our actions are not only cognitive processes but they were based on visuomotor transformations. These important findings thus allowed us to eliminate the primary condition of the existence of a linear process of cognitive development.

It is no longer possible to conceive the design as a process beginning with a memory having accumulated a mass of "pictographs" before incorporating them in the act of conception. Another way of conceiving the design is more than current. We must continue to seek new foundations to build further theories. The issue at this stage is to find the way to deal with this new knowledge and the means to articulate it to the old knowledge, to change and to improve it.

From the visual cognition to the mental imagery a transition and some conclusions

In this context, for additional studies concerning this issue, we propose several axes for researching and synthesis. The most important themes to tackle within the first place are:

The mental imagery and a study based on methodological implications of the theory of mirror neurons. "Mental imagery" is very closely related to the work above displayed. We believe that it is a natural extension that complements the sensory motor imagery accounts and makes them more intelligible. Now, as we know the role of mental imagery in the design process, we are confident that the contributions of neurosciences will be absolutely crucial in understanding of these processes.

The second theme, that we referred above, seems just as important as the theme of space perception and action of others. We postulate that there are strong complementarities between the theory of mirror neurons, this another major finding of neurosciences, and the questions of perception and conception of space.

This paper aims to promote further discussions on the studied subject. This work is, as we said, a first step in a multi-dimensional work. The second stage will consist of understanding the role of memory and the cerebral processes of mental imagery. It will be enhanced by studying the problem of consciousness and also the aspects of the space vision.

Globally the research approach itself as a method contributes to the architectural research by connecting it with the "established" sciences. It concerns specially, the recent development of the neurosciences and provides, for the first time, a sufficient neurophysiological explanation to help the comprehension of the space perception. These latest developments of science, give us new possibilities and paradigmatic shifts from the assumptions of the functional modularity of the brain to a holistic and simulational conception of the mind.

Given what we presented in the above discussion, we now have evidence that "man" is a measure to space by his own body which is reflected in his own brain.

This gives us a strong indication for the architectural design teaching methods and that especially in the early initiation to architecture, supporting the need to focus on exercises to practice space invested by the body, and the immediate near surrounding space. We think then, these are the new entries to the phenomenology of the architecture and thus they create a new balance between its two components: ergonomic and tectonic.●

**All illustrations belong to Ufuk Doğrusöz.*

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Useful Web Resources

- Dehaene Laboratory: INSERM-CEA Cognitive Neuroimaging Unit ([http:// www.unicog.org](http://www.unicog.org))
- Center for Educational Neuroscience ([http:// www.educationalneuroscience.org.uk/](http://www.educationalneuroscience.org.uk/)) A reference site for on-line seminars and discussion of research on neuroscience and education.
- BrainMind.com
- [Http://mitpress.mit.edu](http://mitpress.mit.edu)