Time Effects, Displacement, and Leadership Roles on a Lunar Space Station Analogue

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INTRODUCTION: A space mission's crewmembers are the most important group of people involved and, thus, their emotions and interpersonal interactions have gained significant attention. Because crewmembers are confined in an isolated environment, the aim of this study was to identify possible changes in the emotional states, group dynamics, displacement, and leadership of crewmembers during an 80-d isolation period.

METHODS: The experiment was conducted in an analogue space station referred to as Lunar Palace 1 at Beihang University. In our experiment, all of the crewmembers completed a Profile of Mood States (POMS) questionnaire every week and two group climate scales questionnaires every 2 wk; specifically, a group environment scale and a work environment scale.

RESULTS: There was no third-quarter phenomenon observed in Lunar Palace 1. However, fluctuations in the fatigue and autonomy subscales were observed. Significant displacement effects were observed when Group 3 was in the analogue. Leader support was positively correlated with the cohesion, expressiveness, and involvement of Group 3. However, leader control was not.

DISCUSSION: The results suggest that time effects, displacement, and leadership roles can influence mood states and cohesion in isolated crew. These findings from Lunar Palace 1 are in agreement with those obtained from Mir and the International Space Station (ISS).

KEYWORDS: 3rd quarter phenomenon, displacement, interpersonal interaction, analogue space mission, Lunar Palace 1.

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A number of psychological and interpersonal issues have been reported by astronauts and studies conducted in analogue environments. The emotions and interpersonal interactions of crewmembers have thus gained significant attention.[2,6] Any increase in a mission's duration can prompt psychosocial issues, as discussed in previous studies,[5,10,11] including the effects of time on human emotions and interactions, displacement, and leadership roles.

Astronauts can experience negative influences on their moods and group interactions over time.[11] In a space capsule, the isolated environment, limited communication, and monotonous work schedule can aggravate loneliness and homesickness, triggering negative mental states such as depression and anxiety. The results from the International and Mir space stations have shown that astronauts' emotional experiences during the transition phases of a mission (the first few weeks in space and those back on Earth) become irregular.[7] Similar negative moods have been documented in both polar explorations and space analogue experiments.[9,10] In addition, some studies have attempted to identify the possible changing patterns of emotions. Bechtel and Berning[1] introduced the "third quarter phenomenon," which refers to the observations that occur after the halfway point of a mission's duration, during which the crewmembers experience some negative emotions.

Group dynamic is also an important factor, as it focuses on the interpersonal interactions among the crewmembers and the outside support personnel. It has been determined that within a mission crew there will always be a leader to support and arrange the work, and a supervisor among the outside personnel to monitor and control the overall mission. These two roles can influence the group dynamics in some situations.

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Efficient leadership among crewmembers can facilitate a mission's success. During different mission durations, the leadership roles required by crewmembers may vary.[11] In a short-duration mission, a clear leadership role controlling and executing the mission is required. However, the crewmembers may also need the support of an internal leader during a long-duration mission. Leadership control may be counted on more when the workload is high or when an emergent situation occurs. However, during monotonous periods, leadership in the form of support is preferred by the crewmembers.[2]

Displacement occurs when crewmembers experience high levels of interpersonal conflict that cannot be settled directly, and they may transfer the resultant feelings to people outside their cabin. This can negatively affect their communications with these outside monitoring individuals.[2–4]

Much of the aforementioned content has been examined in previous Mir and International Space Station (ISS) research conducted by Kanas and his collaborators, which involved two or three crewmembers during 4- to 7-mo missions. The results showed that there were no significant second-half decrements in emotions observed regarding cohesion and other group dynamics.[3,5,6] The crewmembers perceived the crew leader's support activities as being positively associated with the level of the group's cohesion, but leadership control did not show the same pattern. In addition, the tension and negative moods revealed a predictable negative correlation with the outside supervisors' support, which confirmed the displacement hypothesis. Following these findings, we conducted tests related to the time effects, displacement, and leadership roles in our simulated experiments in the Lunar Palace 1 under Chinese culture and herein report our results.

METHODS

Subjects

The four crewmembers involved in this experiment were selected from seven candidates and assigned to tasks every day to simulate the astronauts' schedule. The study protocol was approved in advance by the team leader and all of the crewmembers, and each subject provided written informed consent before participating. Crewmembers A and C were Ph.D. students, crewmember B was a graduate student, and crewmember D was an assistant professor. All had been involved in this research for several years and thus had professional knowledge regarding the equipment and its operation. As **Fig. 1** shows, these four crewmembers entered the station at different times and formed three groups.

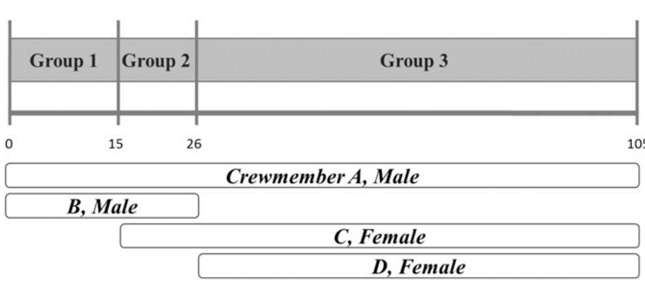

Fig. 1. Crew arrangement of Lunar Palace 1.

Such arrangements were mainly dependent on three concerns: regulating the system's operation, verifying its maximum potential, and conducting psychological research among the variable groups. As previously mentioned, the mission control personnel were trying to find the optimal crew to balance the system supplement by comparing three groups with different members. The system potential of oxygen and other materials was at maximum demand after Group 3 entered. The members were notified that the crew had been formally constituted at that time. In addition, one leader was chosen for Group 3 in the chamber and a supervisory role was clearly defined for the outside personnel. Before Group 3, there was no official leader among the crewmembers, so Group 3 was the focus of the current study, and we defined the last 80 d as one isolation period. Group 3 was confined from the 26th to 105th days of the experiment, such that the first day of the first quarter of the study was day 26 of the isolation, and the first day of the fourth quarter was day 86 of the experiment. The crewmembers in Group 3 comprised two women and one man, ranging in age from 27 to 32.

Analogue Space Station

The experiment was conducted in Lunar Palace 1, an analogue space station at Beihang University that serves as an integration test-bed for the Bioregenerative Life Support Systems. The facility comprised one comprehensive cabin (42 m^2) and one plant cabin (58 m^2). The comprehensive cabin included four private bedrooms, a living room, a restroom, and a room for waste disposal and insect culturing. Several of the biological experiments and psychological research studies were performed in the comprehensive cabin. These experimental settings generated some empirical data to further identify suitable living conditions and countermeasures for the astronauts. The crewmembers' bedrooms were very narrow, containing a single bed, a small table, and a door. The bedrooms were the crewmembers' only private areas where they could connect to the Internet using their personal laptop or smart phone. However, they could not make outgoing calls with their cell phones and, instead, they had to use the one wired phone available. It should be mentioned that this is the first study, to the authors' best knowledge, published in English that addresses the psychosocial issues affecting Chinese crewmembers and mission control personnel.

Measurements

Three questionnaires were used in our study: the Profile of Mood States (POMS; short version), the Group Environment Scale (GES), and the Work Environment Scale (WES). Once a week the crewmembers described their own mood states using the POMS on the computer. Group 3 completed this questionnaire a total of 12 times. This version of the POMS had been modified by a Chinese research team and adapted for the Chinese context. The short version of the POMS was a self-administered measure comprising 40 adjectives rated using a 5-point Likert scale ranging from "not at all" to "extremely." The POMS data were then consolidated into six factors that were analytically derived from mood variables such as Tension-Anxiety, Depression-Dejection, Anger-Hostility, Confusion-Bewilderment, Fatigue-Inertia, and Vigor-Activity, along with a global distress variable (Total Mood Disturbance).

The GES and WES were completed by the crewmembers once every 2 wk for a total of 8 times and contained 90 items each. Like the POMS, the GES and WES were translated into Mandarin. The 90 items that formed each questionnaire were divided into 10 subscales that measured the groups' actual, preferred, and expected social environments. In our study, the GES and WES were used to identify the groups' actual social climate. The 10 subscales in the GES were cohesion, leader support, expressiveness, independence, task orientation, self-discovery, anger and aggression, order and organization, leader control, and innovation. The subscales in the WES were involvement, coworker cohesion, supervisor support, autonomy, task orientation, work pressure, clarity, managerial control, innovation, and physical comfort.

The POMS has been widely used in isolated, confined, and extreme environmental studies[4,8,9] and has been proven to be valid under such conditions. The GES and WES also have high validity, and have been used in related studies.[3–5]

Hypotheses

Our aim was to supplement the research topics related to the psychosocial interactions in a simulated space environment. According to the previous studies, some relationships between psychosocial factors have been predicted. As discovered by Kanas,[3] there were six relationships from POMS, GES, and WES negatively relating with supervisor support. They also found positive correlations between cohesion and leader support, but not leader control. Therefore, based on these predicted directions of relationships, the following three hypotheses were proposed:

- H1: There will be no significant differences in the emotions and interpersonal interactions during the third stage of the 80-d experiment compared to the other three time segments;
- H2: There will be a displacement between crewmembers and outside personnel evidenced by negative correlations between subscales measuring the negative emotions and the supervisor support subscale; and
- H3: The crewmembers will value leadership support more than the leadership control during the time of the mission.

Data Analysis

One-way ANOVA and Friedman tests were conducted to identify the differences in the emotions and group climates among the four quarters. We also used a Spearman correlation and mixture model to test displacement and leadership roles.

RESULTS

The mission duration was split into four sections and the data were analyzed by one-way ANOVA and Friedman Test. Before the difference test, we first analyzed the homogeneity of variance among all 17 subscales. One-way ANOVA was conducted on those subscales with variance homogeneity, while the Friedman test was employed on those without.

The results of the POMS showed that there was no significant difference in the values across the four quarters except for fatigue, as shown in **Fig. 2**. Generally, there was no evidence of a unique third quarter effect on crewmembers' emotional states. However, the fatigue subscale of the POMS showed a significant difference among the four quarters [$F(3,33) = 2.980$, $P = 0.045$]. Tests showed that the fatigue subscale scores had homogeneity of variance ($P = 0.577$), so the least-significant difference test was chosen to compare each pair of four quarters. Fatigue in the first quarter was significantly higher than the fourth quarter (M = 3.444, SE = 1.155, $P = 0.005$). The crewmembers' fatigue scores decreased at the end of the confinement period, which is significantly less than the scores in the first quarter. According the postmission interview, crewmembers reported very heavy workloads in the first few weeks, with little time for relaxation or entertainment. We assume that this was why the fatigue score decreased during the mission.

The results from the GES and WES exhibited no half-way decrements, as reflected by all of the subscale scores. However, some changes among the autonomy subscale were found [$F(3,14) = 3.694$, $P = 0.038$]. Regarding the autonomy subscale, variance homogeneity ($P = 0.303$) allowed us to use the least-significant difference test. Results showed that the crewmembers were more autonomous in the fourth quarter than in the first and second quarters (Q1 to Q4: M = −1.667, SE = 0.617, $P = 0.017$; Q2 to Q4: M = −1.333, SE = 0.504, $P = 0.019$). Because the crewmembers' work schedules were almost always decided by the outside personnel, this suggests that the crewmembers grew progressively more sophisticated in their

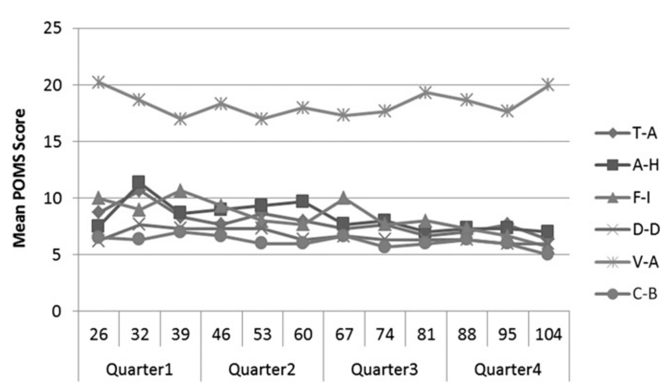

Fig. 2. Changes over time in the POMS. The data represent changes in scores from different subscales. T-A represents the Tension-Anxiety subscale; A-H the Anger-Hostility subscale; F-I the Fatigue-Inertia subscale; D-D the Depression-Dejection subscale; V-A the Vigor-Activity subscale; and C-B the Confusion-Bewilderment subscale.

daily work, which in turn was reflected in the gradually increasing autonomy during confinement.

All differences we found among the time periods were not uniquely between the third quarter and others, which suggested that our results did not support the third quarter impact, but instead were explainable as the result of crew integration and improvements in efficiencies that would naturally occur. Our first hypothesis (H1) is supported by these results.

Displacement occurs when crewmembers experience a high level of interpersonal conflicts that cannot be settled directly. To operationally test for displacement, Kanas et al. assumed that there would be a negative association between negative emotions and supervisor support.[5] In our study, the indicators of negative emotions were Tension-Anxiety, Depression-Dejection, Anger-Hostility, Fatigue-Inertia, Confusion-Bewilderment, and Total Mood Disturbance from the POMS, plus anger and aggression from the GES, and work pressure from the WES. The supervisor support subscale was used to measure the outside support.

We used a Spearman correlation and mixture model to identify these relationships. Usually, the Pearson correlation coefficient requires approximately unbiased multivariate normal distribution data. Due to our small sample, we used a nonparametric approach, the Spearman correlation, instead of the conventional Pearson correlation. Moreover, because we used repeated measurements on the crew, we also used a mixed model to deal with the repeated measurements' effect on the data. We treated supervisor support as the dependent variable and the others as independent variables. The slope of the model represented the direction and intensity of the two variables. Because the direction of the relationship between emotions and supervisor support has been supposed, a single-tailed test was used.

Evidence was found to support the displacement hypothesis because significantly negative correlated pairs were determined for seven of the eight indicators (**Table I**). Confusion-Bewilderment did not exhibit a significant relationship with supervisor support in either the correlation analysis or the mixed model. Furthermore, the relationship between work pressure and supervisor support became less remarkable through the mixed model analysis. All of the predicted indicators were negatively correlated with the perceived support from the outside supervisor. These results provided further support for the second hypothesis (H2).

Table I. Displacement in Group 3.

	SUPERVISOR SUPPORT			
SUBSCALES	**CORR.**	**SIG.**	**SLOPE**	**SIG.**
Tension-Anxiety	**−0.620**	0.003	**−0.427**	<0.001
Anger-Hostility	**−0.615**	0.003	**−0.252**	0.008
Fatigue-Inertia	**−0.617**	0.003	**−0.375**	0.007
Depression-Dejection	**−0.800**	<0.001	**−0.819**	<0.001
Confusion-Bewilderment	−0.181	0.236	−0.380	0.081
Total Mood Disturbance	**−0.436**	0.035	**−0.074**	0.002
Anger-Aggression	**−0.551**	0.009	**−0.595**	0.032
Work Pressure	**−0.419**	0.042	−0.064	0.423

Corr. is the Spearman correlation with a single-tail test. Sig. is significance. Slope represents the slope parameter of a mixed model with a single-tail test. Bold indicates a significant correlation coefficient or slope with $P < 0.05$.

The group leader in Group 3 had been clearly identified, along with an outside supervisor. We measured both types of leadership roles in the experiment; that is, supporting and controlling leaders. As previously mentioned, efficient leadership can facilitate the space mission and the cohesion of the crew. Thus, we extracted the relationship dimensions (cohesion and expressiveness from the GES and involvement and coworker cohesion from the WES) from both group climate scales to discover the effects of different leadership roles. We did not use supervisor support, which we left out in the relationship dimensions, because we only focused on within-crew relationships in this part. The Spearman correlation and mixed model were also applied to test the relationships. Leader support and leader control were dependent variables in the mixed model. What's more, as we had predicted certain directions for how the leadership role would affect group dynamics, according to previous studies,[9,10] single-tailed analysis was also used here.

As **Table II** reveals, a positive correlation was found between cohesion, expressiveness, and leader support. However, there were no such relationships between these factors and leader control. Coworker cohesion positively correlated with both leader support and leader control. The mixed model analysis also confirmed such patterns, suggesting that the crewmembers were more concerned about how much support they received from the group leader than about how much task direction was placed on them.

Furthermore, the subscale for involvement showed different results on two analysis approaches, correlating positively with leader support (which reached significance using the Spearman correlation) and negatively with leader control (which reached significance using the mixed model analysis). Nevertheless, in both methods, the two leadership roles exhibited different effects on involvement. They also showed that crewmembers preferred leader support to leader control within the group, supporting the third hypothesis (H3).

DISCUSSION

In general, this was the first psychological experiment to be conducted in an analogous space station in China and with the crew also comprised of all Chinese members. Despite the different cultures, we found our results to be similar to those of previous research from Mir and the ISS,[3–5] on which the crewmembers were from the United States and Russia.

We failed to find significant changes in the groups' moods or social climate over time in Lunar Palace 1, consistent with Kanas et al., who found that time in a space station did not seem to be a factor in predicting changes in a group's moods or social climate.[4] According to Kanas, the outside mission control support was very important. Thus, in Lunar Palace 1, the countermeasures used by the outside personnel and the crewmembers themselves, such as an open network in the chamber, daily physical exercise, and full support from outside, helped the crew to deal with monotony, boredom, and conflict, and may have been useful in the late mission stage. However, when

Table II. Leadership Roles in Group 3.

	LEADER SUPPORT				LEADER CONTROL			
SUBSCALES	CORR.	SIG.	SLOPE	SIG.	CORR.	SIG.	SLOPE	SIG.
Cohesion	**0.512**	0.015	**0.897**	<0.001	0.333	0.089	0.160	0.104
Expressiveness	**0.839**	<0.001	**0.709**	0.010	0.253	0.156	0.156	0.063
Involvement	**0.405**	0.048	0.420	0.158	−0.215	0.195	**−0.295**	0.039
Coworker Cohesion	**0.696**	0.001	**0.684**	<0.001	**0.497**	0.018	**0.166**	0.017

Corr. is the Spearman correlation with a single-tail test. Sig. is significance. Slope represents the slope parameter of the mixed model with a single-tail test. Bold indicates a significant correlation coefficient or slope with $P < 0.05$.

compared with previous simulated experiments conducted on the ground, such as the Mars 500 and the Antarctic expedition, where significant emotional fluctuations were observed during stage-changing periods, our findings did not indicate such patterns.[12] Hence, it remains unclear how the time effect will influence future expeditions to Mars. Due to the mission's longer duration and the more complicated crew structure, more research is needed on this topic.

Our findings support the presence of displacement in the crew. This phenomenon was also found in the studies conducted on the Mir and ISS, which reported evidence that the crewmembers were exhibiting negative feelings toward the ground personnel.[3,5] According to Kanas, the displacement of negative emotions to outside personnel can occur if the crewmembers cannot resolve intragroup conflicts.[2–4] It is recommended that crewmembers be instructed on how to directly cope with their conflicts before a mission begins, ideally during the training sessions that involve both crewmembers and outside representatives.

In observing the results related to the leadership roles, the findings suggest that compared with leader control, the crewmembers' cohesion relied more on leader support, as in the Mir and ISS results.[4] The leadership role effects are summarized as follows. First, because Group 3 was only comprised of three members, each possessed different skills that were all crucial for executing the mission. This may have weakened the influence of the leader dominance. Second, the crewmembers in Group 3 were a young assistant professor and two Ph.D. students, who were all very competent and thus less easily controlled by others. Third, the crewmembers in the confined environment may have relied more on the leaders who could support them or help with their problems, because they needed to face potentially dangerous situations, such as increasing CO_2 levels in the station or improving the system's unstable factors. Finally, due to the collectivist nature of China's cultural background, leader support may have a more positive effect on group interactions than leader control.

This study still has some limitations. We took a detailed look into Group 3, regarding it as a whole confined mission. Considering that crewmember A had already been in the module for 26 d when crewmember C and D joined in, crewmember A was already established in the habitat and more familiar with it than the other two. This situation, as well as status and gender, may have potentially impacted group dynamics, but we did not take this into consideration.

There are still some methodological problems to settle as well. The small sample size limited the statistical methods that could be used to analyze the research data, which is always a disadvantage in this field. A few more similar experiments are needed and comparisons of each result are required to obtain stronger conclusions. In addition, due to the experimental arrangement, data from outside personnel were not available.

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REFERENCES

1. Bechtel B. The third-quarter phenomenon: do people experience discomfort after stress has passed? In: Harrison AA, Clearwater YA, McKay CP, editors. New York: Springer-Verlag; 1991.
2. Kanas N, Manzey D. Space psychology and psychiatry, 2nd ed. Portland (OR): Microcosm Press; 2008.
3. Kanas NA, Salnitskiy VP, Boyd JE, Gushin VI, Weiss DS, et al. Crewmember and mission control personnel interactions during International Space Station Missions. Aviat Space Environ Med. 2007; 78(6):601–607.
4. Kanas N, Salnitskiy V, Ritsher J, Gushin V, Weiss D, et al. Human interactions in space: ISS vs. Shuttle Mir. Acta Astronaut. 2006; 59(1-5):413–419.
5. Kanas NA, Salnitskiy VP, Ritsher JB, Gushin VI, Weiss DS, et al. Psychosocial interactions during ISS missions. Acta Astronaut. 2007; 60(4-7):329–335.
6. Kanas N, Sandal G, Boyd JE, Gushin VI, Manzey D, et al. Psychology and culture during long-duration spacemissions. Acta Astronaut. 2009; 64(7-8):659–677.
7. Manzey D, Lorenz B, Poljakov V. Mental performance in extreme environments: results from a performance monitoring study during a 438-day spaceflight. Ergonomics. 1998; 41(4):537–559.
8. Palinkas LA, Houseal M. Stages of change in mood and behavior during a winter in Antarctica. Environ Behav. 2000; 32(1):128–141.
9. Palinkas LA, Johnson JC, Boster JS. Social support and depressed mood in isolated and confined environments. Acta Astronaut. 2004; 54(9): 639–647.
10. Palinkas LA, Suedfeld P. Psychological effects of polar expeditions. Lancet. 2008; 371(9607):153–163.
11. De La Torre GG, van Baarsen B, Ferlazzo F, Kanas N, Weiss K, et al. Future perspectives on space psychology: recommendations on psychosocial and neurobehavioural aspects of human spaceflight. Acta Astronaut. 2012; 81(2):587–599.
12. Wang Y, Jing X, Lv K, Wu B, Bai Y, et al. During the long way to Mars: effects of 520 days of confinement (Mars500) on the assessment of affective stimuli and stage alteration in mood and plasma hormone levels. PLoS One. 2014; 9(4):e87087.