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Some Research in Cooperation with Alenia Spazio

E. Fubini

Dipartimento di Biologia Animale e dell'Uomo. Università di Torino

Introduction

Between the Department of Animal and Human Biology of University of Turin and Alenia Spazio there have been 10 years of active cooperation that has developed through common research, theses in collaboration and employment of graduates and PhDs. The main research projects carried out together have concerned the study on workload evaluation of subjects carrying out ergonomic tests in underwater environment (Toscano et al., 2000), the study of the restraint system of some equipment for item storage and transport (Podio et al., 2001) and the study of restraint and support systems for astronauts' mobility.

Workload evaluation of subjects carrying out ergonomic tests in underwater environment

As weightlessness is not completely reproducible on Earth, usability evaluation of space systems is often simulated through tests in an aquatic environment as space analogue. A Neutral Buoyancy Facility test programme was organized in a special pool (Fig. 1 a) to simulate Intra- and Extra-Vehicular Activities on the Columbus module of the International Space Station with the aim of assessing various aspects of crew interface design. The study concentrating on Extra-Vehicular Activities was designed to evaluate workload correlated to visibility, accessibility and operability tests. We determined diving workload through basic physiological measurements, such as pulmonary ventilation and heart rate during underwater operations. As anxiety can influence physiological processes, and consequently also the workload evaluation determined through these parameters, we developed an evaluation methodology to investigate the anxiety level based on a specific questionnaire (Spielberger, 1970) submitted to all subjects before and after the dives.
Heart rate increased in underwater work to a value approximately 50% greater than the value obtained in resting condition while sitting outside the pool. This increase in heart rate was accompanied by an increase in pulmonary ventilation of 200% greater than the value recorded in resting condition while sitting outside the water. The extent of these increases was notable in all the test subjects, who varied in age and stature. Recorded values of workload, heart rate and pulmonary ventilation were evaluated on the basis of Christensen's (1950) and Wells' (1957) classifications. Through this analysis it was possible to determine that the workload correlated to the performance of our neutral buoyancy tests corresponds to moderate physiological work. Fig. 1 b shows an example of heart rate recording for 4 subjects during the simulation of an extra-vehicular operation and the relative evaluation. For test subjects anxiety correlated to underwater performance was light and, among the causes of anxiety, all the subjects indicated the lack of confidence with neutral buoyancy tests and a feeling of lack of safety, typical of aquatic environments.
We can conclude that the context did not produce considerable psychological effects, and consequently the psychological load did not influence heart rate and pulmonary ventilation values that can then be directly correlated only to task workload.

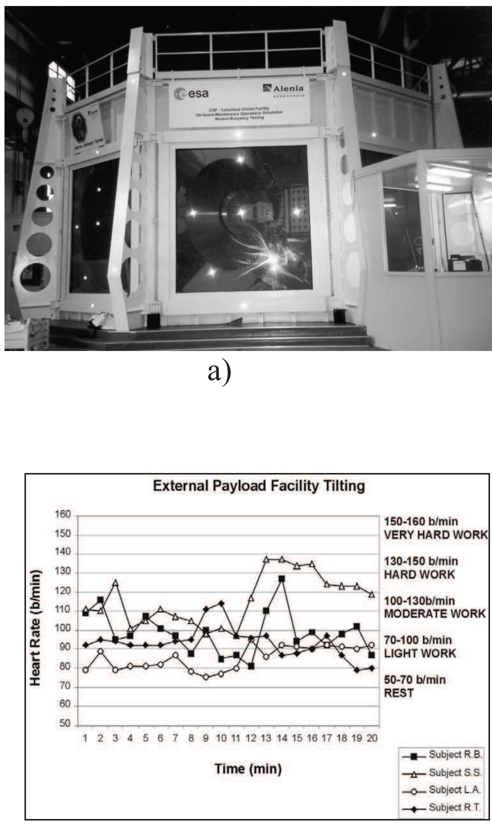

Fig. 1.

Restraint system of some equipment for item storage and transport

Inside the Columbus pressurised module some mobile equipment has to be stored in special racks during both the launch and the activities in orbit. As the astronauts have to move, to use and to replace the equipment in a microgravity environment, it is necessary to design specific envelopes and to correctly plan the arrangement of the equipment in particular boxes, with the aim of facilitating storage and consequently reducing the length of the routine operation and improving personnel productivity. The design process must take into account all the parameters that can influence the astronauts' activity in interfacing with the storage system, the fact that activities will be done in microgravity environment and the operations of removal and repositioning of stored items. In the analysis of stored items it is necessary to evaluate physical parameters such as accessibility, visibility, riconfigurability, operability, maintenance ease and also resistance, fastening and durability parameters. Among the functional requirements, it is necessary to analyse which are the items to be stored and to consider those that need an external envelope. Also the envelopes have many requirements: they have to be fireproof, covered with soft material to cushion the blows and absorb vibrations, to have inside interfaces both to fasten the contained objects and to tie the box to a restraint, to have interfaces/handles to facilitate transport and fastening during their installation and use, while their contents must be able to be individually extracted from boxes. It is also necessary to consider the need of the crew to remove, use and reposition the items in a microgravity environment.
The envelope design focused on two items quite significant for the storage concept, Upper Bracket and Pivot Bracket, shown in Fig. 2 a.

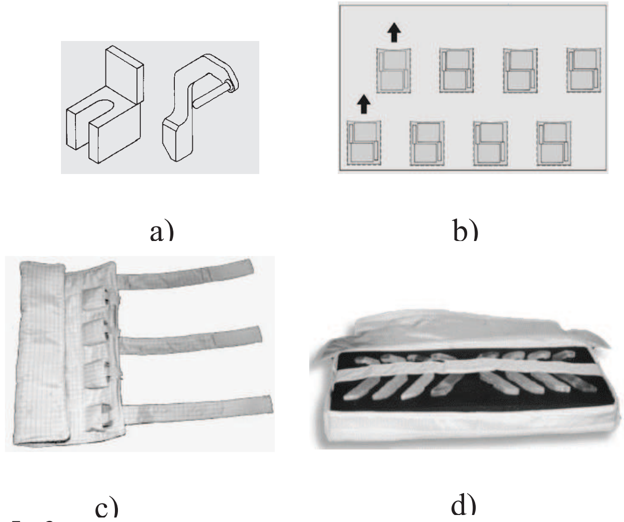

Fig. 2.

All the substances used in the manned areas of a space vehicle have to be tested to get the NASA "space qualification". For the design of restraint system items, we chose Nomex as fabric typology, Velcro as fastening system and Foam as soft filling.
In the analysis of all the possible combinations of item packing, we took into account the use of pairs of both Upper and Pivot Brackets, the fact that it is necessary to take one left and one right Pivot, while, due to the shape and number (16) of the Upper Brackets, it is advisable to pair them up to get a minimum volume occupation. For Upper Brackets we decided to place each pair inside a pocket arranging 16 of them in two rows (Fig. 2 b). This solution has the advantage that each pair is well fixed inside the pocket without the need of strings and moreover it is possible to contemporarily access all brackets. The structure is conceived as a foldable case (Fig. 2 c) to obtain the following advantages: a higher compactness when closed, to use the closing stings as anchorage belts and as handles to carry the object easily. As opening system we chose Velcro, that has an effective grip and is easy to use. For Pivot Bracket we conceived a solution with a foam parallelepiped, moulded on the shape of the object (16 brackets, 8 right and 8 left), inside a container in soft Nomex (Fig. 2 d). The packaging has a handle designed on anthropometric parameters, that allows to grab the object and to extract it from the box.
We also made two mock-ups of the restraint systems, on which we carried out a functional analysis through usability tests in order to evaluate the accessibility of the systems when inserted in storage boxes, the operability of anchorage belts, the system operability and transport effectiveness. Tests were carried out with 6 subjects chosen to be representative from an anthropometric point of view of a population in the range 5% to 95% percentile. Tests have shown some criticalities that we tried to resolve with appropriate solutions.

Study of restraint and support systems for astronauts mobility

We carried out an analysis of the restraint and support systems arrangement of Node 2 of the International Space Station to evaluate if the layout was appropriate and allowed the astronauts to accomplish all the possible internal translations to reach the different worksites. For their movements astronauts essentially use many types of handrails and foot-restraints, that are often placed on foot-bridges. We checked if crew members would be able to move using both hands or just one, as happens when they have to carry some objects or a bag with equipment. The check was done with JACK, a software modelling and virtual simulation tool (Fig. 3 a). We verified the most critical situations, by simulating the tasks carried out by 5th percentile female and 95^{th} percentile male, given that during movement the astronaut never lets go a handle before grasping another one.
To verify movement feasibility we made an anthropometric test, to define the ideal position and the limit one, during movement between two handles, starting from a static position. On a series of subjects of stature ranging from 142 to 197 cm we measured the arm span, considering both the maximum value (Fig. 3 b) and the value that subjects stated as the most comfortable for moving (Fig. 3 c). We found that the preferred maximum distance from a handle to a grasping point is on average about 120 cm. We proved that most handrails and foot restraints of Node 2 were correctly positioned to allow the crew members of

the different percentiles to comfortably move in every area, but it was necessary to make some modifications to take into account our results regarding the arm span. The modifications were accepted by NASA.
As astronauts' comments on other missions mentioned orientation problems inside pressurized modules and handle grasping difficulties, we developed some design proposals to facilitate prehension based on the use of colours, shapes and surface finishing materials (Fig. 3 d).

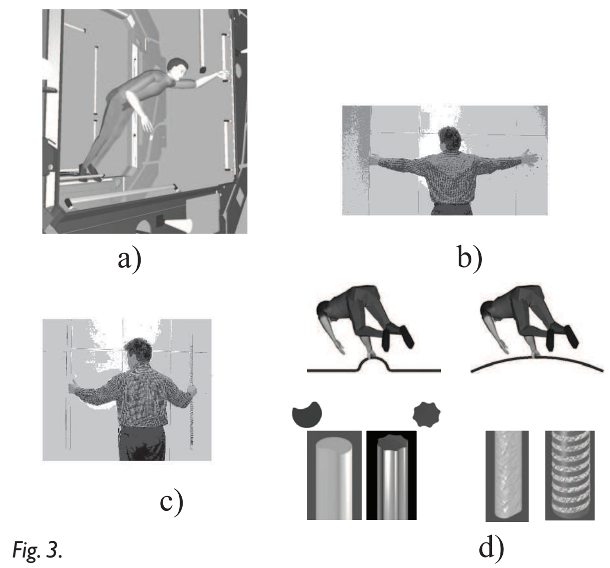

Fig. 3.

New developments

We are now participating in support to the REAL MAN European project to develop a protocol for the correct acquisition of body movements using a passive target tracking system, with the aim of collecting data useful for humanizing 3D computerized models in virtual reality environment. The results of this activity will allow more reliable simulations of human operation in complex systems to be obtained.

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