Team Composition Issues for Future Space Exploration: A Review and Directions for Future Research

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BACKGROUND: Future space exploration, such as a mission to Mars, will require space crews to live and work in extreme environments unlike those of previous space missions. Extreme conditions such as prolonged confinement, isolation, and expected communication time delays will require that crews have a higher level of interpersonal compatibility and be able to work autonomously, adapting to unforeseen challenges in order to ensure mission success. Team composition, or the configuration of member attributes, is an important consideration for maximizing crewmember well-being and team performance.

METHODS: We conducted an extensive search to find articles about team composition in long-distance space exploration (LDSE)-analogue environments, including a search of databases, specific relevant journals, and by contacting authors who publish in the area.

RESULTS: We review the team composition research conducted in analogue environments in terms of two paths through which team composition is likely to be related to LDSE mission success, namely by 1) affecting social integration, and 2) the team processes and emergent states related to team task completion.

DISCUSSION: Suggestions for future research are summarized as: 1) the need to identify ways to foster unit-level social integration within diverse crews; 2) the missed opportunity to use team composition variables as a way to improve team processes, emergent states, and task completion; and 3) the importance of disentangling the effect of specific team composition variables to determine the traits (e.g., personality, values) that are associated with particular risks (e.g., subgrouping) to performance.

KEYWORDS: team composition, individual differences, team performance, space crews.

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Future space exploration will likely include a number of significant interpersonal, psychological, and teamwork challenges for crewmembers. NASA's latest *Design Reference Architecture* for a Mars mission suggests that crews will live and work in an isolated and confined environment for up to 30 mo, and will experience communication delays that will require crews to work more autonomously than current International Space Station (ISS) crews.[18] Future crews are also expected to be diverse in terms of nationality, sex, and professional background.[18] As crews move into deep space, there will be limited abort capabilities, necessitating that the chosen crew can adapt to the demands of the mission. The consequences of mission failure, which can result from issues such as inadequate cooperation, coordination, communication, and psychosocial adaptation, are significant. Optimizing team performance is one way to reduce the likelihood of mission failures.[80]

Prevailing team-effectiveness models suggest that while teams use multiple paths to accomplish their goals, teams can be better positioned for success if they are composed well.[29,31,60] Team composition refers to the configuration of team members' attributes and their relationships.[5] Well-composed teams are staffed with the right mix of individuals who, as a unit, can accomplish the team's tasks.[30,88] A vast body of research supports the importance of team composition in team design; composition is empirically linked to outcomes such as cooperation,[20] social integration,[33] shared cognition,[21] information sharing,[71] adaptability,[57] and team performance.[5] As such, team composition is potentially a powerful means of ensuring effective team performance and crewmember well-being.

Most research on team composition has been conducted in conventional workplaces (e.g., corporate offices, production

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plants). Similarly, most quantitative reviews of the team composition literature[5,6] are based on studies of traditional teams. There is limited understanding of how team composition affects team functioning in extreme environments within which long-distance space exploration (LDSE) crews will be expected to live and work (e.g., isolation and confinement).

To help address this gap, we conducted a literature review of team composition research conducted in LDSE analogue environments; examples include simulations in hyperbaric chambers (e.g., MARS-105) and the Antarctic. Although there are differences between Earth-based analogues and spaceflight,[51,75] analogue environments are thought to more closely approximate the context expected in LDSE missions than traditional workplace settings and are often used to help identify important issues for LDSE.[68]

The goal of our literature review was to identify critical team composition issues for LDSE. Specifically, we focused on variables that will likely affect team functioning. In the remainder of this paper, we describe our methodology, provide an overview of team composition theory, describe the paths through which team composition is likely to relate to LDSE mission success, and provide recommendations for future research.

METHODS

We conducted an extensive search to find articles about team composition in LDSE analogue environments. We searched space-agency databases (e.g., NASA Technical Report Repository), 72 academic databases across several disciplines, and specific relevant journals (e.g., *Aviation, Space, and Environmental Medicine*) using search terms such as team, crew, composition, compatibility, personality, extreme environment, isolation, and Mars-105. We scoured the reference lists of review articles and we contacted authors who frequently publish work related to team composition in spaceflight and LDSE analogue environments. The complete search resulted in more than 400 articles. We reviewed these papers for possible inclusion in our review. Although we were intentionally inclusive of the articles that we reviewed, we did not formally review articles that looked only at the relationships between team members' individual differences and individual-level outcomes. We included articles that focused on one team, provided that data (e.g., debrief interviews) were used to provide insight into a potential composition issue. There were 28 articles identified as providing data on some aspect of team composition or team member compatibility in analogue environments, spaceflight simulations, or spaceflight. These articles are the focus of our review.

We coded articles for fidelity, study design, team composition variable and operationalization, outcome variable and operationalization, and observed effects. To facilitate the interpretation and application of these studies to the LDSE context, we calculated a fidelity score for each study using a coding process similar to Palinkas and colleagues[69] (see **Table I**). We also reviewed information about additional contextual features that might impact team functioning in LDSE missions, including the presence of periods of high and low workload, whether the crew was supported by a larger team (e.g., mission control), and the level of crew autonomy. Because this information was reported less consistently, it was not included in the fidelity score calculations.

Overall, fidelity ratings can range from 4 to 12. The ratings we calculated suggest that the environments in the 28 studies were moderately similar to those expected in LDSE missions ($M = 8.24$; $SD = 1.44$). Most studies were conducted using crews demographically similar to those expected in LDSE missions, though some experimental studies[2,3] used younger, more homogenous participants. In general, crews were confined for short time periods; there were only a few studies in which crews were confined for more than 1 yr.[17,67] Most of the studies were correlational or descriptive, and example outcome variables included team performance,[2] subgroup formation,[77] and compatibility.[17] **Table A** with coding for all 28 studies is available online (DOI: 10.3357/AMHP4195sd.2015).

RESULTS

We first provide an overview of team composition theory and then describe the paths through which team composition relates to mission success. Team composition is important to the extent that team members' configurations on specific variables predict organizationally desired outcomes. To effectively use team composition, one must identify the specific attributes (e.g., personality, abilities) and team-level configurations (e.g., uniformly high, heterogeneous) that predict desired outcomes (e.g., team performance). These identified attributes and configurations can then be used to staff teams that are most likely to succeed. When operational constraints limit the ability to use team composition in staffing decisions, team composition information can inform training needs and countermeasure development and application. For example, if a team's composition has a high likelihood for subgroup conflict (e.g., based on the distribution of demographic characteristics such

Table I. Fidelity Scoring System from Palinkas et al.[69]

FIDELITY CATEGORY	CODING AND SCORE
Similarity to spaceflight	Analogue setting (e.g., polar, undersea); 1
	Space simulation; 2
	Spaceflight; 3
Similarity of participants to long-distance space exploration astronauts	Similar age (average age of 30+) but not gender, education, or cultural diversity; 1
	Similar age (30+) and education (at least college degree) but not gender and cultural diversity; 2
	Similar age (30+), education (college +), gender (mixed or all male) and possibly cultural diversity; 3
Duration of mission	30 d or fewer; 1
	31 to 365 d; 2
	365+ days; 3
Crew size	Large (16+) crews; 1
	Moderately small (9–15) crews; 2
	Small (1–8) crews; 3

as national background), mission control can provide critical work that specifically calls on members from the different subgroups to work interdependently.

Composition research generally focuses on team members' relatively enduring attributes (e.g., personalities, values, demographics) or characteristics that are difficult to train, such as professional background. The focus on enduring attributes can help identify critical composition considerations; more malleable skills can be developed through the extensive training provided to crewmembers. The analogue studies we reviewed indicate that, in fact, enduring attributes such as personality and values likely remain consistent despite the extreme environments that analogue teams face.[12,77,87] It should be noted, however, that needs and attitudes may be somewhat less enduring in extreme environments. For example, in one study that used publicly accessible records (i.e., diaries, interviews), a researcher found that astronauts' in-flight standings on the need for affiliation and the need for achievement were higher than their preflight standings.[11]

Team composition variables have been described as deep- and surface-level variables. Enduring deep-level variables are underlying psychological characteristics thought to shape an individual's behaviors, thinking, and affect across many situations;[5] examples include personality traits, values, and abilities. Surface-level composition variables are team members' overt characteristics and can reasonably be estimated after brief exposure to the team member; examples include age, race, education level, and professional background.[5,32,33] Because surface-level characteristics are easy for others to estimate, they are typically the basis for early judgments, assumptions, and stereotyping.

In general, research in traditional settings indicates that deep-level variables have a stronger and longer-lasting influence on team performance than do surface-level variables.[5,6] Similarly, research consistently shows that the effect of surface-level differences on team processes (e.g., group cohesion, conflict) diminishes over time, whereas the influence of deep-level differences increases.[32,62,70] As team members collaborate over time, they have more opportunity for interpersonal exchange and to observe other team members' behaviors.[22] These exchanges allow the stereotypes and assumptions associated with surface-level differences to become less important. At the same time, deeper-level differences between team members begin to have a greater impact on social integration and performance.[33]

Research conducted in analogue environments supports the increased importance of deep-level differences over time.[47,77] Contrary to the diminished effect observed for surface-level variables, however, research in analogue environments suggests that surface-level composition variables can maintain their influence on team functioning.[65,74] As such, both surface- and deep-level composition variables may be relevant for the effective composition of LDSE crews, and both will be considered further.

Specific configurations of team members' attributes are represented by teams' distributional properties (e.g., team averages, team diversities) or by indices that consider multiple attributes, such as faultline strength. It is important to consider these configurations when compositing teams, as there are ways in which specific configurations of attributes may undermine team performance. For example, faultlines are "hypothetical dividing lines that may split a group into subgroups based on one or more attributes."[49] They are activated when a subset of group members' attributes are salient and similar and are strongest when differences across several attributes (i.e., nationality, sex) correlate highly.[49] An example of a strong faultline would be a team in which all the women are of the same nationality and all the men are from nationalities different from the women. Teams with activated faultlines are more likely to form coalitions, have high levels of conflict, and have lower levels of satisfaction and performance.[38] Strong faultlines result in fewer but more tightly knit subgroups, which may increase the chance of intergroup conflict and reduce communication.[50] Though there are many possible configurations of team member attributes, important configurations can be identified by considering the context in which teams will operate and the theoretical path through which team composition variables are expected to relate to valued outcomes, such as team performance.

Team performance, which is defined as the extent to which a team accomplishes its goals or mission objectives, is important for LDSE crews.[80] Space agencies seek to optimize team performance as a means of reducing the likelihood of mission failures.[80] The extreme environment within which space crews live and work and the expected length of LDSE missions can have a significant impact on both social (e.g., team cohesion, psychosocial adaptation) and tactical (e.g., cooperation, coordination, communication) processes. This impact can undercut team performance.[80] As such, effective cooperation, coordination, communication, cohesion, and psychosocial adaptation serve as proximal markers of team effectiveness and, in addition to team performance and well-being, are considered valued outcomes. Next, we discuss the two primary paths through which team composition is expected to affect these proximal markers of effectiveness and, ultimately, mission success.

First, team composition can affect success by influencing team members' ability to live and work together. Living together for an extended period of time in an isolated and confined space requires social integration and a level of interpersonal compatibility that helps mitigate conflicts among team members and that allows team members to rely on one another for support. There is evidence that interpersonal relationships among members of space crews can be challenging[14,41] and that issues surrounding interpersonal compatibility are likely to become more apparent over time.[76] Compatibility issues may result from crewmembers' differences[26] and crew size.[17,19,25] Conflict and a lack of crew cohesion can impact team performance and crewmember well-being.[63,83]

Second, team composition can influence the team's ability to complete complex, dynamic, and highly interdependent tasks during high-workload periods (e.g., takeoff, Mars landing, emergencies) through its effect on tactile processes such as a team's ability to coordinate, cooperate, and communicate with one another and with other teams, such as mission control. These two paths are not mutually exclusive. For example, better social integration and cohesion is also related to better coordination,[65] and interpersonal conflict can escalate to the point that it disrupts a team's ability to complete its taskwork.[76] In the

following sections, we describe the paths through which team composition can affect mission success in more detail and review the analogue studies in relation to the two paths.

LDSE crews will likely be comprised of members who are diverse in a number of aspects (i.e., gender, culture, functional background). Surface- and deep-level differences between team members can affect social integration, which in turn affects team performance and well-being. Social integration is the degree to which a team member is psychologically linked to others in a group.[10,66] It is a multifaceted construct that reflects attraction to the group, satisfaction with other group members, and social interaction among group members.[45,66] In space crews, social integration is important because it allows the team to form a cohesive unit. Examples of poor social integration include when crewmembers are more psychologically linked to a subgroup or when an individual does not socially integrate into the crew, resulting in withdrawal or alienation. Subgroups or alienated team members can become the target of the other crewmembers' hostilities, which is known as scapegoating. Subgroup formation, alienation, and scapegoating are three problems noted in space and analogue environments.[40,43]

Subgrouping occurs when crewmembers identify more strongly with a subset of crewmembers than with the crew as a whole. Space and analogue studies have reported that subgroups can form around nationality,[72,76] gender,[89] and values.[77,86] Although subgrouping is not always problematic,[47] there is consistent evidence from analogue environments that subgrouping can occur and that subgroup formation may result in conflicts that threaten mission success and crewmember well-being.[40] For example, a secondary analysis of Antarctic teams observed that teams that had identifiable subgroups based on areas of the station (e.g., biomed, library) reported higher levels of mood disturbance as compared to core periphery teams in which a majority of members identified with the station as a unit. The analysis also revealed that the members of the two different types of teams varied in the amount of support they gave one another.[68] In another experiment designed to simulate the living conditions aboard the ISS, conflict between subgroups resulted in the shutting of a hatch and no communication between subgroups for a month.[76,85]

Feelings of isolation and scapegoating are additional problems associated with poor crew-level social integration. For example, during the Salyut 6 mission, a visiting Czech astronaut felt socially isolated from the other crewmembers and indicated that he was kept from doing work by the Russian cosmonauts who were concerned that he would make an operational error.[42] In an Arctic Mars simulation, an individual who had a different primary language than the rest of the crew reported feelings of isolation and pressure to conform to the majority.[9]

Being excluded may have significant consequences for a crewmember's well-being. Excluded crewmembers might develop "long-eye" (e.g., insomnia, depression, agitation),[40] and isolated members may become targets of scapegoating, particularly when they are unlike the majority of the other crewmembers and if they advocate divergent ideas.[40] Scapegoating has been reported during Antarctic expeditions[72] as well as in chamber-isolation space simulations.[27]

In general, social integration occurs when team members are attracted to and approachable to one another.[10] For surface-level variables, team members tend to be attracted toward demographically similar others.[13] For deep-level variables, team members are more compatible with others when they are allowed to express themselves in trait-consistent ways. Personality traits and values are needs,[1] and the inability to express these needs can lead to anxiety.[15,91] For some deep-level variables (e.g., values, need for affiliation), a similar other allows for trait-consistent expression (called supplementary fit). For other deep-level variables (e.g., need for dominance), a dissimilar other better allows for trait-consistent expression (called complementary fit). Research on traditional teams has linked surface- and deep-level diversity to social integration and individual- and team-level outcomes, such as performance.[24,33,48] Analogue research has explored social integration in relation to crew heterogeneity and social compatibility. These studies are reviewed below.

Values are beliefs about desirable behaviors that transcend specific situations, guide the evaluation of behaviors, and are ordered in an individual in terms of relative importance.[81] Values have a strong motivational component[73] and influence daily actions (e.g., working hard or working with others) and lifelong objectives (e.g., personal goals and achievements). Values are studied at a personal (e.g., hedonism) and cultural (e.g., power distance, individualism versus collectivism)[36] level. Because individuals tend to endorse the cultural values of their home country,[36] nationality sometimes is used as a surface-level marker of underlying cultural values. However, there is some level of intra-country variation in people's endorsement of cultural values.

Analogue studies have examined how national- and individual-level value differences affect team functioning. Nationality heterogeneity was associated with increased tension between the crews participating in an ISS simulation; language problems and different attitudes toward gender relations were suggested to have had a major impact on crew relations.[76] Similarly, managing cross-cultural differences were thought to increase the complexity of an expedition team.[53] On the other hand, members of the MARS-105 crew, who participated in a 105-d simulation in a hermetically sealed chamber, experienced tensions with those crewmembers perceived to be dissimilar on value orientations and on assessments of the surrounding social environment rather than on cultural characteristics.[86] Additional analysis of the MARS-105 crew indicated that subgroups were formed around homogeneity of values, specifically in terms of hedonism, benevolence, and traditionalism. These subgroups experienced increased tension over time, which may have been exacerbated by the fact that the crew was given increasingly higher levels of autonomy.[77] Finally, an analysis of crew diaries across 10 space missions and analogues suggested that crews heterogeneous on nationality experienced less deviance (e.g., acts of aggression; acts of deliberation such as violating safety rules; unusual or bizarre behavior).[19] Thus, there is evidence that national diversity may lead to positive or negative outcomes, but that underlying value differences may provide a stronger basis for subgrouping and tensions.

Evidence from analogue research indicates that crewmembers may better integrate with similar others in terms of personality. Expedition teams with similar personalities (e.g., high absorption

and "right stuff" characteristics) were better able to cope with the stressful demands of expeditions.[55] In another analogue study, both crewmembers had well-adjusted personalities and were extraverted, to which their ability to be supportive of each other was attributed.[56] Similarities between crewmembers' approach to dealing with expedition stressors were thought to help reduce the experience of stress and enhance team success,[55] and to be useful for accomplishing challenging tasks.[56] In a 12-mo study of Antarctic stations, homogeneity in conscientiousness among team members was related to more compatibility.[26] An in-depth analysis of data from the HUBES and ECOPSY spaceflight simulations suggested that differences in personality were the basis for a crewmember having an outsider status.[27] In both simulations, the outsider (as regarded by himself and other crewmembers) had problems cooperating with the other crewmembers; the disintegrated psychological climate produced tension and subgrouping. Further, personality differences and behavior styles were thought to contribute to the decision for a two-man team to abort a trek to the North Pole when one of the individuals had severe frostbite.[92] Finally, heterogeneous, as compared to homogenous, dogmatic dyads in confinement were more likely to turn inward (i.e., exhibit emotional symptomatology).[34] It seems that personality compatibility may be important; however, given the methodology of the studies, it is not particularly clear what specific dimensions of personality compatibility may be important.

Multiple analogue studies suggest that it is important for team members to be compatible on the need for dominance and the closely related need for prominence; the studies are less consistent regarding the importance of team-member compatibility on other needs. For example, dyads that were incompatible on the need for dominance (high/high) became more territorial during their time in isolation, while compatible (high/low) dyads became less territorial.[2] In another study, dyads that were heterogeneous on the need for dominance reported less stress as compared to both high/high dominance dyads and low/low dominance dyads.[34] In the ISEMSI 90 spaceflight simulation, there was lasting antagonism between three dominant crewmembers which resulted in the eventual isolation of one of the dominant crewmembers.[78] Another pattern was observed, however, between dominant members in the EXESMI spaceflight simulation.[78] The commander aligned himself with a dominant crewmember whom was also low in task motivation. This alliance seemed to reduce competition, although there was lasting antagonism between the low-task-motivation, dominant team member and a third crewmember. In a study of Antarctic work groups, teams that were homogenous and high on the need for prominence were the most incompatible as compared to teams that were homogenous and low or teams that were heterogeneous.[64] Taken together, it seems that there may be some difficulties associated with multiple dominant members in isolated teams that potentially may be problematic for team functioning.

Other needs show less consistent effects. Dyads that were heterogeneous in the need for affiliation and dyads that were low in the need for affiliation tended to withdraw from one another in isolation, while dyads in which both members were high on the need for affiliation spent more time with each other.[3] Dyads that were heterogeneous in the need for achievement reported more emotional disturbance.[34] Likewise, in teams wintering over in the Antarctic, a negative relationship was observed between variability on the need for autonomy and compatibility.[26] In contrast, another study of teams working in Antarctic stations for 12 mo reported no effect between heterogeneity on the need for achievement and perceived compatibility,[64] suggesting a less conclusive effect for the need for achievement in the long term. Finally, a study that looked at combined compatibility on the need for achievement, need for control, and need for affect found that the hypothetically incompatible groups had more hostility, but found no difference in team members' levels of stress or state anxiety.[82] In sum, there is some indication that crews heterogeneous on need for affiliation and need for autonomy may experience some difficulties; however, the specific conditions under which this may happen are less clear.

Analogue studies have examined deep-level differences in terms of interests, attitudes, and other variables, such as people's backgrounds. There is evidence from the HUBES and ECOPSY simulations that perceived dissimilarity on attitudes was related to crew disintegration.[27] In a series of 10, short-duration (12-d to 20-d) missions run in Tektite II, shared interests between scientists and engineers were related to better relationships and performance.[90] In a 12-mo study of small Antarctic stations, differences in the self-rated importance placed on hobbies and recreational activities, as well as diversity on rural as compared to urban backgrounds, were predictive of less compatibility.[26] Finally, a study of 12 special-unit Danish military Sirius patrols demonstrated some effect of seniority on both coping and expectations about team members' working relationships. Specifically, more senior members were less likely to endorse cognitive coping strategies and had fewer expectations about settling into a routine.[46]

Differences on other attributes have been examined in analogue settings, with results indicating no effect on team functioning. Specifically, occupational rank, sociocultural background (e.g., size of hometown, parents' occupation), and current interests were all unrelated to social compatibility.[64] Likewise, dissimilarity on skills was unrelated to deviance.[19] In sum, some shared attitudes, interests, and background characteristics seem to influence outcomes, social integration, and performance, but further research is needed to understand the key compatibilities over which team members may bond in the LDSE environment.

Research on sex differences has explored both same-sex and mixed-sex crews. Differences regarding stress patterns and group processes have been observed. In a comparison of two teams surviving the Australian outback, the all-male team had higher ratings of group enthusiasm, cohesion, and involvement, while the all-female team was higher on a measure of group morale.[7] All-female teams also have been reported to have high levels of cooperation.[55] In an all-female Antarctic expedition, however, the high concern for the well-being of others was observed to be a source of significant stress.[39]

Analogue studies have suggested potential benefits to sex-diverse crews, including the inclusion of women helping to reduce group tensions[78] and improving group dynamics.[54] A number of issues have also been reported for mixed-sex crews. Rosnet et al.[74] examined psychosocial adaptation in mixed crews

that had spent the winter at a French polar station. In this study, the inclusion of women seemed to improve the overall team climate; however, the women were subjected to inappropriate behavior and harassment. These inappropriate behaviors were more prevalent when the women were also young.[74] During the SFINCSS '99 simulation, a man made unwanted sexual advances toward a female crewmember.[76] Cultural differences regarding how the situation was addressed (e.g., involving mission control, mission control's lack of response) were thought to exacerbate the conflict.[76] Cultural differences in attitudes and behaviors toward women were noted by several members of a mixed-sex, cross-cultural expedition team.[53] In another study, linguistic analysis suggested that there was incompatibility between an all-male crew, which was task oriented, and a mixed-sex crew, which was more socially-emotionally oriented.[28] Finally, in a study of 10 spaceflights and analogue expeditions, researchers found higher levels of deviance among mixed-sex crews.[19] The author did note, however, that all-male crews had more members from military backgrounds, which may have reduced the deviance in all-male crews. Taken together, these results suggest that sex diversity may have benefits (e.g., improving overall climate), but provide an opportunity for other issues, such as sexual harassment, to emerge. Further, issues related to sex diversity may be compounded by or a function of other composition variables (e.g., age, culture, military background). They may also be a function of specific compositions such as tokenism, which occurs when one person (e.g., a single woman on a six-person crew) serves as the de facto representative of a minority group.[44]

Crews that included members from the extreme ends of the age distribution were observed to have poor integration, possibly because of value differences.[16] One study of Antarctic teams indicated a negative relationship between age heterogeneity and social compatibility in winter months, but not during the summer months when the teams were less isolated.[64] Further, in another study of Antarctic teams wintering over, age heterogeneity was unrelated to compatibility.[26] In a study of 10 spaceflight and analogue teams, age heterogeneity was associated with less deviance.[19] Finally, a comparison of six Arctic station crews suggested that average age was inversely related to depression and anxiety in the short term and to hostility in the long term.[67] Overall, these results suggest that a mature, less age-diverse crew may have fewer problems. While the preceding paragraphs focused on the role of team composition in social integration (Path 1), the next section details a second path through which team composition may affect mission success in LDSE missions.

LDSE missions will involve the completion of complex, dynamic, and highly interdependent tasks, particularly during high-workload periods. This requires team members with diverse professional backgrounds and specialized expertise to integrate information among crewmembers, among mission control team members, and between the crew and mission control. Team composition can directly influence available expertise, the development of important emergent states (e.g., shared cognition), and the critical team processes (i.e., coordination) needed for success.[60] Emergent states are "properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes."[59] Team processes are "members' interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioral activities directed toward organizing taskwork to achieve collective goals."[59]

Highly interdependent tasks require team members to integrate their knowledge, skills, abilities, and efforts by simultaneously and sequentially performing multiple processes to orchestrate goal-directed taskwork.[59] In space crews, transition-phase processes (i.e., mission analysis, goal specification, strategy formation, and planning) that focus on evaluation or planning related to goal accomplishment would most likely occur during low-workload periods, while action-phase processes (i.e., monitoring progress toward goals, systems monitoring, team monitoring and backup behavior, and coordination activities) that lead directly to goal attainment would most likely occur during high-workload periods.[59] Both transition- and action-phase processes have moderate to strong relationships with team performance, cohesion, potency, and team-member satisfaction.[58] Further, the team process and team performance relationship has been found to be stronger for teams that have higher task interdependence.[58]

A few studies from analogue environments have examined how team composition relates to team processes and performance. During the recent MARS-105 simulation, perceived similarity in values affected preference for whom crewmembers communicated with and led to subgrouping that resulted in less efficient completion of interdependent tasks.[86] Homogeneity in conscientiousness, the need for autonomy, self-rated importance placed on hobbies and recreational activities, and homogeneity in urban and rural background among team members were all related to more task accomplishment in Antarctic teams.[26] In the 12- to 20-d missions run in Tektite II, performance was better for teams in which team members shared interests and activities.[90] In a Mars Desert Research Station simulation, an all-female crew (also higher in conscientiousness and agreeableness and lower in competitiveness) was more vested in mission goals than was an all-male crew; rather than complying with reporting deadlines, the all-male crew continued extravehicular activities (EVAs) and individual projects.[8] In another example, a 10-d experiment in which dyads completed team tasks, heterogeneity on needs (e.g., dogmatism, achievement, dominance) did not have consistent effects across performance on a series of team tasks. There was one exception: dyads heterogeneous on the need for affiliation seemed to perform worse than homogeneous dyads.[3] Taken together, results from teams in analogue environments provide initial, but limited, support for the importance of composition variables as a means to optimize mission-related team performance.

DISCUSSION

In this section, we integrate the operational circumstances expected for LDSE with research on analogue and traditional teams to identify directions for future research. Specifically, we highlight: 1) the need to identify ways to foster unit-level social integration within diverse crews; 2) the missed opportunity to use

team composition variables as a way to improve team processes, emergent states, and task completion; and 3) the importance of disentangling the effect of specific team composition variables to determine the traits (e.g., personality, values) that are associated with particular risks (e.g., subgrouping) to performance.

First, there is a need to identify ways to foster unit-level social integration within diverse teams that work in extreme environments. Research conducted on traditional teams provides initial insight into factors that influence unit-level social integration. For example, some diversity configurations may be more problematic than others, such as configurations that promote strong faultlines. LDSE analogue research has not systematically investigated the relationship between faultlines and unit-level social integration. Traditional teams research suggests that crosscutting a variable for which subgrouping is likely to occur (e.g., sex) with a second variable (e.g., nationality) can inhibit subgroup formation.[79] Similarly, emphasizing the value of diversity[37] and a commitment to shared objectives[84] has been used to bridge faultlines in traditional teams. The efficacy of these strategies should be investigated in analogue environments.

Another way to foster unit-level social integration is to attend to deep-level composition variables. For example, staffing crews with members who have shared individual-level values should minimize the risk of subgrouping based on other characteristics, such as nationality. Future analogue-based research can help identify the specific shared individual-level values, attitudes, interests, and experiences that play a role in effective unit-level social integration.

Familiarity has been tied to the development of cohesion.[4,52] If a subset of an LDSE crew is more familiar with one another (e.g., as a result of training together or previous flight experience), subgrouping may be more likely to occur. "New" team members could become targets of scapegoating.[40,43] The host-guest problem, observed in Russian missions, is an illustration of the effect of familiarity between a subset of team members disrupting social integration. In these cases, new crewmembers ("guests") join more permanent "host" crews on missions. The host-guest problem is associated with delayed performance and increased tension.[43] Further research needs to explore the extent to which familiarity moderates team composition and outcome relationships over time in analogue environments.

Second, there is a missed opportunity to use deep-level composition variables as a way to improve team performance. Most analogue studies examined the effect of team personality composition in regards to compatibility and its effect on social integration and psychosocial adjustment (e.g., coping). While these outcomes are important, team personality composition also affects goal attainment, team processes, and emergent states that are needed during high-workload periods. Further, the self-sufficiency and adaptability needed by LDSE crews may require a shift in focus from selecting people based on their knowledge, skills, and abilities to selecting people based on their aptitudes. The need for crews to be more adaptable may implicate additional important team composition variables.[57] Team composition provides a potentially fruitful but overlooked means for optimizing team performance in space crews. For example, future research should explore how team composition on specific personality traits enables crew self-sufficiency and autonomy and increases the team's ability to execute highly interdependent tasks.

As mentioned, shared values can be used to improve the social integration of teams whose members are diverse. In addition, values can affect the team processes and emergent states related to task completion. Different cultural values can influence crewmembers' approach to teamwork, which can be problematic if not effectively managed. For example, team members from individualistic, low-power-distance cultures tend to exhibit more conflict with leadership, while people from collectivistic, high-power-distance cultures tend to express higher levels of cohesion, but are less likely to report observed errors or problems.[35,61] People also have personally held values regarding teamwork, conflict management, and communication style. Research suggests that people's values influence whether or not they use a high- or low-context communication style, regardless of the values particular to their culture.[23] Future research in LDSE analogue environments should identify individual-level value compositions that relate to team performance, as well as how these values interact with strategies for managing diverse crews.

Third, to effectively use team composition in staffing, training, and countermeasure development and application, it is important to identify the specific team composition variables and configurations associated with risks to performance (e.g., subgrouping, conflict, poor communication). It is not surprising that the sample sizes in the analogue studies we reviewed were small and that many studies were correlational or descriptive. Given these constraints, it is difficult to disentangle the effects of specific team composition variables to determine which traits are associated with particular risks. Developing standardized measures that can be used to collect data across analogue environments could increase our collective knowledge. The data could be meta-analyzed to help overcome problems associated with small sample sizes.

Finally, while the focus of the preceding review has been on crew composition, team composition issues can extend to the larger network (e.g., mission control). For example, ensuring the compatibility between members in key relationships, such as the commander and the flight director, may be important for mission success. There is currently no analogue research that directly speaks to the relationship between crew composition, mission control composition, and the interactions between the two. LDSE crews will participate in a multi-team system; thus, a consideration of network factors as they relate to team composition issues is prudent.

In conclusion, this review summarizes the team composition literature conducted in LDSE analogue environments. We hope this paper informs and encourages researchers to conduct additional research regarding the composition of teams that work in extreme environments.

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