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Adaptive behavior of an isolated and confined crew during a Mars mission simulation

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We conducted an ethological study during the Mars-500 experiment for a better understanding of the human adaptative process in an extreme environment over extended periods of time. The experiment simulated the isolation and confinement conditions of a 520-day interplanetary flight, within a multi-chamber facility on Earth. We focused the analysis both on non-verbal and verbal behaviors using the Observer XT® software. State events (actions, interactions, communications) and point events (facial expressions, collateral activities) were scored from video recordings made every two weeks at breakfast time and every month during group discussions. The results showed a decrease of behavioral flow over time, limited motor patterns that imply personal actions and visual interactions, cyclic changes of personal actions, periodic variations of visual interactions, and individual and cultural differences in verbal behavior profiles. We drew conclusions about an evolving microsociety during an interplanetay journey and identified some features of a Mars mission scenario.

Keywords : interplanetary flight, Isolated and Confined Environment (ICE), astronaut, behavioral flow, actions, social interactions, communication, culture.

Introduction

One of the challenges of interplanetary exploration is the adaptation of human behavior to isolated and confined environments at the individual and group level. The fundamental question is how the interplanetary crew members optimize their relationships under such extreme conditions by coping with sociopsychological factors. Environmental conditions become more extreme with the duration of the mission, particularly when social deprivation and spatial restriction exceed a 500-day duration, as it is the case in a mission to Mars. In that very long-term perspective, we conducted an ethological study during an unprecedended experiment, the Mars-500 experiment. It was designed to simulate the living and working conditions of a multi-cultural crew during a 250-day trip to Mars, a 30-day orbital stay and a 240-day trip back to on Earth, totaling 520 days inside a limited and closed habitat.

Sociopsychological investigations on small isolated groups have focused on interpersonal conflicts influenced by personality traits, coping styles and the heterogeneïty of the teams (Inoue et al., 2004; Lapierre et al., 2009). Investigations of confined groups have focused on mood profiles (i.e., levels of tension-anxiety), depression (Palinkas et al., 2004) and stress (Bishop et al., 2009. On board the Mir orbital station and the International Space Station, asthenia syndrome was characterizied by fatigue, irritability, depressed mood, loss of

concentration and sleep disturbance (Boyd et al., 2007; Kanas et al., 2009). Other results during polar stays and in simulated situations showed positive effects of social interactions (Suedfeld et al., 2011) as well as an impact of the multinationality on the interpersonal reactions (Kanas et al., 2009). These effects underlie individual differences and suggest that personal values should be considered in the composition of the crew for long duration missions (Sandal, 2011) as intercultural differences linked to language skill, work habits, food preferences, and leisure-time activities govern the rules of microsociety (Draguns & Harrison, 2011).

Our previous ethological investigations were first conducted on real situations of microgravity (space shuttle, Mir orbital station, International Space Station) and on simulations during bedrest experiments (simulating the physiological disturbances), during acrobatic and parabolic flights (simulating the sensorial disturbances), during extra-vehicular activities in swimming-pool (simulating the motor changes), during virtual experiments (simulating the cognitive demands), during isolation and confinement campaigns (simulating the social constraints) and finally in analog environments during polar expeditions (simulating the psychological factors). The first results showed that the sensory and physical features of space missions favored new motor strategies in terms of body orientations, postural attitudes and sequences of movements. The last results showed that the social and psychological contexts of space missions induced new spatial strategies in terms of social orientations, inter-individual distances and use of places (Tafforin, 1999; 2006; 2009).

The present study was performed at Ethospace, whose main objective is to analyze human behavioral strategies in extreme environments which can be observed, described and quantified with the methodological tools used in ethology. Over 20 years, this methodology has been applied to a wide panel of situations with an emphasis on space missions of short-term duration, medium-term duration and long-term duration. Ethological applications in extreme environments are complementary to sociopsychological investigations based on self-report measures. We emphasize the non-verbal and verbal behavior based on objective coding schemes.

The working hypotheses are that (1) the crew would express non-verbal actions and interactions with cyclic and periodic changes during different phases of the Mars mission simulation, and (2) that the verbal communications would vary with the individual and cultural diversity of the crew members.

Methods

Images and videos displayed on the ESA multimedia gallery illustrate the Mars-500 experiment.

The experimental paradigm took place at the Institute of Biomedical Problems in Moscow (IBMP) Russia, from June 5, 2010 to November 4, 2011 (Figure 1). The Mars-500 facility comprised four hermetically sealed interconnected modules (550 m3) and a Martian surface module (1200 m3). The mission control personnel verified 24 hours-a-day the safety and life-support parameters on video monitors. We got a copy of video sequences. The Mars-500 crew was composed of three Russians, two Europeans and one Chinese (n = 6 males; mean age = 32 years). During the Mars surface operations, they were separated in two groups: one staying in the main facility and the other simulating the Mars landing with three extra-vehicular activities.

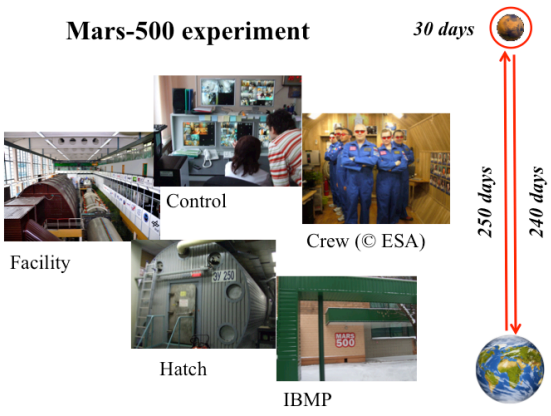

Fig. 1: A 520-day Mars mission simulation (Ethospace, ESA images credit).

Ethological methods were applied in two situations of observation: breakfast time and a group discussion task, using video recordings made respectively every two weeks and every month from day 19 to day 513. We used the Observer XT® software for the descriptive and quantitative analysis. The software intergrated different steps (Tafforin & Gerebtzoff, 2010): definition of a coding scheme (i.e., behavioral repertoire), annotation of videos linked to external data, data selection and data analysis. The coding scheme in the breakfast situation focused on the (p) personal actions (any body segment movements, postural changes), the (v) visual interactions (any gaze directed at one subject), the (b) body interactions (any body contacts between two subjects), the (o) objects' interactions (any manipulations from one subject to the other one), the (f) facial expressions (any face movements such as smiling, laughing) and the (c) collateral activities (any small movements with no manifest functions such as scratching the head, scratching the nose). The coding scheme in the group discussion situation focused on the verbal interactions distinguishing the use of (r) Russian language and (e) English language. The crew's non-verbal behavior and the crew members' verbal behavior were then scored for the data analysis. The numerical outcomes were descriptive statistics (occurrences, durations).

Results

The crew's non-verbal behavior

The behavioral flow (Figure 2) is the global occurrence of non-verbal behavior units (p, v, b, o, f and c) in relative frequency. It shows the number of acts per minute performed by the crew, over the course of the Mars-500 experiment. We observed variations according to the mission day, with a decrease of means along the mission duration. The crew members seemed to reduce the expression of non-verbal behaviors within the confined space. We identified two significant phases. Phase 1 (Day 1 to Day 250) had a higher mean (4.38 ± 0.85) than phase 2 (Day 280 to Day 520) with a lower mean (3.42 ± 0.70) of behavioral flow. There was a difference in expressions between the outbound trip and the return trip of the interplanetary mission.

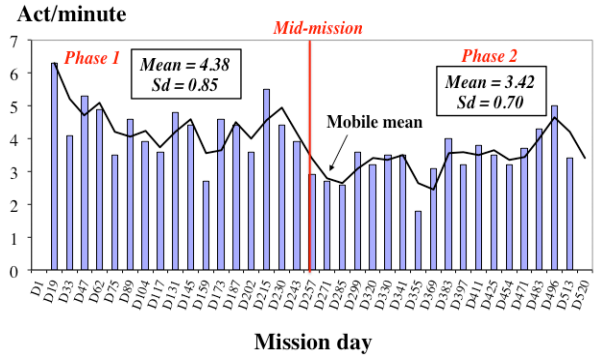

Fig. 2: Crew's behavioral flow at breakfast time, during a 520-day Mars mission simulation.

The behavioral sequences (Figure 3) are the transitions between two units, in absolute frequency, for the total mission days and summed over all subjects. We observed that the most frequent transitions were those from personal actions to visual interactions (absolute frequency = 3582), and vice-versa (absolute frequency = 2870). Alternating occurrences of these two units constituted the main pattern of the non-verbal behaviors (24% and 19%). Considering global sequences, a visual interaction might be followed by a facial expression (8%), followed by a personal action (7%), followed by a collateral action (4%), which was followed by a visual interaction (4%). In the range of possibilities between actions and interactions, the crew members seemed to limit the transitions between non-verbal behaviors. We noted two peculiarities in the behavioral sequences. There was a balance between the personal actions and the visual interactions. There was a prevalence of visual interactions rather than object interactions or body interactions.

Absolute frequency

Sequences	**(p)**	**(c)**	**(f)**	**(v)**	**(o)**	**(b)**	**(d)**	**(s)**	Y0
Personal actions **(p)**	2	642	346	**3582**	139	41	18	0	91
Collateral actions **(c)**	491	406	351	591	44	8	2	0	51
Facial expressions **(f)**	**1093**	421	628	352	35	27	3	0	18
Visual interactions **(v)**	**2870**	461	**1211**	1	72	38	5	0	25
Object interactions **(o)**	185	11	18	76	0	2	3	0	4
Body interactions **(b)**	48	3	20	40	6	0	0	0	0
Diverse **(d)**	18	0	2	9	3	0	0	0	10
Sat position **(s)**	155	0	1	31	0	1	11	0	0
X0	0	0	0	0	0	0	0	199	***14921***

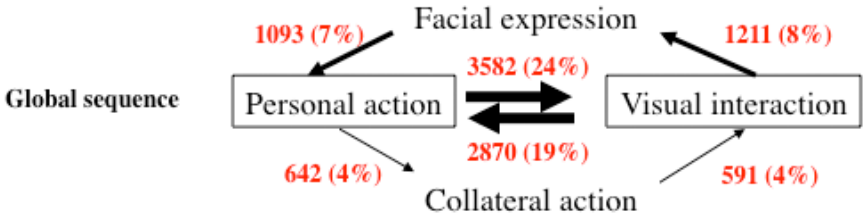

Fig. 3: Crew's behavioral sequences at breakfast time, during a 520-day Mars mission simulation.

The personal actions (Figure 4) are the whole body actions of the crew members. As state events, they are evaluated by the duration, in minutes, and the mean value was summed over all subjects. We observed durations within the range of 12 to 48 minutes from day 19 to day 243 and within the range of 15 to 74 minutes from day 271 to day 513, indicating an increase in the later portion of the mission. Such cyclic individual manifestations could be interpreted as a behavioral strategy for breaking up the monotony of daily-life activities. The crew members would avoid behavioral stereotypes such as performing the same act, at the same time, in the same place. The changes in the duration of the personal actions would compensate for the limited transitions in the behavioral sequences.

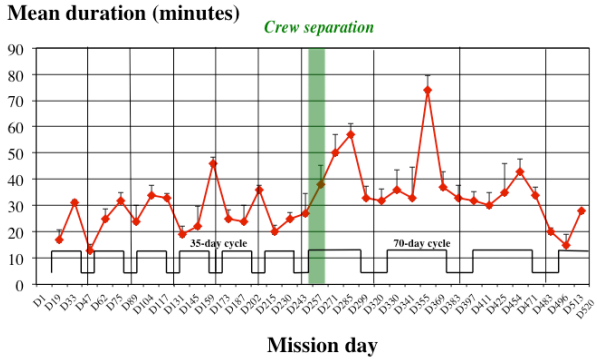

Fig. 4: Personal actions at breakfast time, during a 520-day Mars mission simulation.

The visual interactions (Figure 5) are the main non-verbal interactions between the crew members. As state events, they are also evaluated by the duration, in minutes, and the mean value was summed over all subjects. We observed variations with high, medium and low oscillations during phase 1 and high oscillations during the full phase 2, indicating sub-periods of visual interactions. The crew members would adjust their social relationships by varying the duration of directed gazes.

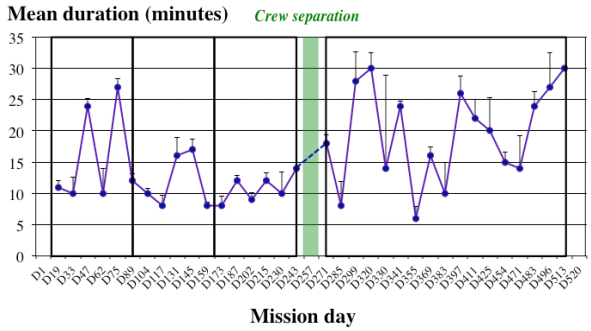

Fig. 5: Crew's visual interactions at breakfast time, during a 520-day Mars mission simulation..

The crew members' verbal behavior

The verbal communications (Figure 6) are the speaking actions towards the crew members, either in English or in Russian. They are state events and are presented per subject on day 487. It is the last day of observation and gives an overview of each crew member approaching the end of the mission. The visual analysis of the occurrences and durations over the task includes topic preparation and group discussion. The track of continuous scored events is visualized as a horizontal bar which represents the behavioral states. We observed that there was not continuous communication, as the item « no verbal interaction » was of longest duration in all the subjects (P1 to P6). The comparison between the subjects shows different profiles of verbal communications. Subject P1 only spoke in Russian, subjects P3 and P4 only spoke in English, and subjects P2, P5 and P6 spoke both in English and in Russian. That supports cultural and individual differences in the verbal communications by the end of the Mars mission simulation.

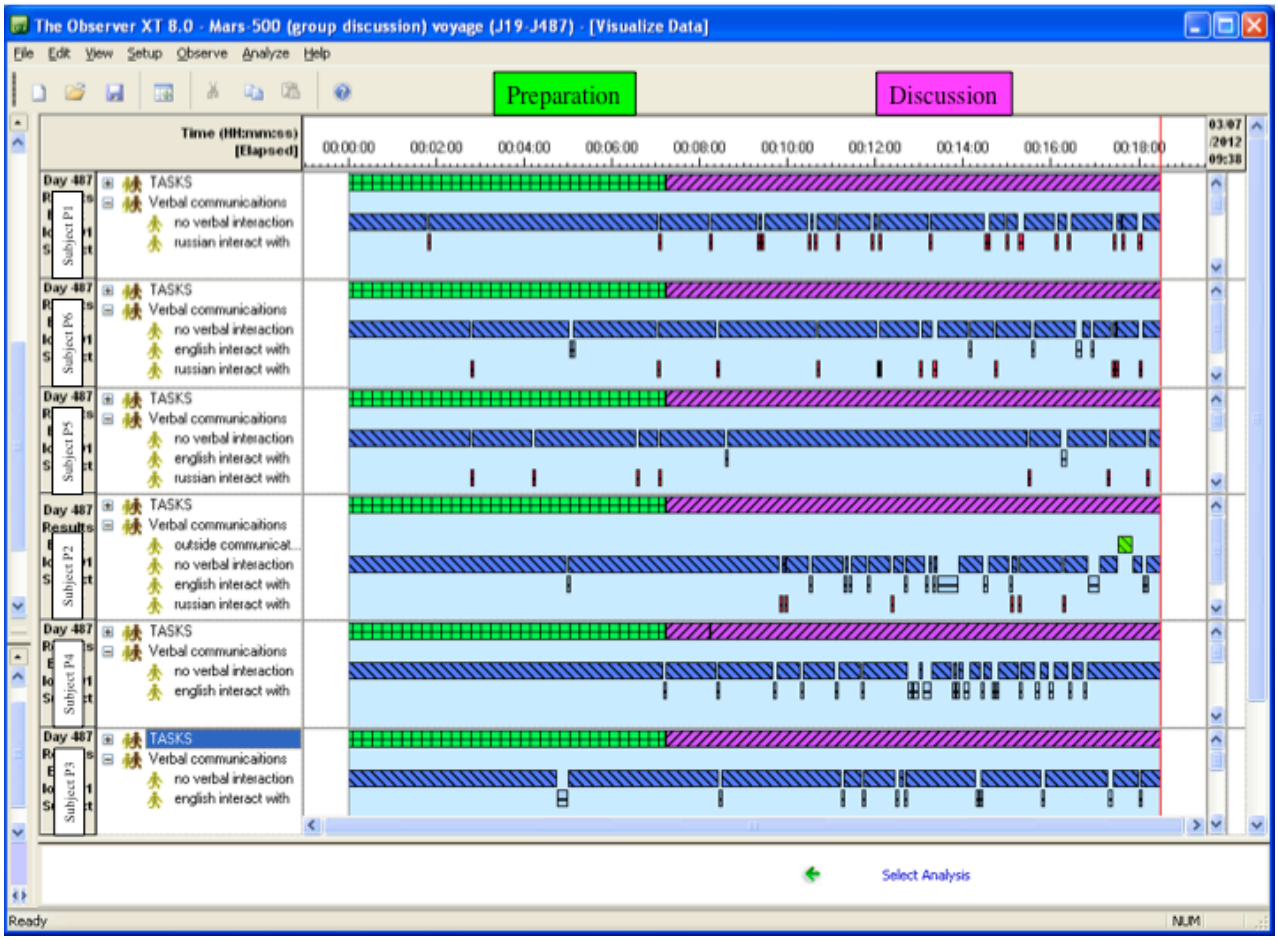

Fig. 6: Crew members' verbal communications during a group discussion task, on day 487 of a Mars mission simulation.

Discussion

During a 520-day Mars mission simulation the crew adjusted to the isolation and confinement conditions by varying their non-verbal behavior according to the time and in diversifying their verbal behavior across individuals and nationalities of the crew members. Their behaviors were manifested, on one hand, through cyclic changes of personal actions and periodic oscillations of visual interactions, and on the other hand, by differences in the profiles of verbal communications. As a result, our study documents a process of adaptation at the individual and group levels. It provides evidence of adaptive strategies such as reducing the behavioral flow in a confined space, and over extended periods of time, such as limiting the behavioral sequences by increasing or decreasing the durations of behavioral events for breaking up the monotony of daily-life activities. Previous studies in similar settings did not reveal such strategies, most likely because the time factor was not long enough. To promote further advances on the interpretation of these findings, in future studies, ethological findings need to be correlated with sociopsychological findings on mood profiles, inter-personal conflicts and physical closeness.

In an evolutionary perspective, during short-term and medium-term orbital flights, human beings develop new spatial and motor behaviors to compensate for the lack of terrestrial gravity. During a long-term interplanetary journey, crew members will have to develop new individual and social behaviors to adapt, far from Earth, to isolation and confinement. When considering this isolated and confined crew as an evolving microsociety, our findings differentiate two phases in the long interplanetary journey. The first phase reflects a temporal structure with cycles and sub-periods of personal and interpersonal actions, whereas the second phase reveals some mismatching of manifestations. After 500 days, cultural and individual heterogeneïty influences interpersonal communications. These could be some of the features of a Mars mission scenario.

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