PSYCHOLOGY AND CULTURE DURING LONG-DURATION SPACE MISSIONS

International Academy of Astronautics Study Group on Psychology and Culture During Long-Duration Space Missions

Final Report

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EXECUTIVE SUMMARY

The International Academy of Astronautics (IAA) Study Group on Psychology and Culture during Long-Duration Space Missions first convened in May 2003 at the 14th Humans in Space Symposium in Banff, Canada. After this initial meeting to define the group's task, members divided into subcommittees and worked on drafts of sections of a study group report via e-mail. Members later reconvened in person several times to discuss the structure and content of the report. These sessions occurred at scientific meetings where many of the members were present. The study group formally convened in 2003 at the International Astronautical Congress (IAC) in Bremen and at the Institute for Biomedical Problems 40th Anniversary Symposium in Moscow. In 2004 it convened at the IAC in Vancouver and at the Annual Meeting of the Aerospace Medical Association (AsMA) in Anchorage. In 2005 it convened at the Humans In Space Symposium in Graz, at the IAC in Fukuoka, and at the AsMA Meeting in Kansas City. In 2006 the group worked over e-mail, and members convened at the IAC in Valencia later in the year to provide input on a draft report. Based on this input, the final draft was completed and submitted to the IAA in November 2006. It was subsequently sent out for peer review by selected IAA non-study group members, and the reviewer's comments were sent back to the study group chair during the following year. These comments were incorporated into this final version, which was sent to the IAA on December 17, 2007.

The objective of this report is twofold: a) to describe the current knowledge of cultural, psychological, psychiatric, cognitive, and interpersonal issues that are relevant to the behavior and performance of astronaut crews and ground support personnel; and b) to make recommendations for future human space missions, including both transit and planetary surface operations on the Moon, Mars, and beyond. Potential readers include members of the IAA; space agency personnel, including astronauts and cosmonauts; and people interested in the psychological and cultural aspects of humans working in space. The focus is on long-duration missions lasting at least six weeks, when important psychological and interpersonal factors begin to take their toll on crewmembers. This information is designed to provide guidelines for astronaut selection and training, in-flight monitoring and support, and post-flight recovery and re-adaptation.

The study group concluded that during long-duration space missions, a number of psychological and interpersonal issues can be identified that affect mission operations and success. These issues may be categorized in terms of crewmember personality and the ability of individuals to cope and adapt to the space environment; factors related to the causes and treatment of potential psychiatric problems; the effects of microgravity and stress on cognition and performance; and interpersonal interactions affecting the crewmembers and their relationship with mission control. All of these issues are in turn influenced by cultural factors, both at the individual and at the space agency organizational level. These psychosocial issues have important implications for pre-mission selection and training, monitoring and support of crews during the mission, and post-mission re-adaptation. Based on this information, the study group made a number of specific operational and research recommendations aimed at increasing our knowledge of these issues and ways they may apply to future on-orbit, lunar, or expeditionary missions to Mars and beyond

The structure of the report is as follows. After a brief consideration of cultural issues, which are addressed throughout the report, four main sections follow: Personality, Coping, and Adaptation; Behavioral Health and Psychiatry; Cognition and Complex Performance Skills; and Interpersonal and Organizational Issues. For each of these sections, there is a review of general issues; implications for mission operations in terms of crew selection, training, monitoring and support, and re-adaptation to Earth; and operational and research recommendations involving future missions to Earth orbit, the lunar surface, or to Mars and beyond. For convenience, the recommendations are summarized below.

Summary of Recommendations

Personality, Coping, and Adaptation

- More attention needs to be paid to human factors in the planning of future long-duration space missions. The IAA can help by continuing to encourage study groups and scientific conferences that deal with the kinds of issues that have been addressed in this report.
- Psychological countermeasures must be implemented before, during, and after space missions that involve crewmembers and their families, as well as relevant ground support personnel.
- To determine the generalization of reported experimental findings for crews in space, the results from analog studies must be compared with those from actual space missions. The IAA can encourage the reporting of such comparisons through scientific conferences and publications in Acta Astronautica and other space-oriented journals and reports.
- More empirical work is needed on defining individual characteristics (e.g., personality, attitude, motivation, skills, coping strategies) and group characteristics that promote optimum coping and adaptation during different kinds of multinational space missions, both short- and long-duration.
- A major challenge in evaluating the efficiency of psychological countermeasures is the use of valid and reliable performance criteria against which they can be tested. The ISS partners should identify and agree on a set of common standards and procedures for the selection, training, support, and evaluation of multicultural crews working in missions involving the ISS, the Moon, or Mars and beyond.

Behavioral Health and Psychiatry

- More attention should be paid to identifying and treating possible psychiatric problems that could occur in space, especially during long-duration missions away from the Earth's immediate neighborhood, such as the Moon or Mars.
- More psychosocial research should be conducted in space, especially in the psychiatric area. The IAA can help by providing research funds and by encouraging national space agencies to support research in psychiatry and other psychosocial areas.
- One area of research would be to help define asthenia as a discrete entity in space and determine if its occurrence is dependent upon one's cultural background.
- Research needs to be done on the effectiveness of voice analysis and telemedicine to diagnose psychiatric conditions and to treat them through counseling or computer-interactive programs.
- Cultural factors related to psychotherapy (e.g., need for counselor-patient cultural match) should be explored, both through research and operational interventions.
- Further studies should be performed on the influence of microgravity on the effects and side effects of psychoactive medications, both in space (e.g., the ISS) and in microgravity simulations on Earth, such as bed rest and water immersion.

Cognition and Complex Performance Skills

- The range of cognitive performance assessment techniques employed in space research has been severely restricted. To obtain a full description and monitoring of the nature of cognitive and psychomotor deficits encountered in microgravity, an integrated test battery should be developed and applied which not only assesses the behavioral aspects of information processing but also includes subjective and psychophysiological measures.
- The relative influence of microgravity stress versus the stress resulting from working in

isolated and confined conditions on basic cognitive and psychomotor functions, as well as complex skills, remains unclear. More research is necessary to resolve the comparative influence of microgravity and work-related stress.

- The effects of radiation on cognitive (and psychological) functioning in space have not been adequately determined, and further research is necessary to evaluate these effects during longer-duration missions beyond the Earth's immediate environment.
- Current research in space and space analog environments has only addressed a narrow range of basic cognitive performance tasks. Examples of issues which have not been studied systematically, but which are of concern for long-duration space flight, include the impact of the space environment on higher-order cognitive processes like decision-making, the impact of culture on performance, and the impact of transient exposure to artificial gravity on mental functions, which will be important if artificial gravity is considered as a countermeasure for future interplanetary space missions. The IAA can help promote these and other areas of cognitive research.

Interpersonal and Organizational Issues

- To encourage crew cohesion during future manned space missions, crewmembers should undergo survival training together in a variety of extreme conditions, such as mountain climbing, polar wintering-over, desert expeditions, parachute jumping, etc.
- It is important that future space flight crewmembers train together during pre-launch operational training. We believe that the longer they train together, the smoother will be their future interactions.

- Some pre-launch training should involve people from mission control in order to enhance crew-ground cohesion and improve the communication between crewmembers and people on the ground.
- Group sensitivity training for astronauts and cosmonauts could reduce the influence of personal, cultural, national, and other peculiarities of behavior during the mission. This training needs to be executed by experienced social and behavioral experts who can supply astronauts and cosmonauts with complete and precise information about their individual and group behaviors.
- Communication and conflict resolution training already used in modern industry (e.g., airline CRM and LOFT programs) could be tailored for use among space crews, with special attention paid to cultural differences. This includes the need to study the language of one's foreign crewmates, with special focus on words and terms describing everyday life related to leisure time and social activities.
- The opinion of crewmembers should be solicited before and during space missions regarding operational issues such as access to logistics, fair workload distribution, and leisure time, so that potential sources of quarrels can be identified and offset. Crewmembers should have many lines of communication, both among themselves and with people on Earth.
- Methods used in the social and behavioral sciences should be applied in the monitoring of intra- and inter-group relations, with the goal of providing a continual supply of objective data about the psychosocial climate of crewmembers in space.
- Crewmembers working on the lunar surface or participating in an expedition to Mars will be more autonomous and less dependent on mission control direction and support than crewmembers engaged in an on-orbit mission. Research needs to done involving the effects of increased crew autonomy during space missions.

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1. Introduction

During the early years of human space exploration, the impact of psychological and interpersonal factors on astronaut behavior and performance was minimal. Missions were relatively short-term and were operated by one space organization, and crews were homogeneously comprised of males from a similar national and professional background. However, with the advent of on-orbit space stations, missions became longer, and crews became more multinational and heterogeneous in terms of gender, cultural background, and professional training. Therefore it was not surprising that anecdotal reports began to hint at the existence of psychosocial problems in such space crews [1-3]. For example, during one Salyut mission a visiting cosmonaut from Czechoslovakia felt socially isolated and complained of being restricted from doing productive work by his Russian crewmates, who were concerned that this foreign "guest" might inadvertently make an operational error. Similarly, a Russian cosmonaut reported discomfort in the crew environment when a visitor from France came to the Salyut, even though the crewmembers all got along during pre-flight training [3]

But long-duration stays aboard an orbital space station represent but one step in the evolution of human space exploration, which also aims at much more ambitious endeavors (e.g., an outpost on the Moon or an expedition to Mars), and these can produce serious psychological and interpersonal consequences. For example, even though some aspects of Mars missions are shared by other settings (e.g., long-duration stays on orbital space stations, historical expeditions to unknown parts of the Earth, wintering-over in Antarctica), there are major differences, mostly associated with the enormous distances involved and the long mission duration [3]. According to currently discussed mission scenarios, a mission to Mars may last up to three years. Depending on the distance between the Earth and Mars and their relative orbital positions, a one-way audio or video transmission between these two planets may take some 22 minutes to accomplish. As a consequence, no real time two-way communication will be possible. Furthermore, there will be no possibility for emergency re-supply or rescue flights. As a consequence, crews on a Mars mission will be exposed to a much higher level of autonomy and long-term confinement and isolation than any previous space crew. At the same time, most strategies of ground-based support that currently are used to foster crew morale and psychological well-being during orbital space missions will be ineffective during expeditions to Mars. This may not only increase the psychological risks related to individual crewmember performance, but it also will produce new psychological challenges never before experienced. One of these challenges has been referred to as the "Earth-out-of-view phenomenon" and is related to the fact that astronauts traveling to Mars will be the first human beings put in a situation where their home planet will be reduced to an insignificant-looking dot in space [3]. The human response to such a situation is unknown. However, given the positive value of looking at the Earth for astronaut well-being [4], it seems almost certain that an seeing the Earth as yet another dot in space will impact negatively on the psyche of Mars travelers.

The objective of this report is twofold: a) to describe the current knowledge of cultural, psychological, psychiatric, cognitive, and interpersonal issues that are relevant to the behavior and performance of astronaut crews and ground support personnel; and b) to make recommendations for future human space missions, including both transit and planetary surface operations involving the Moon or Mars. The focus will be on long-duration missions lasting at least six weeks, when important psychological and interpersonal factors begin to take their toll on crewmembers [3]. This information is designed to provide guidelines for astronaut selection and training, in-flight monitoring and support, and post-flight recovery and re-adaptation.

2. A Brief Comment on Cultural Issues

It is important to keep in mind that cultural issues may impact on each of the areas that are discussed below, in several ways. First, differences in personality styles of coping with stress can occur within any space crew, but the effects are more complicated if the crew is also multicultural. This is because some characteristics, such as emotional expressivity, may be common in some cultures but relatively unusual in others. Second, mental health issues may also manifest differentially across cultural groups. For example, depressed mood may be more likely to co-occur with anxiety among Americans but with fatigue among Russians [5]. Third, cognitive and decision-making styles, along with individual behavior norms such as privacy expectations and personal grooming habits, may also vary by culture. Fourth, cultural differences in social behavior norms, such as how hosts are expected to treat guests or whether everyone is expected to socialize together at mealtime, can also impact on tension and cohesion during missions [6].

In addition, there are additional psychological issues that are unique to culturally heterogeneous crews. For example, international missions may suffer when there are individual differences in language skills or where crewmembers who are in the cultural minority or from a different national culture than mission control [7,8]. In addition to national culture, other relevant types of cultural heterogeneity include professional culture, organizational culture, and the unique culture that a particular group forms over time. Even though diversity may represent an asset to the extent that it adds to the crew's behavior and performance repertoire, having to cope with such differences also adds to the overall level of effort required from crewmembers.

A thorough review of known differences between specific sociocultural groups on these dimensions is beyond the scope of this report. Such differences have been well documented by the psychology, sociology, anthropology, and business literatures regarding the general population, and to some extent regarding airline crews, but they are only just beginning to be documented for space station crews [5,9].

A number of specific cultural issues related to space missions involving humans are imbedded in the four sections that follow (see for example Section 5.5 and 6.3). Our cultural upbringing affects all of us and impacts upon our personality, behavior, cognition, and ways we affiliate in groups. Consequently, it seemed more feasible in this report to integrate culture as an overarching concept into these sections than to expand it into a larger independent section that was separate from the others.

3. Personality, Coping, and Adaptation

The success of most human space missions and the numerous examples of complicated tasks that have been accomplished are generally taken as evidence of the ability of most astronauts to perform and cope in space, both as individuals and as teams. Yet there is considerable anecdotal and behavioral evidence that many crewmembers have experienced psychological and interpersonal difficulties arising from the myriad stressors inherent in space missions, especially those involving longer durations [10]. Psychological and behavioral reactions have included lapses of attention, sleeping problems, emotional lability, psychosomatic symptoms, irritability toward crewmates and/or mission control staff, and a decline in vigor and motivation [11]. Most of these reactions are not specific to spacefarers but also occur in other isolated and confined environments [12-14]. During space missions, psychological difficulties not only affect individual crewmembers, but they may also affect the entire crew, with potentially disastrous effects on the mission (e.g., a clinically depressed astronaut might be unable to perform required tasks in an emergency situation).

By definition, adaptation presumes an accommodation over time. Observations during Russian long-duration space missions [15] and over-wintering in Antarctic research stations [16,17] have suggested that adaptation may occur in stages over time and that the most serious problems are likely to occur around the third quarter. However, empirical evidence for the existence of specific critical phases has been equivocal [13,18-20]. Also, recent studies in space have been limited to on-orbit missions with durations of four to six months. The issue of critical periods in adaptation is important, given that such knowledge may enable both crewmembers and mission control personnel to prepare for problems and intervene before maladjustments result in operational impact.

3.1. Coping Strategies during Short Duration versus Long Duration Space Missions

In the context of long-duration space missions, it may be that the most severe stressors involve monotony and boredom resulting from low workload, hypo-stimulation, and restricted social contacts due to isolation from family and friends. A number of individual factors may impact on the coping ability of crewmembers in dealing with these living conditions. They include: individual experiences, personality, leisure activities, coping strategies, and the kind of social and emotional support available. Also, coping and adaptation are strongly related to interpersonal factors. According to evidence from space and other isolated and confined settings, intra-crew tension, leadership styles, and group dynamics are key factors responsible for exacerbating or ameliorating stress, or facilitating coping and adaptation [3,21].

Efficient strategies to ameliorate stress levels during short-term missions may become problematic or impossible during interplanetary voyages. For example, support provided to ISS crews includes private family conferences via audio or Internet channels in real time will not be possible during a Mars mission due to the communication delays resulting from the great distances involved. Coping based on self-reliance and autonomy will represent important psychological challenges during such missions. There are stable cultural and individual differences in how people habitually deal with stress. Such strategies may be more or less efficient during long-duration isolation and confinement. Although social support may act as a “buffer” against stress, there is anecdotal evidence that the confinement of a small group may lead to openness about a variety of personal matters, and that in some cases such self-disclosure may produce discomfort and regret [14]. Social support factors operate differently in short-duration missions as compared with long-duration missions. In the latter, the burden of support will have to shift away from the “absent” network of family and friends to members of the present crew. This is an area that needs further attention and research.

3.2. What is “The Right Stuff” Personality?

Is it possible to predict from pre-mission assessments how an individual will adapt and perform during long-duration missions? A number of studies addressing the “right stuff” for long-duration space missions have involved analyses of personality factors as possible predictors of adaptation and performance among personnel operating in space analog environments, including Antarctic stations [22] and polar crossings [23]. Several studies have linked superior performance to a personality profile characterized by a combination of high levels of instrumentality and expressivity along with lower levels of interpersonal aggressiveness [13,24,25]. Research in which personality traits have been validated against criteria of astronaut effectiveness during short-term space missions and training sessions have indicated high “agreeableness” and low aggressiveness as general characteristics of high performers [26]. Yet, the “optimal” personality for short and long term missions may differ as a function of mission duration. Research conducted among over-winterers in Antarctic stations suggest that the ideal candidates for long-duration missions have low levels of neuroticism (emotional lability), extraversion and conscientiousness, and show a low desire for affection from others [20]. Although the implications of such characteristics for coping and adaptation during long-term space missions have not yet been investigated, studies like these represent a first step in providing empirical data for defining the “right stuff” for such missions. There is also a need to determine how to translate behavioral data collected in other isolated and confined settings to the space program.

3.3. Implications for Mission Operations

3.3.1. Selection

At the individual level, the objectives of selection strategies are twofold: to eliminate unfit or potentially unfit applicants, and to select from otherwise qualified candidates those who will perform and cope optimally based on their basic aptitudes, personality characteristics, attitudes, and prior experiences. A distinction is therefore drawn between “select-out” and “select-in” criteria. In contrast to select out, select-in criteria need to be developed in relation to specific aspects of the mission, and the weighting of criteria needs to be based on systematic analyses of issues involving mission objectives, duration, and crew composition. In the context of assigning crewmembers for multinational space missions, communication and interpersonal skills, interpersonal compatibility, and cross-cultural competence must be regarded as mandatory. While political and public relations issues will always be contributing factors in assignments for multinational missions, this must not detract from the importance of psychologically-guided crew composition.

Assessment tools used for selection purposes usually include performance tests, personality questionnaires, analyses of biographical data, interviews, and behavioral observations. The combination of several tools is likely to result in the most valid judgment. Particular emphasis should be put on the development and validation of behavioral testing tools (i.e. group exercises, isolation chamber tests) that are suitable to assess interpersonal skills and to predict individual reactions to stress, confinement, and isolation. To date, the absence of formal and valid criteria for astronaut performance, coupled with limited research opportunities, have made it difficult to evaluate the efficiency of crew selection strategies. Such evaluation also requires that select-in criteria not be used in the initial selection process until they have been found to reliably predict astronaut performance. One potential bias in validating selection criteria on astronauts who have already gone through a formal selection process is related to uniformity in the range of personality scores. In multinational pools of applicants, the possible impact of cultural differences in scale usage and response styles also must be considered when personality measures are used in selection. Even though the different space agencies may agree on criteria, a common selection procedure may be difficult to achieve due to differences in preferred methodology.

3.3.2. Training

Psychological training should be provided to both space crewmembers and selected mission control personnel in order to prepare members of both groups for coping with psychological issues during long-term missions. General organizational research and studies from aviation suggest that personality may determine the effects of training programs [24]. The greatest benefit can be expected if selection is combined with pre-mission training that focuses on further development of the coping abilities of individual crewmembers and crews. Training programs should be implemented by each space agency based on international agreements. These programs should include self-care and self-management, teamwork and group living, leadership and followership, and cross-cultural aspects in the preparation for long-term missions. It will be essential for pre-flight training to include a mission simulation that will allow for hands-on training, evaluation, and coaching of the crew under conditions of confinement. An important consideration is that training needs to be tailored to meet the needs of individual crewmembers and specific crews based on differences in personality, cultures, and previous training backgrounds.

3.3.3. Monitoring and Support

Remote monitoring of crewmember behavior and performance represents an important basis for the early detection of impairments and for providing ground-based counseling and advice to the crew. During the mission, crewmembers may be reluctant to give information regarding emotional stress and adaptation. Willingness to discuss personal matters may be reflective of personality differences as well as expectations of the privacy of information. Experience from multinational airlines suggests that there are cultural differences in attitudes regarding discussion of personal problems and fallibility. These issues need to be addressed prior to the mission.

For monitoring purposes, subjective reports used in combination with more objective and non-invasive methods may be most useful. Such methods include computerized performance tests, video recordings of crew meetings, and analyses of speech (including voice analysis). So far, such methods have been utilized mostly in research, and more experience from operational applications is needed. Approaches should take into account the operational constraints of the different mission scenarios. For example, monitoring from the ground, and implementing interventions when problems are detected, might be impossible during future interplanetary missions. During such missions, it will be critical that crews are provided with sufficient training and tools with regards to self-monitoring and resolving their own problems.

During future long-duration on-orbit missions, provision of in-flight support to crewmembers is likely to be an important countermeasure to stabilize emotional state, ensure optimal well-being, and maintain a close contact between space crew and ground. The methods utilized for this purpose will rely on the availability of effective space-ground communication systems (audio-video transmissions) and of re-supply flights that are used for sending support items to the crew. The limited availability of on-site medical or counseling help emphasizes the necessity of accurate and easily available telemedicine/telepsychology consultation. Attention should be given to enhancing individually tailored leisure time activities that take into account changing interests and needs over the course of the mission [3,27]. Other important support activities include private psychological conferences, informal space-ground contact and news from Earth (preferably in the crew member’s native language and from homeland news sources), and opportunities to maintain close contact with family and friends on Earth on a regular basis.

An important issue that needs careful consideration concerns issues related to death, either of a fellow crewmember or of a friend or family member on Earth. An on-board death will affect all of the crewmembers and may best be dealt with at the crew level, perhaps with group counseling mediated by experts on Earth. Bad news from home will primarily affect a single crewmember, and this should be dealt with individually with support from fellow crewmembers. The news should probably be transmitted only after any near-term mission-critical operation has been completed. Providing support for families during the mission can contribute to maintaining the crewmembers' concentration on the objectives of the mission by relieving them of considerations about possible problems at home and feelings of responsibility. In addition, families should be coached in interacting with their in-space family member and be prepared for possible psychological changes during the mission as a result of a psychological crisis.

3.3.4. Re-adaptation to Earth

Family support must not be limited to the in-flight phase. Evidence from various sources (e.g., submarines, Antarctica) has indicated a persistent incidence of reintegration problems for family members absent for long periods of time [3]. Participation in long-term space missions may have similar psychological effects on the participant, which may make it difficult to re-adjust to daily life on Earth and to reintegrate into "normal" family and work.

3.4. Recommendations

More attention needs to be paid to human factors in the planning of future long-term space missions. Psychological countermeasures must be implemented before, during, and after the mission and involve crewmembers and their families, as well as relevant ground support personnel. Current knowledge on long-term effects of coping and adaptation is still limited, and assumptions are based on anecdotal data or research from Earth-bound analogs. To determine the generalization of these findings for crews in space, it is time to compare findings from analogs with psychosocial results from actual space missions. The demarcation of short- from long-term effects is another important issue for future research. Such knowledge would help to assure that selection, training, and support are tailored to meet the demands of the missions.

Much more empirical work is needed on defining individual characteristics (e.g., personality, attitude, motivation, skills, coping strategies) and group characteristics that promote optimum coping and adaptation under different kinds of multinational missions. Also the most efficient methods for assessing such characteristics need to be determined. Such knowledge would be helpful in the development of psychological countermeasures, including selection for crew assignments, psychological training programs, and in-flight support systems. A major challenge in evaluating the efficiency of psychological countermeasures is the identification of valid and reliable performance criteria against which they can be tested. Given the plans to increase the cultural diversity and size of the crews to undertake long-duration stays on the ISS, it would be recommendable that all ISS partners identify and agree on a set of common standards and procedures for the selection, training, support, and evaluation of multicultural crews living and working on the ISS. This initiative would seem to be even more important with respect to lunar exploration missions and an expedition to Mars.

4. Behavioral Health and Psychiatry

In the context of space travel, *behavioral health issues* are normal psychological and interpersonal reactions to the conditions of off-Earth environments. In contrast, *psychiatric issues* are abnormal responses to these conditions. In a given person, genetic, constitutional, and developmental vulnerabilities may contribute to the presence of psychiatric difficulties. However, operational mission stressors (e.g., confinement, danger, microgravity, radiation) and psychosocial factors (e.g., crew tension, cohesion, leadership issues, cultural and language differences) also may play a role and need to be taken into account [3].

Before considering these psychiatric issues, it is important to state that isolated and confined environments can also be growth enhancing and salutogenic [4,14,28]. For example, people in polar environments or space may experience increased fortitude, perseverance, independence, self-reliance, ingenuity, comradeship, and even decreased tension and depression. Some astronauts and cosmonauts in space have reported transcendental experiences, religious insights, or a better sense of the unity of mankind as a result of viewing the Earth below and the cosmos beyond [29,30]. In his diary, cosmonaut Lebedev [31] stated that his Earth photography experiences from the Salyut 7 space station were restful and positive, and he hoped that they would help him gain an advanced degree after he returned from his 211-day mission. Thus, involvement in long-duration space missions and related environments can be quite positive for some people.

4.1. Psychiatric Issues in Space

Mental health problems affect both genders and occur across cultures (although the way they are manifested may vary from one culture to another). Some of these problems are more frequent than others during space missions [3,32]. Most commonly reported are adjustment reactions, which are abnormal responses to internal or external stressors. For example, one astronaut beginning a long-duration space mission had symptoms of clinical depression due to the isolation he felt on-orbit and his separation from his wife and family [3]. These symptoms resolved as he adjusted to his new environment. Psychosomatic reactions also have been reported from space. For example, a cosmonaut wrote in his diary that he experienced tooth pain following anxious dreams he had of a tooth infection [30]. Problems related to major psychotic disorders (e.g., bipolar or manic-depressive disorder, schizophrenia) have not been reported during space missions, probably because potential space travelers are well screened psychiatrically for predispositions to these psychotic conditions based on genetic and family history background. However, such severe psychiatric disorders have been reported in astronaut applicants, and they occur in up to 5% of people working in space analog environments, such as submarines and the Antarctic [3,32].

Post-mission personality changes and psychiatric problems also have affected returning space travelers. These have ranged from positive changes, such as new insights into the meaning of life and the unity of mankind, to substance abuse, anxiety, and major depression that have necessitated psychotherapy and psychoactive medications [30]. Readjustment difficulties also have been reported to affect the families of people returning from long absences [33].

4.2. Asthenia

According to Russian space psychologists and flight surgeons, asthenia is another important psychiatric condition that may affect people in space. This syndrome is defined as a weakness of the nervous system that may result in fatigue, irritability and emotional lability, attention and concentration difficulties, restlessness, heightened perceptual sensitivities, palpitations and blood pressure instability, physical weakness, and sleep and appetite problems [34,35]. In the Russian space program, asthenia is viewed as a problem that affects most cosmonauts participating in long-duration space missions. Although "asthenization" is carefully monitored, and a number of countermeasures are employed to prevent it from progressing, empirical evidence for its existence as a discrete pathological entity has been equivocal [35]. In addition, although the full syndrome was first described as "neurasthenia" in the late 1800s by the American George Beard, there is controversy as to its existence in the United States, and it is not recognized in the current American psychiatric diagnostic system. However, neurasthenic spectrum disorders appear in the international diagnostic system used in Europe, Russia, and China. Thus, if flight surgeons only use the U.S. system, they may under-detect asthenic distress in crewmembers, or label problems from a different perspective than that used in other countries. Indeed, there is some evidence that patterns of mood states are systematically different among astronauts versus cosmonauts [5].

4.3. Implications for Mission Operations

4.3.1. Selection

In terms of selection, formal psychiatric examinations and psychological testing typically occur only at the time when candidates are screened in their application to become astronauts [36]. The emphasis is on selecting-out people who have a history of mental problems, who have documented psychopathology, or who are likely to decompensate under the stressful conditions characteristic of the space environment. However, for a specialized expedition-type mission (e.g., to Mars or beyond), potential crewmembers may be under special scrutiny due to the long duration of the mission and to the unusual stressors to be expected. It is likely that some sort of select-out procedure will be conducted specific to this mission. In addition, relevant select-in procedures may need to be utilized that take into account not only personality traits but also interpersonal skills, with the aim of establishing a compatible, cohesive group.

Formal tests for interpersonal compatibility exist and have been used to enhance cohesion in space analog environments. Examples include the Fundamental Interpersonal Relations Orientation—Behavior (FIRO-B) test, sociometric questionnaires, and the Personality Characteristics Inventory (PCI) [3,24]. Careful attention should be given to cultural differences and minority status in crew composition so that an individual does not feel isolated on the basis of cultural background, gender, or work role. Potential crews should be observed in simulation and other relevant group activities prior to launch to test for compatibility and performance. For missions conducted during programs where crewmembers in space are joined by others in a staggered rotation, a record could be kept of each individual's score on interpersonally-oriented tests, and the total score for a prospective crew could be examined for compatibility before additional members are launched into space. Finally, it is essential that all of the crewmembers are fluent in the language that is considered to be common for the mission.

4.3.2. Training

Crewmembers and mission control personnel need to be involved in pre-mission training, sometimes together, since these two groups are not only mutually dependent in conducting the activities of the mission, but they also may be involved in maladaptive communication patterns. Potential training topic areas for briefings include: the effects of mission duration on crew tension and cohesion, the relationship between crewmembers and mission control personnel, the impact of cultural differences on interpersonal interactions, and the appropriate use of different leadership roles. Team building experiences in aircraft cockpit simulators using Cockpit Resource Management (CRM) and Line-Oriented Flight Training (LOFT) have been useful in exposing interpersonal conflicts and performance problems in flight teams [37], and these kinds of activities need to be adapted for space missions and evaluated empirically in the future. Crewmembers could be taught techniques such as relaxation training, meditation, biofeedback, or autogenic training to calm themselves and to lower anxious arousal by controlling autonomic functions.

4.3.3. Monitoring and Support

4.3.3.1. In-flight monitoring

During future space missions, the interactions of crewmembers in space need to be monitored, and conflicts resulting from psychosocial issues need to be dealt with as they arise. Russian space experts on the ground traditionally have tracked crew-ground audio communications, observed video behavior, and held private conferences to assess crewmember well-being. Formal voice analysis of speech patterns and frequencies has not yet proven to be specific and sensitive enough to be practically useful [38], although recent findings in this area have shown some promise [39]. It is important for crewmembers to monitor themselves, especially during an expedition-type mission to Mars, where two-way communications with Earth could be delayed by times of up to 45 minutes. Although there likely will be behavioral and medical experts on-board who are trained to be sensitive to psychosocial issues, what happens if these people become impaired or are part of the deviant behavior? It is important for all crewmembers to be aware of psychosocial issues and to be trained to respond to them when they begin to impact negatively on crew behavior. Also, NASA doctors are evaluating the use of computerized tests that may help crewmembers assess their cognitive state and their ability to perform certain behaviors at various times during the mission.

4.3.3.2. In-flight support

In past space missions, supportive activities have focused on providing increased novelty and stimulation for space crews during times of monotony or asthenia [3,34]. Such activities have included delivering surprise presents and food via re-supply vehicles, increasing on-board music and lighting, and providing contact with people on Earth in real time. For expedition-type missions, the long distances involved will negate some of these supportive activities, and crews will need to use on-board supplies and facilities for support. Crewmembers should have time set aside to discuss interpersonal differences ("bull sessions") and to debrief problems and other critical incidents that have occurred. Attention should be given to leisure time activities and work/rest schedules that take into account changing interests and needs [27]. Finally, family members on Earth should be supported while their loved ones are on long-duration space missions, either via formal discussions sponsored by the space agencies or via informal groups led by trained counselors or the family members themselves.

4.3.3.3. Counseling

Crewmembers should be monitored for symptoms and signs of developing psychiatric disturbances. In near-Earth orbital missions, counseling sessions or crisis intervention can occur between individuals in the crew and therapists on the ground using private two-way audiovisual links. During deeper space missions (such as a trip to Mars), the distance involved will result in communication delays. As a consequence, supportive encounters will depend on the skills of on-board culturally-sensitive crewmembers who are trained in counseling and the use of psychoactive medications. Facilities also need to be available on board to seclude and restrain a potentially suicidal, violent, or impulsive crewmember.

It is unlikely that a psychiatrist or clinical psychologist will be a member of the crew in early missions involving a lunar base or a trip to Mars. However, it is likely that a physician or some other medically trained person would be a crewmember. This individual should have a knowledge of: 1) individual psychopathology and small group behavior; 2) the individual and interpersonal effects of stressors to be expected during the mission; 3) crisis intervention techniques and the facilitation of group awareness, cohesion, and team-building; and 4) the appropriate use of tranquilizers and other psychoactive medications, including their usefulness and side effects under conditions of microgravity [3,32].

4.3.3.4. Computer-interactive intervention programs

Computer-interactive intervention programs show promise for adaptation to long-duration space flights. A computerized format for presenting prevention and intervention information may be more comfortable for some crewmembers than disclosing highly personal information to others. Outcome research suggests that computer-based intervention programs applying cognitive-behavioral and self-help instruction may be as effective as face-to-face intervention for dealing with mild to moderate depression, anxiety, and other types of psychopathology [40-43].

4.3.3.5. Psychoactive medications

Medical kits are available on-board during manned space missions that contain supplies to help the crewmembers cope with space motion sickness, illnesses, and injuries. Psychoactive medications have been part of the formulary as well. For example, Space Shuttle flights have included medications to counter anxiety, pain, insomnia, depression, psychosis, and space motion sickness [44]. Santy and her colleagues [45] have reported that 78% of Space Shuttle crewmembers have taken medications in space, primarily for space motion sickness (30%), headache (20%), insomnia (15%), and back pain (10%). Newer psychoactive medications are being added, such as the so-called "atypical" antipsychotics (e.g., olanzapine, risperidone) and the selective serotonin reuptake inhibitor (SSRI) antidepressants. Prescribing practices and usage rates may vary across cultures, and this issue needs to be studied further in order to better serve the needs of multicultural crews.

Physiological changes due to microgravity and other effects of space may change the pharmacokinetic characteristics of psychoactive medications, influencing both their dosage and route of administration [46]. In microgravity, blood flow increases in the upper part of the body and decreases in the lower part. Relative disuse of muscle groups can cause atrophic changes as well. As a result of these two effects, the blood available and the amount of atrophy that has taken place at a possible injection site will influence the bioavailability of medication from an intra-muscular injection. For example, intra-muscular promethazine for motion sickness usually is given in the arm rather than in the hip in space, with good results [44].

Other physiological changes also may affect medication absorption and metabolism. The movement of oral medications out of the stomach may be decreased by the weightlessness of the gastric contents in space, and intestinal absorption rates may be reduced by blood and other fluid shifts to other areas of the body. Fluid shifts may also affect the bioavailability of medications sensitive to the first pass effect in the liver, where metabolism occurs [46]. Finally, renal excretion rates also may be influenced by microgravity.

4.3.4. Re-adaptation to Earth

Readjustment to life on Earth after a mission needs to be addressed through debriefings at both the individual and the crew level. Some crewmembers may have had unpleasant psychosocial experiences in space that need to be debriefed. For example, a crewmember who was scapegoated during a mission may have unresolved feelings post-flight that may affect future interactions with his or her former crewmates. Some returning space travelers have experienced psychological problems or personality changes as a result of being in space, in some cases becoming more humanistic, religious, or spiritual after observing the oneness of people on Earth or the infinity of the Cosmos [30]. Other returning individuals may have difficulty dealing with the resulting fame and glory of their mission, especially during a first-of-its-kind mission such as a trip to Mars. Family reentry also may be difficult. For example, studies have shown that many wives of male submariners learned to adjust to the absence of their sailor husband when he was on sea patrol. However, over half experienced depression or marital strife after he returned and tried to reinsert himself back into the family dynamics, which led to the expression: “submariners’ wives syndrome” [33]. Thus, support activities continue into the post-mission period and need to take into account not only crewmembers and mission control personnel but also family members and loved ones who may have their own adjustment issues.

4.4. Recommendations

More attention should be paid to identifying and treating possible psychiatric problems that could occur in space. This would especially be important during long-duration missions away from the Earth's immediate neighborhood where evacuation back to Earth would not be practical, such as on the Moon or an expedition to Mars.

It is time to conduct more psychosocial research in space, especially in the psychiatric area. Studies could help define asthenia as a discrete entity in space and determine if its occurrence is dependent upon one's cultural background. Research also needs to be done on the effectiveness of voice analysis and telemedicine to diagnose psychiatric conditions and to treat them through counseling or computer-interactive programs. Cultural factors related to psychotherapy (e.g., need for counselor-patient cultural match) also should be explored. In addition, further studies should be performed on the influence of microgravity on the effects and side effects of psychoactive medications, both in space and in microgravity simulations on Earth, such as bedrest and water immersion. The ISS provides a good platform for some of this research to be done using multicultural space crews. The results of this research will help future space travelers deal successfully with the stresses of long-duration international space missions as they make their way to the Moon, Mars, and beyond.

5. Cognition and Complex Performance Skills

The work of astronauts in space usually includes a variety of tasks, like operating complex technical systems (e.g., docking or undocking a spacecraft, controlling robot arms), conducting scientific experiments, or performing specific tasks during extravehicular activities. Such tasks place demands on different cognitive and psychomotor functions and skills. As a consequence, maintaining a high level of performance efficiency in astronauts during their stay in space represents an important pre-condition of success and safety of long-duration missions.

5.1. Origins of Performance Disturbances in Space

The lack of the usual gravitational force in space has been shown to affect different brain mechanisms. One particularly important effect is the disruption of congruence between vestibular signals and other (e.g. visual, tactile) receptors, as well as between the vestibular otolith and semicircular receptors caused by the altered signals from the gravity-sensitive otoliths. Another direct effect of microgravity is related to mechanical and proprioceptive changes during the execution of movements, leading to a disruption of the usual relationships among efferent and afferent signals that has been referred to as a state of "sensorimotor discordance" [47]. Both of these effects can be expected to require complex adaptive processes (e.g., a re-weighting of afferent information) and to thus affect the efficiency of cognitive and perceptual-motor skills that have been established on the ground.

In addition to these specific effects of microgravity, the working and living conditions of space can induce stress states in astronauts that in turn can lead to degradations of cognitive and psychomotor performance. Examples of such stress states include decreased alertness and fatigue, high workload, and emotional stress due to interpersonal tension or the long-term effects of confinement and isolation. Performance impairments in these states may result from a shift in the pattern of physiological activation (arousal) into a region that is non-optimal for efficient performance, or from a compensatory performance adjustment aimed at actively coping with stress and high workload by applying less effortful performance strategies [48].

5.2. Effects of Microgravity on Cognitive and Psychomotor Functions

The impact of microgravity on cognitive and psychomotor functions has been primarily addressed in experiments focusing on the effects of microgravity-induced changes in the vestibular and sensorimotor system. The main effect of changes in the vestibular system involves a sensory conflict that seems to be the basic mechanism underlying visual illusions of self and surround motions that are induced by head movement disturbances of spatial orientation and space motion sickness [49]. Although information from the vestibular system and other graviceptors seems to affect different parts of the visual cortex, higher processes of visual perception and cognition have been found to remain more or less unimpaired in space, or at least do not exhibit overt performance decrements [50].

The effects of microgravity on the sensorimotor system involve mechanical and proprioceptive changes, as well as a reduced efficiency of central motor programs which have been established under 1g conditions. Performance impairments resulting from these changes include a loss of precision of voluntary movements, or a slowing of movement times and changed kinematics during execution of these movements, as compared to 1g conditions [51]. Since adaptation to most of the microgravity-induced changes in the sensorimotor system can be achieved very rapidly in space, the emergence of these performance decrements can be expected to be limited to an early flight phase [52].

5.3. Maintenance of Cognitive and Psychomotor Performance in Space

Empirical studies addressing the possible effects of spaceflight-related stressors on human cognitive and psychomotor performance have focused primarily on elementary cognitive and psychomotor tasks. Most of them have been conducted during short-term (< 30 days) spaceflights [52]. In spite of the comparatively small number of studies using different methodological approaches, they have revealed a fairly consistent pattern of effects. Whereas performance in elementary cognitive tasks such as memory-search, logical reasoning, or mental arithmetic seem to remain largely unimpaired in space, significant disturbances have been found in perceptual-motor and attentional tasks [53]. The origin of these effects (i.e., whether they reflect effects of microgravity on the central nervous system or unspecific stress effects) has remained unclear. Whereas impairments of perceptual-motor performance during an early phase of the mission most likely are related to direct effects of microgravity on the sensorimotor system, most of the other effects seem to be related to non-specific stress effects arising from physiological changes, inadequate work-rest schedules, or sleep disturbances during adaptation to microgravity and the extreme living conditions in the space habitat.

Considering the impact of long-duration missions on perceptual, cognitive, and psychomotor performance, little systematic knowledge is available. A comprehensive performance monitoring study was conducted during a long-term mission involving one Russian cosmonaut during a 438-day stay onboard Mir [53]. The results of this study suggest a remarkable resiliency of elementary cognitive and perceptual-motor functions to the impact of spaceflight-related stressors, even during an extraordinary long mission. Impairments of performance, alertness, and subjective well-being were found only during the first two weeks in space and back on Earth after the mission (i.e., during critical phases of adaptation to changed gravitational forces, which also were associated with comparatively high workload). After successful adaptation to the space environment, subjective mood and performance functions returned to pre-launch baseline levels and remained stable throughout the remaining 400+ days in space.

5.4. Maintenance of Complex Cognitive and Perceptual-Motor Skills

Nevertheless, maintenance of operational efficiency and complex skills may become a serious problem, since decrements in operational task performance have been observed during Russian isolation studies and space missions. For example, Salnitski et al. [54] investigated the level of performance of cosmonauts in a simulated manual docking maneuver during their stay in space. They found a considerable loss of skill after a period of three months in space, which was mainly attributed to a lack of on-orbit refreshment training under changed gravity conditions. Other degradations of operational performance in cosmonauts (i.e., errors made by crew members in conducting mission tasks) have been related to non-specific stress effects arising from disturbances of the usual sleep-wake cycle, high workload, or psychosomatic discomfort [55]. But systematic research addressing acquisition and retention of complex cognitive and perceptual-motor skills during space missions is lacking. Apart from a few early studies of operational efficiency during Skylab and the Russian studies mentioned above, research efforts have been limited to just a few studies that were performed during ground-based simulations of spaceflight [56]. The results of these studies did not provide any consistent pattern of effects, and most of them suffered from methodological constraints, such as persistent learning effects throughout the experiment. Other areas of possible concern, like the effects of the space environment on higher-order cognitive processes relevant for space operations (e.g., decision making), have not been studied to date.

5.5. Performance and Culture

The aforementioned research suggests that the specifics of the space environment and the different stressors astronauts are exposed to can cause detrimental effects on basic cognitive, attentional, and psychomotor processes. Much less is known about if and how these effects are moderated by culture. Concerning the effects of microgravity on performance, it does not seem likely that these effects are different for members of different cultures. However, performance may depend on the cultural background of astronauts in other ways. One example regards the effect of lack of privacy and crowding in a confined environment, like a space habitat. Whether lack of privacy is perceived as a stressor, and thus entails detrimental effects on mood and performance, largely depends on the cultural background of individuals [57]. Similar effects may be assumed for other psychosocial stressors as well, like monotony and boredom, time pressure, or workload. In addition, culture might be a factor influencing higher-order cognitive processes, like decision-making or the use of schemes in information processing.

5.6. Implications for Mission Operations

5.6.1. Selection

Current practices of psychological selection of astronauts already ensure that only individuals are accepted as astronaut candidates who show comparatively high levels of cognitive capabilities. Given the fact that attentional and psychomotor skills in particular appear to be prone to performance degradations in space, these kinds of capabilities should be given special weight in future selection activities.

5.6.2. Training

During pre-flight training, astronauts should be briefed about likely performance decrements in space. In particular, astronauts need to be made aware of the possibility of impaired psychomotor performance during their adaptation to the space environment (e.g., the precision and speed of their arm and hand movements may be impaired). These effects also must be taken into account in the planning and scheduling of motor-tasks during the mission, such as the setting up of experimental hardware. In addition, astronauts should be briefed on the importance of sleep and adherence to work-rest schedules in order to protect themselves against any resultant performance decrements. Rotational training on the ground may also help astronauts learn to adjust to spatial disorientation in space.

5.6.3. Monitoring and Support

It has been shown that performance impairments might be expected during adaptation to the space environment and during specific stress states induced by sleep problems, high workload, and/or emotional burden. In order to detect such adverse effects and to provide appropriate support and countermeasures (e.g., re-scheduling of mission tasks, accommodation of work-rest schedules), tools are needed which can discern subtle performance decrements before they escalate. One approach is to monitor the cognitive and psychomotor capabilities of astronauts during their stay in space by repeatedly assessing their performance in specific screening tests, and to compare the results with a self-referenced baseline established during pre-flight training. One example of such a tool that is currently being used on the ISS is the WinScat (*Win*dows-*S*paceflight *C*ognitive *A*ssessment *T*ool [58]). The current focus on cognitive probing tasks should be expanded by including tasks that measure attention and psychomotor functions that have been found to be particularly sensitive to microgravity and stress-related effects during space missions.

With respect to in-flight support and maintenance of performance functions, the currently available results point to the importance of sleep and appropriate work-rest schedules as a significant pre-condition for performance efficiency. In addition, in-flight training of critical perceptual-motor tasks will become more and more important if mission lengths increase. The importance of these factors has been emphasized by the investigations of a severe accident that occurred on the former Mir station when one of the modules was hit and damaged during the manual re-docking of a supply spacecraft. Among the factors that were identified as contributing to this accident were issues of maintaining the operator's docking skills throughout the stay in space and decrements in his performance due to fatigue.

5.6.4. Re-adaptation to Earth

Based on the currently available database, no permanent problems are expected with respect to basic cognitive processes and performance during re-adaptation to Earth. The only exception relates to psychomotor skills that might be impaired for a limited period of time due to re-adaptation to Earth's gravity.

5.7. Recommendations

The current database is small and includes too few empirical studies to warrant definite conclusions about the risks of performance deficits during long-duration space missions. The limits of our current knowledge are related to four different issues:

First, the range of cognitive performance assessment techniques employed in space research has been severely restricted. A full description and monitoring of the nature of cognitive and psychomotor deficits encountered in microgravity will require the application of integrated test batteries which do not only assess the behavioral aspects of information processing (e.g., the speed and accuracy of performance), but also include subjective and psychophysiological measures (i.e., provide information about a possible trade-off between performance and associated psychophysiological costs, as well as about the astronauts' emotional and performance state). Early attempts at such psychophysiological monitoring have been made during Russian space missions [59].

Second, the relative influence of microgravity stress versus the stress resulting from working in isolated and confined conditions on basic cognitive and psychomotor functions, as well as complex skills, remains unclear. More research is necessary to resolve the comparative influence of microgravity and work-related stress.

Third, the effects of radiation on cognitive functioning in space have not been adequately evaluated. This especially will be important during future multi-month expeditions to the Moon or to an even longer duration mission to Mars or other bodies in the solar system. To date, missions have been either in low earth orbit, where the Earth's magnetic field provides shielding to the crewmembers from excess exposure to galactic cosmic rays and particles from solar particle events (SPEs), or have involved brief visits to the Moon, where the mission duration has been less than a month and during which SPEs fortunately were absent. Further research is necessary to evaluate the effects of radiation on cognitive (and psychological) functioning during longer-term missions beyond the Earth's immediate environment

Finally, current research in space and analog environments has only addressed a narrow range of basic cognitive performance tasks. Examples of issues which have not been studied systematically, but which are of concern for long-duration spaceflight, include the impact of the space environment on higher-order cognitive processes like decision-making, the impact of culture on performance, and the impact of transient exposure to artificial gravity on mental functions, which will be important if artificial gravity is considered as a countermeasure for future interplanetary space missions [60].

6. Interpersonal and Organizational Issues

The ways in which crewmembers interact and function as a group can affect productivity and the accomplishment of mission goals. In order to optimize these interactions, it is important to understand several issues that may interfere with crew cohesion. These include: 1) crew tension resulting from environmental stress and factors related to crew heterogeneity; 2) time-related drops in cohesion, especially during the second half of the mission; 3) poor leadership skills (e.g., failure to support the crew during times of low morale); and 4) stress due to cultural and language differences [3].

In addition, during long-duration space missions there is evidence that time may influence the impact of these psychosocial issues. There have been reports that crewmembers in space or in space analog environments may experience psychological and interpersonal difficulties after the halfway point of a mission [3,21,61]. According to this view, a sense of relief that half of the mission is over is outweighed by the realization that another half is yet to come. Another time model incorporates Rohrer's three sequential phases, which include: 1) initial anxiety, 2) mid-mission depression, and 3) terminal euphoria [16,62]. Other time models have emphasized decrements in particular quarters of the mission, especially the 3rd quarter [21,61,63]. However, others have failed to find such time effects in space and space analog environments [18,64,65].

The above issues can result in psychological and interpersonal problems if they are not understood and addressed. These include: 1) decreased crew morale and compatibility, 2) withdrawal or territorial behavior as crewmembers cease to interact with each other, 3) the scapegoating of an individual as a "solution" to group conflict, and 4) the formation of subgroups that compete with each other and destroy crew unity.

6.2. Alienation

Group tension can lead to feelings of alienation and personal isolation. Although mission goals may be achieved, tension could still be stressful for the crewmembers, influencing their mood, sleep quality, and general satisfaction with spaceflight conditions.

Post-flight debriefings have revealed differences in values among crewmembers arising from their differences in professional culture, age or nationality. This corresponds to findings from studies of small isolated groups, where it was shown that in the process of cohesive group formation, crewmembers began to regard each other as very "similar" or "close", sharing common values and belief [66-68]. On the contrary, crewmembers who did not perceive themselves as close and did not make attempts to understand and share common group values ran the risk of becoming the "stranger" or the "alien" in the group [69-73].

The "stranger's" incapability or lack of motivation to transform his or her own system of values and attitudes can be rationalized in two ways: others might be regarded as 1) conforming insincerely or 2) searching for and exaggerating objective factors (which might actually influence understanding). Among these factors, astronauts and cosmonauts who participated in Mir/NASA studies mentioned language barriers, cultural differences, gender differences, professional variation, and differences in perspective [74,75]. Interestingly, in several isolation studies [68,76], the existence of an individual seen as the "alien", either inside or outside (e.g., mission control) of the group, could be a uniting factor that supported group cohesiveness. This is consistent with the sociological literature [77].

Cultural, religious, professional and other differences have played the role of triggers and formed a rationale for tension appearing in space crews. These have, however, been overcome during the course of international space missions [75,78-81]. It could be that the key factor that supports successful adaptation of the group is the individual's capability to share the general values and aims of the group and to establish empathetic relations with partners. In studies simulating the influence of space flight, crewmembers more favorably perceived those they referred to as "supportive", "loving", "warm", "socially competent", and who had an orientation toward empathetic interrelations and the social side of life [68-70].

6.2. The "Host-Guest" Problem

Problems involving "guest" cosmonauts have been observed during Russian on-orbit space missions, when a visiting crew joins the more permanent crew, whose members have already adapted to space flight conditions and are executing their complicated flight program. In one example on the Mir space station where visiting crewmembers came for a short period of two weeks, their working capacity was low due to adaptation to microgravity. However, playing the "hospitable host", the primary crewmembers had to postpone the completion of their own tasks to help the newcomers, which substantially delayed the execution of their flight program. The "host-guest" situation has been a source of psychic tension and decreased effectiveness of interaction on-orbit, and not necessarily only in cases where foreign astronauts participated [18,82,83].

Another aspect of the problem could be discussed from the point of view of Altman's ecological approach [84-86]. A cohesive crew, already adapted to life on a space station, could regard the visiting crew's appearance as a psychological invasion. In the course of space station habitation, the cosmonaut or astronaut forms his or her private psychological space, which feels psychologically comfortable. The arrival of a visiting crew, however, redistributes the station's territory. Even the presence of a newcomer in one's "area" might be regarded as an encroachment and cause a certain discomfort.

6.3. Minority Status and Organizational Culture

Cultural differences were examined during two large international studies that were funded by NASA that involved missions to the Mir space station and to the International Space Station [3, 18, 64, 82, 83]. The Mir study sample consisted of 5 American astronauts, 8 Russian cosmonauts, and 42 American and 16 Russian mission control personnel. The ISS study sample consisted of 8 American astronauts, 9 Russian cosmonauts, and 108 American and 20 Russian mission control personnel. The findings suggested that compared with the Americans, the Russians experienced more direction, support, and self-discovery during the Mir missions; more tension/anxiety during the ISS missions; and less pressure on the job in both studies. These findings may have reflected basic cultural and attitudinal differences between these two groups of people. But there were also differences in the mission profiles that might have influenced these results.

For example, in the Mir program the missions took place in a Russian space station, were largely Russian-operated using the Russian language, and always had a Russian commander. The American astronaut was always in the minority in the three-person crew and had less of an operational relevance. Thus, it is understandable that American participants would have felt less comfortable and supported that the Russian participants.

In contrast, the ISS program had more variable crew compositions, with both sides having clearer work roles but with a decidedly American style of operations. This might have created tension or anxiety on the part of the Russian crew and ground participants, possibly from perceived differences in organizational culture between the two space agencies. For example, it has been suggested that compared with American organizational practices, the Russian space program typically utilizes fewer written procedures and relies more on expert opinion to deal with problems that arise [87-89]. Thus, it is possible that the Russian participants in the ISS study may have been reacting to what they perceived as a less comfortable work environment in terms of familiar organizational practices.

In terms of work pressure being higher in U.S. subjects during the Mir program, working on a foreign space station (Mir) or mission control center (Russian mission control) with relatively unclear goals might have created more job pressure for the Americans, who were also less experienced in conducting long duration space missions. In the ISS program, being primarily responsible for the complex operations involved with the construction of a new space station would be expected to impact more on the workload of U.S. participants.

6.4. Psychological Closing, Autonomization, and Displacement

Psychological closing in space is a phenomenon manifested by decreased communication intensity as well as increased filtration and limitation of the scope and content of crew communication. It has been observed that people in space tend to hide medical and psychological problems that occur in flight from mission control. They also have demonstrated preferences in contacts with mission control personnel, openly rejecting contacts with some people and giving preferences to others [90,91]. This phenomenon is attributed to the combined influence of the "forced" character of communication sessions (e.g., limited time and choice of people to talk with), sensory deprivation and monotony in space, and the intention of space crews to maintain their socially desirable image as heroes.

Autonomization in space is expressed by crew egocentrism and an attempt to deal with an out-group (i.e., mission control). This kind of development in isolated and confined individuals is a natural and even necessary stage of the formation of a cohesive group. Unfortunately, the manifestation of this process sometimes results in mission control personnel being perceived as opponents, not partners, and it sometimes is the source of mutual tension and misunderstanding. The crew becomes more critical in their discussions of operations with mission control, frequently pointing out the discrepancies in their positions [61,68,73,76,79,91,92]. The most vivid examples of autonomization of the crew in space are the famous Skylab strike and the discrepancy in opinions between mission control and one of the Mir crews concerning the need for an EVA to repair some solar batteries.

Another phenomenon of group behavior in space crews that is closely connected to autonomization is *displacement*. This occurs when crewmembers in space experience high levels of anxiety, negative emotions, and interpersonal conflict that cannot be resolved directly. These unpleasant affects may be transferred externally to people in mission control, resulting in a belief that they are unempathic and non-supportive [3,18,31,62,64]. Evidence for the occurrence of displacement has been found during both Shuttle/Mir [64] and ISS missions [93]. Some space psychologists regard this phenomenon as a coping strategy, allowing people in an isolated group to avoid open conflict by draining out negative emotions, thus not perturbing their psychological and interpersonal climate. Whereas this strategy might be effective in the short run, in the long run it encourages negative feelings to fester and build, resulting in blocked emotions, territorial behavior, and poor cohesion.

6.5. Crew Autonomy

The relationship between crewmembers and people in mission control also relates to crew autonomy. In future space missions involving a lunar base or an expedition to Mars, crewmembers will have to function more autonomously than before due to the long distances involved and the types of activities required in setting up camp and exploring an alien surface [3].

In all likelihood, crews will need to plan most of their day-to-day activities without mission control input, and should a problem occur they would have to deal with it themselves. This planning extends to leaving time to sleep, eat and exercise, since nutritional and physiological factors are important in maintaining crewmember health and well-being [94], and they should not be compromised during the course of a busy work day. In addition, crewmembers will have to trust their on-board resources for monitoring life support and providing them with the information they will need to carry out their mission, so the human-machine interface will become even more important. It is time to start thinking about the issue of increased crew autonomy and the role of mission control during such non-orbital activities beyond the Earth's immediate environment.

6.6. Implications for Mission Operations

6.6.1. Selection

From the pool of highly motivated persons with well-developed coping strategies in the astronaut corps, psychologically compatible personalities are selected for a particular crew. It would be useful to have an internationally-approved test battery available that predicted not only the interpersonal compatibility of the crewmembers but also their ability to perform in a group. One such measure that is being used for crew selection in Star City in Russia is the Homeostat [68-70].

6.6.2. Training

People working in space missions need to recognize and deal with psychosocial problems before they deteriorate crew performance and behavior. Training countermeasures could include formal lectures and briefings that address important psychological and interpersonal issues in space, accompanied by training in conflict resolution, cultural sensitivity, and team building [3]. Because the crew-ground relationship is important, especially during on-orbit missions, it would be useful to include members from both groups during some of the training sessions.

6.6.3. Monitoring and Support

Internationally approved procedures for the in-flight monitoring of crewmember interactions and group performance should be created, especially for on-orbit missions. Recent experiences in Russia suggest that the monitoring of crew communication sessions by mission control, including voice frequency analysis, content analysis of speech, and face expression dynamics, gives valuable information about the psychosocial status of the crew. However, such intense monitoring will be less productive during non-orbital missions, such as a lunar base or an expedition to Mars, due to the long distances involved and the need for crews to be more autonomous in carrying out their missions. In addition, the long distances will delay audio or video transmission times, thus hampering traditional supportive strategies that have depended on real-time crew-ground communication, and the possibility sending emergency supplies or evacuating a sick crewmember will be low.

6.6.4. Re-adaptation to Earth

After space missions, both crewmembers and mission control personnel follow a strategy of keeping positive attitudes towards their teammates and reuniting crewmembers with their families. The role of space psychologists is to facilitate this process.

6.7. Recommendations

We recommend survival training of crewmembers in a variety of extreme conditions, such as mountain climbing, polar wintering-over, desert expeditions, parachute jumping, etc. These serve to increase individual psychological resources and enhance mutual confidence among crewmembers. Astronauts and cosmonauts have mentioned the effectiveness of these kinds of training.

In crew training, a well-known method has been to have future spaceflight crewmembers train together in flight operations. If they can better know each other and understand their strong and weak points, they can learn to solve problems in space. The duration of the preparation of the crew is crucial: the longer they train together, the smoother will be their future interactions. In addition, some of this training should involve people from mission control in order to enhance the bonding and improve the communication between crewmembers and people on the ground.

Group sensitivity training for astronauts and cosmonauts could reduce the influence of personal, cultural, national, and other peculiarities of behavior during the mission. This training needs to be executed by experienced social and behavioral experts who can supply astronauts and cosmonauts with complete and precise information about their individual and group behaviors.

The communication and conflict resolution training already widely used in modern industry could be tailored for use among space crews, with special attention to cultural differences. This includes the necessity to study the language of one's foreign crewmates, with special focus on words and terms describing everyday life so that crewmembers can discuss not only their work, but also to talk about leisure and other social aspects of their lives.

The opinion of crewmembers should be solicited and taken into account regarding access to logistics, fair workload distribution, etc., so that potential sources of quarrels can be identified and offset. Crewmembers sharing space aboard the ISS should have many lines of communication, both among themselves and with people on Earth. The "forced" element of standard audio-video communication links could be supplemented by providing all crewmembers with e-mail links so that they might communicate at their leisure.

The methods of the social and behavioral sciences must be applied in the monitoring of intra- and inter-group relations, with a continual supply of objective data about the psychosocial climate in space. Specialized computer tests devised at the Institute of Biomedical Problems include the "PSPA" (used for investigating personality and relations in a small group) and the Homeostat (used for observing small group performance) [68-70, 95]. Another IBMP method is the quantitative analysis of crew-mission control verbal communication as well as the structure of e-mails (e.g., length, verbal composition) sent by the crewmembers [68,69]. Other monitoring techniques continue to be developed.

Finally, research needs to done involving the effects of increased crew autonomy during manned space missions. Crewmembers working on the lunar surface or participating in an expedition to Mars will be more autonomous and less dependent on mission control direction and support than crewmembers engaged in an on-orbit mission. Little is known about how this autonomy will affect operations, and the ISS could provide a test bed for studies that explore this issue.

7. Conclusions

During long-duration space missions, a number of psychological and interpersonal issues have been identified that will affect mission operations and success. These issues can be categorized in terms of crewmember personality and the ability of individuals to cope and adapt to the space environment; factors related to the causes and treatment of psychiatric problems that may occur; the effect of microgravity and stress on cognition and performance; and interpersonal interactions affecting the crews and their relationship with mission control. All of these issues are in turn influenced by cultural factors, both at the individual and at the space agency organizational level. These psychosocial issues have important implications for pre-mission selection and training, monitoring and support of crews during the mission, and post-mission readaption. Specific operational and research recommendations are made that will increase our knowledge of these issues and how they may apply to future on-orbit, lunar, or expeditionary missions to Mars and beyond.

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LIST OF ABBREVIATIONS

AsMA: Aerospace Medical Association

CRM: Crew Resource Management

EVA: Extravehicular Activity (i.e., “space walk”)

IAA: International Academy of Astronautics

IAC: International Astronomical Congress

IBMP: Institute for Biomedical Problems (Moscow)

ISS: International Space Station

LOFT: Line-Oriented Flight Training

NASA: National Aeronautics and Space Administration