Embodied Space: a Sensorial Approach to Spatial Experience

Maria João Durão

Faculty of Architecture, Lisbon Technical University
Rua de Sá Nogueira
Alto da Ajuda, Lisboa
00351916220608 ; mjdurao@fa.utl.pt

Abstract. A reflection is presented on the significance of the role of the body in the interpretation and future creation of spatial living structures. The paper draws on the body as cartography of sensorial meaning that includes vision, touch, smell, hearing, orientation and movement to discuss possible relationships with psychological and sociological parameters of 'sensorial space'. The complex dynamics of body-space is further explored from the standpoint of perceptual variables such as color, light, materialities, texture and their connections with design, technology, culture and symbology. Finally, the paper discusses the integration of knowledge and experimentation in the design of future habitats where body-sensitive frameworks encompass flexibility, communication, interaction and cognitive-driven solutions.

Keywords: Space; Architecture; Design; Body; Sensorial; Social; Materiality; Color and Light
Pacs: 87.23.Ge; 89.65._s; 89.65.Ef

INTRODUCTION

The expansion of Space exploration and the prospects for future manned missions to Moon and Mars with a consequent extension of duration of travel, places an emphasis on habitability issues that encompass the complexity of human behaviour and human-centred aspects of Space habitat design. In the domain of represented space that is apprehended through perceptual and sensorial mechanisms, mobility is the primary vector and provider of meaning. Our concept is determined by the frontalized progression of the body through space in depth. However, this is not so in microgravity where bodies inhabit space and time using a more complex scheme and range of movements. This phenomenological awareness is more evident in aerospace architecture where disorientation and destabilization of the body is accentuated.

Through the body, sensorial data and emotional response interact to create symbolic meaning that ultimately impacts the development of new spatial habitats. The creation of such 'places' requires the understanding of the human-environment interface and integration of territories that range the psychological, social, ergonomic, anthropologic, perceptual, anthropomorphic that radiate into interconnected and intra-disciplinary fields.

BODY AS CARTOGRAPHY OF SENSORIAL MEANING

'Dwelling is the essence of Being-in-the-World' maintains Heidegger (1971), so we are always in relation with things in the world, in a spatial relation characterized by an 'inconspicuous familiarity', a 'belongingness', an 'insideness' and by sensorial inputs known in the body and by the body that occupies a given place. Being - and by extension living - in a place is, therefore, possible only in material embodiment and so it is the body that connects things and places, since we are in a place through our own body. Between body and place there is much more than position, there is the data of our experience and expectations. To have a place is also to exist as a sensible body. Kant shows in his six page essay of 1768, "Ultimate ground of the differentiation of regions in space", that the

CP1103, *Space, Propulsion & Energy Sciences International Forum—SPESIF-2009,* edited by G. A. Robertson

body's role in the *implacement* of things in regions provides these things with directionality that would be inexistent if they were considered as merely occupying positions in relation to each other. Hence, without the role of the body, material entities would be *unoriented*, without the directionality of left and right, up and down, front and back. These directions taken together describe the three dimensions of space, so that in fact, the dimensionality of space follows from the directionality of the body. For space to be experienced as place, corporeal evidence and experience is required.

Body is not separate from the mind and the way the human being perceives space is interdependent on the physical structure of the body that articulates lived experience and is articulated by it dynamically: a concept that resonates in both Eastern and Western cultures. If on Earth gravity determines that orientation of our bodies is made along three axes, in microgravity the number is increased to at least six axes. Top and bottom are perceived in relation to the visual environment of shape, and when ones head is tilted, shapes continue to have the same relationship to their surroundings, since the mind takes into account changes in body position. However, when top-bottom orientation is changed, then shape perception is more affected than with the tilt of the head, or the inverted left-right mirror images. To emphasize this point one needs only to refer to the spontaneity of the perception of symmetry when it exists about a vertical axis, and is explained by biological adaptation and physiological systems which orient the body vertically. Astronaut Gibson of the Skylab 4 crew reports the appearance of the environment in space, where perceptual expectations and habits condition the perception of 'familiarity' of a space (Connors, 1985):

> "Being upside down in the wardroom made it look like a different room than what we were used to. When I started to rotate back and go approximately 45° or so off the attitude which we normally call "up," the attitude in which we had been trained, there was a very sharp transition in my mind from a room that was sort of familiar to one which was intimately familiar. It all of a sudden was a room in which we felt very much at home and comfortable with. It wasn't a gradual thing, it was a sharp transition."

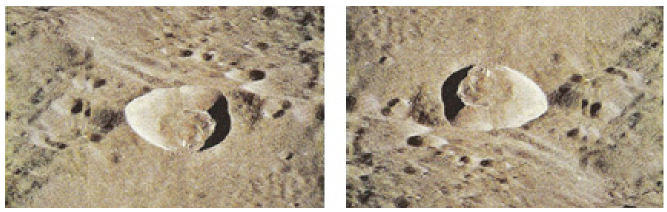
This segment of the report shows that expectations about "up" and "down" are not in accordance with orientation and perceptual experience in weightlessness and encapsulates the essential difference between the effects of gravity that relates not only to identification or legibility of settings, but also to the sense of familiarity that involves many other dimensions of the body as will be discussed later. Familiar things do not look the same when they are upside down as shown in Figure 1. We perceive and expect to see objects oriented in the usual way so that we can categorize them and compare them with what we have stored in our memory. When the world is upside down visual clues don't match. Objects that are shown upside-down are difficult to recognize. Betty Edwards illustrates this difficulty using the famous photograph of Albert Einstein with her drawing students and finds that by printing the image upside down makes identification more difficult.

(a) (b)

FIGURE 1. Body orientation: (a) Aleksei Leonov and Deke Slayton during Apollo-Soyuz and (b) Crew on board the ISS Spacelab

In weightlessness, an ungrounded three-dimensional space is the result of unfamiliarity and consequently normal frames of reference are fundamentally disturbed on a very basic level of space readability or, adopting Kevin Lynch's (1960) terminology, its "legibility", a term that describes the parts of a scene that can be organized into a coherent pattern. Living in space depends on the ability to perceive form, depth or motion, and since our perception assigns coordinates of top, bottom, sides, when the orientation of these coordinates changes, even very familiar shapes can become problematic. Changes in the orientation of a shape will alter our perception of it, for example orientation can determine if what you see is a square or a diamond. Furthermore, when a three-dimensional object is illuminated by a light source, different parts of its surface reflect different amounts of light depending on the angle of the light hitting them. Our visual system assumes that light comes from above and conditions our perception of light and shadow, so the crater is concave shaped and dented inward on Figure 2 (left) while by inverting the same image on the right hand side of Figure 2, the convex shape is bulging out – a crater turning into a hill.

Some space travellers have experienced considerable difficulty in trying to orient themselves in the absence of the familiar cues of gravity, showing a clear preference for rooms with a defined "up" and "down". Connors (1985) questions whether space travellers are able to acclimate with time or familiarity to a directionless world concluding that if their need for a directional orientation persists, then not all surfaces in the spacecraft can be made equally usable.



(a) (b)

FIGURE 2. Moon surface – shadows as cue for depth: (a) as crater and concave shape and (b) the image inverted where the depression becomes a hill and convex shape

A Soyuz 38 cosmonaut reported that use of the Cuban boots reduced the severity of spatial illusions and motor disturbances, phenomena thought to be produced by conditions which also produce motion sickness. These specially designed boots, named after the Cuban cosmonaut Arnaldo Mendez who tested the prototype create a pressure of up to 60 torr to the bottom of the feet, making the cosmonaut feel that he is standing on ground and works as a compensatory mechanism to simulate 1 g conditions (Connors, 1985). Tactile experiences also create intimacy and interaction with space and develop a sense of belongingness. The tactile sense and the visual experience are closely interwoven and as experiments into sensorial deprivation have shown, even though we can temporarily disconnect from sight, odours, tastes or even sound, we can never be free from tactile sensation for we have always the pressure of our body on a surface.

Vision and the tactile sense are fundamental for spatial perception In fact; Plato and Aristotle began by confronting the visual and the tactile to arrive at the differences in their philosophical perspectives. To Plato, vision is the greatest gift to the extent that the universal concepts were accessible to the "minds eye" and the Aristotelian *Metaphysics* approximates vision and the intellect even more. In the Renaissance, the recovering of Greek thought complemented with the invention of representation in perspective, put vision in the centre of the perceptual realm and on the top of the hierarchical system of the senses. With the modern philosophical and scientific thought of the seventeenth century, Descartes equated vision and touch, a sense that he believed to be less vulnerable to error than vision, but the latter was still the most universal and noble of the senses. As today, Berkeley's (1934) theories of vision of 1733, maintained as irrefutable that the cooperation of haptic memory is necessary to the visual apprehension of matter, distance and spatial depth. However, the apprehension of architectural space involves the body as a whole. Merleau-Ponty (1962) explores a very ancient image of the importance of touch and brings it to the realm of phenomenology: that all senses are 'touched' in the act of perception. To see the stars and the sun is to touch them with the eyes, but for the eyes to see they also need to be touched by light. Similarly, touch is involved in the other senses, to smell is to touch with the nose, and so forth.

Color can link groups of structural components, spatial elements, furnishings and act as an element of organization and that enhances the readability of a space and therefore is used for operational and safety purposes to signal, enhance or identify equipment. As for spatial orientation, a more immediate use consists of identifying the typology of a room through color providing spatial orientation and direction cues central in weightlessness (Durão, 2002, 2003 and 2005). A certain color impression not only evokes a momentarily visual sensation, it also involves our entire experience, memory and thought process and appeals not only to the sense of sight but, by synaesthetic association, also to other senses such as temperature, hearing, touch, taste and smell.

Skylab astronauts reported the need to differentiate colors of small objects to better recognize flying items inside the spacecraft, and that the sameness of color was disturbing. In Salyut 6 a color scheme of soft pastels was used to create a comforting atmosphere and in Salyut 7 these were replaced by a right–left color distinction. Color schemes could be explored with different hues varying in chromatic strength and lightness, combined with the study of simultaneous and successive contrast. Research of this nature would create the opportunity to explore the aesthetic qualities of color contrasts as well as their ability to provide spatial orientation (Wise and Wise, 1988).

Smell is arguably the most subtle and powerful sense in its potential for emotional impact on very deep memory layers. Smells define our experience of space in unconscious ways and can be used to model architecture. Early Indian temples were built from sandalwood and in Babylon perfume was added to the mortar and used in temples to lift spiritually. Nowadays, software air handling systems generate smell, so that olfactory ambiences vary in response to the needs and even discover new ones to expand the existing aromatic palette.

When there is withdrawal of stimulation or excess of it, sensory deprivation occurs and can be injurious to the human organism since the brain needs constantly variation of stimulation. The lack of natural references, coupled with sensory deprivation felt over a long period may lead to depression and tension and other symptoms of psychological order. In extreme environments, stimulation on a sensorial level is fundamental for the well - being of the crew.

The orientation in terms of time and place is another significant aspect for astronauts and these clues are given by season cycles, weather changes, smell of nature in its multiple variations, all of which are absent.

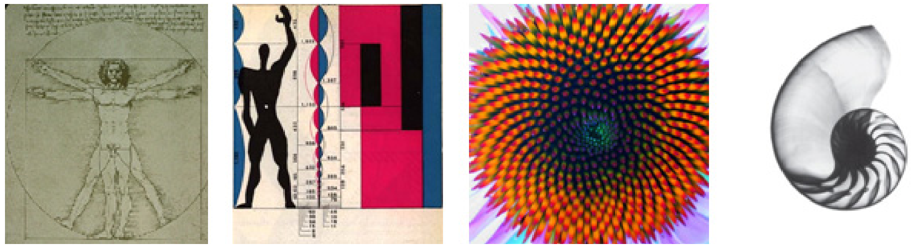
Changing conditions of light during the day and variation including the playful and surprise situations create positive stimuli. To counteract physical enclosure, architecture can operate mechanisms such as lighting systems that change intensity and color to simulate the cycles of the sun, use virtual technologies to bring the outside in - the surrounding outer space - and natural elements of Earth, including water and plants. On the other hand, the contemplation of art in its multiple forms as well as its practice nourishes the symbolic structures of the brain.

Our relationship with spatial settings is by no means confined to the volume occupied by our bodies. Psychological space shrinks and expands: it grows when confined in small spaces and diminishes within vast spaces such as auditoria or cathedrals. Important to take into account as well is that we envisage shape in the mind's eye which includes the parts that we can not readily perceive. The human being is distinguished from the other animals by the capacity of reflection and quality of human emotion and draws meanings from the body and mind but also from the experience of place in an interactive way: the whole environment influences the perception we have of it and in turn, we also influence the environment in a continuously dynamic interaction.

IMAGINATION, FLEXIBILITY AND SELF-PROJECTION OF THE BODY

The requirement of mobility is driving construction to lighter volumes and minimum storage. An interactive environment in the space habitat opens up possibilities for the environment to adapt to the activities of the astronauts and vice-versa, demanding radical changes to the way space habitats are perceived and designed.

Mobile and interchangeable design elements provide variety and multiple functions with sensorial characteristics that are recognizable in terms of coding and orientation cues. The kinesthetic sense is enhanced by color dynamics and contrast in space and in spatial contexts, which also applies to flexible arrangements and furnishings that promote movement and social dynamics. Examples of this include furnishings in aerogel attached to surfaces with velcroed joins; soft rubber inflated ergonomic restraints for anchorage and circulation; soft materials (rubber, elastomers, nylons) for protection of the body from edges; round and soft shapes; colors, textures and materiality according to function and intended mood.



(a) (b) (c) (d)

FIGURE 3. The measures of the Vitruvian body proportioned according to the noble ratio of the golden section and *phi* in: (a) Leonardo's depiction, (b) Corbusier's architectural measures, (c) a sunflower and (d) a nautilus shell.

Soft and pliable inflatable structures contrast with hard, rectangular structures and have similarities to natural organisms. They appeal to our senses and evoke feelings of harmony and comfort. The same phenomenon takes place with the measures of the Vitruvian body that decide the primary dimensions of architectural space and is proportioned according to the noble ratio of the golden section, the Fibonacci series and the number *phi* that is found in nature down as shown in Figure 3. Curvilinear structures and forms are said to produce different subtle energy resonances and according to ecological designer Victor Papanek, various sensory and subconscious triggers released by such structures flood our minds with a sense of joy and well-being. The flexible curve was used by Kiesler in his Endless House. He wanted it to appeal to deep structures of memory, to an umbical space or womb, so instead of using the rectangular, cubical, rectilinear or vertical lines; he used parabolic curves, twisted turns and spheroid curvatures.

Flexibility is a property: there are flexible elements in the traditional Japanese house where there is a fluid interaction between the interior and exterior, elements that dissolve, delimitate or orient in interior space.

Doors and windows are passages that provide communication. A window is also a vehicle of light coming from the exterior and inside windows connect private and public spaces and have great potential for creating new design concepts. However, doors and windows have other functions that protect from sound or light and it is motion that continuously redefines the boundaries between interior and exterior. Objects that are flexible in their structure, because they rotate, pivot, slide or fold, allow the user to manipulate the design outcomes. Besides providing variety, they economise space and permeate different functions and activities, and therefore flexibility.

Since each individual has the desire to communicate and socialize and, simultaneously, the desire for privacy, meditation and individuality, flexibility allows for permeable boundaries between the concepts of interior and exterior. Internal spaces are influenced from forces outside of their control and deterritorialisation unifies a shifting interior by internalizing external forces. While maximizing utility by creating multi-functional spaces and offering stimulation, choice and control, the body adopts an active posture towards the environment.

(a) (b) (c)

FIGURE 4. The body's relationship with Earth: (a) Earth rise – photographed from the Moon; (b) On the final EVA of the STS -61 mission; (c) Astronaut Helms looking out the window of the International Space Station

Raymond Loewy's conquest of 'a window' in the first American Space Station Skylab proved to be one of the most significant design implementations in terms of psychological response of the crew. According to astronauts with a prolonged stay on space stations, viewing Earth from the window has a very profound significance because in this process a sensorial connection is made to the place where we all belong –our blue planet. It also serves as point of reference for measuring relative distance and size and provides a sense of control down as shown in Figure 4. Looking out is an activity that induces self-reflection and self-projection and allows the body to perform ritualistically.

THE BODY IN DISPLACEMENT AND THE SPACE OF FLOWS

A planetary base on the Moon or Mars is essential for future development and exploration of space. This future habitat is the container of the most complex human and technological activities, so the new technologies and architectural concepts are expected to originate environments that respond to the complexities of the missions. New ways of conceptualizing space and spatial relationships will integrate global/local networks of digital communication that have become the backbone of our organizations, economy, media, political and social interaction. This means that the organization of simultaneity of shared practices can be performed by networks of instant interaction - *a space of flows- a*s Manel Castells (Mateo, 2007) characterizes it. The space of flows results from combining different places between which flows circulate, comprising specific places and transportation as well as flows of information, that constantly circulate in these systems of communication.

If, to Kant, orientation required the interpretation of a sense of direction that results from a synthesis of the body and the local cues, Deleuze and Guattari (1987) point to a new connection between body and place, a connection that is specific to being in smooth place. The result is a form of dwelling that is dissociated from the paradigm of the settled, the built places. This perceptual map offers a perceptual *displacement* based on concepts of distance, electronically expanded by radio, telephone, television, video, internet and new media.

Concepts of simultaneity, continuity and interaction refer to spatial and temporal structures with mobility as one of the aspects related to space-time. Places are increasingly mobile and the means of communication makes the world increasingly open and global so that we can be in various places at the same time. Physically we are in one place at a time but we can experience simultaneity of events from a single point in space and time.

On the plane of the imagination we have always been able to travel anywhere, our bodies dislocated from space and time. This happens with the new media of communication that cross the existing physical limitations in a transmutation to the virtual space, a new sense of space that is linked to motion and dislocation. The resulting place is decondensed and desedimented by the structure that makes it an event. It is a “place without place” claims Derrida.

HUMAN BODY AND BUILDING BODY

The knowledge of the environment is based on awareness, experience and understanding and in the active creation of meanings, a process bound in space and time. An existence that may be material or imaginary is defined by relationships of object systems and of actions with fixed and changeable elements, so that place as identity and social construct is based on reciprocity and symbolic interactionism, that is the basis of Norberg-Schulz’s (1979) *genius loci*.

Architecture has always integrated the technological advancements of each civilization in its respective time, reflecting the underlying social structure and philosophy which is what grounds the *genius loci*. This will also extend to the architectural conception for space habitats, but requires a conceptual shift from using technology in space to a dynamically flexible technological space that communicates through a body-sensitive framework.

An interpersonal communication system based on virtual reality can change the perception of a physical space. This can be achieved using a skin with LED and LCD panels to transform it entirely and enact a real time communication habitat and that enables the entry to a global society. The Space Station Module by Oosterhuis (2002) down, as shown in Figure 5, has an interior skin - regarded as a flexible membrane - with the capacity to be adjusted by the astronauts. Each change is calculated in real-time by a computer programme that sends fresh data to pneumatic cylinders and orders them to adjust their lengths. The separate panels form an overall image or text where facts and figures are projected through the LCD panels immersed in the flexible skin. The active data-driven structure works like a bundle of muscles that contracts or relaxes according to the instructions of the brain. Communication between the crew and the ship could lead to continuous alterations of settings, moods and atmospheres.

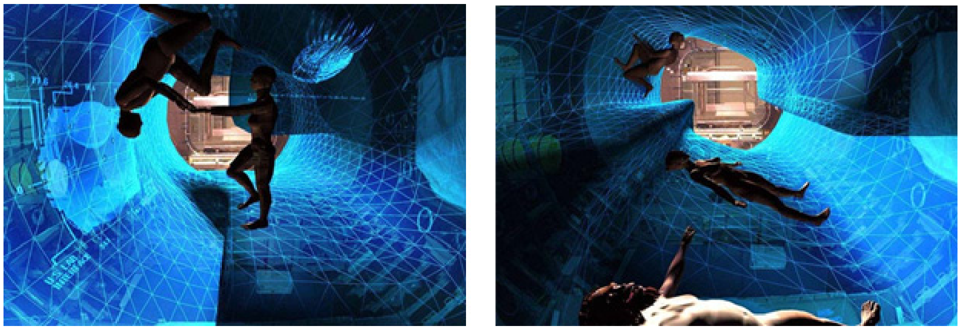


FIGURE 5. Space Station Module by Oosterhuis (2002)

In long-duration spaceflight sensory deprivation is the main psychological problem, coupled with the feeling of isolation, claustrophobia, and depression. In order to minimize these effects, a cognitive-driven architecture could react to an "expert system", interactively exchanging information between the human body and the building body. For instance in a spaceship, the absence of external influences, such as time, weather, day and night would be reinterpreted and incorporated into the technology of the space habitat. This technology explores the integration of body-intuitive interfaces and produces typologies of environments according to the existing needs: text environment or an image-cave with a relaxing or playful environment. We know that the way we walk through a space has potential to influence the mood of a space, but Nox Saltwater pavilion is the first true body building to display real-time behaviour. It is conceived like a "unicellular organism" in which the individual bears the information for the body is generated in the weightlessness digital realm. The pavilion is embedded in an artificial island on Earth and captures raw data from a weather station on a buoy in the sea and transcribes the data into an emotional factor that then translates into changing sound and light from multicolored fibre optic cables that illuminate the Sensorium from behind the polycarbonate skin.

These virtual realities or artificial atmospheres, revolutionize our perception of reality, expanding and assuming the form of a flow continually variable Steele (2001). The immaterial spaces interpenetrate or overlap creating graphically visible, perceptible and sensitive nets as energy flows of the space media or the incorporeal space of art. This recreation and structural force that rises as frontier with the unknown, as a new limit, takes us to a kind of space experimentation intimately related with the body and interconnects the body, concepts of reality and the imagination.

CONCLUSION

Our apprehension of any space is based on perceptual and sensorial data, where different systems of signs co-exist and establish dialogues following from the verification that bodies relate to matter by acting upon it but also by being the subject of its action. Body and space constitute dynamic systems that are interrelated in the overarching domains of the biological and environmental and share such terminology that ranges biologic features to architectural qualities, as in the case of 'cellular', 'skin', 'pneumatic', 'muscle', 'brain', 'skeleton', 'cavity', 'membrane', 'organism'. This affiliation with nature is paralleled to the adoption of behaviour from other bodies, and their implementation into another technology a practice that is not new: the Chinese wanted to make artificial silk 2000 years ago and Leonardo da Vinci wanted to fly 400 years. Learning from the behaviour solutions of the body, whether the human, that of animals or plants, interests scientists, architects and engineers and is explored in the field known as bionics and biomimetics.

Besides functional implications, symbolic meanings should be considered when dealing with tangible and intangible cultural forms in environments that need to create a space for continuous innovation and emotionally spontaneous response- a place to live in. Through the senses, our bodies seek harmony and beauty and since architecture provokes an emotional reaction that influences our body, space must be designed to allow emotional and aesthetic occupation. In Space, behaviour is conditioned by differences with Earth on such levels as time cycles, lighting, atmospheric conditions, temperature, sound, notion of distance, smell, texture, enclosure, orientation, all aspects that have an impact on comfort and well-being. The characteristics that are unique to living in Space represent the basis for the exploration of new paradigms that, in accordance to spatial environmental factors and mission objectives, and create a challenge for the architect's creative imagination to experiment with new concepts of architecture.

REFERENCES

Connors, M. M., "Living Aloft," NASA Scientific and Technical Information Branch, NASA SP, 483, (1985).

Deleuze G., and Guattari, F., *A thousand plateaus.* University of Minnesota Press, Minneapolis, (1987).

Durão, M. J., "Color in Space Architecture" Proceedings of the *World Space Congress*, edited by *American Institute of Aeronautics and Astronautics,* Reston, Virginia, AIAA-2002-6107, (2002).

Durão, M. J., and Favata, P., "Color Considerations for the Design of Space Habitats," in the proceedings of *SPACE-2003*, edited by AIAA, Reston, Virginia, AIAA-2003-6350, (2003).

Durão, M. J., "Research on Colour for Aerospace Architecture," in the proceedings book of the *10th Congress of the International Association,* edited by Nieves J. L. & Hernández-Andrés J., AIC Colour 05 Proceedings, Granada, (2005), pp. 8-13.

Heidegger, M., "Building, Dwelling, Thinking," in *Poetry, Language and Thought,* edited by Harper & Row, New York, (1971).

Lynch, K., *The Image of the City*, edited by MIT Press, Cambridge Massachusetts, (1960).

Mateo, J. L., *Natural Metaphor: An Anthology of Essays on Architecture and Nature,* edited by ETH Swiss Federal Institute of Technology Zurich, Zurich, (2007).

Merleau-Ponty, M., *Phenomenology of Perception*, edited by Routledge & Kegan Paul, London and N. Y., (1962).

Norberg-Schulz, C., G*enius Loci*, Electa, Milan, (1979).

Oosterhuis, K., *Architecture Goes Wild*, 010 Publishers, Rotterdam, (2002).

Steele, J., *Architecture and computers – action and reaction in digital design revolution*, Laurance King, London, (2001).

Wise B. K. and Wise, J. A., "The Human Factors of Colors in Environmental Design: A Critical Review," NASA Contractor Report 177498, under Contract NCC22-404, (1988).