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Space missions: psychological and psychopathological issues

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Abstract

Exploring space is one of the most attractive goals that humanity ever set, notwithstanding, there are some psychological and psychopathological risks that should be considered. Several studies identified some possible hazards of space travels and related physical and psychological consequences on astronauts. If some psychological reactions are obviously inherent to the characteristics of the spaceships (habitability, confinement, psychological, and interpersonal relationships), other (disturbances of sleep-wake cycle, personality changes, depression, anxiety, apathy, psychosomatic symptoms, neurovestibular problems, alterations in cognitive function, and sensory perception) represent a clear warning of possible central nervous system (CNS) alterations, possibly due to microgravity and cosmic radiation. Such conditions and eventual CNS changes might compromise the success of missions and the ability to cope with unexpected events and may lead to individual and long-term impairments. Therefore, further studies are needed, perhaps, requiring the birth of a novel branch of psychology/psychiatry that should not only consider the risks related to space exploration, but the implementation of targeted strategies to prevent them.

Introduction

The history of human beings is accompanied by a constant drive to overcome the limits intrinsic to their nature, like the possibility to fly. As such, it is paved by continuous attempts to accomplish this goal throughout the millennia, from the Icarus' myth to the flying machines of Da Vinci until the first airplane built by Wright brothers. The 20th century was a unique century for the extraordinary developments of flying aircrafts for both war and civil use, as well as for the beginning of space exploration that started in 1944 with the V2 rocket. The soviet cosmonaut Yuri Gagarin was the first man to be launched into the space on the 12th of April 1961, a date that gave birth to the space race.[1]Soviet Union was soon followed by the United States with the renowned Mercury, Gemini, and Apollo programs that led Neil Armstrong and Buzz Aldrin to land on the Moon. Different dates in the following years mark some relevant milestones in the history of space missions, important for present and future space travels. In 1970, the U.S. Apollo 13 mission aimed to land on the Moon for the third time, but during the trip, the spacecraft was damaged and the purpose of the mission was to bring the three astronauts back. In 1971, the USSR launched its first space station, Salyut-1, as a short-lived space laboratory that laid the foundations for subsequent stations and medical investigations of astronauts, followed by the U.S. first space station, Skylab, a top of a Saturn V rocket, in 1973. This served as a solar and terrestrial observatory and as a microgravity and medical laboratory.[2] In 1981, the shuttle Columbia orbiter left its pad at Kennedy space center during the transportation system (STS-1) mission, while heraldeing the beginning of a new era of spaceships that could be reused.[3] The next STS missions played an important role in implementing biological studies.[4] The base block of MIR, a Soviet modular space station, was put in orbit in 1986 and about a month later was joined by its first crew. Although it served primarily as a test for space hardware, more than 100 astronauts from different nations carried out extensive scientific research, especially on the effects of microgravity on living organisms.[5] The two nations ended up forming a successful collaboration over the years that still continues on the international space station (ISS) that represents a unique environment for the study of long-term space missions.

Several countries have then rapidly shown a keen interest in space missions, so that the National Aeronautics and Space Administration (NASA), in collaboration with space agencies from all over the world, is currently planning the Artemis program that is the return of men to the Moon and, in particular, of the first woman. These and other space missions will provide additional foundations to missions primarily planned to reach Mars, included in the NASA projects for the next decade.[6]

Space has long been considered a hostile environment able to provoke several detrimental consequences on human physiology that may lead not only to medical diseases, but also to psycho(patho)logical conditions.[7–13] Maintaining an adequate psychological well-being is, therefore, a crucial and untold task for astronauts, as several factors can hinder it. These can be grouped in physical, habitability factors, and individual or interpersonal psychological factors, and will be briefly reviewed herein.[14,15]

Physical factors

Microgravity, radiation, and habitability stand among the most studied physical parameters with evidence of their potentially negative consequences.

Microgravity

Although the full effects of microgravity on human physiology are still unclear and mainly derived from simulation studies, evidence suggests that it might impact cell structure and differentiation, and both the immune and central nervous system (CNS).[16,17] Indeed, the CNS needs to adapt to microgravity since different somatosensory, visual, and vestibular informations have to be elaborated.[18] A syndrome known as space adaptation syndrome may occur as a consequence of a sensory conflict between inputs from visual and tactile senses and vestibular organs.[19] Furthermore, microgravity can lead to some changes in cognitive functioning, as demonstrated by a reduction in some motor functions (ie, dual-tasking, motion perception, and manual dexterity) in a small sample of eight astronauts following a 6-month period spent on ISS that, however, disappeared four days after landing.[20]

Radiation

There is now a general agreement that space radiation represents a further risk during space missions and, interestingly, NASA shows a huge concern on this matter.[21] The global radiation dose for astronauts is deeply affected by galactic cosmic rays (GCR) originating from outside the solar system and including alpha particles, protons, and high-energy, heavier nuclei components of the former that are called high atomic number and energy (HZE).[22,23] As GCR interact with the shielding material of a space shuttle, a large emission of secondary neutrons may follow, thus potentially impinging on the bodies of cosmonauts.[24] Furthermore, pulses of heavy ion and energetic proton radiation may be the result of solar particle events, including coronal mass ejections and solar flares.[25] Along with electromagnetic field and weightlessness, radiation may lead to several CNS changes, such as shifts in brain fluids, altered sensory perception, and neurovestibular problems.[26] Data from rodent models reported modifications of the CA1 superficial layer pyramidal neurons in the dorsal hippocampus, that may persist after 6 months from the irradiation.[27] This caused learning and memory impairment, as well as increased anxiety behaviors also indicating damage of the amygdala and of some cortical neurons.[28,29] Moreover, astronauts may undergo deficits in executive functions and decision-making due to a functional loss in the medial prefrontal cortex, posterior and anterior cingulate, and basal forebrain.[27,30] Indeed, it is a common assumption that one out of five astronauts taking part in a long space mission would experience similar behaviors, and out of three would instead face struggles in memory processes.[27] Radiation exposure may also be one of the determinants of visual disturbances. During the Apollo, Skylab, and MIR missions, astronauts observed flashes of light, of different shapes, moving across the visual field.[31] Such flashes were more often present before sleep, predominantly white, with elongated shapes and often accompanied by senses of movement perceived as lateral, diagonal or in-out.[32] It has been suggested that these phosphenes can be a consequence of an alteration in perception caused by ionizing radiation on the eye.[33]

Habitability

Several factors of "habitability", a term used with reference to the main characteristics of the spacecraft, may contribute to the overall well-being of astronauts, while including light, noise, vibration, and temperature.[15,34] The light represents the main stimulus of the circadian rhythms that can be deeply affected by changes in luminosity. Therefore, it has been suggested to remove the light from the settings and the spaces dedicated to sleep, or to create an environment with alternating light and dark in the spaces shared by the astronauts.[35] Excessive exposure to noise, mainly due to the equipment and the crew activities, may represent another stressor compromising wakefulness and sleeping, so that cosmonauts have been instructed to wear protection devices.[36]

Whole-body vibration may represent another harmful factor due to the risk of spinal and extremity injuries.[37] Finally, habitability includes the need for privacy that may not be always sufficiently respected.[38]

Psychological factors

The peculiarities of life during long space missions, specifically isolation and interpersonal relationships may represent stressors leading to psychological/psychosocial problems or even to psychopathological symptoms or disorders.

Individual issues

Isolation from family, friends, and the life on the Earth, coupled with hard work continuously monitored, represent some factors of potential psychological distress.[13] During isolation, memory and concentration deficits may occur, along with an increase in the likelihood of making errors and a decrease in reaction times.[39] Long space missions can also induce cosmonauts to monotony that may worsen other psychological stressors, thus potentially leading to impaired performance and behaviors.[40] Furthermore, since crew activities become progressively part of a routine, an increase in free time and a greater likelihood of asthenia, withdrawal, and territorial behavior may follow.[41]

Interpersonal issues

During a space mission, the mental well-being of an astronaut can be affected by factors related to the relationships with other crew members, especially when they are heterogeneous. These may provoke tension, loosening of the team cohesion, subgrouping, scapegoating, communication issues, the creation of a competitive environment and uncertainty regarding individual roles.[7] The relationships between cosmonauts and ground control are also important, as conflicts may arise for disparate reasons, such as delays in communication, ranging from minimal delays to around 24 minutes from the most distant planets, caused by the distance from Earth.[42,43]

Psychopathological issues

The presence of loss of or reduced sleep quality is a critical issue among astronauts, as it may provoke fatigue, concentration

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problems and possible drop in overall performance levels leading to potentially damaging errors.[44,45] The duration of astronauts' sleep seems to be reduced to around 6 to 6.5 hours/day during missions,[46–48] in parallel with a decreased amount of both slow-wave and rapid eye movement (REM) sleep, and a shortening of REM latency.[46] The impact of sleep is highlighted by the results of a ground-based simulation of a mission to Mars involving six individuals isolated for 520 days. Most subjects experienced recurrent reductions in perceived sleep quality, interrupted sleep–wake periodicity, performance deficits associated with chronic partial sleep deprivation, and increased sleep displacement in the daytime period.[49] Not surprisingly, the use of hypnotics during flight is common, as demonstrated in a study on the crew of a shuttle[50]: approximately three quarters of the crew reported taking hypnotics, mainly zolpidem and its extended-release formulation or temazepam.[51,52] Although, while comparing nights with and without a sleeping pill, no difference was present in total sleep time and night-time alertness, significant differences were found in sleep efficiency, latency and, albeit slightly, subjective quality.[50]

It has been hypothesized that extreme environments, like the space, despite their diversity, are a similar potential threat to mental conditions, and specific factors have been proposed that could play a role in the occurrence of psychological and psychic problems among astronauts. A review of data on Arctic confinement showed that personality traits, coping styles, and interpersonal needs are important predictors of depressed mood.[53] During space missions, prolonged and severe isolation seems to correlate with the onset of reduced resilience, apathy, boredom, depression, anxiety, and declines in initiative, general activity and desire.[54,55] Several psychosomatic symptoms have been also described among astronauts during missions, such as headaches, gastroenteric problems, genitourinary symptoms, and fear of illness.[56–58] The issue of asthenia as a problematic syndrome during space missions is quite common, but still unresolved.[59] Despite the fact that abundant nutritional resources are available during missions and there is no increase in energy consumption, astronauts may experience a reduction in their food intake, a phenomenon known as anorexia in space. The cosmonauts' weight loss and reduction in body mass appear to be linked to the influence of microgravity and to changes in the sleep–wake cycle on appetite, food intake, and the functioning of the gastrointestinal system. However, after returning to Earth, the crew members will regain their preflight levels of body mass and caloric intake.[60] It has been suggested that the continuous light environment of space missions is the cause of the reduction in caloric intake to 70% of that recommended.[61]

Finally, the isolation occuring during the missions seems to provoke some psychopathological disorders in the astronauts, such as illusions, hallucinations, and reductions in consciousness. In fact, in situations of sensory deprivation, misrecognition can be a consequence of lack of training and incorrect perception of a stimulus.[54] It is interesting to note that in 2011, the Russian newspaper Pravda reported the presence of olfactory hallucinations among the crew who took part in the 1984 Soyuz T-10 to Salyut-7 missions, but the presence of toxins in the station's atmosphere was cited as the main cause of this phenomenon.[62]

It should be, however, mentioned that space missions do not necessarily may lead to negative consequences, as they may represent personal growth experiences for many individuals, so that they might promote the overall sense of well-being, similarly to other isolation experiences.[15,63]

Psychological aftermath following return on Earth

The evidence of psychological or mental disorders after space missions is weak, if compared with current knowledge about problems arising during the space missions. The careful selection and the psychological screening of cosmonauts operated in the initial phases may explain the apparent lack of evidence. However, it should be noted that up to 5% of the crews of Antarctic expeditions, an environment that shares similar characteristics with the space, may experience psychiatric disorders, including mood disorders.[64] Further, the careful psychological and psychiatric screening performed on astronauts does not predict the absence of behavioral and psychological problems after the missions.[65]

In any case, return on Earth can be stressful and demanding for reasons such as re-joining to an open society and to the family after a period in a small environment.[66] The first 2 weeks after returning to Earth represent a particularly critical period in which negative effects on mood and performance can be expected, induced by changes in gravity and general living conditions, that is, readjustment to Earth.[67] Interestingly, confrontations in the form of either aggressive or assertive interactions in order to resolve a situation have been more frequently reported after space flight, albeit seldom indicated in the course of the mission in a research involving a group of retired cosmonauts.[68]

The most frequent psychological and psychosocial issues reported include depressive symptoms, substance abuse, jealousy and conjugal problems, and divorces.[8–10]

Conclusions

Space exploration is a fascinating human goal that, however, entails a series of hazards with detrimental physical and psychological consequences. Therefore, the issue of psychological well-being and mental health of astronauts has been included in the Human Research Program at NASA that, in 2016, delivered some general guidelines on this topic. The stringent selection criteria of candidates are considered the most important prevention countermeasure during both prelaunch and training phases. The psychotherapeutic support during the mission and upon return to the Earth is also suggested to represent another valid instrument to be provided not only to the the crews, but even to their families/relatives. The possibility of psychiatric emergencies has also been considered, and antidepressants, anxiolytics, antipsychotics, and even physical restraint tools are now available on the ISS.

Although it should be underlined that the available data are still limited and mainly deriving from studies from Earth environments similar to space, nevertheless the mounting interest and implementation of future and long-lasting space missions warn and require appropriate awareness of all the risks that these flights pose to the CNS of the crews, that have been documented in a few magnetic resonance studies.[69–71]

Further studies are urgently needed in this field given the renewed interest and fundings of space exploration, including the Moon landing of the first woman in 2024 (Artemis Project of NASA), and the exploration of Mars and beyond. These exciting programs represent a challenge possibly requiring the birth of a novel branch of psychology/psychiatry devoted to the implementation of targeted strategies to possibly prevent risks related to space exploration and to ensure the maintenance of well-being among astronauts during and after their missions.

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