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REVIEW PAPER

Human challenges in polar and space environments

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Abstract This paper reviews literature on psychosocial adaptation in isolated and confined extreme (ICE) environments, focusing on polar work groups and expedition teams, and simulation and actual space crews. Long-duration missions may involve chronic exposure to many stressors that can negatively impact behavioral health, performance and even safety. In the last decades, anecdotal evidence has been replaced by scientific studies, identifying temporal, social, and individual determinants of psychosocial adaptation, and pointing to countermeasures that may minimize or prevent potential problems. Still, many issues remain that require additional investigation, specifically in relation to the integration of psychosocial and neurobiological adaptation. A recognition of ICE environments as natural laboratories for studies of fundamental questions within psychology may attract more scientists to the field.

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1 Introduction

Characteristics and determinants of human adaptation in extreme and unusual environments has been a central interest of a considerable number of psychological researchers and also of those who are responsible for planning and carrying out expeditions involving such environments. Any environment to which humans are not naturally suited, and which demands complex adaptation can be considered an ‘‘extreme environment’’ (Kanas and Manzey 2003). Still, a definition of ‘‘extreme environment’’ in a psychological sense needs to consider that people may react differently to the same environment. Several researchers have argued that the crucial determinant of the stress response is not the environment itself but rather the meaning that the individuals attach to their experiences (Levine and Ursin 1991). This paper concentrates on a subset of environments that share a number of similarities that most people are likely to find inherently stressful: polar work groups and expedition teams including Antarctic winter-over personnel, and crews of manned space missions and space simulation experiments. Although distinct in many aspects, a commonality of these situations is an isolated, confined, and extreme (ICE) environment in which the harsh physical surroundings present many challenges and dangers, including the need to work in microgravity with the threat of hazardous radiation exposure, or in extreme cold, donned in bulky clothing. In times of crisis, evacuation from these isolated environments may be difficult if not impossible. Challenges from the personal perspective may also include the necessity to interact with a small number of possibly mixed gender, culturally diverse individuals living and working in close quarters, for example, in a small Antarctic winter-over field station, or in a tent at the end of a day of trekking. Moreover, the safety of each person is dependent on others in the group, necessitating highly adaptive group functioning and optimal behavioral health.

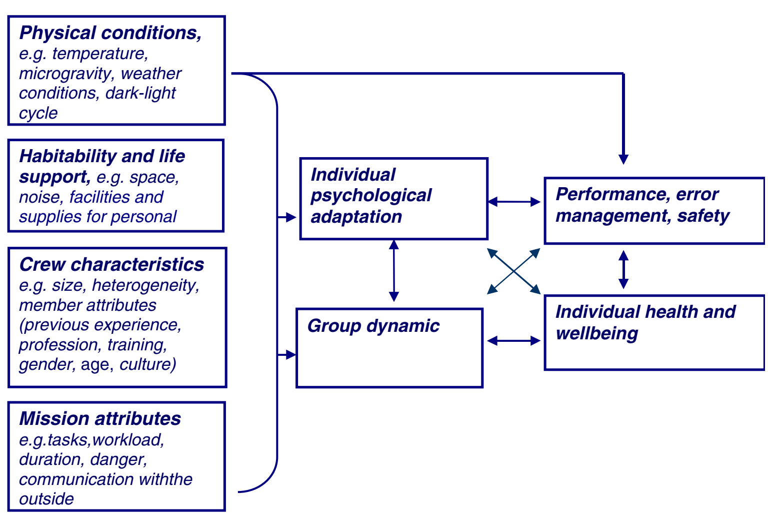
In this paper, we review research dealing with characteristics and determinants of human adaptation in these settings, focusing on individual psychological reactions and group dynamics. The commonalities between the environments has led to the view that research on human interactions in polar expeditions or research stations can be viewed as a space analogue, and informative about living and working in space (Stuster 2005). Nonetheless, the variability that may exist between ICE settings and even between crews operating within the same physical context needs to be recognized. An Input-Process-Output model provides one framework for sorting the myriad of factors affecting human adaptation in ICE environments, and may guide comparisons across settings. Variables and their interrelations are portrayed in Fig. 1. In addition to the accumulation of scientific knowledge, a merit from such studies may lie in their applied value for the development of evidence-based countermeasures to minimize psychological and interpersonal problems among personnel operating in these environments.

2 Environments

2.1 Antarctic station

The psychology of human experience in Antarctica extends back to the very first winter-over experience, the Belgica Expedition of 1898–1899. The field of Antarctic or polar psychology, however, began as a scientific enterprise under the leadership of men such as Eric Gunderson of the United States, Jean Rivolier of France, and Tony Taylor of New Zealand soon after the International Geophysical Year (1956–1957) and the establishment of permanent research stations on the ice. At present there are 47 such stations located throughout the Antarctic and sub-Antarctic

Fig. 1 Factors affecting human adaptation in ICE environments



regions, operated by 20 different nations. The populations of these stations range from 14 to 1100 men and women during the summer months (October–February) and from 10 to 250 during the winter months (March–September). Over the course of a year, the human population of Antarctica varies from approximately 1000 to 5000 men and women, most of who are between the ages of 18 and 60 years. For varying periods of time, depending on their location, the stations are physically isolated from the outside world, with darkness and weather conditions preventing traveling to and from the continent with no prospect of medical evacuation.

2.2 Polar expeditions

Polar expeditions are usually conducted in the spring or summer months when weather conditions are most favorable, and are intended to recreate the experiences of the early polar explorers, set new records for speed and distance, conduct scientific research, and transport supplies and equipment to remote locations. While some expeditions use traditional modes of travel (sled dogs, skis, snowshoes), others use more modern modes of transportation (snowmobiles, tractors, tracked vehicles). Ocean voyages in small sailing craft also fall into this general category. Another form of polar expedition is the summer camp. Such camps are usually for scientific (e.g., glaciology, geology, marine biology) or commercial (e.g., mineral and oil exploration) purposes. Camps range in size from 3 to 300 individuals who reside in tents, Quonset huts, or other temporary shelters. There are also ocean voyages in larger scientific research or commercial (Mallis and Deroshia 2005) exploration vessels. The duration of this form of expedition ranges from two weeks to three months, usually during the summer.

2.3 Space missions

When manned spaceflight began in the early 1960s, the impact of psychosocial factors on astronaut behavior and performance was perceived to be minimal, at least from the U.S. perspective. Space missions had no more than three individuals, were exclusively male, and were drawn from the ranks of test pilots or scientists with pilot experience. With the advent of space stations (e.g., Skylab, Salyut, Mir, and the International Space Station (ISS)), the duration of space missions increased to six months or longer, and crews became more multinational and heterogeneous in terms of gender, cultural background, and professional training. These changes have been assumed to increase the psychosocial demands of the missions and consequently the need for countermeasures aimed to minimize dysfunction in this area (Leon 1999) . Future large advances in the evolution of human space exploration might include a return to the Moon and the establishment of a lunar station as a permanent habitat, as well as flights of humans to our neighboring planet Mars.

Several studies addressing such mission scenarios have recently been conducted by NASA, ESA and in Russia (e.g. Horneck et al. 2003; European Space Agency (ESA) 1992). Technology is just one important aspect of such long-duration space missions. In addition, a number of medical and psychological challenges need to be considered, which might become a limiting factor for prolonged human expeditions into low Earth orbit and beyond. This is particularly true for human missions to Mars, which might not be psychologically comparable to any other undertaking humans have ever been attempted. Specifically, such long-duration missions will require increased crew autonomy and reliance on automation. Also, the distance from Earth either will impede or make impossible the traditional level of communication and support by controllers on Earth which have existed in previous manned missions (Manzey 2003; Sandal 2001b). To date, there have been few research opportunities for collecting psychological data during actual space flights, and much of current assumptions are based on data from personnel operating in so-called analogue environments in which people are exposed to many of the same stressors as those experienced by astronauts in space, although without such environmental components as microgravity and radiation exposure. In addition to evidence from Antarctica winter-over groups and polar expeditions, space simulation studies have been conducted by the use of hyperbaric chamber facilities in which multinational crews have been confined for periods ranging from 28 to 240 days. A basic aim of these studies has been to approximate the living conditions of astronauts on a space station in terms of operational, technical and medical requirements.

3 Issues

3.1 Psychological functioning

3.1.1 Psychological adaptation and time patterns

ICE environments have a significant influence on behavioral functioning. The alterations in light-dark periodicity in polar regions disrupt the circadian sleep cycle, resulting in considerable sleep disturbances during the darkness period, and an associated decline in subjective feelings of well-being and alertness in polar areas (Bhargava et al. 2000; Natani et al. 1970; Palinkas et al. 1995a; Palinkas et al. 1996). Also in space, the loss of the 24-h light/dark cycle, circadian disruption, microgravity, and workload demands may result in performance decrements, decreased alertness and sleep disruptions (Mallis and Deroshia 2005). Subjective reports from astronauts (Santy et al. 1988), as well as results from sleep monitoring studies (Gundel et al. 2001), show that sleep in space is shorter, more disturbed, and often shallower than on Earth, though with a considerable degree of inter-individual variation. Other psychological stress reactions have also been reported. During the long winter-over period in Antarctica, personnel have reported increases in depressive mood, psychosomatic complaints, and interpersonal conflicts, and a decrement in work performance (Bhargava et al. 2000; Ikegawa et al. 1998; Palinkas et al. 1995a, b, 1996; Palinkas and Johnson 1990). Likewise anecdotal and behavioral evidence from space missions show that crewmembers have experienced psychological reactions that have included lapses of attention, emotional liability, psychosomatic symptoms, irritability toward crewmates and/or mission control staff, and a considerable decline in vigor and motivation (Kanas and Manzey 2003; Suedfeld 2005). According to Russian space psychologists and flight surgeons, a psychiatric condition that affects the emotional state of cosmonauts during prolonged missions is asthenia. This syndrome, that refers to a psychiatric diagnostic category, is defined as a weakness of the nervous system that may result in fatigue, irritability and emotional liability, attention and concentration difficulties, restlessness, heightened perceptual sensitivities, palpitations and blood pressure instability, physical weakness, and sleep and appetite problems (Kanas et al. 1991; 2001a, b; Myasnikov and Zamaletdinov 1998). Although ''asthenization'' is carefully monitored, and a number of countermeasures are employed to prevent it from progressing, empirical evidence for its existence as a discrete pathological entity has been equivocal (Kanas et al. 1991, 2001a, b).

Yet, other studies have either found no evidence of psychological or psychiatric symptoms or suggested that such problems pose little threat to the health and well being of the crew or to the success of the mission (Leon et al. 1989). Such studies suggest one of four possibilities: (a) Isolated and confined environments are no more stressful than other environments (Suedfeld and Steel 2000); (b) highly motivated, self-selected individuals who volunteer for such long-term missions are capable of maintaining high levels of performance over long periods of time (Palinkas et al. 2000); (c) motivated individuals simply do better than others; or (d) psychological reactions are strongly affected by interpersonal and cultural factors. Supporting the latter, Ritsher et al. (2005) have presented data indicating that psychological reactions to being in space are expressed differently by people from different cultural backgrounds. Clearly, the resolution of this issue needs further clinical and empirical studies.

While the majority of research has focused on potentially adverse health effects based on a pathogenic model, there has also been an emphasis on psychological resilience and positive aspects. Studies of groups working in polar regions over relatively shorter periods and light conditions have found what is often referred to as a ''salutogenic'' effect'' (Antonovsky 1979), likely associated with removal from the time pressures and stressors encountered in the home setting (Palinkas et al. 1995b; Sandal 2000). In addition, expedition studies have shown that positive mood prevailed over negative mood over the course of the trek (Atlis et al. 2004; Kahn and Leon 1994; Leon 1991; Leon et al. 1989, 1991, 2002), and depressive mood decreased (Palinkas et al. 1995b). Many polar and other ''capsule environment'' crews also reported long-term positive after-effects subsequent to their stay (Suedfeld and Steel 2000).

The timing or sequencing of mood changes and social tensions over the course of a polar or space sojourn has been examined, particularly the presence of a ''third quarter phenomenon'' (Bechtel and Berning 1991). This term refers to an increase in negative mood and social interactions during the third quarter of the stay, as personnel contemplate the duration of time remaining before the end of their particular ICE experience. The attention to the third quarter phenomenon can be traced back to Rohrer's (1961) observation of Antarctic and submarine missions, in which he described three stages of crewmember response: initial anxiety over new experiences in the mission, mid-mission monotony and depression as tasks become routine, and late-mission euphoria and immature behavior as the end is anticipated. Elements of these stages have been reported during long-term Russian space missions and confinement studies, but empirical evidence for the existence of specific critical phases has been equivocal (Bhargava et al. 2000; Gushin et al. 1997; Leon et al. 2002; Palinkas 2003; Palinkas et al. 2000, 2004b; Sandal 2000, 2001a; Sandal et al. 1996; Steel and Suedfeld 1991; Stuster et al. 2000; Wood et al. 1999). For example during a 438-day MIR mission, Manzey and Lorenz (1998) monitored different indicators of mood, but found little indications to support a stage model of adaptation. In another study, Kanas et al. (2001a, b) studied time-related changes of crew interaction and crew-ground communication. Again, only few indications of a stage model was found. Yet, the issue of critical periods in adaptation is important and needs more research attention, given that such knowledge may enable crewmembers and outside personnel to prepare for problems and intervene before maladjustments result in adverse operational or health impacts (Sandal 2001b). Sandal et al. (1996) found different time patterns in psychological reactions when comparisons were made between polar expeditions and crews confined in hyperbaric chambers. They suggested that a stage-model of adaptation is probably more relevant for groups undergoing prolonged confinement in which boredom and monotony are prominent stressors. Thus, time in itself may not be a strong predictor unless taking into consideration aspects of the environment.

3.1.2 Cognitive adaptation

A related issue regarding psychological functioning in polar and space environments is a need to understand and assess patterns of cognitive adaptation. Poor performance due to failure of cognitive adaptation is identified in NASAs Bioastronautics Roadmap as a potential risk to long-duration missions in space. Human performance in space can suffer from both microgravity effects involving vestibular and sensory-motoric processes as well as non-specific stress effects related to workload, sleep disturbances and other factors of extreme living and working conditions in space (Leone 1998; Kanas and Manzey 2003). Empirical studies addressing possible effects of spaceflight-related stressors on human cognitive and psychomotor performance have focused primarily on elementary cognitive and psychomotor tasks. Most of them have been conducted during short-term ($<$ 30 days) spaceflights (Benke et al. 1993; Manzey 2000). In spite of the comparatively small number of studies and the differences in the methodological approach, they have revealed a fairly consistent pattern of effects.

Whereas performance in elementary cognitive tasks such as memory-search, logical reasoning, or mental arithmetic seem to remain largely unimpaired in space, disturbances have been found in perceptual-motor and attention tasks (Bock et al. 2001; Manzey and Lorenz 1998). The origin of these effects, i.e. whether they reflect effects of microgravity on the central nervous system or unspecific stress effects of workload and fatigue, has remained unclear. Studies of cognitive performance in polar environments suggest that such performance is certainly impaired under conditions of hypothermic exposure to cold (Coleshaw et al. 1983), performance may either increase (Mäkinen et al. 2005; Palinkas et al. 2004b), decrease (Barabasz et al. 1983; Palinkas 2001a; Reed et al. 2001), or remain unchanged (Le Scanff et al. 1997) under non-hypothermic exposure. The reasons for these observed differences remain to be determined.

3.2 Group dynamics

Living and working in a relatively small group in an isolated, confined and demanding environment are likely to pose challenges to interpersonal relationships. Studies in ICE environments have identified a number of factors that impact the efficiency and quality of interpersonal relationships, including crew structure and cohesion, leadership style, gender and cultural background of crew members, and inter-group relationships (Gushin et al. 1998; Gushin et al. 1997; Kanas 1990; Kanas et al. 1996; Kanas and Manzey 2003; Sandal 2000). While these factors are general predictors of satisfaction and efficiency in organizational settings (McKenna 2001), there are important questions about how these relationships are influenced by ICE conditions, as well as potential time effects.

3.2.1 Crew tension and cohesion

Polar expedition teams and space crews often experience greater social cohesion by virtue of undergoing a common experience (Atlis et al. 2004; Leon and Sandal 2003; Stuster 1996). Nonetheless, confinement in a small space with the same people for a long time, under conditions of danger, discomfort, fatigue and other stressors, is a potential catalyst for interpersonal hostility. Research has consistently demonstrated that interpersonal conflict and tension is the greatest source of stress in Antarctica (Stuster et al. 2000). Still, inhabitants in ICE environments often seem to be reluctant to express tension openly; rather, it is reflected indirectly in territorial behavior, withdrawal from interaction with others, and clique formation that may occur along national or vocational lines (Kanas 1990; Sandal et al. 1995). One explanation may be the mutual interdependence among the participants. While formation of group identity appears to facilitate the adjustment of individuals to the ICE conditions, participants who do not conform to the group's norm tend to be socially isolated (Palinkas and Johnson 1990) . During space simulation studies in hyperbaric chambers, analysis of communication networks indicated that one crewmember became more and more in the periphery of crew interaction, and at the same time was rated less positively by other crewmembers (Sandal 2001a; Sandal et al. 1995). ‘‘Scapegoats’’ may serve to maintain harmony between the other crewmembers because that person becomes the target of intra-group hostility and aggression. However, these individuals are vulnerable for poor psychosocial adaptation. Problems such as scapegoating are well-documented from more usual working life, but normally individuals who are discomforted by an interpersonal experience have the opportunity to withdraw from interaction, or to seek the companionship and support of other people. Under isolated conditions where there are no possibilities for escape from the adverse situation, the scapegoat is probably at higher risk for some type of health or other adaptation problem.

Tension may also be a consequence of individual patterns of adaptation to ICE environments such as refraining from relying on their fellow crew members for support Palinkas (2003) has distinguished between social dynamics as a stressor and social support as a mediator of the stress–performance relationship. He pointed out that individuals seem to adapt to ICE environments by refraining from reliance on their fellow crew members for support largely because these crew members are facing the same stressors (Palinkas 2003). Relevant to this point, Sandal et al. (1998) found that seeking social support as a coping mechanism was related to poor psychological adjustment during long-duration submarine missions.

Not all isolated and confined crews experience high levels of tension. Studies of Antarctic winter-over crews have found that group cohesion varies from one year to the next (Palinkas 1989), and across national stations (Palinkas et al. 2004b). Use of multidimensional scaling of data collected from the winter-over crews at the South Pole during the same three-year period revealed three distinct patterns in crew structure that seemed to have important implications with respect to tension and anxiety, depression, and anger and hostility (Palinkas, 2003). The crews characterized by a clique structure exhibited significantly higher levels of tension and anxiety, depression, and anger than did the crews characterized by the core-periphery structure throughout the entire winter. Similarly, Sandal et al. (1995) found marked differences in crew structure and group cohesion between space simulation studies in hyperbaric chambers. One distinction between the crew that was highly unified and cohesive compared with the other one, was that the former had been selected based on interpersonal compatibility.

3.2.2 Leadership

The execution and maintenance of leadership may be challenging in ICE settings in which participants live close together for prolonged periods. Communication analysis and post-mission interviews suggested that the authority of the Commander was challenged by other participants during several space simulation studies in hyperbaric chambers (Sandal 2001a, 2004; Sandal et al. 1995). In another study, lasting for 135 days, Kanas and his colleagues (Kanas et al. 1996) found a significant drop in a measure of task-oriented, instrumental characteristics of the appointed Commander over time, which was interpreted as status leveling where the leader assumed a more equal role. Status leveling may be unfortunate in emergency situations in which clear and unambiguous leadership is required. Successful leadership during long-term missions must be flexible. For example, studies of polar expeditions found task leadership to be more important during the initial stages, while supportive leadership became more important during the later phases of the expedition (Stuster 1996). Reviews of studies of personnel in different ICE environments have highlighted characteristics of the best leaders, including the perception by group members that the leader is a role model, soliciting subordinates' advice and judgments when necessary and appropriate, sensitive to subordinates' personal problems and well-being, and clearly communicating roles and responsibilities (Nicholas and Penwell 1995; Stuster 2005). These aspects are not unique to ICE environments, but have consistently been found to relate to group efficiency, motivation and satisfaction in more customary organizations as well, often referred to as transformational leadership (Bass and Avolio 1995; Hetland and Sandal 2003).

3.2.3 Heterogeneity

Heterogeneity in cultural background and gender are assumed to increase the risk of interpersonal tension and miscommunication among isolated and confined personnel. The term "culture" has been defined as widely shared beliefs, expectancies, and behavior of members of a group on an organizational, professional or national level (Hofstede 1980). Evidence from cross-cultural research suggests that the greater the cultural differences among people, the greater will be the difficulties in establishing harmonious and productive relationships (Berry 2004). Based on studies of aircrews (Helmreich and Merrit 1998), large national differences have been identified in individualism, preferred leadership style, and adherence to rules and procedures. It is reasonable to assume that differences could well impede teamwork in the demanding environment of space and polar settings. Interpersonal tension related to language and cultural differences has been reported from both long-duration Russian missions involving people from other nations and earthbound ICE environments. For example, during the Salyut 6 mission, a visiting cosmonaut from Czechoslovakia felt socially isolated and complained of being restricted from doing productive work by his Russian crewmates who were concerned that their foreign guest might inadvertently make an operational error (Kanas et al. 2000). Language and cultural factors were found to socially isolate crewmembers representing minority cultures during EUROMIR missions (Kanas et al. 2000), a 240 days space simulation study (“SFINCSS”) in hyperbaric chambers (Sandal 2004), and on research stations in Antarctica (Sandal 2000). Also, the two former studies showed that the minority crewmembers reported being more unhappy about their work environment.

Clear differences in perceived leader support, work pressure, and managerial control were found between Russian and American crew members who stayed and worked together on MIR (Kanas et al. 2000). Yet, with the exception of the International Space Station, spaceflight experiences with multi-cultural space crews, so far, stem from missions where cross-cultural aspects were inevitably confounded with “host”–“guest” differences, i.e., the missions usually involved one “dominant culture” being the host for crew members from other countries, organizations and professions. This was also the case for the “SFINCSS” confinement study. The relatively small sample sizes also make it difficult to isolate the effects of culture from other factors, such as the personalities, motivations and professional training of crewmembers and the organizational setting in which the project was conducted. Moreover, the interplay between national, organization and professional cultures is conceptually complex and needs to be further explored. Belonging to the same organizational culture (such as the European Space Agency) may reduce the impact of national diversity. It is also possible that on a national level, cross-cultural issues may have minimal impact on crew behavior and performance in space since astronauts and cosmonauts are all part of a common professional “microculture”. So far, very few systematic studies have addressed these issues.

A number of polar, space, and simulation chamber groups have been composed of single gender as well as mixed gender teams (Leon 2005). Women in mixed-gender polar and space simulation groups have often assumed or been placed in a more nurturing and less dominant role and reported feeling stressed by their concerns about other team members (Leon et al. 1989), and have assumed the role of “peacemaker” (Leon et al. 2004; Sandal et al. 1995). All-men expedition teams have exhibited marked competitiveness and little sharing of personal concerns, while all-women expedition groups, or women in mixed gender groups have shown a greater cooperative orientation, supportive relationships, and concern about the welfare of their team members (Bishop 2002; Koscheyev et al. 1992; Leon and Sandal 2003; Rothblum et al. 1998). Based on qualitative interviews, Rosnet and her colleagues (Rosnet et al. 2004) concluded that including women in wintering-over groups on Antarctic stations had positive effects on the general climate of the group by reducing rude behavior, but it also seems to cause stress due to rivalry, frustration, and sexual harassment. Experiences from the “SFINCSS” confinement study also point to possible problems of interpersonal tension. In this study, a conflict situation developed due to unwanted sexual advances toward the lone female crew member, a Canadian, by one of her seven male crewmates who was a Russian (Sandal 2004). Considerable cultural and gender differences in attitudes toward women team members have also been noted (Leon 2005; Leon et al. 1991, 1994).

The Dutch anthropologist, Hofstede (1980) identified important national differences in the view of appropriate gender role behavior, and unless addressed, such differences may cause conflicts and tension in multinational and mixed-gender settings. However, it is also important to consider that in certain cultures, attitudes about appropriate roles for men and women are changing, and an increasing proportion of individuals of both sexes are engaging in non-traditional occupational or other pursuits. Relevant to this point, Musson, Sandal, and Helmreich (2004) found no significant differences in personality scores between final stage men and women astronaut applicants. Moreover, within each gender, there are considerable individual differences in personality, behavioral characteristics, skills, and interests that influence task performance and other behaviors in a particular milieu, whether in ICE or other environments.

3.2.4 Inter-group relations

Long term co-habitation and shared experiences in a highly unique environment are factors that facilitate the development of strong group identification, and therefore help account for the frequently observed psychological distance between ‘‘insiders’’ and ‘‘outsiders’’. Direction of aggression to outside personnel has been reported during both Russian and American space missions (Kanas et al. 2001a, b), in Antarctica, and during space simulation studies (Gushin et al. 1997; Kanas et al. 1996; Sandal 2001b; Sandal et al. 1995). Some of these incidents have been interpreted as a displacement of tension/aggression to help maintain harmony within the crew. This process is often referred to as the ‘‘us vs. them’’ phenomenon, and appears to be one mechanism that functions to unite the confined personnel. Gushin (1995) has noted the tendency of space crews to avoid sharing feelings with others (‘‘psychological closing’’) and information filtration in crew-ground communications. A concern is that these characteristics may also interfere with the capacity of the crew to accurately receive and process information from the ground, thereby resulting in errors in judgment and a decrement in performance.

A potential deleterious outcome of strong group-cohesion coupled with ‘‘psychological distance’’ to outsiders is a phenomenon known as ‘‘groupthink’’, identified by several characteristics such as denial of conflicts, a tendency to channel aggression outside the group, and the existence of external pressure (Janis 1972). Groupthink has been associated with lower-quality performance because group members are too concerned with getting along and reluctant to express disagreement; clearly, this could endanger a mission in situations of crisis.

3.3 Personality predictors of adaptation/optimal performance

Psychological adaptation to isolated and confined environment varies with factors such as personality traits, physiological and circadian rhythm characteristics (Mallis and Deroshia 2005; Van Dongen et al. 2003), prior experience, and training background. However, astronauts, polar expedition members and personnel who winter-over in Antarctica seem to possess common characteristics that differentiate them from people in general. Steel et al. (1997) found that Antarctic expeditioners scored higher on measures of extraversion and openness to experience and lower on measures of neuroticism than population norms. High achievement orientation and low stress reactivity have been found to be predominant characteristics in many polar team members (Atlis et al. 2004; Kahn and Leon 1994; Leon 1991; Leon et al. 1989), Antarctic scientists (Butcher and Ryan 1974) , and astronaut applicants at NASA (Musson et al. 2004). These traits are strongly related to coping with stress and adaptation across populations (see Sandal et al. 1998). Variation in personality traits found in ICE groups is normally much smaller than is typically found in the normal population (Palinkas 2003; Sandal 2000; Sandal et al. 1996). Due to ‘‘restriction of range’’, baseline measures of personality therefore may be a relatively weak predictor of behavior in ICE settings. Nonetheless, personality assessment has been recognized by space agencies and researchers as a helpful tool in screening out unsuitable astronaut candidates (Santy 1994).

Several studies have linked superior performance to a personality profile characterized by a combination of high levels of instrumentality and expressivity along with lower levels of interpersonal aggressiveness and low competitiveness in settings that include aviation (Chidester et al. 1991), military training (Sandal et al. 1998, 1999), short-term space simulation studies (Sandal et al. 1996), and polar expeditions (Leon and Sandal 2003). Likewise, research in which personality traits have been validated against criteria of astronaut effectiveness during short-term space missions and training sessions have identified high agreeableness and low aggressiveness as general characteristics of high performers (Rose et al. 1994). These personality traits have therefore been designated as ‘‘the right stuff’’ for team operations in stressful environments. Referring to the so-called five-factor model of personality (McCrae and Allik 2002), Suedfeld and Steel (2000) proposed that the traits of conscientiousness and agreeableness would be optimal indicators of adaptive personality functioning. Interestingly, retrospective analysis of personality scores of final stage astronaut applicants showed no differences based on personality clusters on those selected vs. those deselected (Musson et al. 2004).

However, not all of these personality characteristics have been demonstrated to be predictive of optimal performance in ICE environments. For instance, a study of French expeditioners found that performance was associated with low scores on extraversion and assertiveness (Rosnet et al. 2000). A person–environment fit model of behavior suggests that the optimal individual characteristics in relation to performance are mediated by environmental factors and mission characteristics, including the duration and crew characteristics (Ursin et al. 1992). For instance, Palinkas and Browner (1995) found that while several features of personality and social factors were associated with concurrent measures of depressive symptoms, pre-deployment levels of depressive symptoms were the only independent predictor of late-winter depression. A similar prospective screening study of Antarctic winterer-over personnel (Palinkas et al. 2000) showed that the best performers were characterized by low levels of neuroticism (emotional liability), low desire for affection from others, low levels of boredom, low need for order, and a high tolerance for lack of achievement. The authors argued that under conditions of isolation and confinement, satisfying a need for achievement and order is often restricted by the environment itself, and that individuals wishing to complete projects on schedule become frustrated at delays in communication with the outside, constant equipment failure, or absence of necessary supplies. Consequently crewmembers adapting best are those most able to revise their expectations to fit the situation.

In the context of long-duration space missions, the most severe stressors may involve monotony and boredom resulting from low workload, hypostimulation, and restricted social contacts including isolation from family and friends. A number of factors may affect the coping ability of crewmembers in dealing with these living conditions. These include their unique onboard experiences, personality traits, leisure activities, particular coping strategies, and the kind of social and emotional support available. Antarctic studies evaluating personnel in a range of occupational positions showed an association between adaptive functioning and narrow interests and a low need for stimulation (Biersner and Hogan 1984). A personality trait termed ‘‘absorption’’ (Tellegen and Waller in press) has been identified in studies of different expedition teams (Atlis et al. 2004; Kahn and Leon 1994; Leon 1991; Leon et al. 1989). This characteristic refers to the ability to become highly engrossed in a particular activity to the exclusion of attending to other events that are happening around the person. For example, becoming so engrossed in the beauty of the Antarctic landscape that the monotony of the extensive physical exertion in a cold and windy environment is not processed as uncomfortable. In a related manner, a number of astronauts have commented that their most enjoyable leisure activity in space was simply looking out the porthole at the beauty of the Earth. This engagement in the beauty of the environment or becoming highly engrossed in a particular task would likely be highly adaptive in coping with the exigencies of living in an ICE environment, including space, for an extended period of time.

4 Future challenges

Despite the advances in our understanding of the human challenges in polar and space environments that have occurred in recent years, a number of issues remain that require additional investigation. One of the primary issues related to psychological functioning concerns the integration of psychosocial and neurobehavioral adaptation. These two domains are usually examined separately and considered individually as risk factors for poor performance (Health Sciences Policy Board 2005). Nevertheless, studies in both space and polar environments suggest that both are interrelated. For instance, changes in thyroid and catecholamine function in polar environments have been linked to poor mood and impaired cognitive performance (Reed et al. 2001). Similarly, stress and mood are believed to influence endocrine, immune, and cardiovascular function in space (Kanas and Manzey 2003; National Research Council 2000). Ultimately, solutions to human challenges in these environments will require multidisciplinary efforts and approaches to understanding the social and environmental factors that contribute to impaired physiological functioning and the neurobehavioral changes that precede behavioral changes and vice versa. Such efforts will include the formation of interdisciplinary teams of investigators and the development of integrated models of human adaptation that are specific to these environments.

Future research should also be devoted to improving our understanding of performance and workload (National Research Council 1998), and the development and evaluation of behavioral, operational and pharmacotherapeutic countermeasures designed to reduce the risk of impaired cognitive performance in both types of environments (Palinkas 2001a). The degree of autonomy that crews expect to have from controllers can have a big impact tension and cohesion during missions (Kozerenko et al. 1999). According to Kanas and Manzey (2003), providing the crew with as much freedom as possible to plan and schedule activities on their own initiative represents a countermeasure for dealing with possible impairments of work satisfaction and motivation.

A particular concern in planning for long-duration missions is how to deal with significant psychological problems and psychiatric disorders that may develop in initially healthy individuals. This situation would affect not only the disabled person, but could also have a detrimental effect on overall crew performance, safety, and potentially, the success of the mission. Information on serious behavioral health problems in space is not publicly available due to issues of confidentiality. However, considering the commonalities between certain polar and long-duration space conditions, including the impossibility of evacuation during specific periods of the mission, it may be possible to generalize about the probability of serious problems developing in space by extrapolating from Antarctic health data.

Aggregation of data on the Australian National Antarctic Research Expeditions (ANARE) collected over a 25-year period indicated a rate of morbidity for mental health disorders below 4% (Lugg 2005). Research conducted on members of the United States Antarctic Program suggest that approximately 5% of winter-over personnel experience symptoms that fulfil criteria for a psychiatric disorder and are severe enough to warrant clinical intervention; Palinkas et al. 1995a; Palinkas et al. 2004a). Psychiatric debriefings of 313 men and women conducted at McMurdo and South Pole between 1994 and 1997 revealed that 3.8% of personnel experienced mood disorders (depression), 3.8% experienced adjustment disorders, 2.6% experienced sleep disorders, 1.3% experienced alcohol or drug-related disorder, and 1.0% experienced personality disorders (Palinkas et al. 2004a). Although these rates are lower than what might be experienced in the general population in the United States, they are noteworthy in that these men and women are required to undergo psychiatric screening prior to the austral winter. However, if a serious psychiatric problem developed in space, for example, a paranoid reaction or immobilizing depression, this could seriously jeopardize the mission. Therefore, the development and implementation of psychological, pharmaceutical, and other countermeasures to deal with these potential problems is extremely important.

With respect to interpersonal relations and social dynamics, there remains a need to identify the criteria to be used in screening and selection of teams intending to live and work in polar and space environments. The research described in this paper has identified several important predictors of individual performance, but studies identifying the determinants of successful group performance remain to be accomplished (National Research Council 1998). Research on predictors of individual performance provides little guidance regarding optimal combinations of individual characteristics across group members and whether crews should be selected on the basis of homogeneous or complementary characteristics (Palinkas 2001b). Similarly, operational and political considerations may preclude the screening and selection of personnel strictly on the basis of psychosocial characteristics (National Research Council 1998). However, an understanding of the effect of these considerations on overall group performance remains to be determined.

The difficulty in overriding such selection considerations also points to the need for further research on the development of policies, programs and countermeasures designed to prevent poor psychosocial and neurobehavioral adaptation in polar and space environments. Prevention is a more cost effective approach to addressing poor adaptation since evacuation from such locales is expensive if not impossible during particular time periods, and treatment of adaptation-related problems may be costly, time-consuming, and feasible only if necessary resources are readily available (e.g., access to qualified personnel to conduct crisis intervention under periods of acute stress, or medications which have bioavailability under conditions of extreme cold or microgravity). Moreover, loss of productivity, increased risk of accidents and co-morbidity can be minimized if not avoided altogether through prevention. Preventive countermeasures or interventions would include training in interpersonal relations and social dynamics, leadership skills and individual coping strategies (National Research Council 1998; Palinkas 2001b), the design and construction of facilities that allow for privacy and space while fostering a sense of community and promoting social interaction (National Research Council 1998), and the development and evaluation of nutritional and pharmacologic countermeasures designed to reduce the adverse effects of the physical environment (i.e., cold, darkness, microgravity) on psychosocial and neurobehavioral adaptation (Palinkas 2001a). However, evidence-based research is required to support the use of one or more of these countermeasures. Provision of in-flight support is another important countermeasure to prevent feelings of boredom, monotony and isolation during long duration space flight. Attention should be given to enhancing individually tailored leisure time activities that take into account changing interests and needs over the course of the mission (Kanas and Manzey 2003; Kelly and Kanas 1994). Other important support activities include private psychological conferences, providing informal space-ground contact and news from Earth (preferably in the crew member's native language and from homeland news sources), and opportunities to maintain close contact with family and friends on Earth on a regular basis. In-flight support of crew members has been applied in Russia since the earliest days of manned spaceflight, and continues to represent one of the main countermeasures in today's ISS program.

Finally, research is required to facilitate the positive aspects of living and working in polar and space environments. Although the positive benefits of successfully coping with the challenges of such environments have been repeatedly demonstrated (Palinkas 2003; Suedfeld and Steel 2000), it is still unclear whether polar expeditioners and astronauts can be trained to experience such benefits, or whether they are inherent features of particular personality types. In either instance, as is the case with prevention, selection, training, and support are likely more cost-effective than treatment (Palinkas 2003, 2001b) in dealing with the human challenges of polar and space environments. However, as with prevention, the development of an evidence base for the use of specific strategies is needed. Such procedures are likely to include both programs designed to screen for and select individuals most likely to have such positive experiences in these environments, as well as training programs to increase the likelihood of such experiences in all polar expeditioners and spacefarers.

5 Concluding remarks

ICE environments have long been viewed as natural laboratories for the study of the effects of isolation and confinement on human behavior. Research results from these settings contrast with the early laboratory studies in which participants were exposed to highly artificial situations, involving isolation from other people and a sharp reduction in the level of variability of physical stimulation and very restricted mobility (Zubek 1969), or military subjects confined in windowless suites of rooms with only research tasks to perform (Haythorn and Altman 1966). A large number of subjects failed to complete several weeks of confinement due to perceived high "stress" and from outbursts of hostility. This situation differs profoundly from the successful adaptation generally reported from groups in less artificial environments. While the last decades have witnessed an increased research interest in ICE environments, most of this research has focused on the abnormality of the setting. As noted by several researchers (Palinkas 2003; Suedfeld 1998), the opportunities that these settings offer for exploring more fundamental and global psychological issues may not have been sufficiently recognized. Contrasting with most natural settings in which people operate, the level, intensity, rate of change, and diversity of physical and social stimuli, as well as behavior settings and possible behaviors are more restricted (Suedfeld 1998). Thus, ICE environments offer a high degree of control over the variables that impact on psychosocial processes while avoiding the artificial conditions of the traditional laboratory. For instance, Palinkas (2003) suggested that the ice is an ideal laboratory for the examination of seasonal variation in behavior related to environmental phenomena, such as cold temperature and limited exposure to daylight. More generally, it is an ideal laboratory for understanding how biological mechanisms and psychological processes interact within a well-defined environment. As such, ICE environments provide unique opportunities for gathering new knowledge and having an impact on serious problems in non-extreme environments, as well as furthering knowledge about optimal adaptation in polar and space settings.

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