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Yoga and Meditation in the Private Sphere of Astronauts: Non-Pharmaceutical Measures of Resilience in Social Isolation and Confinement

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Abstract

Since the inception of space exploration from the 1950s, the selection of astronauts has been a critical component along with technological advancements in rocket and spacecraft development. As missions began to extend beyond six months in the 2010s, the management of daily schedules—particularly in terms of striking a balance between public duties and private time—became essential for sustainable productivity and well-being among astronauts. As space lacks natural day and night cycles, questions have emerged regarding daily routines, the structure of personal time and its potential impact on astronautical performance. Astronaut's management of private time—sleep, rest and leisure—may significantly influence their mental health and the overall success of a mission. This study explores time management strategies for future deep space explorations, including lunar and Martian expeditions in the 2030s. While official schedules are meticulously structured—covering operations, scientific research, maintenance, training, exercise and meals—safeguards for private time remains in place, except during emergencies. The role of this private sphere extends beyond basic rest, thus contributing to human health under extreme environments. In addition to analysing the competitiveness of personal time, this paper argues a new hypothesis that non-pharmaceutical activities of yoga (physical movement) and meditation (mental sustainability) can enhance resilience and psychological vitality among the crews. These feasible practices, although outside the scope of traditional STEM frameworks, may mitigate key internal risks in the space condition of social isolation and confinement. Understanding and optimising the balance between private and public times could be imperative in maintaining the health, safety and team performance of astronauts on future interplanetary missions.

Key words: Mars, astronaut, mental health, social isolation, yoga, confinement

The scientific advancement of private space initiatives since the 2000s has enabled commercial space tourism. The demand for qualified astronauts has been increased with the proliferation in the number of spaceflights. Alternatively, the astronaut selection process has remained rigorous and continued to emphasise professional flight experience, physical and mental health, academic excellence and key interpersonal skills such as teamwork, communication and problem-solving (Guardian 2022). Personal attributes (e.g. adaptability, flexibility, leadership and resilience) are equally critical for navigating unpredictable conditions in space (Gonzalez-Torre et al. 2024, 898–906). For instance, NASA’s basic requirements for astronaut candidates include US citizenship, a master’s degree in a STEM field (or a medical degree), two years of relevant professional experience (or approximately 1,000 hrs of pilot-in-command time), the successful completion of a physical examination for long-duration spaceflight and graduation from a recognised test pilot school (Deiss 2025).

A combination of tests, scales, exercises, interviews and other selection tools are used to assess these qualifications (Schmidt and Spychalski 2021). Although astronaut selection is less frequent, candidates are typically aged between 30 and 55 years, with an average age of 34 years (Kovacs and Shadden 2017, 1–16). Most astronauts retire approximately 48 years, though a few, like space tourists, have flown as late as age 76. A typical career spans around 14.5 years and covers various roles such as commander/pilot, mission specialist, flight engineer, or payload specialist (ibid., 16–23). Training in spatial and robotic operations is time-consuming and costly. Programmes such as Generic Robotics Training (GRT) and Shuttle Robotics Training (SRT) offer immersive virtual instruction in procedures, techniques and strategies for operating robotic arms and payload management (Liu et al. 2013, 38–47).

Team Performance in the Public Sphere of Spaceflight

Team performance is a crucial determinant of success, particularly in long-duration exploratory missions (LDEMs) (Yin et al. 2025, 104–409). Effective collaboration within the public sphere of space involves clear communication, mutual confidence and alignment with shared goals (Larson et al. 2019, 108–114). The essential components of high-performing teams include diversity among members, autonomous decision-making, prioritisation skills and a unified mission focus (ibid.). Team-building exercises, particularly those that target conflict resolution, are key to the preparation of astronauts for the unique interpersonal and psychological challenges of extreme environments. This training also serves as a safeguard against human error in high-risk settings (Croitoru et al. 2021, 81–99). Collaboration between astronauts and mission control personnel is especially significant; attitudes, behaviours and cognitive strategies grounded on teamwork directly contribute to the security and cohesion of life aboard spaceship (Paoletti et al. 2021, 195–216). During public operational time, well-functioning teams demonstrate synergy, adaptability, multidisciplinary thinking and structured efficiency—benefits that are fundamental to the success of LDEMs (Croitoru et al. 2021, 85). However, effective teamwork requires not only technical skills but also maturity, emotional intelligence, a willingness to sacrifice individual comfort and shared resilience.

LDEMs, such as missions to Mars, pose unique challenges such as a mission duration of 2.5–3 years, serious delays in communication with Earth (22 min per direction), increased autonomy, the lack of opportunity for crew rotation or evacuation, restricted living space, minimal privacy and elevated levels of fatigue, stress, interpersonal conflict and psychological strain (Larson et al. 2019, 108–114; Landon et al. 2017, 40–56). According to Landon et al., the success of a mission depends not only on technological excellence but also on enhancing performance skills, emotional stability, group living capabilities, sustained motivation and logical decision-making (ibid. 2017, 35–39).

Countermeasures for Public Team Performance

Scholars widely recognise the Five-Factor Model (or Big Five) of personality as relevant to the prediction of team performance in space environments. In particular, neuroticism or emotional stability has been linked to social cohesion, workload sharing, team viability and flexibility. Astronauts with high levels of neuroticism may face challenges related to anxiety, depression, self-consciousness, hostility, vulnerability and impulsiveness (Landon et al. 2017, 40–42). Extraversion is associated with the intensity of interpersonal interactions and overall levels of activity, while agreeableness reflects interpersonal sensitivity and includes traits such as trust, compliance, altruism and modesty, which are factors that invigorate teamwork, flexibility and cooperation (ibid., 41–43). Characterised by persistence, organisation and goal-directed behaviour, conscientiousness is essential for addressing frustration as a result of communication delays, equipment failure and limited social interaction. Openness to experience supports adaptability and cross-cultural competence, reflecting traits such as curiosity, appreciation for new ideas and emotional receptivity (ibid., 41).

Leadership also plays a significant role in team functioning. Effective leaders motivate teams, mediate conflict, set direction and facilitate group cohesion. Desirable traits include achievement orientation, self-awareness, humour, emotional stability, empathy and negotiation skills (Landon et al. 2017, 46). In terms of category, the self-enhancing, affiliative and coping types of humour support team cohesion, while the aggressive and self-defeating types can undermine group trust (Linhardt et al. 2025, 385–397). While traditional space missions have relied on hierarchical leadership, autonomous deep space missions may benefit more from a collective leadership model. This approach distributes leadership based on expertise, trust, empowerment, feedback exchange and role flexibility (Mulhearn et al. 2016, 466–476).

The dynamics of internal communication become increasingly necessary with the increased in communication lag with ground control. The quality of interaction directly affects workload management, team morale and satisfaction with tasks (Hagemann et al. 2023, 162–175; Migaki et al. 2025, 329–336). For example, findings from the Mars Analog Mission of AMADEE-20 conducted by the Austrian Space Forum demonstrated that the disclosure of clear objectives and efficient information flow significantly improved multiteam system performance.

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High-quality internal communication was associated with decreased levels of frustration and increased levels of task satisfaction—even when astronauts operated independently at a distance (Hagemann et al. 2023, 162).

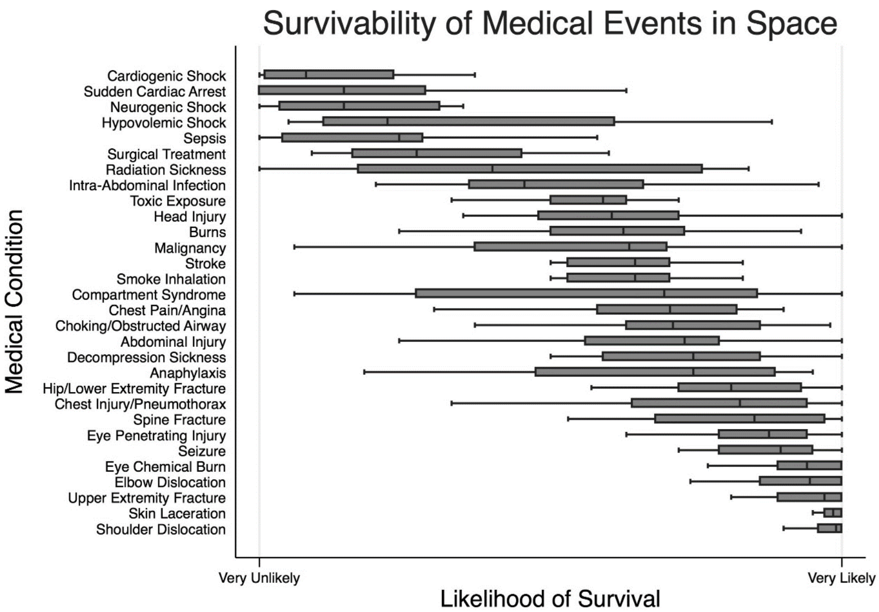

Figure 1: Survivability in potential medical events in space. Source: Robertson et al. (2020, 309).

Medical emergencies pose a significant threat to crew survival and mission success during space exploration. Therefore, the effective management of such risks demands not only advanced technical proficiency but also advanced non-technical skills such as decision-making, communication and teamwork (Figure 1; Robertson 2020, 305–314). Shoulder dislocations, skin laceration and upper extremity fracture are among the medical conditions with the most potential to impact the well-being of the crew; with proper management, these conditions may be survivable even in the event of neurogenic shock. In contrast, cardiogenic shock, sudden cardiac arrest, sepsis and airway obstruction represent conditions with the most severe consequences, as they pose life-threatening risks. Other critical conditions, such as chest injury/pneumothorax, radiation sickness and abdominal trauma, may be treatable under certain mission parameters. Moreover, long-term exposure to space radiation significantly increases the risk of developing malignant tumours, particularly in radiation-sensitive tissues (Babocs et al. 2024, 298). Other high-risk medical events include cardiac arrhythmia, ocular injury, toxic exposure and pneumothorax, which could compromise individual health and overall team performance. Furthermore, cancer and circulatory diseases remain major concerns as a result of prolonged exposure to galactic cosmic rays, especially among astronauts aged between their 30s and 40s (Cucinotta et al. 2020, 529–536).

To enhance crew safety and autonomy, recent studies proposed the integration of AI-driven systems with the capability of supporting medical anomaly detection and response (Bridges 2023, 433). These AI-enhanced support systems for crew performance are designed to enable rapid intervention in unexpected spacecraft or habitat malfunctions, urgent medical situations and rover operations. However, the capabilities of current AI technologies remain limited in terms of maturity, scope and adaptability to deep space missions. Challenges persist, particularly in complex diagnostic tasks such as identifying subtypes of skin cancer, interpreting spinal motor neuron signals for prosthetic control or diagnosing cardiovascular diseases (ibid.). Deep space missions may encounter more than 100 distinct medical conditions, which necessitate robust and reliable systems. Despite initial scepticism among stakeholders, the relevant fields increasingly view human–AI collaboration as a critical component of future spaceflights.

In parallel, ethical discussions on 'biomedical moral enhancement' (=the application of biomedical technology to morally improve individuals in the concept of neuroethics) are ongoing in terms of enabling individuals to act according to internalised moral frameworks (Huttunen et al. 2023, 102–278). The concept of the Smart Habitat, which leverages commercial off-the-shelf (COTS) technologies, offers promising applications that target crew health and well-being. Examples include conversation feedback systems, biometric monitoring (e.g., heart rate and sleep/wake cycles), digital communication tools, crew scheduling interfaces, anomaly detection, deodorisation and motion sensing (Pischulti et al. 2024, 534–549). While much scholarly attention is given to the optimisation of crew performance through efficient public time management, examining the role of private time in maintaining psychological resilience and team cohesion is equally vital. How should personal activities be structured to increase mental health among astronauts in space environments characterised by social isolation and confinement? What forms of recreation, communication, or self-care should be encouraged to support individual well-being and the collective success of missions?

Private Sphere and Resilience in Astronautical Confinement

The effective management of private time can be underestimated as a peripheral concern, but it is in fact a spontaneous factor of mission success. While team performance is frequently emphasised during structured operational periods, individual activities during personal time significantly contribute to the maintenance of motivation, emotional stability and self-confidence—particularly for astronauts engaged in LDEMs (Linhardt et al. 2025, 385–397). A range of physical, emotional, mental and spiritual practices can foster cohesion within the spacefaring community and support psychological resilience (ibid.). Typical examples of leisure and relaxation activities include reading (e.g., books, magazines or online news), listening to music for mood enhancement and engaging with digital entertainment such as augmented and virtual reality (AR/VR) games, movies and streaming television series (Kim 2022). Personal hobbies that promote self-expression and personal development (e.g. quilting, painting, learning a new language or playing a musical instrument) serve not only as sources of enjoyment and contentment but also as cognitive enrichment. When permitted by mission protocols, social media platforms may offer astronauts a meaningful avenue for emotional expression and connection with loved ones. Journaling is another recommended practice for processing thoughts and feelings, contributing to increased awareness and insight (Kim 2024, 21). Nurturing behaviours, such as the consumption of preferred healthy foods or extra sleep, can provide essential physical and psychological restoration. Moreover, creative and mindfulness-based activities of yoga (stress-relieving physical movement) and meditation (psychological sustainability) can illustratively be considered as non-pharmaceutical measures that promote self-care and overall crew effectiveness.

Physical Movement of Yoga

Personal yoga practice offers physical, socio-cultural, psychological and medical benefits for deep space travellers if the technical facilities of spaceship is capable to support. Originally introduced to western societies through its physical aspects, such as postures (*asanas*), controlled breathing (*pranayama*) and mindful movement, yoga has since gained widespread acceptance as a wellness practice and a cultural phenomenon (Chen 2024, 3–5). However, traditional yoga encompasses a broader and more integrated system of well-being. It is defined as a combination of universal ethics (*yama*), personal discipline (*niyama*), physical postures (*asana*), breath control (*pranayama*), sensory withdrawal (*pratyahara*), concentration (*dharana*), meditation (*dhyana*) and, ultimately, self-transcendence (*samadhi*) (Dagar et al. 2025). While a certain degree of conceptual overlap occurs between yoga and meditation, this paper separately examines their roles and benefits. In the context of space health among astronauts, yoga—especially its physical components—can improve muscular strength, flexibility, physical fitness, coordination, balance and general well-being (Price and Brunet 2024, 2).

While certain styles of yoga may not be relevant, its adaptable and scalable nature renders it a compelling candidate for inclusion in health maintenance programmes for astronauts. For instance, Hatha Yoga is a general term that encompasses physical postures and is suitable for foundational practice. Vinyasa Yoga is characterised by flowing sequences coordinated with breath, offering cardiovascular and muscular benefits (Price and Brunet 2024, 3). Alternatively, Iyengar Yoga emphasises precise alignment and frequently incorporates props, which could be adapted for microgravity. Yin Yoga focuses on long-held, passive poses, which aid in joint health and stress relief. Kundalini Yoga integrates breathwork, movement and chanting and targets energy regulation. Bikram Yoga is traditionally performed in a heated environment; although it may not be practical in space, it offers insights into intense physical conditioning (ibid., 5). Restorative Yoga requires gentle movement and deep relaxation with the help of props and promotes recovery and stress reduction. Power Yoga is a vigorous, athletic form that improve endurance and strength. Lastly, Aerial or Air Yoga uses a hammock for support, which could be creatively adapted for use in setting with reduced gravity (ibid., 7).

Physical Benefits

Yoga practice is initially associated with improvements in physical strength and flexibility. Moreover, studies on yoga training report decreased fatigue and that its rehabilitative role aligns with the framework of 'stress adaptation theory':

> When the body is affected by external stressors, specific or nonspecific stress reactions would occur. These stressors are mainly made up of specific diseases and nonspecific diseases, and the nonspecific response of the body to nonspecific diseases is called stress adaptation (Ma and Guo 2024, 127).

Using data on yoga training, Ma and Guo (2024) confirmed that yoga can alleviate physical fatigue for individuals engaged in excessive physical activity. As a result, bodily functions may gradually become increasingly active, which contributes to improved physical performance. Studies on respiratory function also confirm the effects of regular yoga practice. For example, yoga improves the performance and functionality of the diaphragm, the primary inspiratory muscle (Fernández-Pardo et al. 2023). Its benefits are particularly notable in the treatment of lower back pain among individuals with thin diaphragms. From a clinical perspective, yoga is increasingly considered a 'safe, acceptable and feasible transdiagnostic intervention' (Trethewey et al. 2023, 18) for addressing physical symptoms associated with psychological conditions such as eating disorders, including orthorexia (ibid.). Additionally, the physical benefits of yoga are evident in individuals who experienced long-term confinement without social connection. Rojas (2025, 854–861) positively evaluated the impact of yoga on physical fitness and highlighted improvements in muscle strength, endurance, postural stability and balance through its postures, breathing exercises and meditation practices (ibid., 860).

Socio-Cultural Benefits

Given that creative thinking is essential for technological and cultural advancements, scholars have explored the relationship between yoga-induced mindfulness and creativity within the context of navigating the complexities of a dynamic world, including the high-stress conditions of deep space travel (Tastanova et al. 2024). In particular, Yoga Nidra (or 'yogic sleep'), a meditative state between waking and sleeping, is considered a simple but powerful technique for developing and sustaining creative capacities. Tastanova et al. (2024) defined creativity as 'the ability to generate novel and effective ideas or solutions' (ibid., 2), thus highlighting its role not only in social problem-solving but also in humanistic pursuits such as personal growth, well-being and self-expression. Electroencephalograph (EEG) experiments demonstrated that Yoga Nidra influences brain activity, specifically brain wave patterns associated with creativity (ibid., 5).

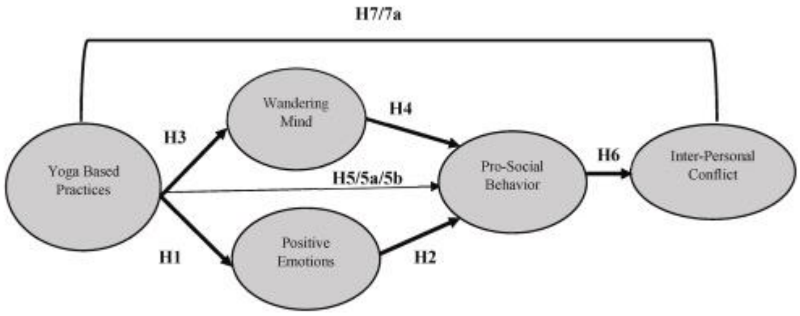

Figure 2. Diagram of the impact of yoga. Source: Dagar et al (2025, 6).

The space community operates in an environment that requires high levels of interdependence, which necessaries continuous collaboration and the formation of critical alliances (Figure 2). In this context, yoga practice is linked to enhanced conflict management skills and positive social behaviours, and evidence indicates that it fosters pro-social attitudes, emotional regulation and reduced mind-wandering (Dagar et al. 2025). From the philosophical perspective, Patanjali Yoga Sūtra is connected to the cultivation of personal excellence (Chaudhry 2023). The Ashtanga Yoga system is presented as a universal principle and practice for achieving self-awareness, holistic well-being and emotional resilience. It intends to awaken extrasensory potentials, reduce psychic tension (e.g. ignorance, attachment, aversion, egoism and fear of death) and eliminate common yogic obstacles such as illness, apathy, doubt, laziness and unstable progress (ibid., 1). An especially relevant aspect of yoga for astronauts is its role in mitigating the emotional toll of social isolation and confinement. As Kern noted, yoga 'cultivates an awareness of embodied being-in-the-world that is tied to place' (2012, 31), supporting psychological adaptation in unfamiliar environments.

Medical Benefits

From the medical perspective, yoga is increasingly recognised as a non-pharmacological intervention that offers preventive and therapeutic effects on a range of physical and mental health conditions. In this regard, regular yoga practice, among adults aged 25–45 years, has been reported to reduce inflammatory responses to stressors and contribute to an improved quality of life (Han and Hu 2024, 5). It also positively influences 'the autonomic nervous system, supporting cardio-respiratory function, metabolic efficiency and the management of chronic conditions such as type 2 diabetes, chronic venous disease and obesity' (ibid., 5). However, while smoking is widely known to impair vascular function and increase the risk of venous insufficiency by decreased blood flow, yoga does not serve as a direct cure for venous disorders. Instead, it offers supportive symptom management, which helps to relieve venous pain and discomfort (Fengcai Wang and Fei Wang 2025). For example, practitioners have recommended specific poses, such as Tadasana (mountain pose) and Viparita Karani (legs-up-the-wall), for improving leg strength and flexibility within high-stress or sedentary environments (Pan et al. 2025, 261–265). Inverted postures and gentle movements can also support lymphatic drainage and reduce oedema (Fengcai Wang and Fei Wang 2025).

Yoga has also been introduced as a supportive therapy for individuals diagnosed with gynaecologic cancer. Apart from its physical benefits, yoga facilitates emotional acceptance, composure and personal growth. In Price and Brunet (2024), 15 women with gynaecologic cancer (aged 28–66 years) engaged in yoga sessions and reported positive changes in body image perception over time. Although the instructor played a key role, the participants reflected on their changing experiences, which indicated the long-term psychological and emotional impacts of the practice (ibid., 10). These reflective outcomes align with the broad neurobiological and anti-ageing benefits of yoga. Ageing is an inevitable biological process that is often driven by cellular senescence, oxidative stress and telomere shortening, but yoga is associated with the mitigation of such effects. Chen underlined the role of yoga in 'reducing oxidative stress, modulating chronic inflammation, enhancing immune function and preserving telomere length—key indicators of cellular aging' (2024, 1). These physiological effects are further evident in improvements in musculoskeletal strength and cardiovascular health.

Mental Benefits

While the central neurobiological mechanisms of yoga remain partially understood, its role in cultivating interoceptive awareness (i.e. the ability to perceive and respond to internal physiological signals) is increasingly recognised as essential for mental health (Eusebio et al. 2022). Yoga's profound capacity to alleviate stress and foster relaxation is well-documented; Chen's research demonstrates that its stress-reducing effects support cognitive function and emotional resilience (Chen 2024, 5). In particular, yoga may aid in the regulation of cortisol, the body's primary stress hormone, thereby mitigating the harmful physiological effects of chronic stress (ibid.). He further emphasises that mindfulness techniques in yoga enhance one's awareness of the present moment and cultivate inner tranquillity, which empowers individuals to navigate challenges with greater resilience and equanimity (ibid., 5). Likewise, it is proposed that breathing practices, such as deep breathing and alternate nostril breathing, can activate the parasympathetic nervous system, which triggers the body's relaxation response and counteracts the stress reaction (ibid.).

Yoga also exhibits therapeutic potential for addressing psychiatric conditions induced by trauma, especially in the context of long-duration space missions. Experiences with psychological trauma, including sexualised, physical or emotional violence, harassment or interpersonal conflict, can contribute to complex trauma. Lorentzen et al. (2025) conducted a synthesis of qualitative evidence and revealed that yoga, when practiced by adults with these backgrounds, provided a new means of engaging with the self, which improved coping in daily life and offered pathways to personal growth. They noted that yoga, as a mind-body practice, supports the development of essential regulatory functions such as emotional tolerance, autonomic regulation and bodily awareness (ibid., 2). Participants reported an increased feeling of centeredness, self-compassion and improved social relationships, which advances the role of yoga in promoting personal and communal well-being (ibid., 10). Moreover, cultivating self-compassion can counteract negative self-perceptions such as doubt, anger, unworthiness and self-criticism. Although yoga lacks universal acceptance as a scientific treatment modality, its multifaceted therapeutic benefits pose it as a relevant and supportive practice for maintaining mental health in the private sphere of astronauts.

Psycho-Medical Well-Being of Meditation

While yoga is typically associated with physical movement, the primary objective of meditation is to induce mind regulation, which encompasses varied cognitive, emotional and attentional strategies. Przyrembel and Singer described as ‘a family of heterogeneous cognitive, socio-emotional and attentional strategies developed for various ends’ (2018, 82). Rooted in diverse cultural and contemplative traditions, meditation can be practiced using various postures—including seated (on a chair or floor), standing, kneeling or lying down—thus assisting flexibility based on context or individual need. In environments characterised by social isolation, meditation can play a significant role in fostering positive mood, healthy sleep patterns, self-discipline and pain tolerance. By promoting awareness, attentional focus and psychological resilience, varying forms of meditation offer unique methods of mental training and well-being support.

Among them, Vipassana meditation emphasises a mindful observation of breath and bodily sensations with the objective of integrating insight into the nature of reality (Travis and Parim 2017, 86–94; Cho et al. 2025). Transcendental meditation involves the silent repetition of a personalised mantra and is practiced twice daily to reduce stress and induce deep relaxation (Berghmans 2023, e13–e23; Singh et al. 2025). Visualisation meditation uses mental imagery to evoke specific scenes, emotions or desired outcomes, providing support for emotional regulation and goal-setting. Focused meditation trains attention by concentrating on a single object, such as the breath, a candle flame or a mantra, to increase awareness of the present moment and decrease cognitive distractions (Delorme et al. 2021, 197–202). Movement meditation, which include practices like walking or Tai Chi (=a Chinese martial art that has been evolved into a sport and form of exercise), integrates physical movement into a mindful awareness of bodily sensations. Guided meditation typically involves listening to an instructor or a recorded narration and is based on storytelling or specific themes to guide a meditator through a particular experience (Przyrembel and Singer 2018, 82–101). These varied techniques help astronauts within confined environments with adaptable tools for managing stress, improving mental clarity and supporting emotional well-being.

Psychological Benefits

Regular meditation provides substantial psychological benefits but may pose potential risks. Individuals may experience feelings of detachment or dissociation during intensive practices. In rare cases, these practices have been associated with psychotic episodes or manic symptoms, prompting caution in application to vulnerable individuals (Ketchell 2024). Nevertheless, its positive impacts on mental health are well-documented, particularly in the context of high-stress environments. Meditation has been depicted to reduce physiological markers of stress, such as elevated heart rate, blood pressure, cortisol levels and sleep disturbances. Moreover, clinical studies report improvements in symptoms related to irritable bowel syndrome (IBS), post-traumatic stress disorder (PTSD) and fibromyalgia (Pascoe et al. 2017, 156–178). For individuals with generalised anxiety disorder (GAD)—characterised by excessive, uncontrollable worry—mindfulness meditation (MM) has been associated with decreased symptoms of anxiety, including fear, insecurity and social discomfort. Scholars also maintain that MM can reinforce positive self-talk, stress regulation and resilience to workplace stress, which are relevant to demanding environments of space mission (Bostock et al. 2019, 127–138; Goyal et al. 2014, 357–368). Experimental findings by Kiken and Shook (2014, 22–30) emphasise that meditation practitioners exhibit less negative thoughts in response to emotionally disturbing stimuli. Meditation also promotes self-understanding, self-confidence and emotional growth, which encourages individuals to become the best version of themselves (Gryczynski et al. 2018, 23–30). It has been linked to reduced feelings of loneliness and improved social connectedness, which are critical in settings that induce social isolation and confinement (Lindsay et al. 2019, 3488–3493; see also Figure 3).

Outcome	MA (n = 58)			MO (n = 58)*			Control (n = 37)			Time × condition difference
	Pre	Post	d	Pre	Post	d	Pre	Post	d	
Subjective perceptions of loneliness										
Diary loneliness	2.25 (0.15)	1.76 (0.15)	0.44†	1.97 (0.15)	1.99 (0.15)	−0.02	2.26 (0.19)	2.27 (0.19)	−0.01	$\chi^2(2)$ = 11.46, P = 0.003
Objective social isolation										
EMA social interactions	2.58 (0.21)	2.98 (0.21)	0.31†	2.60 (0.21)	2.55 (0.21)	−0.04	2.40 (0.26)	2.42 (0.26)	0.02	$\chi^2(2)$ = 8.36, P = 0.015
Diary social interactions‡	9.06 (0.77)	10.82 (0.77)	0.47†	10.19 (0.77)	10.72 (0.77)	0.13	10.55 (0.95)	10.52 (0.96)	−0.05	$\chi^2(2)$ = 6.06, P = 0.048
Diary interaction partners‡	6.92 (0.60)	8.26 (0.60)	0.39†	7.79 (0.60)	7.51 (0.60)	−0.04	8.84 (0.74)	8.03 (0.75)	−0.15	$\chi^2(2)$ = 11.23, P = 0.004

Data are reported as means (SE) adjusted for day of week (EMA and diary) and time of day (EMA only). d = Cohen’s d effect size estimate.
*n = 57 in diary analyses.
†P < 0.05.
‡ Means calculated from estimated number of social interactions; time × condition differences and effect sizes calculated from raw data (*Measures*).

Figure 3: Ecological Momentary Assessment (EMA) and end-of-day diary assessment of loneliness and social isolation. Source: Lindsay et al. (2019).

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For tasks that require attention control, such as during complex space operations, Focused meditation (FM) can increase concentration, accuracy and resistance to distraction. Brief daily practices (e.g., 13 minutes) have been proved to enhance visual attention and performance (Delorme et al. 2021, 197–202; Tsai et al. 2018). Meditation may also offer neuroprotective benefits. Practices that combine mantras or chants with repetitive finger motions have displayed potential in slowing memory decline related to age and well-maintaining working memory, long-term recall and overall cognitive function (Khalsa 2015, 1–12). Among emotional practices, Metta (loving-kindness) meditation fosters kindness and compassion. It encourages warm, pro-social attitudes, such as friendliness, affection and benevolence, not only toward the self but also toward colleagues, which encourages team cohesion (Przyrembel and Singer 2018, 92; Galante et al. 2014, 1101–1114). Furthermore, Jhana meditation (or *dhyana* in Sanskrit) represents a deep, concentrative form of practice characterised by mental absorption, clarity and tranquillity. Yang et al. (2024, 1) mentioned that these states are marked by elevated attention, effortlessness and bliss, leading to a unified awareness and freedom from distraction—a highly relevant state for astronauts operating in high-risk contexts.

Medical Benefits

Goyal et al. (2015, 357–368) demonstrated that MM can increase pain tolerance, thereby reducing chronic pain. Apart from pain management, meditation contributes to health maintenance in confined environments in a holistic manner. Notably, meditation can aid in blood pressure regulation by reducing cardiovascular strain. Elevated blood pressure increases cardiac workload and promotes atherosclerosis, which increases the risks of heart attack and stroke (Bai et al. 2015, 653–662). Meditation serves to relax nerve signals that control tension in blood vessels, heart function and the ‘fight-or-flight’ stress response, which increases alertness during stressful situations (2013, 1805–1810). In turn, improved stability in blood pressure helps sleep quality by alleviating issues such as insomnia, physical tension and restless sleep (Ong et al. 2014, 1553–1563).

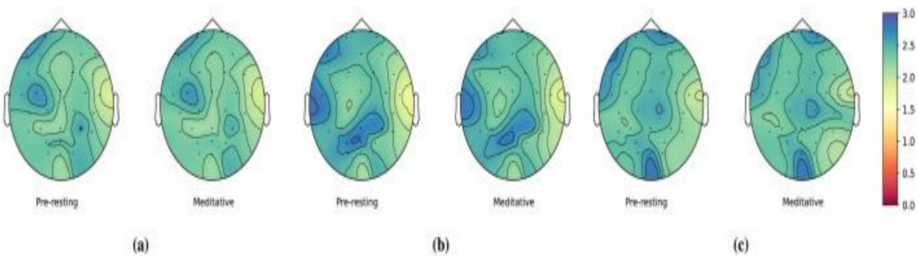

Figure 4: Brain activity of a group during the pre-resting state and meditative states. Source: Singh et al. (2025).

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Short-term mantra meditation interventions have been shown to induce distinct brain activities and develop cognitive functions, specifically working memory, attentional control and executive function (see Figure 4; Singh et al. 2025; Srivastava 2025, 62–73). The brain exhibits a large-scale intrinsic network, which is more active during rest and typically deactivates during cognitively demanding tasks (Travis and Parim 2017, 86–94). Transcendental meditation influences this neurophysiological mechanism, improving cognitive performance; however, effects may vary across individuals. Using a neurophenomenological approach, Lutz et al. (2025, 411–424) examined dynamic shifts in experiential content and consciousness during meditation and reported the presence of novel behavioural and neurodynamic markers linked to pain regulation, self-dissolution and acceptance of mortality. These findings imply a biological basis for mental illness and its treatment (Li et al. 2025). MM, characterised by ‘focused attention and non-judgmental internal awareness’ (Prakash et al. 2025, 350), modulates the core structural and functional brain networks that are involved in segregation, integration and influence. This modulation includes changes in key ‘connector hubs such as the anterior cingulate cortex, thalamus and mid-insula’ (ibid.).

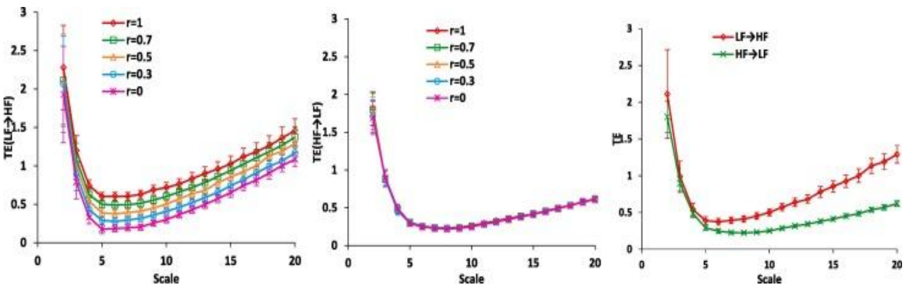

Figure 5: Averaged modified multiscale transfer entropy (MMTE) values. Source: Tian et al. (2023).

Human organs are interconnected and interact within physiological systems; as a result, the failure of one organ can impact the condition of others (Figure 5). For example, Tian et al. (2023) identified this complex, non-stationary interrelationship between the cardiovascular and respiratory systems during meditation. The study demonstrated that ‘meditation might have immediate physiological effects on cardio-respiratory and sympathetic-parasympathetic couplings’ (ibid., 3). Specifically, differences in inter-coupling within the cardio-respiratory systems and intra-coupling within the cardiac system revealed that the respiratory system exerts a stronger influence on cardiac activity than vice versa, while sympathetic activity exerts a greater driving effect on parasympathetic activity than the reverse (ibid., 8).

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Spirituality of Prayer

Prayer and spirituality also offer significant contributions to the holistic well-being of astronauts during social isolation (Ameling 2000, 40–48). Cognitive spirituality refers to the intersection between cognitive science and spirituality; this field mainly analyses cognitive processes that influence and are influenced by spiritual experiences (Yilmaz 2021, 150–154). Typically, a part of spiritual meditation, prayer helps deepen religious meaning and connection with a higher power through practices such as Christian prayer, Hindu japa mala, Sufi dhikr (remembrance of God as an abstract concept) and Jewish kabbalistic rituals (Berghmans 2023, e13–e23). Meditational prayer can be practiced in private or in communal worship and offers sacred growth and hope during risky situations through perceived miracles. In Christianity, prayer takes many forms: conversational, meditative, ritualistic and intercessory (Jantos and Kiat 2007, S51–53; Roberts et al. 2009). Dossey and Hufford criticised scientific studies on prayer and argued that prayer experiences are uninterpretable and challenge empirical foundations, because science does not address the supernatural (2005, 109).

However, a valid evidence links prayer to human health, which renders it a well-known therapeutic method among sincere practitioners. Jantos and Kiat (2007, S51–53) outlined four mechanisms that explained this connection. First, prayer acts as a relaxation response by inducing physiological changes like slowed breathing, reduced heart rate and blood pressure, peripheral warming, slower brain waves and a hypometabolic state. Second, a placebo effect, which accounts for 50%–70% of benefits in certain medical treatments, can partially explain its effects (ibid., S52). Third, prayer fosters positive emotions that promote well-being: 'the health benefits of… prayer are due to the health-promoting effects of the positive emotions they engender' (Levin 2001, 146). Lastly, apart from naturalistic explanations, prayer serves as a channel for supernatural intervention on the basis of personal faith in a divine being that transcends scientific evidence—existing beyond logical systems as a miracle or mystical experience (Jantos and Kiat 2007, S51–53).

Masters and Spielmans demonstrate that increased prayer can improve psychological and physiological functions, which enhances overall well-being and health outcomes as individuals seek divine comfort and wish for healing (2007, 332–334). The authors underscored sense of empowerment and noted that during 'stressful times, people [including astronauts] tend to focus on how divine purpose and plan will help them' (ibid., 332; Lekhak et al. 2023). Prayer can be ecologically interpreted in relation to well-being, because daily prayer helps buffer stress by eliminating negative emotions. From the cognitive-behavioural perspective, prayer 'provides a means of appraising life events and making sense of them' (Newman et al. 2023, 10). Additionally, prayer is described as 'a repeated practice of paying attention to one's internal mental world' (Schille-Hudson et al. 2024, 6), in which the frequency of prayer is closely connected to experiences of God, spirits, divine voices, or a sense of a sacred presence. Private prayer, especially within Christian traditions, is associated with low levels of depression and anxiety (Anderson and Nunnelley 2016, 635–641). Regular prayer practitioners also tend to exhibit high levels of optimism and positive functioning, even under challenging conditions (Hollywell and Walker 2009, 637–651).

While non-pharmacological therapies for pain are intended to address crucial medical needs, prayer can be considered an effective adjunctive therapy for mental, biological, social and physical pain. For religious individuals who are undergoing pain, praying to their God is often viewed as a preferred and beneficial intervention regardless of outcome (Illueca and Doolittle 2020, 681–699). Among Christians and Jews, the belief in Yahweh’s power to perform miraculous healing is widespread. However, this healing differs from conventional medical practice, because it occurs unpredictably (A. Narayanasamy and M. Narayanasamy 2008, 394–398). Furthermore, scholars have comprehensively unveiled the relationship between anxiety (=uncertainty) and prayer (Upenieks 2022, 1810–1831) and highlighted that religious healing through prayer constitutes a social phenomenon that is distinct from biomedical data. Dein and Brown acknowledged this perspective by noting that ‘the efficacy of prayer cannot be judged solely by biomedical criteria’ (2024, 156), for prayer also influences the emotional and spiritual dimensions in the personal sphere of people.

Conclusion

Time management during deep space exploration is a critical factor of the safety, resilience and success of a mission, especially given the extended duration of social isolation and confinement—approximately 2.5 to 3 years. The team of astronauts need to carefully strike a balance between regular operational duties by prioritising scheduled and unexpected tasks. The efficient use of time is essential not only for the maximisation of productivity but also for the maintenance of each crew’s well-being, which is vital for the successful completion of the Mars return project (e.g. SpaceX’s Starship). Given relativistic effects, like time dilation caused by gravity and velocity, astronauts will benefit from scientific and technological strategies for scheduling, time tracking, performance monitoring and achievement evaluation. Daily routines can be designed to closely resemble life on Earth, and clear divisions between public and private spheres should be established to optimise benefits. Public time is directly connected to STEM responsibilities and the objectives of the mission, while private time is intended to support personal wellness. Training and rehearsing team performance are key to the operation of autonomous space travel systems that require minimal mission support from mission control. While collective leadership and effective communication are encouraged, intense workloads and potential conflicts may increase distrust and detestation, which poses risks to team cohesion through the emergence of egotism.

This paper explored the key characteristics of the private sphere, which plays a indispensable role in enhancing the resilience of astronauts, consequently supporting positive behaviours during public time. Maintaining a consistent sleep schedule is essential for operational performance and overall health (Guo et al. 2014). Astronauts are also guaranteed private time; each one can close the door to their own resting space and enjoy moments of quiet solitude. Even in space, weekends are designated as off-duty periods to provide crucial opportunities for recuperation and relieve the stress of demanding work schedules. During private time, astronauts engage in spontaneous activities (Kim 2022). This study argued the metaphysical epistemology of yoga and meditation as promising new methods of self-care, as they offer holistic benefits that may further support mental and emotional composure in space exploration.

While various prescriptions in space medicine address the astrobiological and physiological challenges faced by astronauts, non-pharmaceutical measures of resilience, apart from purely scientific approaches, also warrant consideration as a support mechanism for sustaining psychiatric health within the space community. This paper analysed yoga practice, which, although controversial at times, demonstrated numerous benefits across the physical, socio-cultural, medical and mental domains. The personal application of yoga offers therapeutic modalities that are relevant to human health in confined environments. Similarly, the positive influence of meditation has been recognised on psychological and medical well-being by effectively reducing bodily stress. Meditation supports the development of self-confidence, fosters compassion for others and contributes to mission accomplishment—especially during emergency situations. Lastly, the critical role of prayer is proposed as an additional therapeutic dynamic in meditative practices. From the psychological perspective, prayer functions as a channel through which divine comfort and hope can be sought, thus addressing mental, biological, social and physical pains as well as fear, uncertainty and selfishness. Although the supernatural dimensions of yoga and meditation in the private sphere of space life may not conform to empirical logic or provide clear data, examining these mind-training techniques as valuable non-pharmaceutical interventions remains imperative to perceive. The reason is that these approaches can embody confidence, willpower, mental resilience and interpersonal dynamics, which are cognitive prerequisites for the public security and success of deep space missions.

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