J. Biol. Res. 2006 n. I - Vol. LXXXI - Rubbettino - Soveria Mannelli

Interior design and sensorial perception in microgravitational Outer Space environment

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KEY WORDS: outer space, microgravity, human adaptability, design

Abstract

In a microgravitational space environment the human biorhythm, its sensory perception and all its psycho-physiological system, comes completely upset by the absence of gravity and of external terrestrial references, beyond the effects of constraint in a limited space. This type of environment is defined like confined extreme. In order to create a "human centered design", in sight of missions of long duration, we will have to consider, above all, these factors, in order to try to increase the comfort and the productivity of the astronauts. In this context we have elaborated a design concept that forecasts to resume the variety and the variability of the terrestrial stimuli, through factors like the light and the color, so as to recreate the input of the circadian cycle.

Foreword

One of the dominant characteristics of the Space confined habitats is the absence of the earthlings solar and lunar cycles references. The Sun and the Moon are, indeed, the main references and guidelines of the "biological compass". Innovative searches in this field were those of Leo Pardi, carried out in the Zoology Institute of the Turin University, on the ability of the crustaceans *Talitrus saltator* to use such astronomical references in order to return to the shoreline all along the shorter distance of the beach (Papi and Pardi, 1953)

The ability of the biological organisms to orient themselves and synchronize on the variations of the solar rhythms is a fundamental aspect in the planning of the human habitat, above all when habitat is confined in the Space, the planetary and in satellite outer space settlements. In order to simulate the experience of the astronauts in long duration missions, the researcher Stefania Follini, sheltered up herself for five months in a 30 m^2 cave in the New Mexico. Completely isolated from the external stimuli and particularly the day-night cycle, slept 10 hours and were wide awake 20. When she returned at the surface, she thought to have been underground for two months (Guidotti, 2002). The photobiology studies demonstrated that the light has directed effects on our organism whose functions are regulated from the variation of the light in the round of the 24 hours. The "circadian rhythms", (Latin: "circa "and" dies "=" the cycle nearly a day"), have been discovered in 1700 in studies of plants movement by the French scholar Jean-Jacques d'Ortous de Mairan. These cycles are regulated by a sort of "biological clock", presumably localized in the hypothalamus. The more obvious examples of this "clock" are the heartbeat, the menstrual cycle, the variation of the body temperature and the hormonal production during the day. In an extreme confined habitat as in the Outer Space, people find themselves to have serious problems of the sleep-waking cycle regulations, caused by the gravity lack, that inhibit the muscular apparatus to relax yielding to the gravity force, the lack of the earthly references that regulate the biological rhythms like those of the circadian cycles. The interior design (Masali et al., 2005) of these environments must hold in account these factors as vital in case of long duration missions to create adequate comfort, also to improve productivity of the astronauts (Ferrino and Gaia, 2001).

Space Habitat on Phobos

During an ESA 2005 (European Space Agency) workshop one of us, Irene Schlacht, had the opportunity to apply these theories in designing of a base on Phobos, the larger one of the two moons of Mars.

Phobos will be a good starting point for excursions to the surface of Mars because of the proximity and the low gravity (0,085g). In site resource would refuel spacecrafts from and to Mars or other bodies in the Solar system. Actually Phobos could be used as a relay station for spacecrafts. Due to the hostile Phobos environment and long-term missions, the specific need of the project where at least 90 m^3 of habitable space per person, with a high level of sustainability and operable in microgravity, measures against isolation such as psychologically friendly environment and private quarters, versatility and flexibility

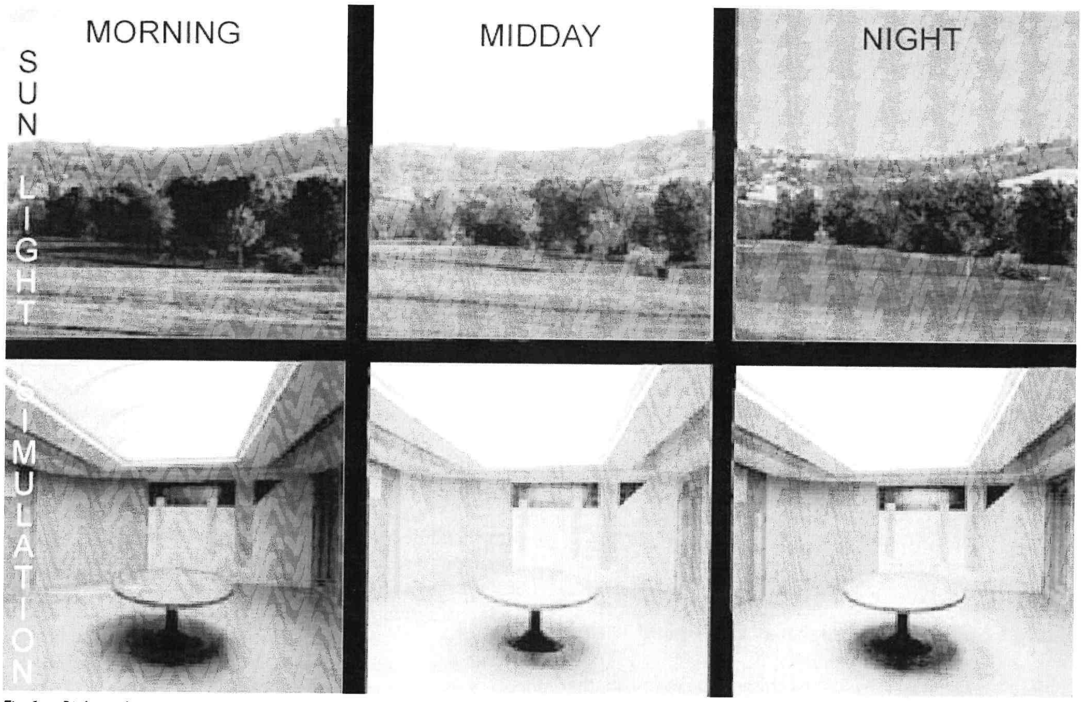
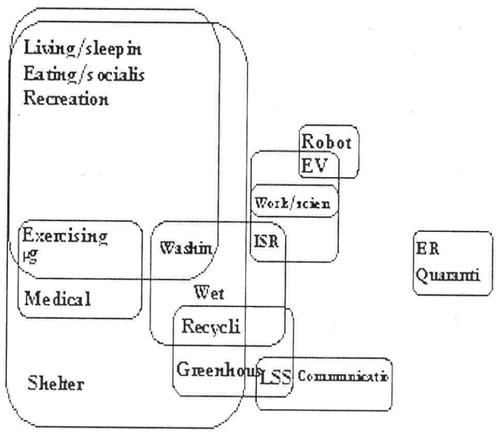


Fig. 1 - Biological input



SCHEMA

- centrifuge to induce gravity, particularly for sleeping, which holds the crew's private quarters with beds and storage for personal effects;
- cylindrical running track for exercise;
- medical area;
- gym shells for complete muscle group exercise:
- galley and mealtime area;
- hygiene facilities;
- spacecraft docking area;
- large "Cupola" that allows all the crew to use this area for socializing and eating, and Mars viewing:
- greenhouse in a separate body
- nuclear generator (1 km distant in a natural groove of the moon surface)

of the environment are requirements to get the maximum advantage of the base volume and protection from radiation and meteorites, safety measures for the crew. The design task was to establish the internal arrangement of the main habitat module considering a scenario of 2 years isolated environment, with the objectives of simplicity, safety, functionalism, friendly approach, well being, optimization of the space, variability, flexibility, adaptability. The main structures of the habitat to be considered are: The proposed structure has a "Spider web" configuration to provide flexible space with a large number of combinations with the use of multilayer foldable screens. Color will be changeable, and studied as to the effects of µg on color perception.This aspect is the core of Irene Schlacht ongoing project tested in parabolic flights (sept. 2006). Color combinations are suggested to cover the whole spectrum and balance between hot and cold colors. Light is provided by foldable multilayer screens to simulate the circadian rhythm. Screens also provide the flexibility to project images, videos etc., while natural light can be

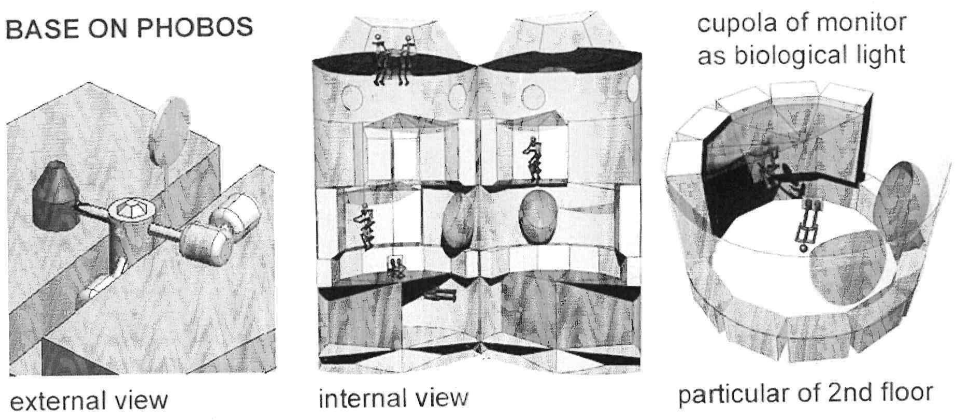


Fig. 2 - Space Habitat on Phobos

captured using optical fibers and redirected to where it is needed.

Design of Color and Light as Biological Imput

In these habitats it is therefore necessary to reproduce the color and intensity of the solar light variations along the arc of the day, according to defined scientific programs, assuring a better performance of the human organism. The color and the light in the habitat actually influence also the psychological reactions and the physiological well-being, influencing factors like the perception of the time duration up to the social relationships as in the case of proxemic interaction.

In microgravity the inputs sent from the organs that regulate the space orientation (as the vestibular organ) may go in conflict with the visual perception and create vertigos, dizziness, sickness and other malaise.The organism answers to these events making silent the information from these organs and giving the control to the information from the visual system. For this reason it is necessary to use an immediate visual arrangement, created according to instinctive answers to "natural signals" to which we are accustomed in the earthly life, like the sky "up" and earth "down". The colors can guide the user to the orientation in the several functions through biological inputs active on the earth: "what is observed by the person must be coherent to its ability to interpret the information as it happens in the terrestrial environment" (Bretagna, 2005). In the "Phobos" project, the "multilayer foldable screens" are the monitors posed in the "ceiling" of the habitat and are made of liquid crystals and covered with kevlar, they form a modulate and flexible structure for different arrangements and different visions. It projects all the solar light frequencies and the images that the subject needs. These are characterized from the emission of an environmental light that restores the earthly solar cycle for intensity and temperature of color, to irradiate the subject with the same frequency beams present on the earth, concurring maintain factors like the perception of passing of time, the regulation of the biological clock and the hormonal production, beyond that the production of the D vitamin very important for the astronauts to reduce the risk of osteoporosis. The monitor is arranged visually to form a gleaming roof visually simulating a cupola of transparent glass that shows the open sky. Another quality of the monitor is the opportunity to project every thing, from the land to the sky, to video conference. The absence of natural light and the isolation in the confined space and from the earthling natural biological inputs creates inevitable changes of the psico-physiological conditions of the astronaut. An artificial environment without variety and variability takes to strong psico-physiological consequences like the depression, while artificial environmental stimulations like the light, the colors, the variations of the air, the wind, the warmth, the cold, the scent, the flavors, normally present on Earth, can activated implicit vital mechanisms.

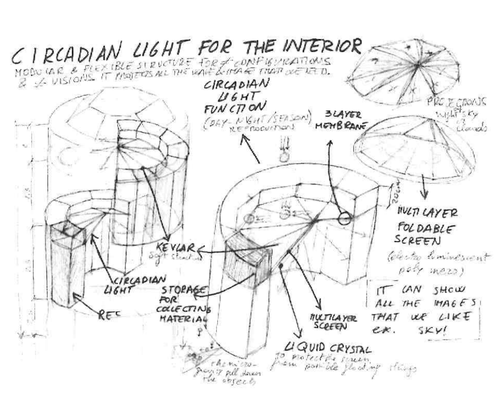


Fig. 3 - Design of Color and Light as Biological Input

References

Bretania G. 2003. Dispensa:'Il colore nello spazio abitato', Laboratorio Colore, Politecnico di Milano, Milan, Italy.

Burzio L. 2001-2. Thesis: Abitare lo spazio. Politecnico di Torino, Torino, Italy.

De Grandis L. 1996. Teoria e uso del colore, Mondadori, Milano, Italy.

Déribéré M. 1968. Dipingere la casa. Zanichelli, Bologna, Italy.

De Mairan, J. J. d'Ortous 1729. Observation botanique. Histoire de l'Academie Royale des Science: 35–36.

Durao M.J. 2002. Colour in space architecture AIAA 2002-6107, Houston, Texas.

Ferrino M, Gaia E. 2003. Workplace for the future: a multidisciplined approach for living in Outer Space. 8th International Conference on Human Aspects of Advanced Manufacturing: Agility & Hybrid Automation HAAMAHA 03, 26-30 May, Rome

Flaborea M. 2002-2003. Sistema a luce dinamica per l'illuminazione ambientale della stazione spaziale internazionale. Politecnico di Milano, Milan, Italy.

Itten J. 1965. Arte del colore. Milan, Italy: Il Saggiatore.

Mahnke F. 1996. Color, Environment and Human Response. New York: Van Nostrand Reinhold.

Masali M, Ferrino M, Schlacht I.L. 2005. L'Uomo nello Spazio: Ricerche di adattabilità. Il Colore e il Design estetico per l'Abitabilità umana in Missioni Spaziali di lunga durata" XVI Congresso degli antropologi Italiani (Genova, 29-31 Ottobre 2005)

NASA, 1988 August. The Human Factors of Colors in Environmental Design: *A Critical Review* (Contractor Report 177498) Barbara K. Wise, James A. Wise, Department of Psychology, University of Washington, Seattle, Washington. (Prepared for Ames Research Center under Contract NCC22-404).

NASA, 1995 August. International Space Station Flight Crew Integration Standard (SSP-50005 Revision B NASA-STD-3000/T). National Aeronautics and Space Administration, Space Station Program Office, Johnson Space Center, Houston, Texas.

NASA, 2001 February. International Space Station Interior Color Scheme (SSP 50008 Revision C). National Aeronautics and Space Administration, Space Station Program Office, Johnson Space Center, Houston, Texas.

Pardi L, Papi F. 1953. Ricerche sull'orientamento di Talitrus Saltator (Montagu) (Crustacea-Amphipoda). Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology.

Rita L. May 2000. Article: Ambienti confinati. Newton.

Romanello I. 2002. Il colore: espressione e funzione. Hoepli, Milano, Italy, 35 (6): 459-489.