FMARS 2007: Stress and coping in an arctic Mars simulation

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ABSTRACT

In 2007, the Mars Society conducted a 4-month simulated Mars exploration mission at the Flashline Mars Arctic Research Station (FMARS) on Devon Island, Nunavut, Canada. In addition to an intense mission research profile, the team operated on the Martian *sol*, (39 minutes longer than the 24-hour Earth day), for over a month. Team members completed questionnaires on stress, coping, and mood on five occasions throughout the mission. Descriptive analyses indicated differences between individual coping styles across time as well as differences in how the genders coped. Stress increased for males while decreasing for females. Males consistently used more avoidant coping while females utilized task coping and social emotional coping. Males also demonstrated higher levels of excitement, tiredness, and loneliness. Simulations situated in environments characterized by prolonged real isolation and environmental challenges appear to provoke true demands for adaptation rather than temporary situational accommodation as has been evidenced by shorter simulations in laboratories or more benign environments.

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1. Introduction

Only a limited number of systematic studies have focused on measuring the impact of confinement and isolation on small groups in real, operational extreme environments [1–9]. Most often, investigations of the impact of extreme environments on small groups are conducted in *pure simulation* conditions, [10–12] or on teams convening for expeditions or missions in which the research is of secondary priority, (e.g., submarine crews [13], Antarctica [14–16], aviation [17] or space [18–20]). For a number of years, the Mars Society has operated two habitats that bridge the gap between pure simulation and operational environments specifically designed for such studies: the Mars Desert Research Station (MDRS) situated in a desert location in Utah, USA, and the Flashline Mars Arctic Research Station (FMARS), located in the High Canadian Arctic on Devon Island, Nunavut, Canada. Historically, simulations at MDRS run for two weeks while simulations at FMARS typically run for four weeks. In the summer of 2007, the Mars Society conducted a 4-month simulated Mars exploration mission at the FMARS with seven crew members. This study quadrupled the previous duration record for in-situ Mars mission simulations and provided realistic conditions of isolation and confinement. The Canadian–American team was composed of volunteers willing to dedicate four months for an extraordinary experiment in which the minute details of their lives would be scrutinized and evaluated. The mission profile called for conducting a comprehensive program of geological and microbiological

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field exploration operating under similar constraints that human explorers would face on Mars as well as completing a number of repeated psychological and group functioning assessments designed to investigate sources of interpersonal stress and strategies to cope. Crew members were not given any special training in this regard, and the crew was not screened or selected on any dimension of compatibility. The crew used a 20-minute time delay in communications as part of their mission protocol to simulate the Earth–Mars time delay. In addition to an intense mission profile of research data collection, analyses and reporting, station maintenance, and educational outreach, the team also operated on the Martian *sol* (39 minutes longer than the 24-hour Earth day) for over a month to evaluate the effects on crew psychophysiology and mission operations.

The FMARS psychosocial study was part of a multi-year, multi-site study investigating a number of psychological and physiological assessments in numerous isolated, confined environments (ICE) with a particular interest in the role of mood, stress and coping in adaptation, and group functioning in extreme environments. The transactional theory of stress [21] designates stress appraisals as key cognitive mediators of stress related outcomes. Primary appraisal of relevancy, positive or stressful, frames the event for further assessment as harm/loss, threat, and challenge. An event interpreted as a challenge is linked to perceptions of possible positive outcomes despite the amount of resources that may be needed. Conversely, harm/loss or threat appraisals are typically made when demands exceed available resources leading to negative outcomes. Secondary appraisals involve the perception of available resources (e.g., physical, social, psychological, and material resources) needed to respond to perceived stresses as well as an evaluation of one's ability to use them (self-efficacy) in dealing with demands [21]. The interaction of primary and secondary appraisals triggers specific coping strategies in response. Therefore, the assessment of the perceived stressfulness related to adversity is critical to understanding the mechanisms of psychological and physiological adaptation and resilience [22].

Stress is an inherent characteristic of environments characterized by danger, remoteness of assistance, isolation from others and confinement with its attendant reduction in social networks and diminished environmental stimuli. Projections for long duration space missions must also add the as yet unquantified impact of prolonged weightlessness, extraordinary loss of contact with humankind, a high radiation environment, and unknown dangers. Therefore, factors which counter the deleterious effects of stress are central to both mission accomplishment and the well-being of crews.

In general, groups offer people social support, which is traditionally related to decrease in stress [23]. In situations where people have a strong affiliation with the group, research has indicated that they can be expected to become more motivated to achieve group goals, work harder and strive for group success. However, under these conditions, interestingly, levels of stress can actually increase as the group strives to reach those goals [24]. On the other hand, where interactions between sub-groups become more strained and conflicted, stresses can also increase [25]. Thus, the relationship between group affiliation, stress and group functioning is not linear but, rather, affected by the person-situation fit and the social capital available within the group structure to buffer the negative effects of performance stress and avoid interpersonal conflict and stress. Accurate assessment of predictable stressors and identification of those that can be obviated by informed selection and appropriate training is paramount.

Any examination of stress is incomplete without also examining coping. While there is no right or wrong coping strategy, differences in coping and resilience to stress can operate to mitigate or exacerbate dysfunction, especially within confined groups where opportunities to vent and engage in support seeking from external others is limited or nonexistent. Coping strategies are key to individual management of stressful life events [26]. Windle and Windle noted that different coping approaches could exert either positive or negative influences on adaptation [27]. Most current models of coping acknowledge that it is the interaction between disposition and situation which is most effective in predicting coping behavior [26,28]. Coping strategies have been clustered into three global approaches: *task oriented* emphasizing a focus on problem solving, *emotion oriented* emphasizing emotional response to stress, and *avoidance oriented* where the focus is on avoiding the problem [29]. Avoidance coping has been found to further decompose into two subcategories of distraction and social diversion activities [29]. The newest evolution of coping models has noted the need to address the antecedents, mediators, and outcomes of stress with respect to coping [30]. When utilizing multivariate statistical approaches, (e.g., structural equation modeling), these approaches do not propose mediation of specific strategies but, rather, mediation of the adoption of specific styles, (e.g., problem-focused or emotion-focused), within the transactional model of stress [31].

In past studies, coping styles have proven to be indicative of successful adaptation to environmental, interpersonal, and situational stressors. Individuals typically use a variety of coping styles to deal with various psychological challenges. As stress duration increases and psychological and physiological exhaustion mounts, behavioral flexibility and confidence in self-efficacy decreases, resulting in a retreat to habitual or familiar predominant response styles that may be maladaptive. Thus, coping strategies and, especially, coping self-efficacy are seen as key to successful individual management of stressful life events [22,29].

Particular styles have been persistently associated with better or poorer adaptation. For instance, task coping (problem oriented) styles have been found to positively impact adaptation and health while emotional oriented coping negatively impacts adaptation and health [29]. A robust body of evidence from a wide variety of environments, situations, and populations persistently supports the conclusion by Norris that "avoidance coping is problematic" as is assignment of blame [32,33].

Research on teams in extreme environments has demonstrated the negative impact of avoidance coping strategies to effective adaptation under extraordinary demands [34].

Finally, mood was of interest since it provides a secondary window into the emotional and psychological landscape of individuals and groups. Mood is proposed to be a continuous transactional process between internal and external factors in which cognitive and behavioral responses can be caused by, or causal of a particular affective state [35]. Unlike emotion, mood's function is to adjust or bias cognition [36] as individuals filter their perceptions through its lens, whereas emotion adjusts or biases action [37]. Where we typically are not experiencing emotions constantly, the prevalent view is that we are constantly experiencing some state of mood. Generally, emotions are shorter in duration and more intense in nature than moods [35]. The transactional model of mood [38] is an extension of Lazarus' Transactional theory of stress that incorporates mood as part of the primary phase cognitive appraisal. Mood influences information processing which influences perception and, therefore, appraisal of the event. This appraisal then leads to choices in response, (e.g., coping) that results in outcomes that present new information for perception and appraisal. Thus, the contribution of mood can be antecedent, consequence, a mediator, or a moderator depending on the point one focuses on in the process.

Understanding the dynamic transactional relationships between mood, stress, and coping is critical to identify fission and fusion factors that will allow us to successfully structure teams and missions. Group fission factors are those that contribute to discord while group fusion factors contribute to group cohesion. A particular factor can be either and even change over time, (e.g., leadership). This precludes standard static assessment approaches and requires a consideration of the myriad interactions and transactional dynamic emergent nature of these factors. Additionally, a transactional approach may help explain contrasting findings heretofore found between studies. For instance, both mood and coping have been shown to independently contribute to adjustment to chronic illnesses [39] while failing to be predictive of each other. Similarly, gender differences in mood regulation have been shown to differentiate strategies of pain management and pain experience [40]. Many studies of analog environments have generally shown a decrease in perceived stress as crew members adapt to the environment across pre-mission to post-mission periods [41–45]. However, research on the Mir space station crews during the Shuttle/Mir program found the opposite with higher group cohesion, more opportunities for self-discovery and evaluations of the group as more organized and task oriented at the beginning of their mission than later on [46]. Adopting a transactional approach to stress, coping, and mood would allow us to eventually incorporate a multivariate approach to evaluating the contribution of each of these components to adaptation in a stressful environment.

The core psychological scientific objectives for the multi-year, multi-site parent study included assessments of personality, group functioning, mood, stress, coping and group dynamics. This paper will address the following:

- Exploration of differences and similarities in mood, stress, and coping individually and by gender.
- Identification of group fission and fusion factors.

Due to the small sample size, there was no intention to address formal hypotheses since parametric analyses would be inappropriate. Rather, the intent was to evaluate individual and group responses at the descriptive level in order to provide insight into factors that could be improved in future simulation missions and guide future research. This bootstrapping approach is a common heuristic of existing sustained programs of study that routinely involve small groups. The intent is to demonstrate commonalities in small samples that justify larger meta-analytical approaches at future dates similar to the meta-analyses of Antarctic data conducted by Shea, Leveton and Palinkas [47]. With a few historical exceptions (e.g., early health studies on American Antarctic winter-over populations [48,49]), there is little opportunity for large-scale research in any extreme environment. The larger bases in Antarctica (e.g., McMurdo, Concordia) are characterized by extensive obstacles in researcher access and/or low rates of participation. Hence, analog research will continue to be largely dependent on small groups in which issues of confidentiality and statistical validity will be the challenges.

2. Methods

2.1. Design

The current study was a longitudinal, descriptive, single group design with repeated measures across five assessment periods (baseline and monthly) over a 4-month period. Crews gave baseline measures on all assessments on Day 1. Repeated measures were then taken at the end of each month throughout the mission.

2.2. Sample

The crew consisted of seven individuals, four men and three women; three Canadians, two Americans and two American–Canadians, aged 34–28. The mission was led by a female geologist graduate student (American–Canadian) who had extensive experience in similar simulations at MDRS in Utah. Two males and one female were also graduate students. One male and one female were staff at academic institutions and one female was a faculty member. Several members also had prior experience in MDRS missions and all members participated in at least one training mission at the Utah facility prior to the 2007 Arctic season.

2.3. Site

The habitat was a circular 24-foot diameter, two-deck structure mounted on landing struts with private sleeping

accommodations for six crew members. The seventh crew member was bunked in a loft space also used for storage of food supplies. Along with the environmental challenges, crew members had to also contend with the possibility of polar bears that inhabit the region, which required armed escort by assigned crew members for each of the extravehicular activities (EVA) conducted by the team. Simulation space suits were utilized by EVA teams upon all egresses necessitating considerable effort and preparation time. Due to safety requirements and to preserve confinement protocols for the majority of the crew, two team members were initially designated as the "out-of-simulation" team and allowed to exit the habitat without suits to maintain the generators and equipment and provide armed escort during EVAs. For the armed escort, a third member was added to the rotation to reduce the workload of the other two members. The in-simulation team routinely used an airlock depress/repress procedure upon each exit and entry to the habitat. There was no live TV, no radio, or mobile phone. The habitat was equipped with a satellite phone for use in emergencies and short wave radio for communication with team members while outside the habitat. All routine communication with the outside world was conducted via computer text, audio and video messages including any initial medical emergencies. Medical assistance for the majority of the mission was only available via lifeflight services several hours away.

2.4. Measurement

2.4.1. Protocol

Prior to deployment, all participants were asked to complete the Mars Habitat I, a web-based battery of psychological questionnaires that assessed various dimensions of personality, baseline stress, mood, and coping strategies. At the end of each month during the mission, participants were asked to complete a second questionnaire battery using the same set of instruments each time, the Mars Habitat II, (web-based or hard copy), which included assessments of group functioning, mood, stress, and coping. Only measures of stress, mood, and coping will be addressed in this paper.

2.4.2. Instruments

Subjective stress was assessed with Cohen's perceived stress inventory (PSS), a 10-item self-report measure of stress (0=*never* to 4=*very often*) that has been used extensively in a multitude of studies across numerous environments [50]. Coping was assessed using the 60-item cope questionnaire (COPE) that measures 15 subscales related to coping strategies, which can be grouped into three global dimensions: task coping, avoidance coping, and social emotional coping [51]. Mood was assessed with a 0–5 point Likert rating (How much do you feel at the present moment… *not at all*, *very slightly*, *a little*, *moderately*, *quite a bit*, *extremely*) of current state on 11 moods (strong, tired, excited, frustrated, lonely, upset, determined, stressed, enthusiastic, hostile, and irritated).

2.4.3. Interviews

Immediately after return, all members were e-mailed semi-structured open-ended questions regarding their experiences during the mission. Inquiries were made into a wide range of issues: for instance, events that provoked different opinions about appropriate approaches, issues of contention, activities that the group shared, activities that the group sought to do alone, privacy issues, communication, physical and emotional well-being, and issues with external factors (e.g. mission control, family, media) that affected the group/self (positively or negatively). A follow-up debrief interview was held at the 1-year anniversary of the mission in which private 1–2 h interviews and group sessions were held with the principal investigator (PI) following the same semi-structured question set. It has been the experience of the PI that debriefs immediately after the completion of missions are characterized by feelings of euphoria and self-congratulation for successful completion; whereas debrief content at a later date is more reflective and balanced in consideration of both negative and positive events and interactions. This observation was supported by the two debriefs for this mission. The anniversary interviews were overwhelmingly more forthcoming in content, richer in detail, and more complete in responses. All analyses regarding the qualitative interviews are drawn from the later set of interviews.

2.5. Data analyses

Given that the sample size for this mission was small, our analyses are primarily descriptive. In addition, preservation of confidentiality precludes linking crew member roles or other identifying demographic data with specific assessments. It should be kept firmly in mind that such small sample sizes do not generalize to other samples or represent evidence for a population in general. This is also true for any gender comparisons, which should be evaluated simply as to whether they are consistent with previous research or in contrast. It is our hope that continued data collection over multiple missions in these kinds of environments will result in sufficient numbers to address issues that can be appropriately treated with parametric statistical approaches, meta-analytic approaches [47], or newer structural equation modeling approaches.

One problem with analyses at the group level is that subgroup differences become obscured. The issue of gender composition of crews cuts across almost every mission consideration and generates impassioned rhetoric on both sides of the debate. While examining gender groups within already small sample sizes further exacerbates statistical interpretations, not examining potentially powerful behavioral and interpersonal differences in adaptation to the stresses of an extreme environment would be even more egregious. There were three women and four men in the FMARS team, as evenly split as a team of seven can be. The team leader was a woman and one of the most experienced of the crew. Confidentiality precludes analyses at the leader-group

level, but explorations of gender differences are worthwhile to pursue at the descriptive level.

Therefore, our analytical approach used correlational and nonparametric methods of comparison in order to generate rank means that accommodated the differences in metric for different scales as well as avoided issues of heterogeneity and its deleterious effects on computation inherent in small samples. For comparisons across groups at each point in time, Mann-Whitney U z-scores were computed. For comparisons of within group changes across time, Friedman's nonparametric repeated measures were used. Although error bars are included (based on the standard error of the mean (SE)), they are for purely descriptive reference comparisons.

3. Results

3.1. Stress

An examination of stress patterns across the seven crew members in Fig. 1 shows at least two individuals (Members 5 and 6) with comparatively high levels of stress initially. Both these individuals show notable declines across the mission, especially Member 6. Four of the seven crew members show an elevation of perceived stress at the midpoint of the mission at the end of Month 2. The majority of individuals were able to maintain equilibrium across the mission indicating effective management of stress levels, with the exception of Member 3, who displayed increasing levels of stress across mission duration and was highest of all members at mission end. This steady increase in perceived stress and distinctive trending in the opposite direction of the group would suggest a member with unresolved difficulties in coping progressively increasing across time.

3.2. Mood

3.2.1. Group results
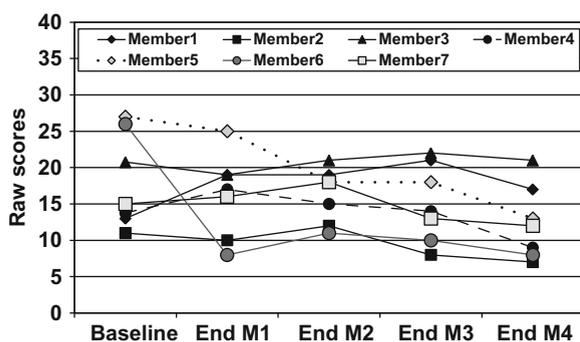As mood is the lens through which we perceive the world, an examination of the relationship between mood and stress seemed to be a reasonable first step. Fig. 2 displays the change in the 11 moods assessed over the five data periods (arrival to mission end). It is clear that all moods except for excitement (which was already elevated) increase by the end of Month 1. There were significant changes across time for feelings of strength, tiredness, loneliness, upset, hostility and irritation. Peaks in the negative moods were predominantly seen at the end of Month 1 (tiredness, frustration, loneliness, upset, mood stress (not to be confused with measures of perceived state stress as measured by the PSS), and hostility). Positive moods peaked towards the end of the mission during Months 3 and 4. Changes in any of the moods may be indicative of more systemic changes in the group. For instance, the substantial increase in the negative moods of frustration, loneliness, feeling upset, hostile, and irritated displayed at the end of Month 1 would be noteworthy to monitor. Early stages of adaptation and integration are typified by increase in negative interactions as the novelty and excitement of a new situation wears off. Decline in these negative moods across the remainder of the mission would be indicative of successful adaptation by the team. However, the continued rise in irritability through Month 3 would suggest an accumulative strain for some team members, which, if unresolved, would risk affecting individual performance and interpersonal relationships within the team. The fall in negative moods and increase in positive moods seen at Month 4 is also very common, as individuals foresee the end of the mission approaching and anticipatory excitement boosts morale.

3.2.2. Mood and stress
Table 1 shows the correlations between mood and perceived stress at the end of each measurement period (baseline was Day 1 on arrival) for the group. Since small sample sizes require enormous effect sizes to reach statistical significance, it is more useful to focus on effect size alone to evaluate relationships. Using a conservative criteria of $r=.50$ or larger, there are several patterns that emerge. In general, all relationships are in the expected direction, i.e., high positive affect is associated with low perceived stress, and high negative affect is associated with high perceived stress and vice versa. These congruencies are violated twice in the baseline period (negative correlation for lonely and near zero correlation for irritated), twice at the end of Month 1 with near zero correlations for strong and determined, four times at the end of Month 2 with near zero correlations for excited, hostile and irritated and a negative correlation for tired, four times at the end of Month 3 with near zero correlations for excited, stressed, and enthusiastic and a negative correlation for irritated and only once at the end of Month 4 with a negative correlation for mood stress. The decoupling of moods and evaluation of perceived stress seen at baseline and Month 4 at the end of the mission represent a cognitive interpretation of perceived stress as acceptable and productive. In the case of loneliness at baseline, the excitement of arrival understandably displaces any feelings of separation from family and friends. Homesickness and loneliness are typically moods that

Fig. 1. Individual stress scores across time.

M ranks	strong	tired	excite	frustra	lonely	upset	determ	stress	enthus	hostile	irritate
Base	1.64	1.79	2.79	2.29	1.36	1.86	2	1.79	2.29	1.43	1.86
M1	3.36	4.29	3	4.07	3.93	3.93	3.07	3.93	3.29	3.93	3.21
M2	2.79	3.79	2	3	3.5	3.5	2.71	3.07	2.5	3.36	3.43
M3	3.93	3	3.21	3.36	3.36	3.14	3.71	3.14	3.29	3.14	4.21
M4	3.29	2.14	4	2.29	2.86	2.57	3.5	3.07	3.64	3.14	2.29
	**	**			**	*				**	*

*p<=.05
**p<.01

Fig. 2. Group mood scores across time.

Table 1
Mood and stress correlations.

Mood	Stress baseline (n=5)	Stress Month 1 (n=7)	Stress Month 2 (n=7)	Stress Month 3 (n=7)	Stress Month 4 (n=7)
Strong	−.81	.02	−.54	−.77	−.29
Tired	.56	.56	−.14	.63	.48
Excited	−.43	−.25	.05	.09	−.45
Frustrated	.34	.67	.40	.46	.40
Lonely	−.38	.86	.61	.73	.90
Upset	.53	.60	.33	.61	.40
Determined	−.50	−.06	−.39	−.56	−.74
Stressed	.93	.91	.44	−.01	−.31
Enthusiastic	−.62	−.25	−.78	−.07	−.55
Hostile	.53	.33	.01	.38	−.33
Irritated	.03	.45	−.03	−.11	.26

emerge after the novelty of a situation has worn off. This is clearly seen in the large sustained positive correlations between loneliness and perceived stress displayed for the rest of the mission. The decoupling of mood and evaluations of perceived stress were more prominent in assessments at the end of the Months 2 and 3. Feelings of excitement, enthusiasm, hostility, and irritation show disruptions in patterns that are consistent across other periods. Similarly, mood stress evaluation shows the beginning of cognitive reframing at the end of Month 3, which is strengthening by the end of Month 4. These results emphasize the importance of evaluating mood and perceived stress in the context of the chronology of the mission. The decoupling of some moods and perceived state stress seen at the midpoint assessment (end of Month 2) which persisted through the third quarter (Month 3) may help explain why past research finds contradictory evidence for or against the *third quarter effect*, where behavioral problems and highest levels of emotional distress are proposed to peak during the third quarter of long duration missions [52].

3.2.3. Mood and gender differences

Mood change patterns were distinctly different between the genders across time. Males reported higher levels of strength and determination at baseline compared to women and evidence a pattern of increases and decreases of similar magnitude for each of the positive moods (Fig. 3a). In contrast, female team members were surprisingly low on determination and strength but displayed significant increases ($p < .05$) for both across the mission and showed higher shifts towards all positive moods than men at mission end (Fig. 3b). There were notable declines in excitement and enthusiasm at the end of Month 2 for both groups with women being more pronounced marking the half-way point as a particularly stressful period for the team.
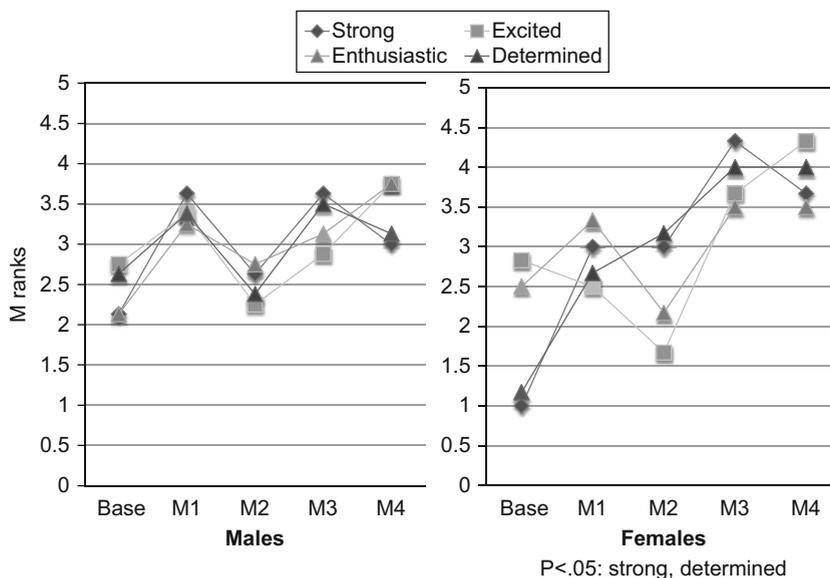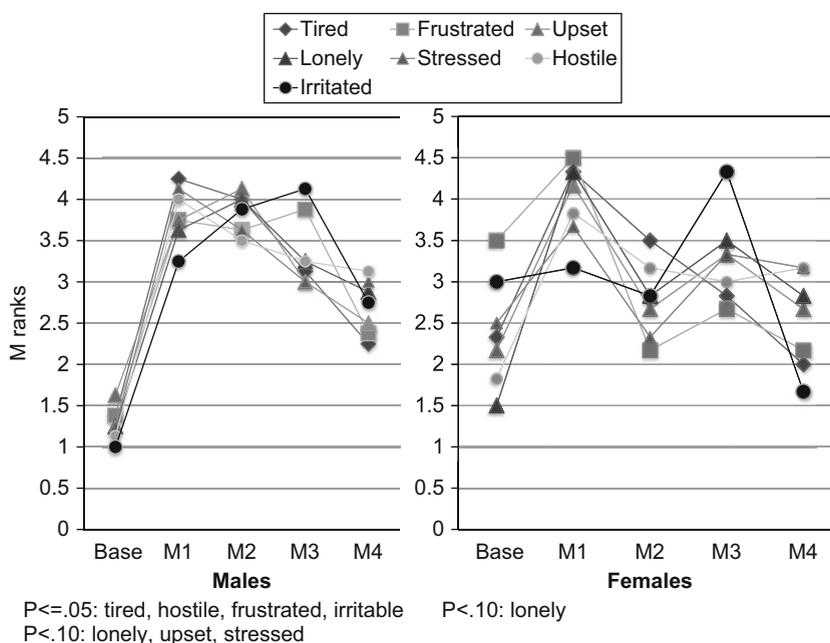
Fig. 3. Positive moods by gender.

Fig. 4. Negative moods by gender.

Negative mood profiles were also distinctly different between the genders (Fig. 4a, b). Females displayed comparatively higher initial levels of negative affect except stressed mood and hostility at baseline. However, negative moods for both the groups showed large increase by the end of Month 1 which precedes the drop in positive moods displayed in Fig. 3a, b. Female team members showed declines at Month 2 with some rebound in Month 3 before declines at mission's end. Males consistently reported more feelings of negative affect in general, especially tiredness, loneliness, frustration and irritation across the mission. It is interesting to note that the peak of male negative mood is coincident with the nadir for women at the end of Month 2. Both groups demonstrate increased irritation at Month 3, which may be indicative of the third quarter effect reported. Month 3 also coincided with the period of maintaining the Martian sol schedule. To what extent the additional negative mood was reflective of the strain of the slightly longer Martian schedule or its asynchronous drift with the external world

(e.g., mission control, family, and friends) cannot be ascertained. These patterns would suggest that a clearly different process of adaptation was being experienced between the genders.

3.3. Coping

3.3.1. Coping and stress

Since coping is always contextually tied to a stimulus, an examination of coping strategies across the mission is compared to levels of perceived stress. The transactional model of stress posits that the management of stress is dynamic and interactive with effective strategies reinforced by positive outcomes. The problem is that short-term stress reduction may be gained by coping strategies that contribute to negative outcomes under prolonged duration. Hence, consideration of coping approaches has to factor in the lag between aversive outcomes and the incorporation of new approaches. The small sample size does not allow analyses that would be able to assess whether positive coping moderated diminishing levels of stress or whether an increase seen in negative coping was triggered by increasing levels of stress in this study.

An examination of correlations between the various coping strategies and perceived stress indicates support for both a lag effect and a third quarter effect. The increase in levels of perceived stress reported at the midpoint for over half the crew noted in Fig. 1 is reflected in the strongest pattern of relationships with stress evidenced at the end of Month 3 where the lowest levels of positive coping approaches and highest levels of negative coping approaches are found (see Table 2). Several negative coping approaches show sustained relationships with stress across the entire mission (i.e., venting, behavioral disengagement, and suppression of competing activities). It does seem that reciprocal relationships between various coping strategies existed. For instance, the highest and lowest levels of venting were seen during the lowest and highest levels of mental disengagement indicating that psychological withdrawal from interpersonal interaction was effective in mitigating complaining and emotional venting. However, the use of avoidance techniques such as disengagement have been found to negatively impact group cohesion, performance and be indicative of poorer adaptation in the long-term [53–55].

#### 3.3.2. Coping and gender differences

Since coping styles are shaped by both nature and nurture [56], the issue of gender differences in coping is particularly salient, especially when dealing with individuals who are high-performing and operating under extraordinary environmental restrictions to resources normally available, (e.g., family and friends). As noted by other investigators in the field [56–58], coping approaches have demonstrated distinct differences between the genders that may have implications for long duration, isolated confined environments. Of special interest are the findings which suggest that gender differences are both historically and situationally shaped by the resources available. Thus, resource limited environments would pose particular challenges for some styles of coping. Since stress levels and resources to deal with stress are the drivers for coping, it is important to note gender differences in stress as we examine coping.

Two analytical approaches were taken to assess coping: (1) a comparison of coping strategies *between* the two genders at *each* point in time, and (2) a comparative analysis of coping strategies used across time *within* each gender that focused on how each gender changed compared to prior strategies favored in the previous assessment period. Mann-Whitney U nonparametric analyses were used for the between group analyses and Friedman's nonparametric repeated measures analyses were used for the within comparisons.

In the comparison across genders, the pattern of stress (Fig. 5, black) was dramatically different between males and females at mission beginning with females substantially higher. However, males displayed a significant increase between baseline and the end of the Month 1 and stayed elevated above females until mission end. Females displayed a reduction of similar magnitude by the end of Month 1 with steady reductions thereafter until a slight elevation at mission's end.

Table 2
Relationships between coping and perceived stress across time.

Coping	Stress Month 1	Stress Month 2	**Stress Month 3**	Stress Month 4
Growth (+)	.53	−.01	−.54	.68
Mental disengagement (−)	.25	−.18	.07	.32
Venting (−)	.84	.67	.87	.80
Instrumental support (+)	.37	.34	.42	.22
Active coping (+)	−.08	−.26	−.50	−.47
Denial (−)	.05	−.14	.49	−.06
Religion (+)	.70	.20	.26	.04
Humor (+)	.46	.05	.26	.49
Behavioral disengagement (−)	.20	.65	.61	.73
Restraint (−)	.04	−.10	.28	.02
Emotional support (−)	.51	.37	.56	.13
Substance use (−)	–	–	.48	.40
Acceptance (+)	−.02	.23	−.28	−.09
Suppression of competing activities (−)	−.50	−.53	−.49	−.50
Planning (+)	.01	−.33	−.50	−.25
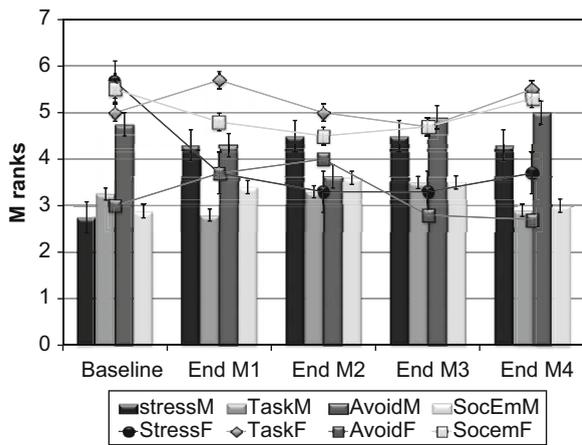
Fig. 5. Comparison across genders on global coping over time.

Comparisons between genders on global coping styles across mission duration shown in the same figure indicated that males persistently relied upon avoidance approaches (commonly found with males) with social emotional coping generally second in usage (not typically found with males). Females used avoidance coping the least across all time points with a predominant preference for task coping (not typically found in general studies on women) with social emotional coping a close second (typically the most predominant in female coping patterns). The combination of avoidance coping with social emotional coping for males would indicate coping responses that would be oriented towards emotional arousal but reluctance to confront or address issues. Female predominance in task and social emotional coping reflects a style focused on "fixing" problems by doing something rather than avoiding the issues and emotional arousal when efforts to resolve problems were thwarted. Although small sample size prevents any conclusions based on this data, the efficacy of task coping and inefficacy of avoidance coping has been supported consistently in previous studies. Coupled with emotional coping (generally not conducive to effective adaptation), the predominant usage of avoidance coping may actually delay effective adaptation and contribute to individual and group stress. These two styles would be equally stressful for each of the other to deal with over long periods of time.

When examining the changes in coping *within* each gender across time, several interesting patterns emerge that further illuminate differences in how the two genders adapted. Assessment of male stress relative to prior levels peaks at mid-mission, stays elevated through the third quarter and falls to below baseline levels by mission end (Fig. 6). Coping strategies start out with all equally elevated at baseline, fall equally in use to the lowest point by the end of Month 1, and begin to differentiate by mid-mission. At that point in time, relative to prior usage, social emotional coping appears to increase substantially above task and avoidance with avoidance usage increasing the least. However, avoidance continues to
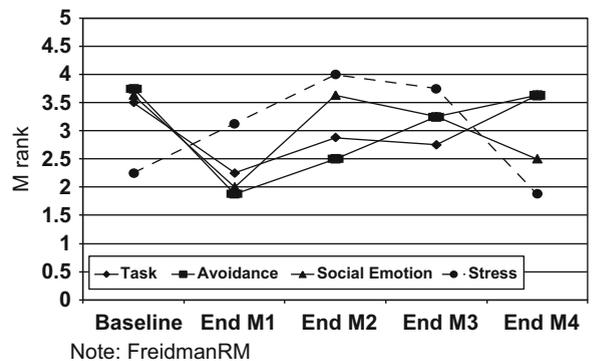

Fig. 6. Male use of coping strategy changes across time.
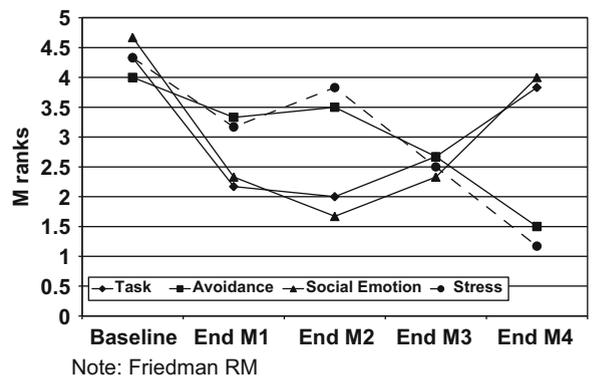

Fig. 7. Female use of coping strategy changes across time.

increase at each assessment period relative to prior use, mirrored by similar increases in task coping. By mission's end, males have returned to baseline levels of task and avoidance coping relative to prior usage.

For females, the within analysis also reveals nuances in changes across time (Fig. 7). Compared to initially high and equal utilization of all three global coping styles, use of social emotional and task coping by women declined dramatically across time to their lowest points by mid-mission with recovery to near baseline levels by mission's end. Use of avoidance coping relative to usage in previous periods declined less precipitously (with a small upturn at mid-mission) and continued decline to lowest usage at mission's end. Of interest is the fact that the pattern of avoidance coping for females closely shadows within assessments of perceived stress.

3.4. Interview data—group fission and fusion factors

One goal of studies of groups in extreme environments is to identify group fission and group fusion factors. It is difficult to define a priori which factors should be assessed since the conditions of isolation, confinement and restriction of resources may impact the role of various factors in ways different from non-extreme environments. Repeated emergence of the same factors across groups and environments will identify issues that can be more

proactively addressed in future studies and missions. The state of knowledge in this regard is still in its infancy. Thus, results from the qualitative interview data has been structured to illuminate quantitative results with regard to identifying potential fusion and fission factors that could be mitigated or enhanced in future missions and studies.

3.4.1. Fission factors

3.4.1.1. Group composition. Although the FMARS team was a convenient sample of volunteers, there was some attempt to solicit individuals who had had some prior experience in simulations or other extreme environments. An effort was made to recruit an equal number of males and females although there were not any strict gender quotas. Mars Society requires someone with geology background on the crew due to the focus on geological exploration and science at both MDRS and FMARS. It was pure happenstance that nationalities were only American and Canadian. However, it is a mistake to presume that one can dismiss the impact of national affiliations between countries even as closely aligned as Canada and America. For instance, the inclusion of a member whose mother tongue was not English provided for feelings of isolation and pressure to conform to the majority in matters of differences. A wealth of evidence from social psychological research has clearly underscored the negative impact of the token individual whether that is based on gender, ethnicity, professions or, in this case, nationality. Experience on Mir by American Astronaut, Norman Thagard, graphically highlighted the negative impact of the loss of culturally familiar daily interaction with those that speak the same language and share similar cultural backgrounds. Astronaut John Blaha reported on his own struggle with the enhanced sense of isolation as the only American on a three person Mir crew and the need for proactive, conscious efforts to counteract the deleterious effects [59].

A parallel issue to the need for similar others is the need to be a part of the core mission. The relegation of some members to purely supportive roles placed them in positions of gatekeepers (of time, resources, access) and enforcers (safety, regulations, protocols) with none of the opportunities for discovery, creation and recognition which other members had. This secondary status enhanced feelings of isolation and homesickness, contributed to loss of motivation, boredom and apathy and set these individuals apart from those invested in the larger scientific mission. Efforts after arrival by the FMARS team to generate contributory projects for these team members were not successful. The lack of meaningful contribution to the discovery role of expeditions has persistently been found to contribute to lack of ownership of mission goals by team members [49,60]. It is not enough to just support the team. One must feel a part of the excitement and contribution to the generation of new knowledge and a valued contributing member of the higher mission.

Another composition concern frequently raised with mixed gender teams involves romantic or sexual attraction between members. A sensitive topic that is more often side-stepped, the FMARS team dealt with the issue first-hand. Besides the frequently cited danger of polarizing the group for or against individuals involved, one emergent problem that has not been addressed in previous considerations of the issue is the impact on group trust. During the FMARS 2007 mission, a member tasked with an authoritarian role became compromised as a key player in reoccurrences of unreciprocated sexual interest, which, as an explicit source of discord, was actively monitored and addressed by the group. However, the more insidious impact was emergent in which trust in the motivation behind unpopular necessary maintenance of protocols and safety procedures for which the individual was responsible, was undermined. The team sought to address these issues through both group and individual supportive confrontations with the individual and proactive attempts to separate functional roles and responsibilities from interpersonal issues. Although the situation was felt to have been "managed" adequately, interview data indicated that all, including the principals involved, felt the situation evolved largely from unexpectedly strong feelings of isolation and loneliness generated by unanticipated homesickness, an ancillary support role with little involvement in discovery, and a personality not well suited to the characteristics of a confined environment. It was a common conclusion that a true selection process for crew composition would have effectively identified these mismatches and possibly prevented the situation from evolving.

3.4.1.2. Expedition expectations. Beyond the individual situational factors that affected mood, the patterns of positive and negative moods reported by team members strongly suggest there was a difference in expectations and framing of the expedition that generally, but not uniformly, aligned along gender lines. The higher levels of reported excitement and enthusiasm by male participants coincide with repeated reported incidences where male team members deferred duties in favor of pursuing prolonged exploration while on EVAs, indicating a greater willingness to supplant mission schedules with personal preferences. The lower levels of excitement and enthusiasm evidenced by the women reflected a more pragmatic framing of the mission as a challenge to successfully complete the mission. These differences may have contributed to perceptions of the women by the men as less flexible, more compliant, and more rule-bound with reciprocal perceptions on the part of the women of the men as less mission-focused. These generalizations have been noted in other studies of men's and women's teams [5]. However, it should be emphasized that there were individuals of both genders who were more similar to their cross gender counterparts than to their same gender cohorts.

3.4.1.3. Subgroup formation. Subgroup formation is the natural tendency of individuals to develop closer ties with a subset of individuals within a larger group. Subgroups may form around job roles (e.g., scientist and military), interests (e.g., religious, leisure, sports), social status (e.g., "geeks" and "jocks"), age, nationality, professions, and so on, ad infinitum. Within small groups, the danger

of perceptions of or actual exclusion of members poses very real challenges to group cohesion. In the FMARS group, several factors contributed to incipient subgroup formations. Unsurprisingly, the emergent nature of these factors contributed to a lag between recognition of the negative impact and counteractive response by the group. For instance, there were numerous incidences where the in-simulation and out-of-simulation groups found themselves at odds. Out-of-simulation members took advantage of various opportunities to relieve the stress of confinement (e.g., forays to the beach, prolonged periods of outside activities, use of the generator hut for additional privacy) that were not available to the in-simulation group, which served to heighten feelings of disparate contribution to the verisimilitude of the mission. Maintaining a joint crew with non-equivalent mission roles will always be a challenge. For the most part, the team effectively dealt with this issue by bridging the groups with a floating member who could advocate for both subgroups. In this regard, several individuals were uniformly lauded by group members as being key sources of leadership and support for these and other situations involving group contention and discord. The emergence of these boundary role persons has been repeatedly shown to be critical to effective team functioning [8]. They serve to bridge the various interests of subgroups and individuals and provide the social ties that hold groups together.

One subgroup problem that was not uniformly resolved during the mission was the issue of majority versus minority decisions taken by the group. When resources are minimal, perceptions of equitable access becomes of paramount importance to group functioning. In general, the group adopted a consensus approach to all decisions including those involving group leisure activities. However, the desire to follow a popular TV show, *Lost*, by a majority of the team overshadowed prior commitments by the group to equitably rotate the choice of evening leisure activities. The fact that some of these alternative activities involved viewing media that required English subtitles further heightened cultural differences and difficulties of mixed nationality crews. The situation was exacerbated by the lack of familiarity of the out-group member with the storyline which made participation that much more difficult. The prevailing majority rationalized their decision to watch the next installments of the program by interpreting the reticence of the dissenting member to confront the group and demand equitable access as agreement rather than coerced acquiescence. However, during debrief most team members admitted that they were acutely aware of the distress this caused, recognized and regretted the unfairness of the majority decision, and uniformly indicated that it would have become an even greater source of discord over a longer duration mission.

Finally, the effort to *avoid* subgroup formation produced its own distress. The team reported feeling stressed from pressures to be inclusive of all members in all activities. Several members reported feelings of reluctance to indulge in retreats to private bedrooms for one-on-one conversations, since this could be seen to be exclusionary. The loss of significant others in restricted environments makes all possible incidences of preference for others far more salient than they would be under normal circumstances. Awareness of this perception can become a source of behavioral inhibition that, over time, is stressful to maintain.

3.4.1.4. Privacy. Taking private time away from the group was difficult to accomplish and often frustrated by the lack of auditory privacy. While visual privacy could be accomplished by retreating to one's room, all conversations were discernable from almost any part of the habitat with few exceptions. The out-of-simulation members often resorted to shirt-sleeve private conversations in the generator hut, but this was not easily available for in-simulation members who had to don suits to leave the habitat. Similarly, there was an ongoing struggle to provide for privacy for the team member who had to bunk in the loft area where backup supplies were kept. The repeated unannounced intrusions of others into this person's "bedroom" provoked efforts to establish visual boundaries by placing a curtain at the top of the ladder to the loft in order to remind others. The fact that this attempt was only partially successful (with the attendant continued feelings of violation and frustration) highlights the importance of clearly delineated personal space that is considered inviolate by others.

3.4.1.5. Communication. Coping with stress was manifested in ways that were sometimes surprisingly differentially perceived. For instance, the use of e-mail provided substantial resources for venting and emotional relief, both within the team and with external others, (e.g., family). However, the use of e-mail conversation as a private mode of in-group communication was perceived by some as insulting, impersonal, and reflecting a lack of willingness to deal with issues face-to-face. Conversely, others found it a useful and effective mechanism for within-group private conversation. This differential opinion of the appropriateness of using e-mail for within-group conversation was not recognized until late in the mission.

Finally, although the crew observed a 20-minute communication delay protocol with external contacts, this was periodically violated for media interviews, educational outreach exchanges, personal contacts with bankers/travel agents, group counseling sessions with one of the principal investigators, and, occasionally, even personal phone calls to family. The sheer ability to make these real-time contacts as well as the knowledge that civilization and home was a supply flight away in Resolute, Nunavat, and beyond, certainly played a part in mitigating the impact of isolation. This is of key importance since such immediate relief generated by real-time contact with family and friends will not be possible for long duration missions to Mars. Within-group modalities will need to be far more effective than a reliance on external e-mail communications with family for such missions to manage stress and conflict.

3.4.1.6. Summary of fission factors. In summary, reported feelings of isolation, frustration and loneliness, their use

of avoidance coping, and elevated feelings of arousal and excitement by men were mirrored in reports of incidences involving individual conflict and tension between group members. Post mission debrief interviews indicated a number of occurrences involving interpersonal conflicts in group choices of entertainment, communication problems embedded in language differences, unreciprocated attraction, personality differences, challenges to authority, and schedule compliance that were centered on male crew members. The lack of such personal scientific projects left some members without meaningful roles in group identity activities, which contributed to subgroup formation and social isolation for those members. Most of these issues were addressed by the team in such a way as to keep tensions at manageable levels; however, multiple crew members acknowledged the high likelihood that these same issues on a longer duration mission would have produced significant problems for the crew.

3.4.2. Fusion factors

While there were numerous challenges and sources of fission factors for the team to overcome, there were also numerous sources of fusion factors, some of which were generated by the fission elements, which strengthened crew member skills in dealing with the negatives.

- During the mission, emergent co-leadership roles evolved that incorporated a number of strengths of the group.
- With members of both genders and subgroups represented, this structure was able to bridge many of the instances of communication breakdowns that are inherent in any group.
- All members adamantly felt that prior experience had been highly beneficial in preparing them for many of the challenges of the prolonged confinement and isolation. It was unanimously agreed that those who did not participate extensively in prior training were at a disadvantage and were less integrated into the group.
- It was also apparent that a meaningful role in the generation of knowledge and accomplishment of scientific goals was critical to the development of a shared mission identity. For those with projects, feelings of camaraderie and collegiate cooperation were in evidence and promoted high motivation, dedication, and determination to accomplish mission goals.
- Contact with family and friends was deemed of critical importance by all team members. Such contact was credited with successful personal management of intergroup conflicts and stress, as well as mitigating individual feelings of isolation and loneliness.

4. Conclusion and discussion

In the FMARS team, stress was clearly evident across the mission for both genders and all individuals. It is impossible to parse the impact of the environment from the contribution of interpersonal frustration, loneliness, and intergroup conflict, which were all evident during the 4 months. A certain amount of intergroup conflict is inevitable for all groups, and overall, the FMARS team members remained focused on the global mission goals. Some sources of conflict can be avoided by better selection and training. Some can be mitigated by avoiding structures that lend themselves to high likelihood of conflict or role stress. All of these sources were evident for this team.

One of the strengths of the FMARS mission was the opportunity to explore patterns of change across time frames longer than those offered in short-duration expeditions and MDRS missions. The within analyses were particularly informative, revealing shifts in preferred coping styles relative to prior usage that displayed increases and decreases that the between comparisons obscured. Men appeared to be shifting strategies to more social emotional coping, which is characterized by greater venting, requests for help, advice, sympathy, and substance use. Women shifted to a higher use of avoidance coping characterized by mental and behavioral disengagement, denial, restraint, and acceptance, possibly in response to the increase in demand for emotional supportive coping displayed by the men. Qualitative analyses seem to suggest that several ongoing areas of conflict and stress involving subgroup differences (e.g., in-simulation versus out-of-simulation, group leisure activities) and the need to deal with persistent issues (e.g., unreciprocated sexual interest, violations of privacy) certainly contributed to the concurrent utilization of these coping strategies in the short term.

Numerous substantial questions about stress and coping still need to be addressed. The experiences of the FMARS team was consistent with previous studies wherein males were more likely to utilize an avoidance pattern of dealing with interpersonal conflict and personal stress, and females are more prone to seeking instrumental and emotional support [9,27–29,31,33,34,56,57]. This also may be highly influenced by cultural characteristics; thus results with different nationalities may show different patterns. Some evidence seems to support the view that coping differences may be more related to available resources and habitual usage of those resources than inherent gender differences [56]. A study by Hobfell and London [61] identified the *pressure cooker effect* in their study on Israeli women during the Israel–Lebanon War. When many stressors communally tax a group, both supporters and supportees are affected. Those women who sought and received more support reported more distress because their resources were taxed as a group; and, by seeking others out, they added further burden to those being asked for support.

Persistent evidence suggests that the use of avoidance coping over the long term appears to delay problem resolution and intervention [32]. Avoidance patterns would tend to frustrate task-focused individuals and contribute to greater stress. In turn, demands by task-focused individuals to actively address problems would be perceived as pressure by avoidance copers.

Additionally, as noted by Carver et al. [51], many coping strategies employed by individuals may have been highly successful in the past when access to various resources (e.g., significant others, space, privacy) allowed for effective responses. For instance, men tend to use task/problem solving approaches in situations where they have control over the resources and avoidance approaches in situations where they do not. In the latter situations, it appears that men turn to women more for instrumental and emotional support. Because women are more culturally practiced at emotional monitoring, they find themselves seen as resources by individuals who have lost normal supportive resources. This would make them at risk for the pressure cooker effect. For high performing women who may not be any more likely to seek support from others than their male counterparts, the solicitation and expectation of support would represent a significant demand. The reciprocal patterns of change evidenced by the men and women of FMARS showed that increase in instrumental and emotional support seeking by the men was mirrored by increase in avoidance coping by the women. In environments characterized by substantial restrictions in resources, including few others from which to seek help, strategies such as seeking instrumental and emotional help can translate into simply another source of stress for team mates. Similarly, delays in addressing conflicts, denial, and passive acceptance would tend to allow a vicious cycle of self-fulfilling prophecy through the generation of negative moods, which affect perception and cognition that, in turn, produce maladaptive coping responses and so forth.

However, the "fix" to avoidance coping is not to indulge in persistent confrontation over minor events and constant vocalization of one's unhappiness. Research on the impact of focusing on and venting of emotions strongly suggests venting leads to heighten attention to negative emotions that can impede adjustment, especially if persistent for long periods [62]. The act of venting raises the salience of distress, which may act to exacerbate the distress and may also distract people from active coping efforts and movement beyond the distress [63].

For the FMARS team, the pattern of positive and negative mood suggests that males were feeling more isolated and frustrated, which may have contributed to feelings of fatigue, or conversely, been exacerbated by extreme physical tiredness. Combined with an avoidance coping style, resolution of interpersonal conflict would have been slow to be resolved. The pattern of mood, stress, and coping suggests that mid-mission may be a particularly good point to introduce additional supportive activities dealing with interpersonal differences and conflict resolution. The identification of such critical windows for the introduction of countermeasures is a highly sought outcome of ICE research.

Despite the persistent issue of unreciprocated attraction, the crew strongly endorsed the inclusion of both males and females on the team. Research on mixed gendered teams strongly suggests that the presence of females normalizes social functioning in groups, allowing males to disclose more easily [64]. This would be a beneficial counter to avoidance coping styles. It remains to be seen whether more effective coping approaches can be inculcated in team members through training.

Post mission debriefs at 1 year clearly indicated that all crew members had accurately identified critical events and issues, as well as constructive reflection on better ways these could have been handled. Thus, each of these individuals are better prepared and likely to be more effective in future groups, as well as better able to evaluate the fit between their own personality strengths and weaknesses and mission characteristics. This post mission learning supports an iterative approach whereby future potential teams should be given opportunities to complete mini-missions as part of their training. There is no substitution for experience. The best fit individuals will be those who become most proficient at rapidly translating lessons learned into actual practice. The benefits to incorporating such empirical training in the selection and preparation of long duration crews could not be made more eloquently than by the experiences of the FMARS crew.

In closing, this was an extraordinary group of individuals who were willing to put themselves under substantial duress and challenge. They were successful in meeting all the scientific goals outlined by the mission objectives. The kinds of intergroup conflicts and challenges they grappled with are indicative of those that future crews will also face. It is not the presence of conflict that is critical but the manner in which the group manages conflict that determines successful group functioning. The FMARS team members met some of those challenges successfully, while others eluded long term effective resolution. As a group of volunteers who were not screened or matched on personality or skills before the mission, one must count their overall success in maintaining a functioning group as laudable. Their contribution to future studies cannot be understated.

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