Pers Ubiquit Comput (2011) 15:491–496
DOI 10.1007/s00779-010-0324-6

ORIGINAL ARTICLE

Space anthropology: physical and cultural adaptation in outer space

Melchiorre Masali · Marinella Ferrino · Monica Argenta · Franca Ligabue Stricker

Received: 1 October 2008 / Accepted: 1 October 2009 / Published online: 22 July 2010

Abstract Humans are the product of biologic and cultural adaptation to our Planet achieved over million years of Primates and Hominids species evolution which has led us to a specific development of intelligence, speech, and manual capability. Interface usability mainly depends on human characteristics that are also modified by variations in the environment. In outer space, body shapes may be different, things may not be in the expected place and models of conventional social relationships may be hardly transferred to prolonged missions. The process known as *exaptation*, according to which traits developed by a species as a response to a specific need are later "recycled" with new functions in a different environment, will be considered. Biologic and cultural built-in mechanisms belonging to our past cannot be left out in the analysis of design and man–machine interface in the Outer Space.

M. Masali (✉)
Torino University, Via. G. Servais 200/E8,
10146 Turin, Italy
e-mail: melchiorre.masali@gmail.com
URL: http://www.extreme-design.eu

M. Ferrino
Thales Alenia Space Italia, Alenia Spazio S.p.A,
Strada Antica di Collegno 253, 10146 Turin, Italy
e-mail: marinella.ferrino@thalesaleniaspace.com

M. Argenta
Freelance, Belluno, Italy
e-mail: ponidora@gmail.com

F. L. Stricker
Faculty of Sciences, Turin University,
Turin, Italy
e-mail: franca.ligabue@unito.it

1 Introduction

Living in the Outer Space has recently inspired a vast literature in the fields of both physical and cultural Anthropology. As mankind is facing peculiar environmental conditions affecting locomotion, working capabilities and general living, new forms of biologic and socio-cultural adaptation are likely to occur. This represents a big challenge for the studies of our species. Since good interior design and interface usability also depend on human characteristics that are modified by variations in the environment, the urge to rethink the whole concept of human "well-being" is felt.

In a spacecraft, body shapes are different, reflecting not only the variability of human populations but also of physiologic changes. Everyday objects, such as laptops or simple toothbrushes, may not be found in the expected place due to the lack of "up-and-down" references. During extremely long space missions or settlements, social relationships are most likely to develop into new solutions, as it happened among the seventeenth century Caribbean Buccaneers when the institution of the "matelotage" used to bring together two heterosexual men in a sort of marriage bond. Concepts such as power and gender, strictly linked to the human bodies and their symbolic and physical functions, are going to change in a place where gravity may be absent, distorted by centrifuge or weakly produced by constant acceleration engines.

Gravitation is the most stable environmental factor on Earth and all the evolution history of the living beings involves a positive adaptation to it. Furthermore, upright

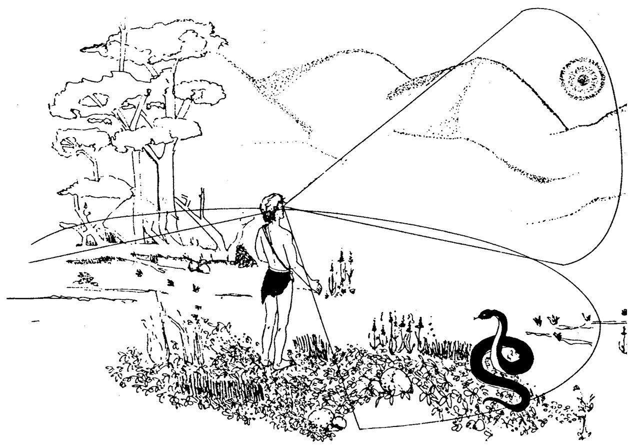

Fig. 1 Vestibular versus Frankfurt plane head and visual orientation (courtesy of E. Masali)

walking Hominids are a typical product of a gravitational adaptation by antagonism.

2 Adaptation to microgravity and evolution theory

Zero gravity, Moon gravity, and solar system Planets and Moons hypo- and hyper-gravities are conditions never experienced by terrestrial organisms except, perhaps, microorganisms dispersed in the space by the solar wind. So, how may adaptation occur, according to the current evolution doctrine? In Space Anthropology, the time available for adaptation is insignificant compared to millenniums and the process of adaptation can be only found in the domain of *Exaptation* [11].[1] In simpler words, this means that the "archetype" structures developed by an organism for a specific need are required by the new environment to evolve into new functions.

Body movement, orientation, and posture are stoutly influenced by gravity that acts on the "vestibular apparatus[2]" of the inner ear first and foremost represented by the ampoule and semicircular canals. The system is silent in microgravity steady and uniform motion conditions, but reacts to linear and angular inertial variations (Fig. 1).

We shall consider the orientation of the sight line to understand our body shape and comprehend the deep changes that the microgravity human–environment interaction may encompass.

On Earth the sight line drops 25–30° down in respect of the *Frankfurt horizontal Plane*.[3] Humans look about five meters away on the ground to see way ahead and avoid obstacles and perils. According to the studies of Napier and Napier [19] confirming the hypotheses of Delattre and Fenart [4, 5], the process started about 65 million years ago with our tree-dwelling, upright forest ancestors who were clingers like most of modern Lemurs. They may have been also 0g ballistic leapers, at least in agreement to what we recognized with a little bit of imagination, as a proper comparative model[4] to the zero gravity behavior on board of spacecrafts [10, 15].

In an evolutionary frame, the bipedal upright posture means an extraordinary conflict of temporal bone that contains the stably oriented equilibrium organ with the rotation of the *basicranium* (skull base) and the up righting of the backbone. According to Delattre and coworkers [5], a positive effect of this process was the *hominisation* (becoming Man) of the head giving rise to a bigger brain and a bent pharynx, allowing for the development of intelligence and speech. The rotation of the body axis in respect of gravity vector direction led to a "*gravitational revolution*" for mankind and we perceive those in space to be undergoing of a second "revolution" in which microgravity plays the dominant role [15].

In 0g environments, where our vestibular and self-perceptive systems are defective, auditory, visual, and tactile responses become extremely important in the attempt to assess how our body is positioned in space. Vision, in particular, becomes of paramount importance.

3 Human body shape, size, and microgravity

Body shape, according to D'Arcy Thompson (1917, [3]), depends on the interaction of the body itself to the surrounding physical world: "*As Nature operates respecting the proportions, all things have their correct measure*". In the past Marcus Vitruvius Pollio and Leonardo da Vinci used geometric grids based on the ancient Greek canons to obtain measurements and proportions for painting, sculpture and design.[5] These canons, however, are simply a *ludus geometricus*, an amusement of square and compasses, lines and circles, as in Dürer and in Le Corbusier "Modulor": gorgeous art works, perfect proportions, but definitely not a biologic reality. Man has no predefined

[1] (from Latin ex = previous and aptus = adapted, able to).

[2] Reconsidering the studies of Delattre and Fenart [5] about the function of the "vestibular plane" generated by the slope of the so called "horizontal canal" [16, 17] as a stabilizing factor of head orientation (something like a gyroscope) playing a paramount role in the process of acquiring an upright posture of Hominids (*Australopithecus* sp., *Homo* sp.).

[3] (Ohr-Augen-Ebene (OAE) or Frankfurter Verständigung 1884: The head posture of Man that looks at the horizon in the classic view of the anthropological tradition).

[4] Referring as a model to *Propithecus* a living Madagascar Lemur.

[5] Ancient Greek: *οργνα* the measure of the extended arms divided in eight feet.

structure or form; there is no archetypal Plato's Hyperuranium which gives a body its proportions. (Fig. 2)

Body size can only be drawn from an anthropometric survey. Although scarcely known, *Anthropometry is* the *Measure of Man,* a branch of Physical Anthropology, a field which has produced a series of useful inputs for ergonomic design. It provides both a wide base of knowledge about the characteristics of Man and the methodologies for the quantitative definition of human traits functional to the design of the man–machine–environment interface. In countries where Ergonomics has a long and rich history, this role is clearly recognized. For instance, Hutchinson [13] states that "physical anthropologists are providing data on the worker's body, reach profiles, and viewing angles and limits that have implications for establishing dimensions of the workplace, for example, work surface height, knee clearances and seat design" (Fig. 3).

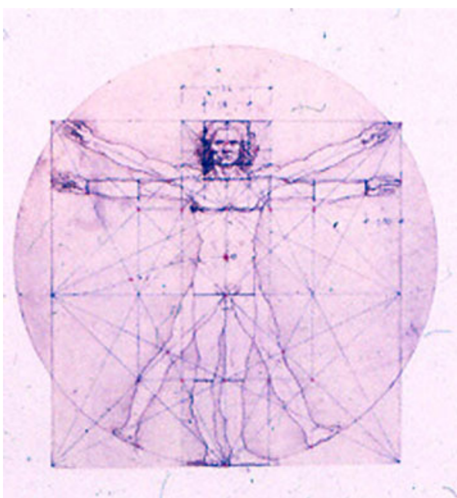

Fig. 2 Leonardo's "homo quadratus" with superimposed the praxis of square subdivision [14]

Fig. 3 Weightless Neutral Body Position (courtesy of ESA—Novaespace)

Nevertheless the human body, as all living beings, is not the outcome of a drawing board blueprint, but the result of a natural process. In earthly gravity, a healthy person will reach his own predictable dimension and shape through a growth process regulated by genetic heritage, orthostatic mechanisms, bone–muscle strength interaction, and self-perception, visual and vestibular reflexes. Ethnic cranial deformation practices [21], environmental stimuli, such as touch early in life which increases growth, or a biologic stimulus, such as in certain forms of mental retardation in which growth regulators fail to appear in certain brain regions, affects the proper development of brain localization may be significant examples of the body's flexibility to environmental natural and artificial stress. Furthermore, the consequence of pathologies like Polio may be taken as models of microgravity effects on unstressed bones and muscles (Yanongo [18, 22]). Keeping the healthy body shape of adults is quite a medical and kinesiological challenge! The well-known neutral posture in 0g is certainly not a pathological condition and its effects may be fully reversible, but generates a distorted relationship among the bodily geometry, such as between the expected position of the hands and sight line as in the case of the use of a laptop computer (Fig. 4).

4 Microgravity human centered design: an experience

Developing technologies in microgravity lead researchers toward new ways of working which may provide the basis for studies into the relationship between human strategies using space and environment. The purpose is to provide a conceptual approach, a way of thinking about the problem which will allow further investigation of these central but relatively neglected aspects of man–environment interaction. The scope is to create a work and living place with respect to the changing individual, social and atmosphere contexts.

In our experience, two different approaches were followed: the first is "object oriented", based on Video Data supported by Proxemic methods [12, 20] targeted to a flexible and adaptive design solution. The second is "subject oriented", based on Virtual Reality Environment that allows for evaluating human perception and cognitive aspects related to a specific task. These data may be correlated to the real human perception in space, in order to define a set of methodological guidelines to orient the Design Project.

- Proxemic parameters (body and head reciprocal position and orientation of between interacting subjects head distance; sociopetal/sociofugal axes orientation) in on-place activities and in displacement interpersonal actions.
- Dyadic/group interaction (2 or more subjects interacting in 0g body orientation such as “traditional” and “upside-down” interaction) and single and dyadic behavior in absence of Up Down Spatial Reference Coordinates.

A laptop computer environment has been selected as a typical case study. This case study has been selected considering the present evolution in the Human Computer Interaction and digital environment trend. Other scenario, may be on-board experiment, is designed to be mostly supported by already available on-board equipment as well as it is foreseen a limited utilization of crew time.

Therefore, time, space, social roles, and task typologies need dedicated tools to define a new index of socialization and comfort to orient innovative design concepts. A comparison was made between the “neutral body posture” as a natural and adaptive posture on orbit and the body postures which astronauts actually assumed in microgravity working on Laptop. (Burzio et al. 2002).

From this point of view it seems important to redesign habitability criteria versus future conceptual design starting from the real needs and life conditions living in extreme environment thinking that as E. T. Hall said “Cultures won’t change unless everyone changes. There are neurologic, biologic, economic, historic and culture psycho dynamic reason for this”.

In view to elucidate a human factor multi-disciplined approach to this kind of query, an attempt was planned to define usability guidelines to orient new design solutions for living and working in the microgravity environment of Outer Space [1, 2]. The study was conducted considering a device, a laptop computer in this case, that surely goes along with an astronaut as it contains its operational pre-flight, in-flight and after-flight memory (Fig. 5).

Such computers have a keyboard/monitor opening angle that should be a function of the space environment where the astronaut decides or is constrained to operate. The human interacting posture and position is constrained either by an unconventional workplace or by the way the notebook is positioned. In production notebooks conceived for the 1g environment, the display unit opening angle has a range commonly between 0 and 180° which seems an unnecessary constraint for computers used in outer space. A simple widening of this angular range was one of the main recommendations proposed to allow for keyboard-display relationships which may seem very unconventional on Earth, but would be comfortable when the hand–eye link is distorted by weightlessness as body shape is changed by neutral posture, so the hands may not be where expected (Fig. 6).

5 Concluding remarks

With a subject-oriented approach, the main ergonomic query was to demonstrate in-flight postural strategies that would spontaneously solve both the environment and interface boundaries with a focus on interface constraints in particular. The main constraints are related to the severe difference between the expected 1g posture and the real 0g neutral posture. The neutral posture adopted by humans in space offers a range of new body movements, gestures as well as repositioning of the body in unexpected manners defining a different workspace envelope. It is therefore necessary to identify the new postural parameters, postural coordinates and their relationship within the man–object interface (ergonomic approach) as well as the interpersonal relationship of those working together in zero gravity field (proxemic approach).

The initial step was to describe the human-centered guidelines aimed to define the design variables for usability in 0g conditions. The relationship focuses on Space environment, positioning of the layout such as the keyboard,

Fig. 4 0g parabolic flight 5th ♀–95th ♂ European percentile interaction in physical exercises during ESA CROMOS experiment 2006. (Courtesy of ESA—Novaespace, “Extreme-Design”, “Italia si misura” and “ZER0gYMN”)

Fig. 5 0g use of laptop computer: Original NASA photograph with superimposed a "Jack" digital mannequin (Courtesy of Alcatel Alenia Space Italy)

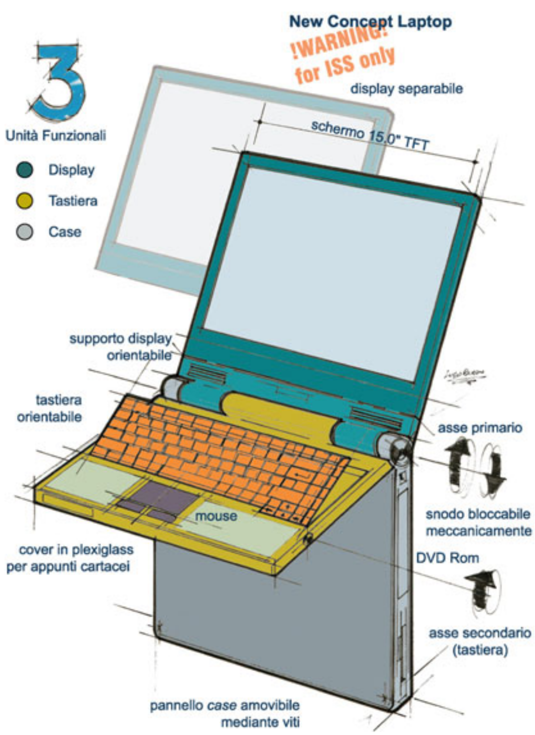

Fig. 6 0g Laptop design concept layout [1]

display unit/monitor opening arrangement, astronaut/operator posture and behavior or strategies, starting from the neutral body posture, considering anthropometrical outline and angular positioning of body segments and limbs.

It must be taken into account that the possible orientations of the human body and objects in space have more degrees of freedom than on Earth as they are not constrained by gravity; therefore, concepts such as floor and ceiling do not have the usual meaning [6–9]. Our investigation follows a reverse procedure to usual spacecraft design by recognizing a range of "comfortable" postures derived from the neutral space posture to envisage a new design that may better integrate into the spacecraft habitability. This has been further enhanced by reviewing the workplaces, considering the high degree of violation of the expected terrestrial layout.

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