



Short Communication

Effects of long term isolation on the emotion change of “Lunar Palace 365” crewmembers

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ARTICLE INFO

Article history:

Received 29 April 2019

Received in revised form 11 May 2019

Accepted 13 May 2019

Available online 23 May 2019

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The psychological health risk is one of the most serious and difficult risks to mitigate during manned deep space exploration [1]. In a space capsule or station, the environment is isolated, and communication with the outside is limited to telephone or delayed video. The monotonous working schedule also aggravates loneliness and homesickness, which could trigger negative moods, such as depression and anxiety. Therefore, an astronaut's unstable emotional state could be a threat to the safety and performance of a space mission.

Current strategies to further explore space, such as NASA's Design Reference Architecture or China's Lunar Exploration Program [2,3], strongly demand the development of bioregenerative life support systems (BLSS) that fully incorporated into space stations, transit vehicles, and eventually habitats on the Moon and Mars [4,5]. A BLSS is an artificial ecosystem with highly regenerated materials (food, oxygen and water) that are essential for human life support. Obviously, a BLSS-based closed isolation environment is unique because it composes of both biotic and abiotic factors. This distinguishes BLSS-based closed isolation environment from the physical-chemical based or other closed isolation environments [5–7]. It is imperative to investigate the crewmembers' psychological changes and identify how these changes influence their mental health and performance in the BLSS, and also to find possible counter-measures for these psychosocial issues.

Fortunately, the “Lunar Palace 365” project enables us to study the psychological change of crewmembers in the BLSS. The “Lunar Palace 365” project was a 370-day, multicrew, closed experiment carried out in a ground-based experimental BLSS platform named Lunar Palace 1 (LP1). By integrating four biological units, the

“Lunar Palace 365” mission achieved the longest isolation time and highest closure coefficient among all reported BLSS experiments through bioregeneration of life support necessities [5,7,8]. Located at the Institute of Environmental Biology and Life Support Technology, Beihang University, Beijing, China, the LP1 was upgraded based on the stage I facility built in 2014 [5]. Currently, it has a total area of 160 m² and a total volume of 500 m³. It consists of a comprehensive cabin and two plant cabins. The comprehensive cabin includes four private bedrooms, a living room, a bathroom, and an insect culturing room (Fig. 1a). Eight crewmembers were divided into two groups (2 females and 2 males each). Group 1 (Fig. 1b) included crewmembers A (female), B (female), C (male) and D (male), Group 2 (Fig. 1c) included crewmembers E (female), F (female), G (male) and H (male). The isolation experiment consisted of three phases with four crewmembers for each (Fig. 1d): the first phase lasted for 60 d with four crewmembers of group 1 (from May 10 to July 10, 2017), the second phase lasted for 200 days with four crewmembers of group 2 (from July 10, 2017 to January 26, 2018), and the third phase lasted for 110 d with four crewmembers of group 1 (from January 26 to May 15, 2018). During the experiment, the crewmembers followed a fixed schedule for working, breaking, physical training and sleeping. In particular, they worked on plants for more than 4 h/d (Fig. 1f, g), their lifestyle was regular and particular. In this study, the questionnaires for Symptom Checklist 90 (SCL-90) and profile of mood states (POMS) were filled out by the crewmembers once to twice a month before and after the experiment, and once to twice a week during the experiment. This study was approved by the Science and Ethics Committee of School of Biological Science and Medical Engineering in Beihang University, Beijing, China (Approval ID: BM20180003).

We did not find psychological disturbances or distress with the eight crewmembers during the whole experiment. In contrast with

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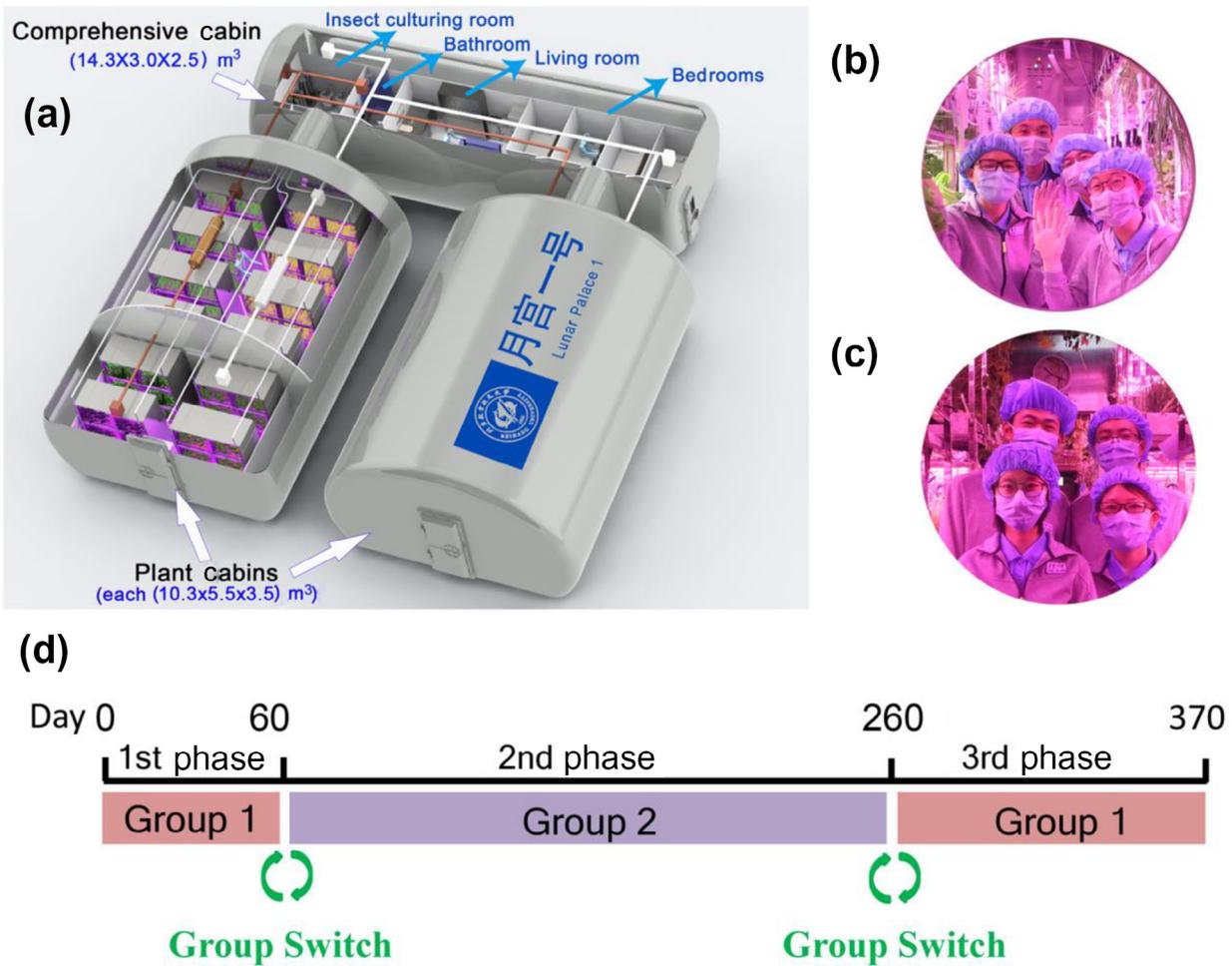


Fig. 1. Lunar Palace 1 and Lunar Palace 365 project. (a) Lunar Palace 1 model; crewmembers of group 1 (b) and group 2 (c); (d) mission arrangement of the “Lunar Palace 365”.

a previous report in which the crewmembers in “Mars 500” mission demonstrated the highest average POMS total mood disturbance score throughout the mission. They reported symptoms of depression in 93% of mission weeks, among which, mild-to-moderate levels were reported in over 10% of the mission weeks [1,9]. The major difference between the “Lunar Palace 365” and the “Mars 500” missions was that the “Lunar Palace 365” experiment was based on the BLSS, while the “Mars 500” was not. This could be a major contributor to better maintenance of the crewmembers’ psychology during the experiment, which benefit the crewmembers both psychologically and physiologically. In this experiment, each crewmember spent more than four hours a day to work in the plant chamber full of crops. Firstly, the daily work of taking care of crops made the life of crewmembers more fulfilling, which not only made them feel a sense of accomplishment, but also effectively reduced the negative emotions caused by boredom. Secondly, we believe the visual aesthetics of plants helped to elicit feelings of inner peace, which generates positive emotions toward a meaningful appreciation of life. Direct contact with plants guides the individual’s focus away from stress and enhance their overall quality of life [10]. Finally, BLSS provided the crews with a high-plant and high-fiber diet which may also be beneficial for the maintenance of healthy gut microbiome [11,12], and subsequently the mental health via the microbiota gut-brain axis.

BLSS is composed of organisms and artificial environmental factors. The system’s operation is driven by their inseparable interrelations and interactions. As Crewmember’s mood is susceptible to other biotic and abiotic units, theoretically a set of hypothetical

stochastic differential equations could be used to express the influencing mechanisms of biotic and abiotic factors on the dynamic response of crew’s mood. If a well-designed BLSS could provide sufficient sustenance support and spiritual consolation for the crewmembers, they could be psychologically acclimate themselves to the closed environment. Under this assumption, the crewmember’s emotion variations should be a stationary stochastic process. We adopted the autocorrelation function (ACF) to testify the above assumption by evaluating whether the ACF would be only dependent on the time interval, rather than time. In agreement, our autocorrelation analyses (Fig. 2, Figs. S1 and S2 online) show that the crewmembers’ mood variations had no significant autocorrelation, and they were stationary stochastic process, suggesting that the crewmember’s emotion had no reliable changes with time during the experiment. In contrast, significant depression, mood and visual analog scale scores changes between mission quarters were observed in Mars 520 Project. The crewmembers had stronger feelings of sickness in the second half of the mission compared with the first half. And the reported tiredness was maximal in the second mission quarter [1,13]. In our study, the BLSS system effectively avoided the negative impact of the isolated time. In addition, there was no evidence of a unique 3rd quarter effect [14]. Using the questionnaires data and interview record, we observed significant inter-individual differences ($P < 0.001$) of the Total Mood Disturbance (TMD) and all subscales of the POMS between the crewmembers in each group, (Table S1 online). The inter-individual difference is consistent with previous studies that performed in Lunar palace 1 and the Mars 520 mission [15].

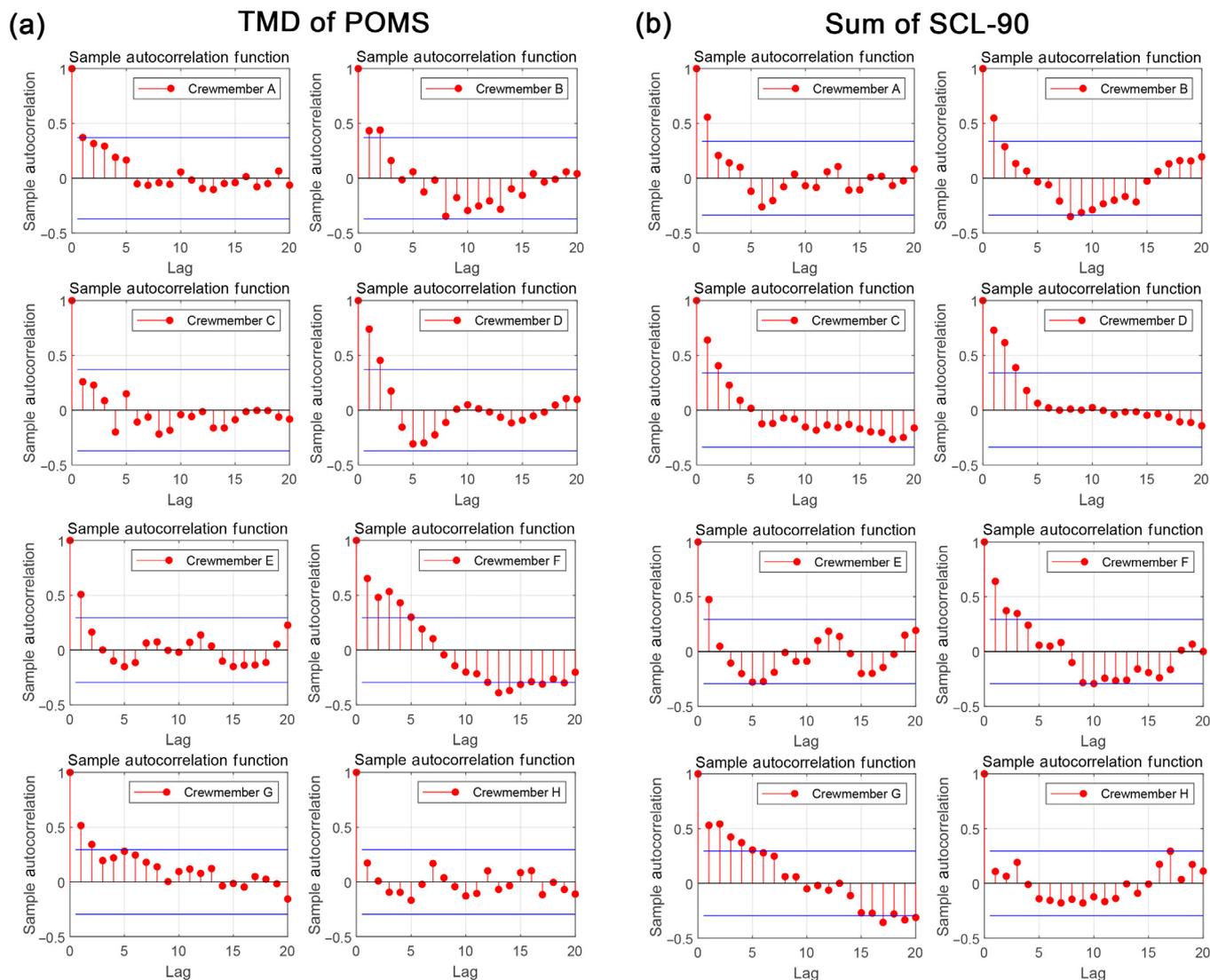


Fig. 2. The sample autocorrelation function plots (ACF) of the Total Mood Disturbance of POMS (a) and the emotional total score of SCL-90 scale (b). Blue lines indicate upper and lower range of confidential region, sample autocorrelation that falls into the confidential region indicate stability of the emotion. The results showed no significant autocorrelation and the crewmembers' emotion variations were stationary stochastic process.

In summary, crewmembers showed neither behavioral disturbance nor psychological distress during the 370-day period of mission confinement, despite significant individual differences were identified. Using ACF, we found that the crewmember's emotion variations were not dependent on the time of isolation, suggesting a stationary stochastic process. This result provides evidence from a psychological perspective to support the necessity of a BLSS for future long-term space explorations. Moreover, our results offer a reference for the psychological changes of crewmembers in BLSS in the future, which will help to efficiently select and train the crewmembers, and provide them with adequate, individualized countermeasures during a long-duration mission.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (81871520). We wish to thank the Lunar Palace

365 project and the eight crewmembers and Leyuan Li for helpful comments and language touch.

Author contributions

Zikai Hao, Hui Liu and Hong Liu designed the study. Hong Liu supervised the study. Zikai Hao, Yinzhen Zhu, Siyuan Feng and Chen Meng performed the psychological research. Zikai Hao, Yinzhen Zhu and Dawei Hu performed data analysis. Zikai Hao, Hui Liu and Hong Liu wrote the manuscript. Dawei Hu contributed to the editing and revision of the manuscript. All authors read and approved the final manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scib.2019.05.019>.

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Hui Liu is a post-doctoral researcher at the Advanced Innovation Center for Biomedical Engineering, Beihang University. Her current research project is the influence of long-term isolation on psychological emotion and biological rhythm, and how to solve this problem with plant ecological methods. Her research interest focuses on the horticultural therapy and higher plant cultivation in special closed environment.



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