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From the Individual to the Cultural Space Group

Carole Tafforin

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Abstract

From a behavioral point of view, human crews into Space will have to both live and work in physical environment (microgravity, 1/3 g, 1/6 g), confined environment (spatial restriction, social constraints, and sensorial privation), and isolated environment (familiar privation, cultural background, and remote communication) that involve a multisystem adaptive model on a long-duration process. Physiological, medical, psychological, sociological, anthropological, and ethological impacts have been emphasized in a wide panel of investigations. The current results are presented with a focus on relevant methods in ethology based on the observation, description, and quantification of (i) the individual behavior from short-term orbital missions; (ii) the social behavior during inter-planetary missions simulated in terrestrial environments; and (iii) the cultural behavior in considering manned missions on Moon, on Mars, and beyond. Global analysis highlights that the crewmembers going into Space will be definitively interactive men and women with personal experiences, social rules, and new cultural habits. They will have their individual identities and they will be a group entity for extended periods of time.

Keywords: space exploration, human behavior, adaptation, orbital mission, isolated and confined environments

1. Introduction

When a human crew takes flight from Earth for the purpose of staying in Space, what could happen from an adaptive perspective? In the evolutionary history, the human being adopted the supine posture for walking. The possibility of movement of the individual then led to the evolution of kinds of socialities that resulted in cultural habits (**Figure 1**).

Firstly, just as gravity plays an essential role in terrestrial locomotion [1], microgravity is the new environmental factor that will lead to changes in sensory-motor activity. Secondly, the crew will be exposed to unusual environment factors as the space habitat will be isolated



Figure 1. Evolutionary steps of human being on Earth.

and confined. Coping with monotony and facing up to autonomy thus becomes essential for adaptability. Furthermore, when moving out of space habitats during extra-vehicular activities (EVAs), such hostile environment is another factor to consider for survivability. Thirdly, all of these factors have to be taken into account in synergy with the temporal aspect of going far from Earth and for extended durations.

In sum, the human crew has to adapt to a new, unusual, and hostile environment for living and working in Space, and for extended periods of time. Many studies in ethology, i.e., the science of behavior, were performed in these extreme settings (**Figure 2**), in real situations (orbital missions), in simulations (parabolic flights and bed rests), during confinement experiments, and in analogue environments (polar stations). On the one hand, missions in orbital station or in space shuttle are new conditions of weightlessness; parabolic flights create the physical characteristics; bed rests simulate the physiological consequences. On the other hand, confined habitats are unusual conditions and South Pole stations or Arctic expeditions are hostile environments analogous to space exploration missions.

Generation and applications of extraterrestrial environments on Earth [2] contribute to an exhaustive and global knowledge of what constitutes Space, from its physical characteristics to its behavioral aspects within the relationship between the individual and the environment.

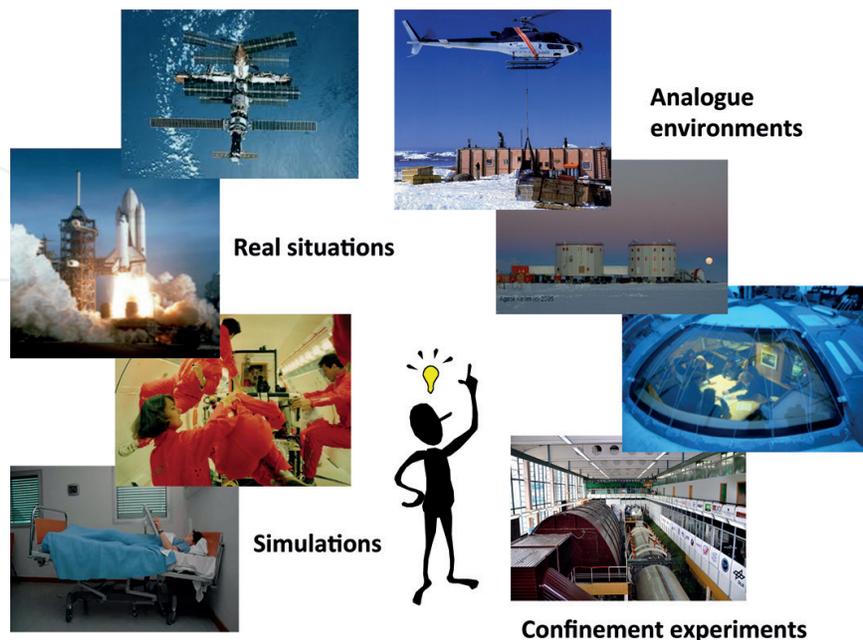


Figure 2. New, unusual, and hostile environments on Earth.

Interplanetary missions are regarded as prime opportunities to highlight the psycho-physiological issues of man and woman under both microgravity and isolation and confinement conditions over very long durations. During these space travels, the crewmembers will have to adapt to a wide range of environmental factors such as weightlessness, social constraint, closed module, monotonous panorama, familial privation, and cultural diversity. They will also have to cope with the restrictions imposed by life-support system. The ethological works were particularly concerned with these interfaces [3, 4].

In this complex network, the adaptation model to space environment (**Figure 3**) considers the individual as a whole with all the facets, concerning maladaptive reactions and adaptive strategies. It puts into action a “hard” system (*left facet of the model*), in terms of conservative regulation, which tends to recover the initial states of the sensorial mechanisms and the physiological mechanisms. For instance, deficits or variations in the environment induced by microgravity will generate, at the physiological level, a redistribution of fluids and electrolytes followed by a cardiovascular reaction leading to endocrinal and metabolic changes. At the sensorial level, the weightlessness will transfer the information from the inhibited vestibular function to the visual function, which will be reinforced. Consequently, a “soft” system (*middle facet*) will be activated, in terms of innovative regulation, to express new behavioral strategies by the adjustments or modifications of body orientations, postures, and movements. New motor learning will conduct to a new representation of the space environment (*upper facet*) involving psychological functions, cognitive skills, sociability, and cultural ability.

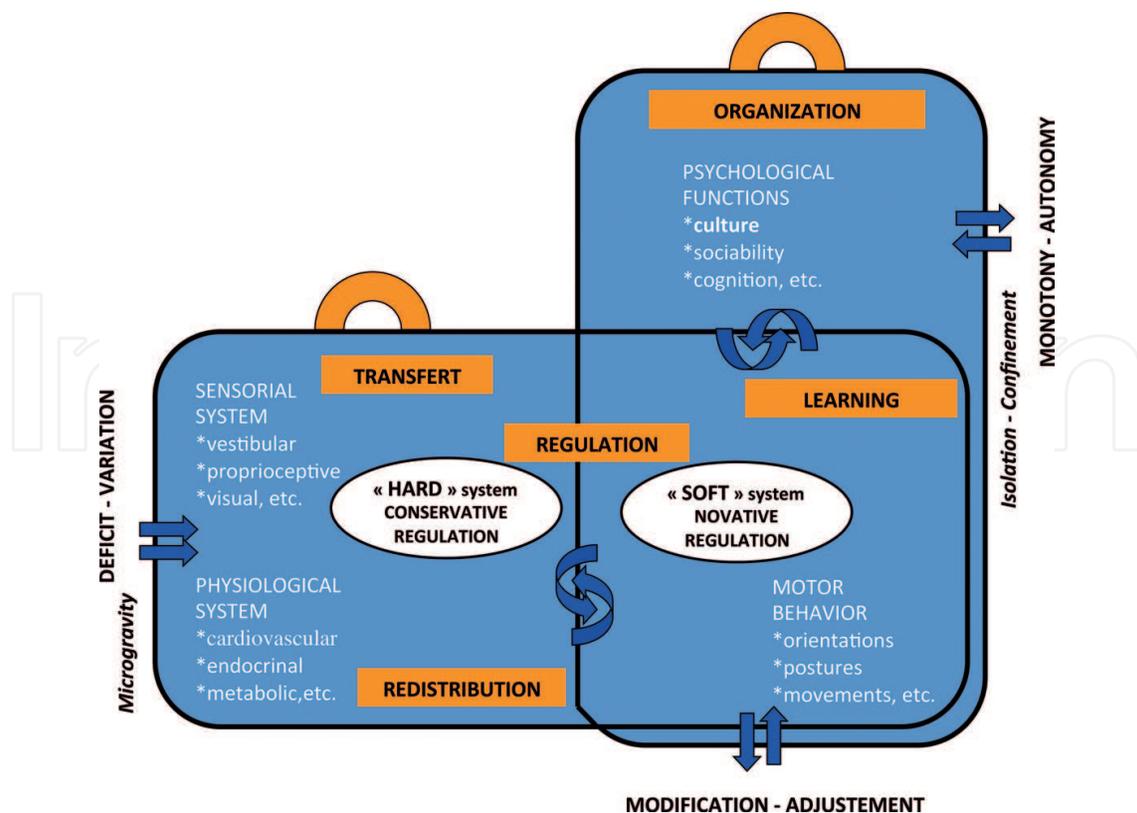


Figure 3. Multisystem adaptive model in Space.

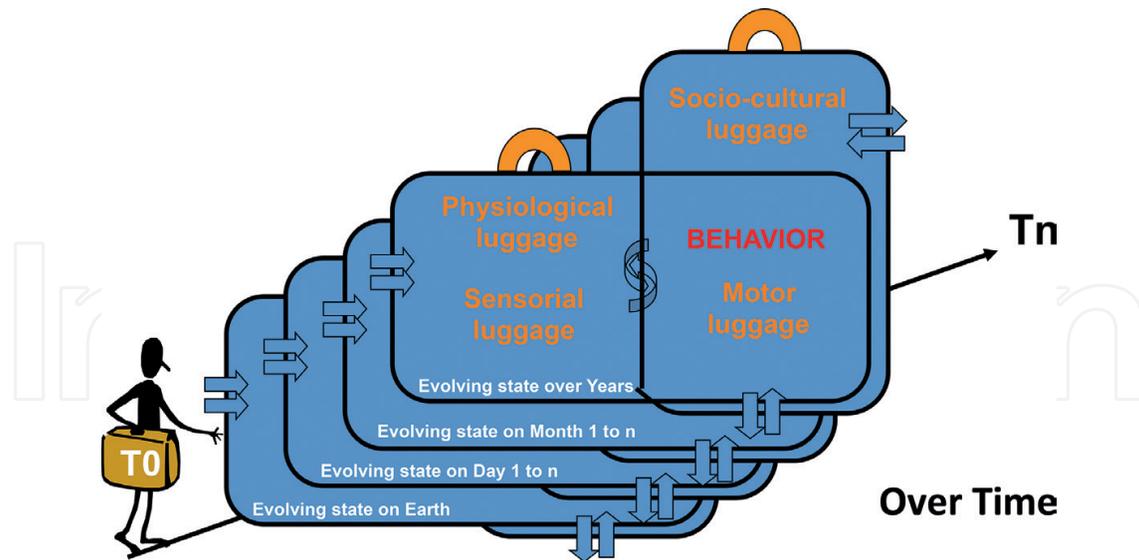


Figure 4. Dynamics states of adaptation to Space.

Overall, the space traveler, fitted with his physiological luggage and sensorial luggage, equipped with his motor luggage and impacted by his sociocultural luggage, will follow an adaptive dynamics, day after day, month after month, year after year as evolving states of the individual behavior, the social behavior and the cultural behavior (Figure 4).

2. Individual behavior

When experiencing for the first time, reduced gravity in parabolic flights, neophyte subjects were in confusing referential cues with inadequate body moving [5]. Their performance, described by the optimization of orientations in a three-dimensional space, improved over time. As they gradually develop harmonious coordination between sensory-motor and cognitive experience, spontaneous, preliminary, followed by integrative stages of adaptation underlie new relations between the body references and those of the physical environment. As a result, the individual behavior is characterized by a multidirectional motor activity.

Once in short-term orbital flights, the man or woman in space, i.e., the spationaut, has to perform domestic and professional tasks like those done under terrestrial gravity, whereas the "body tool" available to him/her has been placed in new conditions that require significant behavioral changes [6]. Microgravity has the most obvious effect of diversifying movements, postures, and orientations. The vertical position is thus no longer the only one possible. This means that in order to efficiently perform tasks, the individual has to invent new motor strategies that transform the quality of locomotion and manipulations with new orientation possibilities in weightlessness. In ethological studies, modifications of the motor behavior are treated as observable evidence of the human adaptation to space. In addition to the conservative physiological homeostasis, the quantitative description of what the moving individual is doing in microgravity is postulated as innovative regulation in the multisystem adaptive model.

Whether onboard the orbital Mir station or in the space shuttle where we analyzed video recordings, the results showed how humans in space elaborated a new world of perceptions and actions through the changes of body orientations. As an example of spationaut adapting to this new environment, after three days of space sickness induced by vestibular-ocular conflicts, we observed the occurrence of head-down orientations as main changes in the motor activity (**Figure 5**).

Holistically, the physiological challenges facing man and woman going into Space have been well documented in books and chapters, with examples such as fundamentals of space physiology [7, 8] and space medicine [9, 10]. Exposure to microgravity and radiation has important physiological implications for the maintenance of medical health. Also, behavioral health is of prime importance to keep the missions operational. Psychology of space exploration is a new challenge for long-duration interplanetary flights and stays on planets far from Earth [11]. Humans in Space might answer issues regarding psychological hurdles [12].

On the one hand, individuals' health status has to be optimum, with medical and physical requirements. The spationaut, with his/her physiology, has to regulate loss of weight, loss of bone, loss of muscle, loss of vision, and loss of proprioception. Microgravity effects are minimized with medical training before going into Space, special countermeasures on physical activity when staying in Space, and physical reconditioning when returning to Earth. Specific emphasis is placed on cardio-vascular responses by developing individual countermeasures [13] and on musculo-skeletal responses because there is an individual variability in spite of exercise regimes [14]. Emphasis is also placed on neuro-cognitive responses while maintaining a high level of performance [15] from body-disorientation to related stress in microgravity. That has an impact on the individual behavior in terms of behavioral health.

On the other hand, the individual's behavioral health should be positive with congruence and assertiveness requirements [16]. The spationaut, with his/her psychology, has to cope with loss of mental ability, loss of wide sociability, loss of close family contacts, loss of privacy, loss of large landscape, and a multitude of odors. Isolation and confinement effects are prevented with

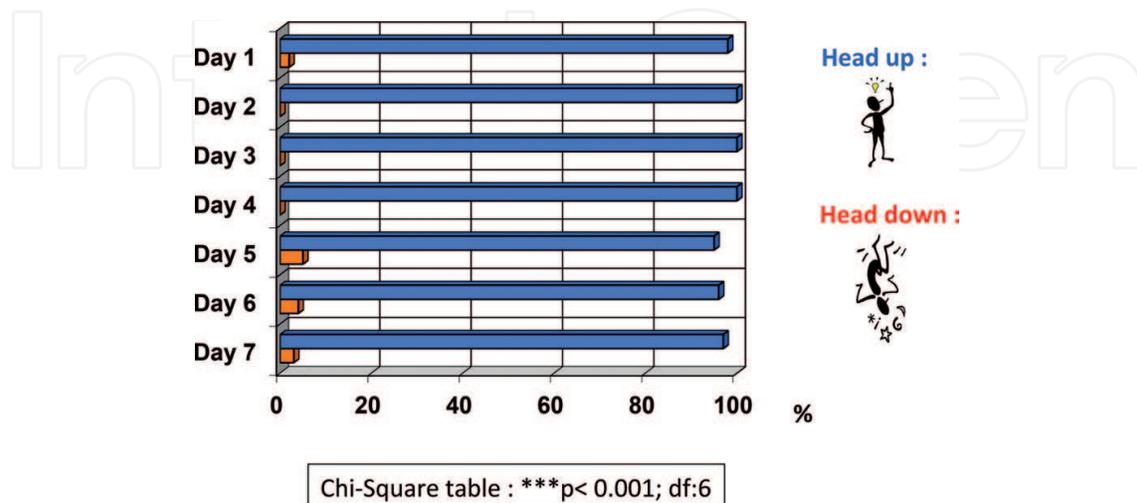


Figure 5. Head/body orientations in microgravity during a 7-day orbital flight.

ground support [17] as far as communication with Earth is possible. Relevant researches are conducted on personal value [18], personality trait [19], emotional state [20], communicative profile [21], and mental health, with the need of defining individual characteristics upon strong motivation [22]; in other words, all that has an impact on the individual behavior in ethological terms.

Good health, both medico-physiological and etho-psychological, is the key to quality of life and to successful work. The individual behavior in its optimal and positive meaning is the first link of the well-being and good-spirit of the crewmember within social contexts constrained by isolation and confinement once he/she has settled into Space.

3. Social behavior

The isolated and the confined crewmember observed using the ethological approach has demonstrated that confinement generates stress manifestations versus isolation; that isolation enhances social relationships versus confinement, and that the crew adapted positively to both environments [23]. From the individual in orbital flight to a small group inside confinement chambers or inside polar stations, research works need continued sharpening on adaptation of the human being on Earth to the human being in Space, period by period [24].

The main results from the research showed three adaptive periods: initial, mid and final periods over a 28-day Isolation Study of the European Manned Space Infrastructure (ISEMSI) campaign; over a 60-day Experimental Campaign for European Manned Space Infrastructure (EXEMSI); and over a 135-day Human Behavior in Extended Spaceflight (HUBES) campaign. In these limited habitats, the personal distances decreased and the public distances increased among the crewmembers. We observed high values of social distances and body mobility from the initial period to the final period. An increasing spatial dispersion with decreasing social orientations was also noted among the crew at the midpoint of the medium-term simulations [25]. Over a 520-day Mars-500 experiment, the crew simulated how to live and work together like a real mission with a 250-day Earth-Mars travel, a 30-day Mars landing, and a 240-day Mars-Earth travel. The results showed that time had a major impact on the individual and interindividual behaviors in terms of personal actions, visual interactions, object interactions, body interactions, facial expressions, and collateral acts. The crewmembers followed phasic, periodic, and punctual behavioral changes in extended periods of time, as it was observed at the Antarctic Concordia station and during the Arctic Tara expedition, to avoid monotony. Be it space simulators or analogue settings provided by these extraterrestrial environments on Earth for going into Space (**Figure 6**), the behavioral adaptation is mainly related to social interactions with an emphasis on visual interactions (**Figure 7**).

Along with physical and mental health, the social behavior in terms of nonverbal interactions and verbal communications has become of new interest to investigate interplanetary missions from the perspective of multidisciplinary approaches. For instance, correlation of etho-social and psycho-social data during the simulated Mars-500 interplanetary mission aimed at identifying crewmembers' behavioral profiles for better understanding Space groups of future explorations. We found significant negative correlations between anxiety and interpersonal

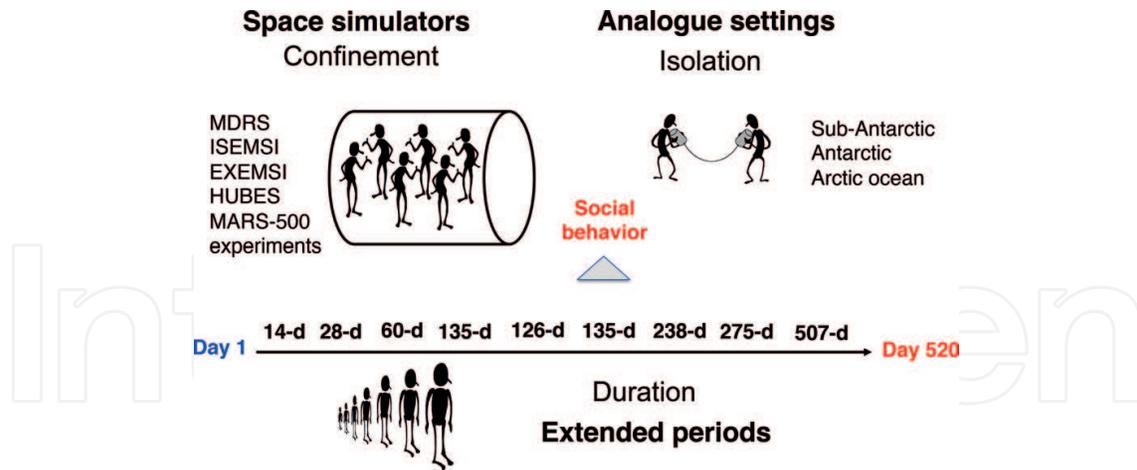


Figure 6. Environmental and temporal factors simulated on Earth.

communications, and between the sociometric parameter “popularity in leisure environment” and anxiety level. We also found significant positive correlations between the sociometric parameter “popularity in working environment” and interpersonal communications, and facial expressions; and between the sociometric parameter “popularity in leisure environment” and interpersonal communications, and facial expressions. This highlighted complementary viewpoints in the field of life sciences and social sciences: objective versus subjective, active versus discursive, exhaustive versus restrictive, and descriptive versus introspective [26].

Crew relations also play important roles in the success of missions where crewmembers stay one year and beyond in isolation and confinement. Wireless monitoring of interactive behaviors correlated with individual questionnaires, and video analyses of collective activities showed that the amount of time spent together during free time is highly associated with the intensity of relationships [27].

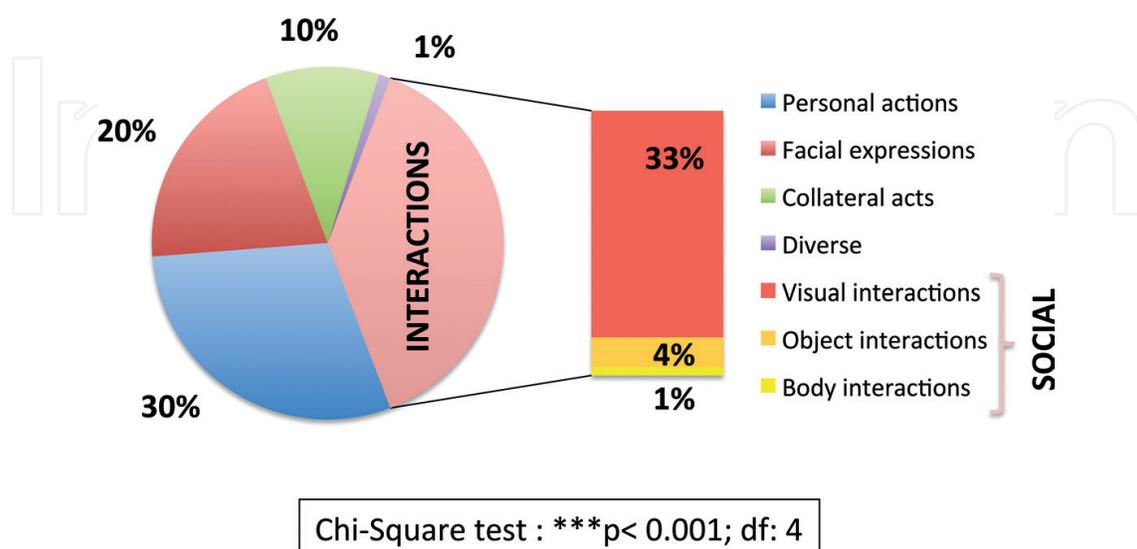


Figure 7. Social interactions in isolation during a 506-day Tara-Artic expedition.

Interpersonal and organizational issues were already raised within the first long-duration stays onboard the orbital Mir station and onboard the International Space Station (ISS). Negative effects included low crew cohesion, poor leadership skills, and crew tension resulting from environmental stress and related to crew heterogeneity [22]. However, positive effects of group experience inside space habitats need to be highlighted. For instance, from the human point of view, being in Space along with being in microgravity are unique opportunities for evidence of Earth observation as a whole. It is actually a salutogenic experience, as reported by the ISS inhabitants [28]. Despite constraints of social monotony, social isolation, and social confinement, the crewmember can create distance from the crew by widening the vision of the surrounding to a faraway environment. According to the classification of Hall [29], there is a shift from a social space to a public space (120–360 cm ad infinitum). Salutogenesis means that individuals who adapt positively to an inhospitable or extreme environment can derive benefit from their experience [30]. One example of positive coping strategy in dealing with the stress of being in Space is seeking social support, which is defined as effort to obtain sympathy, help, information, or emotional support from other persons [31]. It is a component of social behavior.

For interplanetary missions, selection criteria should include social compatibility. Then training should enhance interpersonal skills, leading to the best way of psychosocial adaptation in Space [32]. The crew's effectiveness and safety will be thus enhanced. Interpersonal interactions have gained attention in studies conducted on different groups in analogue space stations referred to as Lunar Palace 1 [33]. Significant individual differences were identified, as well as crew structure was a determinant, even with mononational crewmembers. Results showed that group climate was a good state for a successful mission. However, intercultural interactions are new aims to emphasize. Culturally related differences in values and behavioral norms could influence cohesive group formation [34]. Multinational crews become cultural space groups on a long-duration process by sharing values from their individual experiences and perceptions of different terrestrial regions.

4. Cultural behavior

Small groups of three to six members, mixed-gender and multicultural compositions would be core features of terrestrials gathered for deep space exploration. Such a group is a dynamic organization where all the forces are in equilibrium and regulated to obtain optimal efficiency structures [35]. The rules of adaptive dynamics of an isolated and confined crew could thus be compared to the laws governing self-organizing systems. These laws are based on the heterogeneity of their own elements. International composition is the first characteristic that may have an impact on the cultural behavior for building adaptive strategies. Also, gender composition is an element of heterogeneous organization and helps in mitigating the interpersonal conflicts for developing cooperative strategies [36]. This leads to new goals of investigations into intercultural relations with an emphasis on use of space, use of language, and use of time. The analysis of mean durations of collective activity, while free grouping at meal times during the Mars-500 experiment (**Table 1**), showed significant differences regarding

Subject	RU1	RU2	RU3	FR1	IT1	CH1
Mean (minutes)	23	22	14	25	16	16
Standard deviation	±6	±7	±5	±6	±8	±6

Table 1. Collective activity duration in confinement during a 520-day Mars-500 experiment.

cultural background and mission goal. On one side, the French group-member (FR1) spent the longest time at meal as it is customary in daily life activities in a given country or region. On the other side, the Russian-Italian-Chinese group (RUS, IT1, and CH1) spent the shortest time at meal as a specific fact attributed to Martian crew versus Orbital crew (RU1, RU2, and FR1). The latter stayed on the Mars-orbit, while the new space group simulated planet landing and staying. These results suggest that if individual differences could generate conflicts within the group members, cultural differences could enhance cohesion of the group, with cultural behavior viewed as positive way to live and work together very far from mother Earth and for a very long time away from family links.

Constructing micro-society models for cultural space groups is thus relevant from an anthropological perspective. The “notion of space” holds a major place in field studies and has an obvious relation with the notion of culture [37]. This approach takes into account spatial relations as a central variable that influences the cultural behavior and the underlying cognitive process. In the history of humanity, there has been a revolution in cognitive capabilities and in learning skills that brought *Homo sapiens* from real to virtual integration [38]. In the future of space exploration, there will be an evolution of the human adaptability to autonomy that will bring *Homo spatius* to virtual integration of the surrounding world, thus avoiding etiological factors of the environment (isolation, confinement, monotony, etc.). We know that cooperation was a behavioral response of survival in the ancient civilizations and ethnicities [36]; equivalent responses might occur in future micro-societies and on remote planets, from surviving to adapting and then evolving. Hence, it is of prime importance to consider the cultural values of the space group [4].

Consider a manned mission on Moon, under hypogravity (1/6 g). Life-support system, rover exploration, navigation innovation, and basic technologies have resulted in the highest readiness for the development of planetary habitats in the conception of a Lunar village [39]. After having walked on the lunar surface, living, and working on the Moon need to be considered. With that aim, test beds were performed in analogue environments with an emphasis on field investigations at the Mars Desert Research Station (MDRS) that examined, for instance, communications in multilingual crews. The international and mixed-gender composition of small Euro-Moon-Mars crews properly simulated the very next isolated and confined groups who would land on the planet. Ethological studies on language skills showed that verbal communications and nonverbal interactions were influenced by cultural background such as the mother tongue [40]. Crew-members using nonnative languages compensate with interaction abilities. With the evolving of daily life habits in Space and over time, some will actively interact, others will actively communicate, and the whole will progress in a common cultural behavior.

Consider a manned mission to Mars, under reduced gravity ($1/3 g$). In addition to key technologies and habitat designs, communication time to Earth is delayed by 20 min. Autonomy and auto-organization of the cultural space group become crucial. In case of lack of contact with mother Earth, in actual isolation, it is also crucial to break the monotony and to find new centers of interest within the group. A personal account of the Mars-500 experiment said that multiculturalism was seen as an advantage rather than a disadvantage because the crew attempted to understand each other and looked for new knowledge accumulated by every crewmember from their own living and working experiences [41]. It is important to take into account the need of rituals. In African villages, for instance, far from any civilization, there are small ethnic groups defined by their customary dwellings in small living places and in grouped huts to promote exchanges. Cultural behavior is associated with a region as well as a nation. In a Mars village, rituals of the inhabitants should be invented.

Considering the early humans, the evolutionary context began with the genus *Homo*. Originating in Africa, *Homo* dispersed widely across the terrestrial globe and was exposed to biological changes but more importantly influenced by culture, upon development of complex behaviors including advances in technology [42].

The discussion is open. Human nature would develop further with interplanetary humanization and Space colonization, beginning with physical evolution and extending over cultural evolution.

5. Conclusion

In future research, the adaptation strategy of each spationaut and of the whole space group will be shown as a multisystem integration, from survivability factors (cardio-vascular deconditioning, hormone regulation, immune response, radiation reaction) to adaptability factors (motor behavior, cognitive demand, social interactions, verbal communications, cultural profiles, living habits). The main interest of transdisciplinary approaches is to investigate synergetic effects of the multiple determinants involved in human well-being, as positive facts, from the medical, physiological, psychological, sociological, anthropological, and ethological viewpoints. This would contribute in preventing negative environmental impacts on future interplanetary missions.

Once the space traveler reaches the Moon, Mars, or beyond, who will he or she be? They will definitively be an interactive man or woman, with their own social rules and cultural habits. He or she will have their individual identity and they will be as a group entity, by building the same language code and communication rules based on multinationalities.

From an individual behavior with new body orientations in microgravity, a social behavior with specific interactions and interindividual distances in confinement, to a cultural behavior with proper rules of communications within the space group after separation for a long time (**Figure 8**), we may draw an adaptive scenario of human crew in Space.

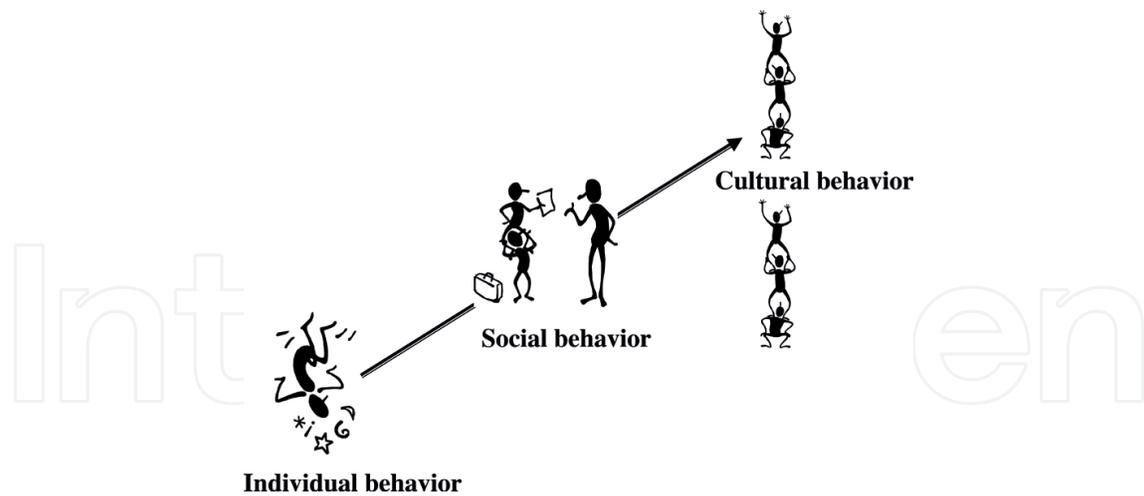


Figure 8. Adaptation scenario of the crews' behavior in Space.

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