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Examining Psychosocial Well-being and Performance in Isolated, Confined, and Extreme Environments

Final Report
31 July 2014

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Executive Summary

The purpose of this document is to provide a systematic review of the literature characterizing the well-being-performance relationship in isolated, confined, and extreme (ICE) environments. This report also examines temporal effects on well-being and stress/negative psychosocial functioning over the duration of ICE missions. In doing so, this report aims to help address research Gap BMed5, as identified by the Behavioral Health and Performance (BHP) element of the NASA Human Research Program (HRP): "What individual characteristics predict successful adaptation and performance in an isolated, confined and extreme environment, especially for long duration missions?" A brief summary of the findings is as follows:

Well-being and Performance in ICE Settings

- Three overarching factors of well-being (hedonic well-being, eudaimonic well-being, and psychological capital [PsyCap]) were identified as relevant in ICE environments and were used to organize evidence of the well-being-performance relationship in this report.

- A broad set of performance-related criteria that include both direct and indirect (e.g., work attitudes) measures of performance and stress/symptomatology was employed for analyses in this report.

- Indicators of eudaimonic well-being have been those most often studied in ICE settings, followed by indicators of hedonic well-being and PsyCap.

- Indicators of PsyCap have been most strongly positively related to direct measures of performance (e.g., supervisor/peer performance ratings), while indicators of all three factors of well-being have shown consistently moderate positive relationships with indirect measures of performance (e.g., self-reported team cohesion and group functioning).

- Positive affect, an indicator of hedonic well-being, has been most consistently (negatively) related to stress measures; indicators of eudaimonic well-being have been most consistently (negatively) related to symptomatology measures.

Temporal Trends in Well-being in ICE Settings

- Primary research examining temporal effects on psychosocial health within the ICE literature has not resulted in consensus over patterns of change across mission duration.

- Meta-analytic evidence reported here suggests the beginning, and to a lesser extent the end, of missions to be marked by the greatest changes in both positive (i.e., well-being) and negative indicators of psychosocial functioning (i.e., stress/symptomatology), while functioning remained relatively stable during the interim stages.

- Moderator analyses of temporal trends suggest similar effects across short- and long-duration missions. This finding suggests that short-duration analog missions might

effectively be used to understand temporal trends in well-being during long-duration missions.

- Evidence regarding crew characteristics (crew nationality and gender) suggests that homogeneous crews may experience somewhat greater and more stable psychosocial health throughout mission duration. However, evidence does not suggest that heterogeneous crews will typically be detrimental to crew psychosocial health, and there appears to be a fairly clear dichotomy between those who do and do not thrive, at least, in multi-gender crews.

We offer the following recommendations for the future study of well-being in ICE contexts:

1. Validation of well-being measures specific to ICE settings is needed:

    - The present research has shown that indicators of well-being are statistically related to measures of performance. Better understanding the role of well-being in ICE settings can inform health surveillance efforts in long-duration spaceflight settings and can contribute to long-duration spaceflight selection and training procedures.

    - Using the hedonic well-being, eudaimonic well-being, and PsyCap framework, future research should aim to determine which specific well-being indicators demonstrate significant relationships with performance and psychosocial health criteria in ICE settings.

    - Next, specific well-being predictors should simultaneously be examined using a regression framework to determine the incremental effects of each on outcomes of interest. Doing so will identify which factors are most efficient in predicting specific outcomes deemed most vital to long-duration mission success (e.g., task performance, group functioning, stress resistance).

    - Indicators of PsyCap are more strongly related to direct measures of performance than either hedonic well-being or eudaimonic well-being. Findings suggest that emphasis should be placed on these indicators of well-being in order to explore the potential preventive and salutogenic effects of resilience and resilience-based protective factors during long-duration ICE missions.

    - HRP is currently undertaking health surveillance efforts to identify the signs, symptoms, and diagnoses of neurobehavioral health in ICE and spaceflight settings. HRP would benefit by supplementing this effort or similar future efforts with an examination of the relationship between indicators of well-being and neurobehavioral health in such settings. Doing so would provide a comprehensive study assessing the ability of well-being indicators to predict adverse health and behavioral outcomes.

    - The research presented in this report suggests that specific indicators of positive and negative behavioral health likely follow different temporal trends over the course of ICE missions. Assessing how specific indicators of well-being and symptomatology covary and/or differ over the course of a mission can be used to develop countermeasures to enhance specific aspects of well-being, to counteract the negative effects of stress and symptomatology, or both, at various points during a mission.

- Studies to validate ICE-specific measures of well-being can be conducted in a variety of settings. Earth-based analogs provide the most efficient settings for validation studies to take place initially. These studies could be carried out among individuals and teams in analog settings such as Polar expeditions; submerged settings such as NASA Extreme Environment Mission Operations (NEEMO); and analogous Mars settings such as the Hawai'i Space Exploration Analog and Simulation (HI-SEAS).

- Ultimately, low Earth orbit settings such as the International Space Station (ISS) will provide the most suitable analog for inquiries related to long-duration exploration-class missions. Examining the relationships between well-being and performance, and well-being and health in this context will allow researchers to validate a comprehensive measure of well-being for use in a long-duration mission to Mars.

2. Increase focus on the well-being of ground support and family members:

   - NASA is currently investigating the applicability of resilience training for ground crews. It is recommended that NASA continues this effort and also assesses the effects of maintaining and enhancing well-being among mission controllers. Understanding and enhancing the well-being of crew-mission control may increase the communication effectiveness of ground crews, which may ultimately serve to enhance crewmember performance.

   - Families serve as a critical point of support for individuals in ICE settings. To date, very little research has examined the well-being of crew-members' families. Even less research has examined how family well-being can impact the well-being and performance of crew members. Work should be done to examine the effects of crewmember family well-being on crewmembers' psychosocial functioning and performance.

3. Continue to assess well-being of crew members after the mission has ended:

   - Research is needed to assess lasting effects of ICE missions on crewmember well-being. This information can be used to inform and develop post-mission support procedures, if necessary.

   - Research is needed to identify post-mission factors of healthy psychosocial functioning and growth to inform crew selection for future long-duration missions.

   - Assessing the post-mission well-being of astronauts and individuals in ICE settings will be especially critical to understanding the potential impacts of multiple flights/ICE missions on well-being.

Introduction

The first manned mission to Mars is expected to become a reality within the next 25 years (Steinberg, Kundrot, & Charles, 2013). Although this may seem a distant goal, a complex set of hurdles must be overcome for this prospective expedition to be successful. One of the greatest priorities is to ensure crewmembers' psychosocial health and effective functioning on such a mission. However, because a mission of this kind has never been attempted, predictions of what factors are most relevant need to be grounded in research of individuals in similar environments. Literature on isolated, confined and extreme (ICE) environments has been quite comprehensive in identifying the factors of long-duration missions that can induce stress, both in space (Morphew, 2001) and analogue settings (e.g., polar stations; Palinkas & Suedfeld, 2008). Considerable concern has been raised over the adverse effects these factors can have on crewmembers' health and performance, as well as on overall mission success (Bishop, 2004).

The unique features of a mission to Mars only exacerbate concerns over individual crewmembers' health. The initial Mars expedition is expected to exceed two-and-a-half years (Steinberg et al., 2013). To date, the 18-month Mars500 space simulation, completed by a six-person international team (Basner et al., 2013; Belavý et al., 2013; Morukov et al., 2013), stands as the longest-duration ICE crew to be studied, while the longest continuous spaceflight stands at approximately 14 months, completed by Russian cosmonaut Valeri Poliakov (Manzey, Lorenz, & Poljakov, 1998). Thus, a Mars expedition represents a mission duration far exceeding that of anything for which effects on psychosocial health have been previously studied. However, mission duration is not the only unprecedented characteristic of such an expedition. Given the physical distance of Mars from Earth and limitations of current technology, a Mars expedition crew must also cope with significant communication delays (20-45 minutes, one-way) throughout the bulk of the mission, which can lead to miscommunication and frustration (Fischer et al., 2014). Related, the mission will require crewmembers to manage excessive periods of free time intermixed with intense periods of work. Finally, crewmembers will be the first humans to experience the "Earth-out-of-view phenomenon," as the crew journeys beyond Earth's orbit on its way to Mars. The effects of these unique circumstances on crewmembers are currently unknown (Kanas & Ritsher, 2005), but they will likely test individual limits like never before, and the importance of maintaining psychosocial health and functioning to mission success is an issue that cannot be overstated (e.g., Davis, Fogarty, & Richard, 2008; Dawson, 2002; Inoue, Matsuzaki, & Ohshima, 2004).

The purpose of this report is to contribute to current knowledge regarding crewmember psychosocial health and functioning in long-duration spaceflight. More specifically, this report aims to help address Gap BMed 5, as identified by the Behavioral Health Program (BHP) element of the NASA Human Research Program (HRP): "What individual characteristics predict successful adaptation and performance in an isolated, confined and extreme environment, especially for long duration missions?" This report will help address this research gap in multiple ways. First, the ICE literature has placed far greater emphasis on studying psychosocial dysfunction in contexts relevant to long-duration spaceflight than on psychosocial well-being. However, positive psychosocial functioning, as opposed to the simple absence of dysfunction, may have important consequences for individual and team health and functioning, as well as overall mission success. Thus, the first purpose of this report is to identify factors of well-being within the broader psychology literature that are most likely to be relevant to long-duration spaceflight (Aim 1). Using this framework, this report systematically summarizes the state of current evidence regarding the effects of well-being on performance in ICE environments (Aim

2). Finally, there are important questions that need to be answered regarding the extent to which and how individuals' psychosocial health and functioning change across the duration of ICE missions. A number of primary studies have sought to answer these questions, and a variety of temporal change patterns have been observed. Thus, the final purpose of this report is to review existing evidence regarding temporal change in psychosocial health indicators throughout the duration of ICE missions (Aim 3).

Effects of ICE on Psychosocial Health and Performance

ICE environments present a number of unique challenges which may adversely affect individuals' psychosocial health and performance. Scholars have identified an extensive list of potential stressors associated with spaceflight and analogue ICE settings (e.g., Davis et al., 2008; Dawson, 2002; Lapierre, Bouchard, Martin, & Perreault, 2009; Mophew, 2001; Nechaev, Polyakov, & Morukov, 2007), which can be organized succinctly into three categories: physical/environmental, social, and psychological (Geuna, Brunelli, & Perino, 1996). Physical/environmental stressors include: ambient noise, hardware/computers, long-duration confinement, microgravity, radiation exposure, and inability for rescue (e.g., Kelly & Kanas, 1992; Pattyn et al., 2009). Social stressors include: isolation, lack of privacy, demographic heterogeneity, language barriers, and communication issues/lack of communication with ground control, loved ones, and Earth (e.g., Boyd et al., 2009; Weiss & Moser, 1998; Stuster, Bachelard, & Suedfeld, 2000). Psychological stressors include: periods of boredom and monotony and periods of intense performance demands (e.g., Gushin, Zaprisa, Kolinitchenko, & Efimov, 1997). Additional sources of stress specific to long-duration spaceflight have also been proposed to include comparatively extreme mission duration/distance, communication delays, increased levels of autonomy and responsibility, and amount of free time, as well as the Earth-out-of-view phenomenon (Kanas & Ritsher, 2005).

In general, long-term isolation and confinement has been shown to lead to maladjustment and decrements in psychosocial health through increased anxiety, depression, fatigue, and stress (e.g., Dinges et al., 2014; Palinkas, Cravalho, & Browner, 1995; Palinkas & Houseal, 2000; Stuster et al., 2000). Prolonged isolation and confinement has also been linked to reductions in cognitive control and physiological reactivity in these contexts, mitigating cognitive (Pattyn et al., 2009) and physical performance (Belavý et al., 2013).

Negative effects on interpersonal relations have been those most consistently evidenced within the ICE literature (e.g., Kanas, 1991; Kanas et al., 2001c; Stuster et al., 2000). For example, interpersonal tension among crewmembers has been found to be driven by individual differences in crewmember values (Sandal, Bye, & van de Vijver, 2011), personality (Bishop, Santy, & Faulk, 1998; Inoue et al., 2004), and culture/language (Inoue et al., 2004), as well as due to competition over group roles (Krins, 2009; Sandal, 2001, 2004). These issues can have serious consequences on group performance and overall mission success. To demonstrate, during the 105-day Simulation of the Flight of International Crew and Space Station-1999 (SFINCSS-99) a physical fight broke out among two of the crewmembers, a sexual harassment incident was reported, and one protesting crewmember withdrew from the study (see Inoue et al., 2004). In the context of spaceflight, where individual escape or mission termination is rarely an option, events such as this will certainly place individual psychosocial health and performance, as well as mission success, in extreme jeopardy. Related to interpersonal issues among crewmembers, issues regarding leadership have also been evidenced. For example, one simulation crew leader became increasingly dominant over the mission duration, leading to progressively lower leadership evaluations (e.g., Bergan, Sandal, Warncke, Ursin, & Værnes, 1993; Kansas, 2005). Finally, interpersonal tension has also been observed between crews and mission control (e.g., Bergan et al., 1993; Inoue et al., 2004; Kanas, 2004, 2005; Kanas, Salnitskiy, Grund, Gushin, & Weiss, 2002; Kanas et al., 2007a, 2007b, 2007c; Lapierre et al., 2009; Stuster et al., 2000). Tension between the crew and leader and crew and mission control have important consequences for the execution of mission tasks, via effective communication, and mission success (Bergan et al., 1993).

Finally, it is important to note that the adverse effects of isolation and confinement likely do not end with the mission. As described below, the potential for adverse effects following experiences in extreme environments has driven much of the military psychology literature (e.g., Hoge et al., 2004), and evidence has demonstrated the consequences of long-duration spaceflight on crewmember health post-mission, both in terms of changes in personality and family dynamics (see Kanas, 1998). Taken together, evidence suggests the importance of developing a better understanding of the effects of ICE missions on psychosocial health and performance (e.g., Davis et al., 2008) in order to improve selection, training, and countermeasure procedures and mitigate the potential for adverse effects during such missions.

Positive Consequences of ICE Experiences

The stress associated with long-duration spaceflight is expected to test crewmembers' psychosocial functioning. However, some scholars have suggested that there exists a bias within the ICE literature towards overgeneralizing and dramatizing the potential adverse effects of such missions (Mocellin & Suedfeld, 1991), and a growing body of literature has evidenced the positive effects ICE experiences can have on individuals' psychosocial functioning (see Suedfeld & Steel, 2000). This counterargument appears plausible when one considers the screening process individuals typically must pass prior to being selected for ICE missions. Particularly in the context of long-duration spaceflight, increasing emphasis is being placed not only on selecting candidates with the "right stuff" (e.g., Bishop, 2004), but also on preflight training aimed at improving crewmembers' ability to effectively manage the stress that will inevitably arise due to the circumstances of spaceflight (e.g., Rose, 2014). Moreover, advances are being made in the ability to monitor crewmembers' psychological and physiological functioning during spaceflight in order to provide countermeasures when necessary (e.g., Mollicone et al., 2014). This implies that crewmembers may be better adjusted and equipped to handle the elevated risk associated with ICE environments, and these individuals may also be more likely to view ICE conditions as challenges from which they can benefit psychosocially.

A review of polar expedition groups indicates generally high well-being among team members across missions, as well as generally low anxiety, depression, and stress reactivity (Leon, 1991). For example, crewmembers completing a seven-week high-Arctic expedition reported low levels of stress throughout the majority of the expedition, as well as generally high mood, satisfaction with and enjoyment of the expedition, and camaraderie (Leon, List, & Magor, 2004). Similar effects were found among a two-woman team completing a 97-day Antarctic expedition, including high positive personality dimension scores (i.e., absorption, work and positive expressivity) and low verbal aggressiveness scores (Atlis, Leon, Sandal, & Infante, 2004). In addition, interview responses by team members depict how enjoyment and awe of surroundings increased psychological strength, and one member indicated feelings of a sensed presence, which was reported to provide motivation during periods of fatigue and disappointment. Palinkas and Suedfeld (2008) identified a number of positive characteristics among Antarctic winter-overs, that may be relevant to long-duration spaceflight: excitement over experiencing the unknown; free time to self-improve, exercise, and think; and the opportunity to remove oneself from daily hassles and negative aspects of life on Earth. The authors went on to posit a number of salutogenic effects that may result from such missions, including: increased affiliation with other crewmembers; a sense of achievement, cooperation, excitement and curiosity; resilience, individual growth, and self-efficacy; as well as changes in worldviews. Consistent with this, unanimous positive reactions to spaceflight have been reported among surveyed astronauts and cosmonauts (Ihle, Ritsher, & Kanas, 2007; Ritsher, Ihle, & Kanas, 2005), and in autobiographies, memoirs, interviews, personal diaries, and oral histories of astronauts of various nationalities (Suedfeld & Brcic, 2011). In addition, astronauts and cosmonauts taking part in MIR and International Space Station (ISS) missions reported higher positive mood scores and greater cohesion than was found in a normative sample (Kanas et al., 2001a), and despite physical performance decrements over the course of the 520 day Mars500 simulation, individuals' motivation remained consistently high (Belavý et al., 2013). Taken together, this suggests that experiences in ICE environments can be positively associated with well-being. However, it is less clear how well-being affects psychosocial functioning within these environments.

Well-being in Long-duration Spaceflight

Definition and Conceptualization of Well-being

Within psychology, far greater attention has been paid to identifying and treating psychological dysfunction and disorder than to improving healthy functioning and well-being (e.g., Myers & Diener, 1995; Ryan & Deci, 2001; Ryff, 1995); research on psychosocial factors in ICE has been consistent with this trend. In this vein, well-being has often been equated with the absence of psychosocial symptomatology. However, well-being is not simply the absence of the negative, but instead the presence of positive experiential and emotional characteristics (Ryan & Deci, 2001; Ryff, 1995; Sin & Lyubomirsky, 2009). Within the field of psychology, research has periodically emphasized the importance of positive psychosocial functioning and well-being. For example, humanistic psychology enjoyed popularity during the middle of the 20th century (e.g., Maslow, 1971). The 1980s saw the rise of research exploring the effects of self-esteem (Rosenberg, 1979) and positive affect (Watson, Clark, & Tellegen, 1988), and with the 21st century came the field of positive psychology (Seligman & Csikszentmihalyi, 2000), focusing on positive traits, emotions and experiences.

There is no shortage of descriptions of what it means to be well. For example, well-being has been defined through indicators such as happiness, positive affect, positive emotions, mental health, global or domain satisfaction (e.g., job), self-realization, autonomy, and purpose and meaning in life (see Sin & Lyubomirsky, 2009; see also Frederickson & Joiner, 2002; Wright & Huang, 2012). Many definitions of well-being include a complex set of these and other relevant indicators. For example, one recently-proposed model describes well-being as a multi-faceted construct that includes: competence, emotional stability, engagement, meaning, optimism, positive emotion, positive relationships, resilience, self-esteem, and vitality (Huppert & So, 2013). To accommodate these various, and often complex, descriptions, well-being has also been defined as anything affective, behavioral, or cognitive, that is important in an individual's life (Rath & Harter, 2010). Research has also aimed to identify the overarching facets of well-being, and two overarching components—hedonic and eudaimonic well-being—have emerged throughout much of the literature (see Ryan & Deci, 2001). This has led to differences in explanations of what it means to be well. Nonetheless, both hedonic and eudaimonic well-being are likely to be relevant in the context of long-duration spaceflight, and the dichotomy provides a framework for organizing some of the specific indicators described above. In addition, evidence from the broader psychology literature suggests that both factors relate to performance.

Hedonic Well-being

The hedonic facet represents the pleasure-driven qualities of well-being (e.g., Diener, 1984; Wright & Doherty, 1998). Potential indicators of hedonic well-being include: happiness; positive affect, emotions and mood; and life, social and work satisfaction. Researchers taking the hedonic approach have most often assessed well-being, or "happiness", through the presence of life satisfaction and positive mood and the absence of negative mood, what Diener and colleagues describe as subjective well-being (SWB; e.g., Diener, 1984; Diener, Suh, Lucas, & Smith, 1999). Further, it is theorized that hedonic indicators can be broken down into life evaluations (i.e., satisfaction) and positive emotions (Kahneman & Deaton, 2010).

Evidence has demonstrated hedonic indicators to be related to a wide range of relevant outcomes. For example, the robust effects of positive affect/happiness have been demonstrated meta-analytically, with evidence indicating that happier people experience greater success at work ($r = .27$) and in relationships ($r = .27$) and are healthier ($r = .32$; Lyubomirsky, King, & Diener, 2005). In the context of long-duration spaceflight, hedonic indicators are likely most influential on crewmembers' day-to-day functioning, such as in maintaining positive interpersonal relationships and effective task performance.

Eudaimonic Well-being

The eudaimonic facet represents the self-realization-driven qualities of well-being (e.g., Deci & Ryan, 2000; Ryff, 1989, 1995; Ryff & Keyes, 1995; Ryff & Singer, 1998). Potential indicators include autonomy; competence; engagement, meaning and purpose in life and work; positive relationships; self-realization; spirituality; and vitality. While hedonic well-being is typically assessed through SWB, eudaimonic well-being is most often assessed through psychological well-being (PWB; Ryff, 1989), often characterized as “self-fulfillment” reflected in self-acceptance, positive relations and growth, and meaning/purpose in life (Keyes, Shmotkin, & Ryff, 2002; Ryff, 1989). Self-determination theory (SDT; Deci & Ryan, 2000) represents a related conceptualization of eudaimonic well-being. That is, SDT holds sufficiently met needs for autonomy, competence, and relatedness as the core of well-being (Ryan & Deci, 2001).

Eudaimonic indicators have also been shown, in the broader literature, to be related to outcomes believed to be important in spaceflight. For example, meta-analytic evidence has demonstrated work engagement, autonomy, and perceived competence to be positively related to work commitment (Halbesleben, 2010; Mathieu & Zajac, 1990); work engagement, autonomy and indicators of positive relations have been demonstrated to be negatively related to burnout (Halbesleben, 2010; Lee & Ashforth, 1996). Thus, in the context of long-duration spaceflight, eudaimonic indicators likely have the greatest impact from a longer-range perspective through commitment to the mission and sustained motivation and psychosocial functioning.

Psychological Capital (PsyCap)

There exist in the psychological literature a number of multi-dimensional constructs indicative of well-being, beyond those captured by the definitions of SWB (i.e., hedonic) and PWB (i.e., eudaimonic). Due to the work-related nature of ICE missions, one such construct that may be particularly relevant is psychological capital (PsyCap; Luthans, 2002; Luthans, Youssef & Avolio., 2007). Positive organizational behavior, an emerging field in the organizational literature, emphasizes identifying, developing and maintaining indicators of healthy employee functioning and well-being, specifically in the work context, as a means of optimizing individual and organizational performance (e.g., Luthans, Avolio, Avey, & Norman, 2007). Much like

SWB and PWB, PsyCap has been argued to be a higher-order construct indicative of well-being in work contexts assessed through four lower-order constructs: hope, efficacy, resilience, and optimism. Meta-analytic evidence indicates a significant relationship between PsyCap and job performance (Avey, Reichard, Luthans & Mhatre, 2011). Moreover, research has also suggested that PsyCap is associated with lower levels of perceived stress (Avey, Luthans, & Jensen, 2009) and higher levels of psychological well-being (Avey, Luthans, Smith & Palmer, 2010). Meta-analytic reviews of individual components of PsyCap have demonstrated relationships with both work-related performance (self-efficacy, $r = .38$; Stajkovic & Luthans, 1998) and psychological adjustment (efficacy, $\rho = .58$; optimism, $\rho = .41$; Lamp, 2013).[1] Thus, the potential contribution of PsyCap indicators to overall well-being during long-duration spaceflight, beyond that of SWB and PWB, is likely shown through the improved ability to adapt to ICE environments and to buffer the effects of stressors that may arise throughout the mission.

Summary

Overlap certainly exists between the facets described above. For example, evidence suggests SWB and PWB to be related-but-distinct constructs (Keyes et al., 2002). However, this trichotomization of higher-order well-being factors provides a parsimonious model by which lower-order well-being indicators relevant to ICE contexts may be conceptually organized. As described above, limited research attention has been given to well-being within the ICE literature. However, where possible, we differentiate between these facets to provide insight as to which types of indicators have received greater attention in the literature, as well as whether these facets show differential temporal changes or have differing effects on relevant outcomes.

[1] Rho (ρ) represents the meta-analytic correlation (r) corrected for measurement error (see Hunter & Schmidt, 1990).

Relationship between Well-being and Performance

Factors that have been identified to positively affect performance in ICE environments include: age, experience, high emotional stability/maturity, expressiveness, instrumentality, and motivation, effective social skills and leadership, low extraversion, conscientiousness, and assertiveness, low need for affection, and an absence of anxiety and depression (Palinkas, Gunderson, Holland, Miller, & Johnson, 2000; Palinkas, Keeton, Shea, & Leveton, 2011; Rosnet, Le Scanff, & Sagal, 2000; Sandal, Værnes, Bergan, Warncke, & Ursin, 1996). Many of these predictors have also been shown to be positively related to well-being in the broader psychology literature. For example, research employing large national samples indicates age and emotional stability to be positively related to both PWB and SWB (Keyes et al., 2002; Soto, 2014). Predictive analyses among a similarly large sample demonstrated that individuals high in eudaimonic well-being were more than two times less likely to be depressed 10 years later, even when controlling for personality and economic factors, physical and mental health, and history of depression (Wood & Joseph, 2010). Given the disparities across definitions of well-being, it has also been argued that many of the factors described above are, themselves at least, distal indicators of well-being (e.g., Huppert & So, 2013).

However, the practicalities of ICE environments lead to some unique considerations regarding the expected relationships between psychosocial predictors, indicators of well-being and performance. For example, meta-analytic evidence from the broader organizational psychology literature suggests conscientiousness to be a robust predictor of performance across occupational groups, and extraversion to be an efficient predictor of training proficiency (Barrick & Mount, 1991). However, these characteristics have been shown to have the opposite effect on performance in ICE environments (see Palinkas et al., 2011). That is, in ICE settings, highly conscientious individuals are more likely to become frustrated when variable external factors and limited resources hinder their ability to successfully complete tasks, and extraverted individuals may find it difficult to adjust to the limited social stimuli associated with ICE settings (Palinkas, et al., 2000). Further complicating the matter is that evidence from a large national sample has indicated that conscientiousness and extraversion, along with agreeableness and emotional stability, positively predicted subsequent SWB scores (Soto, 2014). Thus, it remains unclear how the unique effects of extraversion and conscientiousness influence the relationship between well-being and performance in long-duration spaceflight.

Literature examining the effects of well-being on performance in ICE settings remains relatively scarce. This may be largely the result of methodological limitations of research in ICE contexts. First, evidence of psychosocial health in ICE environments has thus far focused on individual ICE teams, with few studies examining multiple teams simultaneously (e.g., Inoue et al., 2004). This has resulted in a complete absence of evidence comparing between-group differences in psychosocial health and their effects on performance. Second, the development of, and access to, valid performance criterion measures has long been an issue within the psychology literature (see Austin & Villanova, 1992), an issue intensified in ICE psychosocial research. Objective measures of individual performance may often not be practical in these contexts, and these measures are noticeably absent in ICE research studying indicators of well-being, particularly in ICE settings beyond that of Antarctic stations. Unfortunately, the use of subjective performance measures (e.g., supervisor/peer ratings) has not been common within the body of literature studying well-being ICE environments either. Taken together, this suggests that future research is needed that directly examines the well-being-performance relationship, both at the individual and team levels.

Meanwhile, expanding the pool of criteria to proxies more distally indicative of performance, as well as relying on concurrent self-report measures of well-being and performance-related evidence may be necessary to begin to understand this relationship. With regard to indicators of hedonic well-being, correlational evidence from the Mars-105 pilot mission has demonstrated positive affect to correlate strongly with self-reported problem-solving (Nicolas, Sandal, Weiss, & Yusupova, 2013), which may be indicative of effective performance. Among an Antarctic expedition team, those who reported high work satisfaction also reported high group cohesion (Sarris & Kirby, 2005). Expanding the criteria pool limits our ability to draw firm conclusions regarding the direct well-being-performance relationship or the nature of causality among variables, but it may provide important insight moving forward by establishing which well-being indicators and performance criteria may be most fruitful to pursue.

In addition, it is often assumed that individuals selected to take part in ICE missions are well-adjusted, motivated individuals. Thus, it may be expected that effective performance (e.g., problem-solving, task performance, effective communication and leadership, group performance and cohesion, and overall mission success) may be at least partially due to individuals' high standing on indicators of well-being. In this vein, evidence has shown that well-adjusted individuals, based on pre-mission assessments, remained motivated to complete a 56-day expedition to the North Pole, despite extreme physical conditions that resulted in two members of the team to be flown out of the mission early due to injuries (Leon, McNally, & Ben-Porath, 1989).

Evidence suggesting a relationship between well-being and performance is not completely absent from the literature. Within ICE environments, indicators of eudaimonic well-being, specifically autonomy and positive relations, have been most frequently studied and shown to relate to performance criteria (proximal and distal). For example, allowing crewmembers taking part in a 105-day space simulation the autonomy to plan their own schedules led to an increase in perceived group cohesion (Gushin et al., 2012; Kanas et al., 2010). In addition, emotional support and respect for others were identified as critical to mission success among multiple teams carrying out polar expeditions (Leon & Sandal, 2003). Strong social networks have also been shown to be related to effective emotional adjustment during winter-overs in Antarctica (Palinkas & Johnson, 1990), and among surveyed astronauts and cosmonauts, contact with loved ones has been reported to positively affect mission performance (Kelly & Kanas, 1993). Finally, evidence demonstrates the positive relationship between leader support and crew cohesiveness among Shuttle and Mir astronauts and cosmonauts (Kanas & Ritsher, 2005). Alternatively, the lack of strong positive relations among crewmembers has been demonstrated to have detrimental effects on crewmember functioning and overall mission success (e.g., Inoue et al., 2004; Sandal, 2004).

Well-being in Extreme Contexts: Research on Military Personnel

The major stressors associated with military service likely differ from those associated with isolation and confinement. Nonetheless, the military context and associated combat operations represents an extreme and unusual environment which may yield useful information for understanding well-being in spaceflight and ICE contexts. Moreover, considerable efforts have been made within the military context to understand the range of factors which influence psychosocial health and performance. These efforts may be best represented by the Millennium Cohort Study in which over 75,000 U.S. service members enrolled in the initial stages of the study in 2001, and a substantial number of whom continue to be tracked, at present. Evidence originating from Millennium Cohort data demonstrates a wide range of relationships between baseline health and a variety of health and behavioral outcomes. For instance, this research has shown that baseline health can predict vulnerability to post-deployment stress disorders (Gehrman et al., 2013; LeardMann, Smith, Smith, Wells, & Ryan, 2009). These findings speak to the importance of selecting individuals who are both physically and psychologically able to take on critical missions such as deploying to a combat zone. However, it must be noted that one Millennium Cohort study found psychological resilience (PsyCap indicator) to be quite common among deployed service members, as over 80% of soldiers indicated no elevated risk levels of post-traumatic stress following a deployment (Bonnano et al., 2012).

Consistent with the broader psychological literature, researchers studying psychological health and well-being in the military have typically focused on the negative aspects of health, or the absence of well-being. This is illustrated by recent Department of Defense (DoD) reports that have focused on the rates of psychological problems experienced by deployed and non-deployed service members (MHAT 6, 2009; J-MAT 7, 2011), as well as the broader literature on stress and its relationship with health and job performance data (e.g. Pflanz & Ogle, 2006).

Recently, however, research has begun to focus on the positive indicators of psychological health. The U.S. Army's Comprehensive Soldier and Family Fitness (CSF2) program (see Casey, 2011; see also Cornum, Matthews, & Seligman, 2011), for example, focuses on assessing positive psychological attributes, including indicators of hedonic (e.g., positive affect) and eudaimonic well-being (e.g., character strengths, engagement, social connections, spirituality) and PsyCap (e.g., adaptability, optimism), in soldiers. Research conducted by CSF2 has demonstrated these indicators to be associated with performance-related outcomes. Specifically, the research has shown soldier adaptability, coping styles, character strengths, positive affect, optimism, engagement, social connections, and work engagement to negatively relate to adverse outcomes, such as suicide, documented drug use, and violent criminal offenses (Lester, Harms, Bulling, Herian, & Spain, 2011a). These indicators have also been related to positive indicators of performance, such as: early promotion and selection for special assignments (Lester et al., 2011b). However, it should be noted that these effects have typically been quite small.

A limited amount of additional research has examined indicators of well-being and their relationships with performance outcomes, and not all evidence has demonstrated a strong well-being-performance relationship. For example, the relationship between coping strategies and a variety of job-related stressors, such as role overload, role ambiguity, and lack of stimulation at work has been examined, with findings suggesting "positive" coping strategies (e.g., problem-focused coping, positive emotion-focused coping, and seeking information and emotional support) to be unrelated to health and behavior complaints (Day & Livingstone, 2001). The use of "negative" coping strategies (venting of emotions and denial/disengagement), however, led to a greater incidence of complaints. Most importantly, interactions demonstrated that the use of venting and disengagement had the potential to exacerbate the effects of both acute and chronic stressors upon physical and behavior health complaints. Taken together, these findings suggest that avoiding "negative" coping strategies may be more important than using of "positive" coping strategies to reduce the odds of health complaints among soldiers.

On the other hand, evidence has demonstrated the potential effects of optimism on mitigating the onset of adverse psychosocial health (Thomas, Britt, Odle-Dusseau, & Bliese, 2011). That is, dispositional optimism was found to reduce post-deployment posttraumatic stress disorder (PTSD) symptoms, depression symptoms, and work impairment. Dispositional optimism was also found to interact with warzone stressors such that high levels of dispositional optimism reduced the effect of warzone stress upon PTSD symptoms. Analyses also showed that dispositional optimism attenuated the relationship between deployment demands and depression symptoms, and also attenuated the effects of PTSD symptoms and depression symptoms upon the probability of work impairment. In short, dispositional optimism was found to be an important buffer against the effects of mission-related stressors.

Finally, studies have also examined perceptions of leadership and social support as indicators of well-being in military contexts. Recent DoD reports identified leadership and unit cohesion as two of the primary buffers against the stressors of combat (MHAT 6, 2009; J-MHAT 7, 2011). Organizational support has also been identified as a buffer against combat stress and depression and anxiety (McFadden, 2013). Other research has also found that perceptions of social support can enhance well-being and job satisfaction among military personnel (Limbert, 2004).

Summary

There has been a dearth of research examining the relationship between well-being and performance in either the ICE or military literatures. However, expanding the pool of relevant criteria to more distal correlates of performance (e.g., psychosocial and behavioral problems) being studied in ICE settings may provide greater insight into the well-being-performance relationship. In this regard, research in the military context has the potential to inform the research initiatives of NASA, as the focus in the military literature has traditionally been to mitigate the likelihood of soldiers developing pathologies (e.g., depression, posttraumatic stress disorder), which may subsequently lead to performance decrements.

Temporal Effects on Well-being

Primary research in ICE environments has sought to demonstrate the temporal pattern of psychosocial effects during isolation and confinement. Temporal effects on psychosocial health have been studied using a wide range of variables representing both well-being and psychosocial symptomatology. These variables include: mood, morale, personality, positive and negative affect, satisfaction, sleep quality, and stress (Atlis et al., 2004; Bhargava, Mukerji, & Sachdeva, 2000; Bishop, Kobrick, Battler, & Binstead, 2010; Gushin et al., 2012; Koscheyev, Roschina, & Makhov, 1994; Palinkas & Houseal, 2000; Steel, 2001; Wood, Lugg, Hysong, & Harm, 1999).

Researchers have often suggested the presence of a third-quarter phenomenon, wherein adverse effects on psychosocial functioning peak between half and two-thirds of the way through the duration of missions. The concept was developed based on anecdotal observations and reports of negative mood in various ICE environments (Bechtel & Berning, 1991), and has received some empirical support in analogue settings. For example, self-reported stress peaked at the midway point of the mission among males taking part in a four-month ICE simulation at the Flashline Mars Arctic Research Station (FMARS). Among female crewmembers, self-reported stress and avoidant coping strategies also saw an uptick midway through the duration of the simulation, before progressively receding throughout the remainder of the mission, while the inverse trend was found for the use of healthy coping strategies (Bishop et al., 2010). Evidence has also demonstrated interpersonal rapport among individuals wintering-over in the Antarctic reached its lowest points during the third quarter of the stay (Bhargava et al., 2000), and similar effects have also been found in relation to morale among an Antarctic research expedition crew (Wood et al., 1999). Finally, content analyses of diary entries completed by individuals serving at remote stations in the Antarctic and South Indian Ocean provide additional documentation of this phenomenon (Stuster et al., 2000)

Research has demonstrated a number of alternative temporal change patterns. For example, stable increases in anxiety and hostility have been observed among individuals wintering-over in the Antarctic (Evans, Stokols, & Carrere, 1987; Sasaki et al., 1980), as have ratings of stress among ISS astronauts (Dinges et al., 2014), and ratings of homesickness among individuals taking part in polar expeditions (Sandal et al., 1996). However, Sandal et al. (1996) also reported stable increases in coping and decreases in anxiety and depression among hyperbaric chamber crews. Findings have also demonstrated non-linear effects that deviate from the temporal pattern described as the third-quarter phenomenon, such as heightened stress at the onset and end of a 25-day simulation, and low stress during the middle of the simulation (Bergan et al., 1993; Mocellin & Suedfeld, 1991; Sandal, 2001). Similar effects were found among individuals wintering-over at two Antarctic stations, who showed decreases in various negative mood scales (anxiety, depression, anger, confusion, fatigue) throughout the austral winter, only to report increases in anxiety and fatigue, as well as decreased vigor, during the latter part of the mission (Palinkas & Houseal, 2000). Evidence from spaceflight missions has demonstrated a novelty effect among astronauts that declined non-linearly across the duration of the mission (Kanas et al., 2001a, 2001b, 2001c). Still other winter-over evidence has demonstrated a more complex circannual rhythm, by which psychological and physiological systems create a feedback cycle (Palinkas et al., 2001).

What should be made of this evidence suggesting various temporal change patterns in ICE environments? It is possible differences in temporal patterns are driven by factors other than time. That is, some research has found support for critical events being more indicative of changes in psychosocial problems than time-based factors (e.g., Inoue et al., 2004; Leon et al., 2004, Steel & Suedfeld, 1991). Related, researchers have begun to employ multilevel modeling statistical analyses (Hox, 1998; Singer & Willett, 2003) to establish the amount of variance in scores due to individual, group, and temporal effects. Using this approach research has demonstrated that the majority of variance in weekly team climate and perceived social support scores (57%-71%) among Antarctic expedition crews was due to individual differences, while far less was due to temporal effects (Schmidt, Wood, & Lugg, 2004; 2005). However, evidence has shown scores on different psychosocial health and well-being indicators to peak and trough at different phases of the mission (e.g., Bhargava et al., 2000), as well as different indicators to be more malleable to temporal change than others (Steel, 2001). Additionally, characteristics associated with different settings may also influence temporal effects on psychosocial health indicators. For example, the selection and training requirements, age, and average education level, likely differ between spaceflight and many analogue settings. Moreover, differences in mission duration and the physical and environmental characteristics of these settings have also been described (e.g., Manzey, 2004). Given the variability across observed temporal trends in psychosocial health, a key research objective is to better understand the underlying sources of these differences (Aim 3).

Operational Tempo and Well-being in the Military

Given that one objective of the present report is to summarize the temporal effects on indicators of psychosocial functioning over the course of a mission, it may be useful to briefly review the literature on the impacts of deployment lengths upon these factors in the military. Research has shown that simply being sent on a combat deployment can have a detrimental impact on health and behavioral outcomes, irrespective of what happens during a deployment

(Fear et al., 2010; Polusny et al., 2009; Vasterling et al., 2010). Additionally, consistent with the sensitization perspective of stress reactance, research has shown that longer deployment lengths are positively related to depression and post-traumatic stress symptoms (Adler, Huffman, Bliese, & Castro, 2005), and a review of multiple studies showed that deployment lengths are predictive of decreased physical and psychological well-being among service members deployed to combat (Buckman et al., 2011).

Only a limited amount of research has focused on the effects of dwell time—the time between combat deployments—on mental health among soldiers experiencing multiple deployments. A recent study of Marines showed that a greater ratio of dwell-to-deployment time served to lower the risk of developing mental health issues following a second deployment (MacGregor, Han, Dougherty, Galarneau, 2011), presumably because longer dwell times reduce the number of threat appraisals and allow for service members to replenish the pool of resources used to effectively cope with stress. In contrast, other research has demonstrated that longer dwell times may increase the likelihood of developing mental and physical health issues, with longer dwell times being associated with PTSD, anxiety-related disorders, and depressive disorders (Armed Forces Health Surveillance Center, 2011). This is, perhaps, because longer dwell times allow service members time to fully readjust to normal life before having to fully reestablish the "warrior" mentality necessary for effective psychosocial functioning while on deployment. It should be noted that there is a lack of evidence within the military psychology literature tracking temporal changes among soldiers throughout the course of a deployment. Thus, evidence stemming from military personnel may not provide direct insight into Aim 3. However, indirectly, evidence from the military literature does suggest that temporal changes in psychosocial functioning, such as increased stress and anxiety, can appear during the lead-up to long-duration deployments and post-mission, during the period of reassimilation into normal living conditions (e.g., Bliese, Wright, Adler, Thomas, & Hoge, 2007). This knowledge may be important to the interpretation of temporal patterns found during ICE missions, particularly at the beginning and end of missions.

Summary: Research Aims of the Present Report

Primary evidence exists regarding the relationship between well-being and performance in ICE settings as well as for the temporal effects on well-being and psychosocial functioning over ICE mission duration. However, no attempt has been made thus far to systematically review the evidence of either. With regard to the former, the lack of summary evidence may be due to the absence of a theoretically-supported organizing framework of the range of well-being indicators that have been studied in ICE environments, and/or the absence of evidence linking well-being indicators to measures directly reflecting performance. In the present report we address these issues by organizing well-being indicators into three distinct factors (hedonic well-being, eudaimonic well-being, and PsyCap) and qualitatively reviewing the effects of each in relation to a broad set of performance-related criteria. With regard to the latter, various temporal trends have been observed in relation to indicators of both well-being and stress/symptomatology within the empirical ICE literature. A quantitative summary of such evidence may contribute greatly to the ongoing discussion of the temporal effects on these variables. However, differences in both the measurement scales used and length of mission studied in primary ICE research of temporal effects has made summarizing this data difficult. Therefore, we use an innovative approach of converting primary study response scale and mission duration data into comparable and easily interpretable intervals to provide meta-analytic evidence that maps the temporal trends of indicators of both positive (i.e., well-being) and negative psychosocial functioning (i.e., stress/symptomatology) across both individuals and crews.

Method

Systematic Review

Again, the systematic review has two primary purposes: 1) to summarize the effects of well-being indicators on performance-related criteria, and 2) to examine the temporal change in a broader set of psychosocial factors (both well-being and psychosocial stress/symptomatology) experienced by individuals across ICE missions. To identify potentially relevant studies we conducted a systematic search of multiple databases: PsycInfo, Medline (First Search), and Medline (PubMed). Prior to conducting our search we developed a broad and comprehensive set of search terms to be used. We identified 21 primary search terms, which we paired with an additional 23 secondary search terms. Primary and secondary search terms are presented in Table 1. All systematic searches of key terms were conducted within study abstracts.

Using the terms depicted in Table 1, the PsycInfo search produced a total of 55,951 results. We found multiple primary search terms used in the PsycInfo search to return a vast number of articles, most of which were not identified as potentially relevant, while other search terms yielded very few articles, none of which were identified as potentially relevant. In total, we identified seven primary search terms that were associated with one of the above issues. Thus, these terms were eliminated prior to our conducting searches in the Medline First Search and PubMed databases. Search terms retained for these subsequent searches are also noted in Table 1. Our search of the Medline (First Search) and Medline (PubMed) databases produced an additional 16,302 articles. This resulted in a total of 72,253 articles. It should be noted that a number of articles were returned multiple times across our searches. Given the vast number of articles our searches produced the exact number of duplicated articles contributing to this total estimate is unknown. However, within our initial PsycInfo search we identified 580 potentially relevant articles. Of these, 306 had already been retained through previous key term searches, resulting in a total of 274 relevant articles from PsycInfo. Within our Medline searches a total of 303 potentially relevant articles were identified. However, 258 had already been retained through previous searches, resulting in a total of 45 additional potentially relevant articles. The total number of unique and potentially relevant articles identified through database searches was 319. In addition, we conducted a secondary search based on a review of the articles obtained via database searches and identified an additional 45 articles that were potentially relevant. This resulted in the identification of a total of 364 articles to be examined for possible inclusion.

Table 1. *List of Search Terms*

PsycInfo search	**Retained**	**PsycInfo search**	**Retained**
Antarctic	x	Adapt	x
Arctic	x	adaptability	x
astronaut	x	adaptive	x
capsule	x	adaptation	x
Concordia	x	Attitude	x
confined	x	conscientiousness	x
cosmonaut	x	citizenship	x
desert		Control	x
enclosed habitat	x	depression	x
extreme		emotion	x
Greenland		Health	x
ICE		individual difference	x
inextremis	x	mindfulness	x
isolated	x	Mood	x
long duration	x	Morale	x
McMurdo	x	performance	x
space		personality	x
spaceflight	x	resilience	x
submarine	x	satisfaction	x
unusual		self-esteem	x
unusual environment	x	self-efficacy	x
		Stress	x
		well-being	x

Inclusion Criteria

Again, this systematic review was designed to summarize the effects of well-being indicators on performance-related criteria (Aim 2), and to examine the temporal change in a broader set of psychosocial factors (both well-being and psychosocial symptomatology) experienced by individuals across ICE missions (Aim 3). The inclusion criteria for studies differed somewhat across these two purposes. However, as a general inclusion criterion, studies were required to be conducted either within ICE environments (i.e., Antarctic or Arctic stations/expeditions, deep sea dives, hyperbaric chambers, submarines, simulated space capsules, bed rest, underground bunkers, and spaceflight) or through retrospective data collection efforts regarding previous ICE experiences. Further inclusion criteria were specific to each of the two purposes of this review, and are discussed below.

Aim 2: Well-being-performance relationship. Studies were required to report quantitative evidence regarding the effects of indicators of well-being on performance-related outcomes. As noted above, well-being is a broad construct so indicators were organized under three separate factors based on the broader existing psychological literature: hedonic well-being, eudaimonic well-being, and PsyCap. Variables and scales identified in the studies meeting Aim 2 inclusion criteria as indicators of well-being are classified according the three well-being factors presented in Table 2. Emotional stability was identified as a broad indicator of well-being that has also been used within the ICE literature, but does not reflect any specific factor more than the others. Thus, we describe emotional stability as an indicator of general well-being, and present evidence regarding this indicator separately after our review of evidence regarding the effects of hedonic well-being, eudaimonic well-being, and PsyCap.

Table 2. *Primary Study Variables Classified by Each Well-being Factor*[2]

Hedonic	• joy in work • perceived fairness • positive affect and negative affect (reverse coded)[3] • satisfaction (i.e., general or domain-specific) • vigor/activity
Eudaimonic	• altruism • autonomy • competence (i.e., mature defense mechanisms, positive instrumentality, perceptions of challenge) • control • drive • positive social relations (i.e., perceptions of fit, friendship, group identification) • meaning in work (i.e., job morale; organizational commitment, perceptions of job importance, job/work involvement) • positive self-image congruent with others' perceptions of self • sense of coherence
Psychological capital	• optimism • self-efficacy (i.e., personal and collective efficacy, self-confidence) • resilience, ability to adjust successfully, and hardiness

Initially, Aim 2 of this review was to summarize the well-being performance relationship. However, there were very few studies within the existing ICE literature linking well-being to performance, as it is traditionally described in the broader literature (see Austin & Villanova, 1992). Thus, we expanded consideration to measures reflecting various work attitudes and aspects of psychosocial functioning, which either may proximally relate to or subsequently influence performance. These indicators were categorized according to two broad factors: performance/work attitudes and stress/psychosocial symptomatology. Table 3 depicts our

[2] Other indicators of well-being have been defined as representing hedonic well-being, eudaimonic well-being, and PsyCap. For example, PsyCap includes a fourth component, hope. However, this table includes only those for which empirical evidence exists within studies meeting inclusion criteria.
[3] As reflected above, our position is that well-being is not simply the absence of negative psychosocial qualities and states. However, subjective well-being (i.e., hedonic well-being) operationalized as a function of life satisfaction, positive affect, and (the absence of) negative affect is well-established in the literature (see Diener et al., 1999). Thus, in this instance we considered the absence of negative affect as an indicator of hedonic well-being. Further, it should be noted that the absence of negative affect, in terms of indicating well-being, may be far removed from the absence of, for example, depressive symptomology.

classification of relevant indicators that we were able to identify within included studies into these two factors.

Table 3. *Primary Study Variables Operationalized by Each Performance Factor*[4]

Performance/Work attitudes	• amount of crew-mission control communication • adaptation to ICE environment • attitudes towards ICE experience (i.e., intentions to return for a subsequent mission, motivation to return, whether or not actually did return, willingness to recommend experience to others) • crew cohesion and functioning (includes group conflict, group polarization and alienation from the group) • peer and supervisor dimensional ratings of performance (e.g., leadership, task, interpersonal, overall) • performance-related trait characteristics (i.e., instrumentality, mastery, work orientation, and achievement strivings) • psychomotor task performance • self-reported task performance accuracy and efficiency • team decision-making quality • work attitudes (e.g., role clarity/conflict, job satisfaction)
Stress/Psychosocial symptomatology	• anger/aggression/hostility • anxiety symptoms and sensitivity • confusion • depressive symptoms • fatigue • immature defense mechanisms • perceived stress • poor quality of life • posttraumatic stress disorder symptoms • work pressure

In order for studies to be included in our review satisfying Aim 2 of this report, studies were required to report quantitative evidence regarding the relationship between at least one indicator of well-being (Table 2) and one indicator of performance (Table 3). In total, we identified 24 studies providing such evidence. However, three studies were identified as using the same sample as a study already included, while other studies provided data sufficient for us

[4] As with indicators presented in Table 2, Table 3 reflects only those variables for which evidence exists among the included studies.

to extract multiple unique samples. Thus, the total number of independent samples (k) included for achieving Aim 2 of this review was 31. Appendix A lists each of the included samples, as well as depicts study characteristics (sample size, homogeneity of sample nationality, sample sex, ICE setting, and mission duration) and the indicators of well-being and performance examined.

Aim 3: Temporal Change in Psychosocial Factors. In order to examine temporal effects included studies were required to report variable scores at a minimum of three distinct time points over the duration of an ICE mission. Moreover, included studies reporting temporal effects needed to do so for one of two types of indicators. The first type of indicator was that of well-being (i.e., positive psychosocial functioning). The same broad set of indicators was considered for Aim 3 as was considered as representing hedonic well-being, eudaimonic well-being, or PsyCap for Aim 2. However, the focus of Aim 3 was on positive psychosocial functioning, in general. Thus, we did not further separate indicators by well-being factor for Aim 3 analyses. In addition, there is considerable overlap in the well-being indicators included for Aim 2 (Table 2) and Aim 3. However, some of the indicators employed by studies meeting the inclusion criteria for Aim 2 were not employed by studies meeting the inclusion criteria for Aim 3, and vice versa. Thus, well-being indicators differ slightly across Aim 2 and 3. The second type of indicator was that of stress or psychosocial symptomatology (i.e., negative psychosocial functioning). The same broad set of indicators was considered for Aim 3 as was considered as representing the stress/symptomatology factor for Aim 2 (Table 3). Again, there is considerable overlap in the stress/symptomatology indicators included for Aim 2 and Aim 3, and again, some indicators employed by studies meeting inclusion criteria for one aim were not employed by studies meeting inclusion criteria for the other aim of this review. Thus, the specific indicators employed differ slightly across Aim 2 and Aim 3 analyses. Taken together, for studies to be included they were required to report scores at a minimum of three time points on at least one indicator reflecting either positive (well-being) or negative psychosocial functioning (stress/symptomatology). The variables identified among included studies and included in Aim 3 analyses are reported, by study, in Appendices B and C.

Individual-level and Group-level Change. For Aim 3 we conducted two sets of analyses. Given that studies of ICE missions often include small crews (e.g., ≤ 6 crewmembers) there was an opportunity to combine individual scores across a series of $k = 15$ studies into a single dataset in order to examine temporal effects on psychosocial functioning throughout the duration of ICE missions without losing the variability associated group-level data aggregation. This resulted in a single sample containing data for $N = 67$ individual ICE crewmembers. Appendix B lists each of the included samples for individual-level temporal change analyses, as well as depicts study characteristics (sample size, homogeneity of sample nationality, sample sex, ICE setting, and mission duration) and the positive and negative psychosocial functioning indicators examined.

Although the unique sample characteristics of ICE missions allowed for the examination of individual-level temporal effects, the majority of studies did report temporal effects only at the mean level. Thus, we subsequently analyzed temporal effects at this level by including mean-level data from 32 studies providing a total of $k = 41$ independent samples. Appendix C lists each of the included samples for group-level temporal change analyses, and indicates study characteristics (sample size, homogeneity of sample nationality, sample sex, ICE setting, and mission duration) and the positive and negative psychosocial functioning indicators examined.

Standardizing Response Scales and Time Points. Within the included studies, specific indicators of positive and negative psychosocial functioning were often measured using response scales with differing numbers of response options (e.g., Measure A = 7-point scale; Measure B = 4-point scale), an issue that became even more pronounced when comparing response scales across studies. Thus, it was first necessary to convert the various response scales used into an equivalent scale in order to examine either individual- or group-level temporal effects across indicators and studies. To convert raw scores into scores on an equivalent scale, we used the percentage of maximum possible score (POMP; Cohen, Cohen, Aiken, & West, 1999), which can be used to convert response scales with any number of points into a score on a 0.00-1.00 scale. The formula for standardizing raw scores using POMP is:

$$\text{POMP} = [(\textit{observed} - \textit{min.})/(\textit{max.} - \textit{min.})]$$

where *observed* represents the observed raw score on the original response scale, *min*. represents the minimum possible score on the original scale (e.g., 1-7 scale = "1"), and *max*. represents the maximum possible score on the original scale (e.g., 1-7 scale = "7"). The advantage of POMP scoring is that, while it preserves the relationships between variables, it also increases the interpretability of scores by transforming scores into a percentage. For example, using the formula above with a response scale that ranged from "1" to "7", a score of "1" would be transformed into 0.00 (0%), while a "7" would be transformed into 1.00 (100%).

In addition to the existing variability in the response scales used among positive and negative psychosocial functioning indicators both within and across included studies, there was also variability in the time points at which indicators were measured. This was typically an issue observed across studies, but one that created variability in the number of time points at which indicators were measured, as well as the time, relative to the full mission duration, at which indicators where measured. Three time points was the minimum at which each indicator was required to be measured in order for temporal trends to be appropriately examined. However, many studies included many more measurement time points. Even when studies employed the same number of measurements of relevant variables, the specific time points during the mission at which those variables were measured often differed across studies. Related to this issue was that the duration of ICE missions also differed greatly. Given these issues, we converted the observed measurement time points to reflect the percentage of mission complete, a slight variation of POMP, as it is described above. For example, if an individual reported well-being at Month 1 of a four month mission, then that time point was computed as .25 (or 25%) complete.

Results

Well-being-Performance Relationship Sample Descriptions

Appendix A depicts the characteristics of studies included in this review. With respect to study setting, the vast majority of research examining the well-being-performance relationship has been conducted among crews in analogue settings. The analogue setting most studied among included studies was Antarctic winter stations (k = 14), followed by simulation settings (k = 8), submarines (k = 3), Arctic expeditions (k = 1), and spaceflight (k = 1). Four studies (k = 4) were conducted retrospectively on ICE experiences, two of which were among those who had experienced spaceflight (the remaining two were submariners and Antarctic winterers, respectively). The mean sample size was quite large, M = 75.77 (SD = 122.76), which reflects the strong influence the large number of Antarctic station studies exhibited on mean sample size. Average mission length across samples was approximately seven months, M = 207.28 days (SD = 170.05 days). Seventeen samples consisted exclusively of male crewmembers (k = 17). Eleven included both males and females (k = 11), although the proportion of females within these samples was typically small. Crew sex information was not reported for *k* = 3. Finally, seven studies included multi-national crews (*k* = 7), the nationality of 20 crews was homogeneous (*k* = 20), and nationality information was not reported for *k* = 4. Among homogeneous crews, 15 were American (*k* = 15), two were British (*k* = 2), one was French (*k* = 1), one was Norwegian (*k* = 1), and one was Japanese (*k* =1).

Examining the frequency with which the three well-being factors are represented across these samples, eudaimonic indicators were most often linked to relevant outcomes (*k* = 17), followed by PsyCap indicators (*k* = 12) and hedonic indicators (*k* = 10). In addition, indicators of general well-being appeared in examinations of five of the included independent samples (*k* = 5). Among outcomes, performance/work attitudinal indicators appeared more often (*k* = 24) than did indicators of stress/psychosocial symptomatology (*k* = 12).

To present the systematic review of the well-being-performance relationship we have separated existing evidence into three distinct sections, reflecting each of the three overarching well-being factors: hedonic, eudaimonic, and PsyCap. Within each section we further separate evidence according to the broad outcome factor: performance/work attitudes and stress/psychosocial symptomatology. As described above, a final section reviews the effects of emotional stability, which was not clearly classifiable under any of the three well-being factors and is treated as an indicator of general well-being.

Hedonic Well-being

Hedonic Well-being and Performance and Work Attitude Criteria. The most direct measures of performance available within the included data (i.e., peer and supervisor performance ratings) include evidence from Antarctic winterers on measures of joy in work and positive and negative affect. For example, using retrospective survey methodology, Rose, Fogg, Helmreich, and McFadden (1994) found astronaut-reported joy in work to be positively, but weakly and non-significantly, related to peer ratings of interpersonal (r = .19), technical (r = .12), and leadership abilities (r = .05), as well as supervisor performance ratings (r = .16). In a second study, Grant et al. (2007) used scores on a series of measures completed by individuals prior to wintering-over in Antarctica to predict commanders' post-mission ratings of whether individual crewmembers demonstrated exceptional adaptation during the stay. Among these pre-mission predictors were measures of positive and negative affect, both of which were non-significant. Importantly, the authors observed reductions in both positive and negative affect between pre-mission and midwinter, suggesting that winterers experienced an overall flattening of affect, but also that those reporting smaller reductions in positive affect showed significantly greater adaptation. The same moderating effect, however, was not observed for negative affect scores.

Additional evidence exists in relation to hedonic indicators and less-direct measures of performance. These include: crew cohesion, crew-mission control communication frequency, perceptions of team decision-making quality, and attitudes towards involvement in future ICE experiences. In addition, this evidence implicates a somewhat broader set of hedonic indicators than those described above, including: job satisfaction, perceptions of ingroup positive and negative affect and outgroup positive and negative affect, vigor and perceived fairness. Finally, although hedonic well-being-direct performance evidence is constrained to the Antarctic station setting, evidence examining the relationship between hedonic well-being and a broader set of outcomes indicative of performance comes from Antarctic stations, Arctic expeditions, simulations, and spaceflight.

Three studies have examined the relationship between hedonic indicators with measures reflecting crew cohesion. Sarris and Kirby (2005) found job satisfaction to be significantly related to reported group cohesion (r = .36) among Antarctic winterers. Among a small group (N = 11) of Soviet and American Arctic expeditioners seeking to cross the Bering Strait land bridge, perceived fairness was shown to relate strongly to perceived disruption to group cohesiveness (r = -.83) and interpersonal conflict (r = -.83; Leon, Kanfer, Hoffman, & Dupre, 1994). Finally, in the first of five studies (Study 1) conducted by Krins (2009), the author examined concurrently-measured relationships between ingroup (and outgroup) positive affect and group cohesion and polarization at four different time points during a month-long simulation mission. Reported ingroup positive affect related moderately to reported levels of group cohesion during the first week of the mission (r = .27) and strongly during the remaining weeks of the mission ($r_{\text{week 2}}$ = .76; $r_{\text{week 3}}$ = .91; $r_{\text{week 4}}$ = .99). With respect to the remaining relationships examined, an inconsistent trend was found in individuals' reports of outgroup positive affect and cohesion across time points (r = .00 to .99), and non-significant relationships were found for ingroup and outgroup positive affect with outgroup polarization.

Moving beyond cohesion criteria, three additional studies examined three unique hedonic indicator-performance relationships. First, among ISS astronauts, astronaut-reported vigor related negatively to the amount of communication between ISS crewmembers and mission control (Kanas, Gushin, & Yusupova, 2008). Initially, this finding may seem somewhat unexpected. However, Kanas et al. also found astronaut-reported anxiety, depression, hostility, fatigue, and confusion related positively to communication quantity. This suggests that greater communication reflects more instances of crewmembers displacing psychosocial problems onto controllers, a phenomenon observed by Kanas and colleagues (e.g., Kanas, 2002: Kanas et al., 2001d) in earlier work on space crews. Second, Leon et al. (1994) found perceived fairness to be strongly related to perceptions of team decision making quality (r = .75) among a multinational Arctic expedition crew. Finally, among a cohort of Antarctic winterers, Sarris and Kirby (2005) found job satisfaction to be positively, but weakly, related to individuals' intentions to return (r = .13), willingness to recommend the experience to others (r = .07), and whether individuals actually returned for another Antarctic stay (r = .10).

Hedonic Well-being and Stress and Symptomatology Criteria. Much of the evidence relating hedonic well-being to stress and psychosocial symptomatology comes from the study of positive and negative affect, with outcomes ranging from stress to quality of life and depressive symptoms. For example, the positive affect-stress relationship has been examined in a pair of simulation studies. First, during a month-long simulation (Krins, 2009, Study 1) ingroup and outgroup positive affect significantly related to perceived stress during the second week of the simulation mission (r = -.55 and -.91, respectively). The relationship between ingroup and outgroup positive affect and perceived stress was non-significant during the remaining three weeks. However, at least in the case of the ingroup positive affect-stress relationship, this was more an issue of low statistical power, as effects found during the first and third weeks were also potentially practically significant (r = -.33 and -.44, respectively). Second, among a seven-member crew taking part in a four-month FMARS simulation mission, Bishop et al. (2010) found positive affect to be strongly related to stress when measured at baseline (r = -.59). A far weaker relationship was observed during the first month of the mission (r = -.14), but it increased in magnitude over the remaining months, returning to near baseline levels ($r_{\text{month 2}}$ = -.42; $r_{\text{month 3}}$ = -.33; $r_{\text{month 4}}$ = -.51). A somewhat different trend was found across the mission duration in the relationship between negative affect and stress. That is, while a strong relationship was found at baseline (r = .49) and during the first month of the mission (r = .59), only a weak-to-moderate relationship was found during subsequent months ($r_{month\ 2}$ = .17; $r_{month\ 3}$ = .33; $r_{month\ 4}$ = .15).

Positive and negative affect have also been linked to various symptomatological criteria. Controlling for the effects of a range of other predictors in a multiple regression model, negative affect scores remained significantly (positively) related to poor quality of life (β = .20), among a sample of submariners (Brasher, Dew, Kilminster, & Bridger, 2010). Interestingly, the researchers observed an almost identical effect for positive affect scores in the same analysis (β = .18). Given the large number of predictors included in the regression model, however, this unexpected positive relationship may have resulted from variable suppression and should be interpreted with caution. Contrary to the findings of Brasher et al., positive affect related strongly to the use of immature defense mechanisms (r = -.60), across the duration of the 105-day Mars500 pilot simulation mission (Nicolas et al., 2013). However, no relationship was found between negative affect and the use of such mechanisms (r = -.03), and both positive affect and negative affect showed trivial relationships with depressive symptoms (r = .06 and -.04, respectively).

We identified only a single study linking an indicator of hedonic well-being, beyond that of positive or negative affect, to stress/symptomatology criteria. In a study of Antarctic winterers, Palinkas and Browner (1995) found satisfaction with social support to be significantly related to depressive symptoms at both baseline measurement (r = -.32) and as the end of the mission (r = -.44). In addition, baseline satisfaction with social support was the only significant predictor of depressive symptoms at the end of the mission (r = -.34) in their model, beyond that of baseline depressive symptoms.

Hedonic Well-being Summary. Indicators of hedonic well-being appear to be only weakly but positively related to the most direct measures of performance available in these data (i.e., peer and supervisor ratings of performance), as well as to individuals' own attitudes towards their ICE experiences. Conversely, a stronger relationship has been consistently observed between hedonic well-being and measures of group functioning (e.g., crew cohesion). In fact, this evidence indicates that, relative to other outcomes reviewed, the role of hedonic well-being may be most beneficial to improved group functioning. Most existing ICE research examining the effects of hedonic well-being on stress and symptomatology has employed measures of positive and negative affect. Evidence suggests affect to be moderately related to stress, in general. However, both studies reviewed indicate that positive and negative affect related differently to stress over time, a finding that may be further elaborated on through our analyses as part of the second purpose of this review. Little evidence was found for the effects of negative affect on symptomatology, and multiple studies indicated the positive affect-symptomatology relationship to be complex. As a final note, it should be mentioned that fewer studies included stress/symptomatology outcomes, relative to those employing performance/attitudinal outcomes, and only limited evidence was available beyond that relating outcomes to positive and negative affect.

Eudaimonic Well-being

Eudaimonic Well-being and Performance and Work Attitude Criteria. There exists some evidence linking eudaimonic well-being indicators to direct measures of performance (i.e., subjective performance ratings made by peers and supervisors, objective measures of psychomotor performance), though the evidence does not suggest this relationship to be strong, or even consistently positive. For example, among surveyed astronauts, Rose et al. (1994)

sought to use astronaut-reported work involvement, job involvement, and individual drive in predicting peer and supervisor-rated performance. Individual drive and work involvement scores were shown to be weakly and largely negatively related to peer (i.e., interpersonal, technical, and leadership ability) and supervisor-rated performance (r = -.17 to -.04 and r = -.11 to .01, respectively). Individuals' reported job involvement showed a similar relation with peer ratings of performance (r = -.04 to .02), with a somewhat stronger positive relationship with supervisor performance ratings (r = .16).

Two additional studies further examined the effects of eudaimonic indicators on subjective performance ratings. First, Palinkas et al. (2000) found locus of control to significantly predict peer ratings of leadership ability (β = .10), but not additional peer-rated criteria (task ability, emotional stability, social compatibility, and overall performance). Second, among separate samples of enlisted Navy and civilian personnel wintering in Antarctica, Doll and Gunderson (1969) examined the relationships between individuals' reported job morale and job importance and peer and supervisor performance ratings. Findings showed considerable differences between Naval and civilian personnel. That is, trivial effects were found regarding to the relationships between well-being factors and peer and supervisor performance ratings (r = .01 to .05) among Naval participants, while much stronger effects were found across those same relationships among civilian scientists (r = .27 to.47). This may suggest that differences in either the nature of the work or the work culture between these two groups contributed to the differential effects observed.

An additional study provides evidence of the relationship between eudaimonic well-being and objective performance measures. Rosnet et al. (2000) sought to examine the relationship between self-image and psychomotor performance tasks. One may expect those with positive self-images and who also perceive that others view them positively to possess the greatest eudaimonic well-being. However, the researchers found these individuals actually performed worse than those with incongruent self-images (e.g., negative self-images with perceptions that others view them even more negatively) on a series of psychomotor tasks. In fact, positive self-images congruent with one's perceptions of others' view of him or her were negatively related to cognitive performance scales.

Additional evidence comes from studies employing indirect measures of performance (i.e., crew cohesion/functioning and attitudes towards past ICE experiences). This evidence yields somewhat more positive evidence regarding the effects of eudaimonic well-being. Through a series of studies Krins (2009) provides fairly consistent evidence of the effect of eudaimonic well-being on group functioning. For example, among a simulation crew (Study 1), the researcher observed a strong relationship between concurrently measured group identification and group cohesion throughout all four weeks of a month-long mission (r = .79 to .97). However, concurrent measures of group identification and group polarization were not found to be significantly related at any of the four measurement time points. In a second study conducted by Krins (2009; Study 2), among a crew taking part in a two week simulation at the Mars Desert Research Station, the researcher found that those who showed greater group identification also showed lower scores on perceived alienation—that is, perceptions of the self or others being alienated (r = -.56). However, group identification was unrelated to group functioning (r = -.01). In a final study by Krins (2009; Study 5), which was conducted among winterers at the Concordia station, reports of group identification, but not friendship among crewmembers, were found to be significantly related to reports of cooperation with other crewmembers (r = .68 and r = .59, respectively).

In the study of the Bering Strait land-bridge expedition team, Leon et al. (1994) found altruistic behavior to be strongly negatively related to disruptions in group cohesion (*r* = -.72). In retrospective reports of group cohesion during a past Antarctic stay, Sarris and Kirby (2005) observed comparatively weaker but still practically significant relationships between two measures capturing individuals' perceptions of how well they "fit" with the Antarctic station culture and environment and their perceptions of group cohesion (*r* = .47 and .39).

Researchers have also examined the relationship between eudaimonic indicators of well-being and both self-reported performance and retrospective attitudes towards their ICE experiences. Kanas et al. (2011) tested the effects of increasing the autonomy on self-reported performance accuracy and efficiency among crewmembers of the Mars105 simulation, finding little-to-no change in reports of post-manipulation (Cohen's *d*s ranged from .00 to .11). Three studies (two independent samples) have examined retrospective attitudes towards ICE experiences. Sarris and Kirby (2005) sought to examine the relationship between fit and measures of attitudes toward past ICE experiences. Their findings indicate that scores on both fit measures weakly related to individuals' reported intentions to return (*r* = .03 and .07) as well as reports of whether they actually did return (*r* = .09 and .09). Slightly stronger relationships were found between the two fit measures and individuals' reported willingness to recommend the experience to others (*r* = .22 and *r* = .10). The relationships between cultural styles and work attitude outcomes were further explored among the male respondents within the same data (Sarris & Kirby, 2007). Of particular interest in those analyses was the effect of what the authors described as a "satisfaction culture," which reflects humanistic, affiliative, achievement, and self-actualizing styles. The presence of a satisfaction culture was significantly associated with greater perceptions of role clarity (*r* = .23), job satisfaction (*r* = .54), and intentions to return (*r* =

.26), as well as weaker perceptions of role conflict (*r* = -.31); a non-significant relationship was found with individuals' willingness to recommend the experience to others (*r* = .14).

A final study examining work attitude outcomes comes from van Baarsen (2013) who, among the Mars500 simulation crew, examined the concurrent relationships between multiple eudaimonic indicators (two measures of autonomy, one of perceived challenge, and one of altruism) and motivation to participate in future ICE research. Concurrent measurements were taken at baseline and at five different time points throughout the 520 day simulation. The mean correlation between concurrently-measured motivation to participate in future ICE missions and autonomy (*r* = .66) and altruism (*r* = .29) represent moderate-to-strong positive relationships. However, the mean correlation between motivation to participate in the future and motivation regarding the challenge of the simulation was found to be negative (*r* = -.19).

Eudaimonic Well-being and Stress and Psychosocial Symptomatology Criteria.

Available evidence generally fails to support a strong relationship between stress and eudaimonic well-being. For example, using hierarchical regression, Sandal, Endresen, Vaernes, and Ursin (2003) demonstrated positive instrumentality/expressivity to be negatively, but non-significantly, related to reported stress due to social factors, leadership/workload, homesickness, or isolation during the initial stage of multiple submarine missions. Using the same technique to examine these relationships again during the final stage of the same missions, the researchers showed positive instrumentality/expressivity to be significantly, negatively related to stress due to social factors and isolation, but non-significantly (negatively) related to stress due to leadership/workload and homesickness. Similarly weak evidence has been demonstrated among individuals completing a month-long simulation mission, wherein group identification was found to be unrelated to concurrently-measured perceptions of group stress at each of the four time points the variables were measured (Krins, 2009; Study 1).

Other research suggests somewhat more positive evidence of the eudaimonic well-being-stress relationship, specifically for evidence examining autonomy as a eudaimonic indicator. For example, although Kanas et al. (2010) found greater autonomy among the Mars105 simulation crew to result in reports of substantially greater work pressure (Cohen's $d = 1.06$), further evidence of the autonomy-stress relationship presented by Kanas et al. (2010) based on data from two NASA Extreme Environment Mission Operations (NEEMO) program crews paints a somewhat different picture. The first crew, the NEEMO 12 crew, was provided low levels of autonomy throughout the 12-day mission, while the second crew, the NEEMO 13 crew, was exposed to five days of low autonomy followed by five days of high autonomy. Researchers measured outcomes midway through and at the end of both missions in order to capture the between-group effects of the autonomy manipulation. The researchers found an increase in fatigue among the NEEMO 12 crew (low autonomy) during the second half of the mission, while a reduction in fatigue was observed among the NEEMO 13 crew (high autonomy). Also, while the NEEMO 13 crew showed no increase in reported work pressure during the second half of the mission, a small increase was observed among the NEEMO 12 crew. Taken together, these findings suggest that greater autonomy may promote resistance to fatigue and work pressure. However, it should be noted that the researchers did find that high autonomy crewmembers reported greater confusion than did low autonomy crewmembers during the second half of the mission, likely the result of issues associated with the transition to greater autonomous functioning.

Only one study each has linked eudaimonic well-being to anxiety symptoms and poor quality of life. A study conducted among Japanese winterers found individuals' reported sense of coherence to correlate negatively with their reported anxiety sensitivity (r = -.43; Weiss, Suedfeld, Steel, & Tanaka, 2000). Examining quality of life, Brashner et al. (2010) used regression analyses with submariner data to examine the effects of autonomy and control and organizational commitment. Results indicated a non-significant effect for autonomy and control scores, but a significant effect for organizational commitment scores in predicting poor quality of life (β = .41).

Greater attention has been given to depressive symptoms. Two such studies were conducted among the Mars105 simulation crew. In the first, Nicolas et al. (2013) demonstrated intermediate and mature defense mechanism scores, which reflect the characteristics possessed by emotionally healthy individuals (e.g., altruism, mindfulness, humility, and courage), to only weakly relate to depression scores (r = -.20 and -.06, respectively). In the second study, increased autonomous functioning was shown to lead to a considerable drop in individuals' depression (Cohen's d = .77) and anger (Cohen's d = .63). Among a group of almost 100 winterers, Palinkas and Browner (1995) examined the relationship between locus of control and depressive symptoms, both of which were measured at baseline and the end of the year-long Antarctic stay. Two points are worth noting regarding their findings. First, the relationship between locus of control and depressive symptoms was weak, both when examined concurrently (r_{baseline} = .13 and $r_{\text{mission end}}$ = .14, respectively) and when baseline locus of control scores were used to predict depressive symptoms at the end of the mission (r = .06). Second, the positive directionality across effects suggests that those reporting greater locus of control also reported greater levels of depressive symptoms, a finding counter to what may be expected.

Finally, two studies have examined the relationship between eudaimonic well-being and what might best be described as maladaptive coping strategies. First, Sandal et al. (2003) found positive instrumentality to be significantly negatively related to problem avoidance (r = -.29) among submariners. Second, Nicolas et al. (2013) found intermediate and mature defense mechanism scores differentially related to immature defense mechanism scores among the Mars105 simulation crew, with mature scores being negatively related (r = -.43) and intermediate scores being positively related to immature scores (r = .66).

Eudaimonic Well-being Summary. Eudaimonic well-being showed a fairly weak relationship with direct measures of performance, and a consistently stronger relationship was shown when examining less direct measures of performance, in particular group cohesion and functioning. This is a similar trend in the effects observed for hedonic well-being. However, among the eudaimonic evidence, the weak relationship with direct measures of performance (e.g., both subjective and objective) was consistently shown to be negative, suggesting greater eudaimonic well-being to be associated with worse performance ratings. As mentioned, evidence linking eudaimonic indicators to measures of group cohesion and functioning has been more encouraging regarding the potential positive contributions of these indicators, and evidence regarding the eudaimonic well-being-work attitude relationship suggests these two are moderately related. Evidence has consistently shown eudaimonic well-being to not diminish perceptions of stress. In addition, its effects on depressive symptoms have been mixed. Moderate negative relationships were observed between eudaimonic well-being and additional outcomes: anxiety, poor quality of life, and maladaptive coping strategies. However, there may be too few studies employing these outcomes to draw any strong conclusions.

PsyCap

PsyCap and Performance and Work Attitude Criteria. Two studies have examined PsyCap indicators along with direct measures of performance. First, Doll, Gunderson, and Ryman (1969) examined the predictive validity of a series of selection tests in relation to peer nominated/supervisor rated performance criteria collected at the conclusion of an Antarctic winter-over. Among these were clinical evaluations of individuals' likelihood of successfully adjusting to the conditions associated with wintering-over. The researchers examined the predictive validity of clinical evaluations separately for Navy construction personnel, Navy technical and administration staff, and civilian scientists. Clinical evaluations were ineffective at predicting peer/supervisor rated emotional stability among Navy construction or technical-administrative personnel (6.2% and 0.0%, respectively), but were the strongest predictor of the selection tests among civilian scientists, successfully predicting emotional stability among 31.3% of the sample. Clinical evaluations were ineffective at predicting peer/supervisor task ratings across all three samples (0.0% to 6.2%). Clinical evaluations were also ineffective in predicting peer/supervisor rated social compatibility among Navy technical and administrative personnel, but moderately effective among Navy construction personnel (12.5%) compared to the other predictive tests, and the most effective predictive test among civilian scientists (37.5%). Clinical evaluations were most effective test in predicting peer/supervisor leadership ratings among Navy construction (31.3%) and technical-administrative personnel (68.7%), but not among civilian scientists (0.0%). In examining the effects of individuals' self-reported optimism on peer and supervisor ratings on a series of performance dimensions, Palinkas et al. (2000) found that optimism significantly predicted peer ratings of emotional stability ($\beta = .18$) and social compatibility ($\beta = .14$). Optimism did not significantly predict the remaining three criteria (task ability, leadership, overall performance).

Two additional studies have examined less direct indicators of performance. First, Grant et al. (2007) found highly optimistic winterers to be 2.6 times more likely than less optimistic winterers to show exceptional levels of adaptation to Antarctic station winter-over conditions. Second, personal self-esteem was shown to strongly and consistently relate to concurrently-reported group cohesion throughout the four week simulation mission (r = .76 to .84; Krins, 2009, Study 1). In the same study, the relationship between perceptions of collective self-esteem and group cohesion was less consistent, with correlations ranging from r = .46 to .92 across measurement time points. The relationship between both personal and collective self-esteem and group polarization was inconsistent in both magnitude and directionality across time points.

PsyCap and Stress and Symptomatology Criteria. Five studies have empirically examined the relationship between PsyCap indicators and a range of stress and symptomatology measures. To begin, two studies have examined the relationship between self-esteem and such outcomes. First, evidence from a four-week simulation study showed the relationship between personal and collective self-esteem and perceived stress to be inconsistent across measurement time points both in terms of relationship magnitude and directionality (Krins, 2009, Study 1). Second, a study among Antarctic winterers demonstrated self-confidence to be moderately related to concurrently-measured depressive symptoms at baseline (r = -.34) and the end of the mission (r = -.31), while a slightly weaker relationship was shown between baseline self-confidence scores and depressive symptoms at the end of the year-long mission (r = -.23; Palinkas & Browner, 1995).

The remaining studies linking PsyCap indicators to measures of stress and symptomatology have focused on resilience or the closely-related characteristic of hardiness.

For example, Eid, Johnsen, Saus, and Risberg (2004) linked hardiness with PTSD symptoms and scores on a measure reflecting poor life quality during a week-long disabled submarine mission. Overall hardiness scores were significantly related to the negative impact of the event (r = -.52) and poor quality of life (r = -.47) and non-significantly related to PTSD symptoms (r = -.29). In a separate study, hardiness has also been linked to anxiety sensitivity among Japanese winterers (Weiss et al., 2000), wherein the two were shown to be moderately related (r = -.43). In a final study, one which employed three separate bed rest simulation conditions, Zuckerman, Persky, Link, and Basu (1968) assessed the relationship between self-reported resilience to isolation conditions and anxiety, depression, hostility, and two measures of stress. The strongest effects of resilience to isolation scores on psychosocial symptomatology scores were found among those completing the least extreme bed rest simulation condition, with correlations ranging from r = -.44 (anxiety) to r = -.25 (stress due to the tediousness of the simulation conditions). The next strongest effects were found among those completing the median extreme simulation condition, with correlations ranging from r = -.28 (anxiety) to r = -.05 (hostility). Interestingly, self-reported resilience to isolation was most weakly related to the majority of the psychosocial symptomatology measures, among those completing the most extreme simulation condition, with effects ranging from r = -.02 (hostility) to r = .15 (both stress scales).

Summary. Of the three factors of well-being, the least amount of evidence exists regarding the effects of indicators of PsyCap on measures of performance, work attitudes, stress, and symptomatology. However, among studies that have considered these indicators, the evidence appears to suggest consistently moderate effects of PsyCap indicators across outcomes. Particularly noteworthy is that among available evidence relating each of the three well-being factors to direct measures of performance that which exists for indicators of PsyCap may be the most convincing. Moreover, whereas the evidence regarding both hedonic and eudaimonic well-being has been mixed in relation to measures of stress and/or symptomatology, the literature reviewed examining the effects of indicators of PsyCap has been quite consistently moderate. Taken together, we remind the reader that only a limited amount of evidence exists with respect to the effects of PsyCap indicators in ICE settings, but that which does exist suggests that the further exploration of these effects may prove fruitful to the psychosocial health and performance of individuals in ICE settings.

General Well-being

As described above, we identified a set of studies that examined well-being indicators that could not be clearly identified as hedonic, eudaimonic, or PsyCap. Three such studies provided evidence examining the well-being-performance relationship, each including a measure of emotional stability as a well-being indicator. Two of these studies linked survey data to performance-related outcomes. The first study found emotional stability among astronaut applicants to be significantly related to a number of self-reported trait characteristics that potentially contribute to effective performance (instrumentality, $r = .39$; mastery, $r = .24$; work orientation, $r = .22$; achievement strivings, $r = .20$). Emotional stability was also shown to be negatively related to verbal aggressiveness ($r = -.27$), an indicator of psychosocial symptomatology (Musson, Sandal, & Helreich, 2004). The second study linked astronaut emotional stability scores to actual peer and supervisor ratings, finding emotional stability to be only weakly related to actual performance ratings ($r = .09$ to $.21$; Rose et al., 1994). More encouraging evidence has been shown in the final study we identified as indicative of general well-being, which was conducted among wintering U.S Naval construction (i.e., Seabees), U.S. Naval technical-administrative, and civilian samples (Doll & Gunderson, 1970). The researchers found peer-nominated emotional stability to be consistently and fairly strongly related to peer-nominated task performance (Seabee r = .46; Technical-Administrative r = .53; Civilian r = .47), social compatibility (Seabee r = .56; Technical-Administrative r = .50; Civilian r = .61), leadership skills (Seabee r = .38; Technical-Administrative r = .57; Civilian r = .38), and whether or not individuals would excel in a future Antarctic winter-over (Seabee r = .74; Technical-Administrative r = .74; Civilian r = .67). Unfortunately, given the small number of studies and the range of effects that have been found it may not be appropriate to make any strong conclusions based on these data.

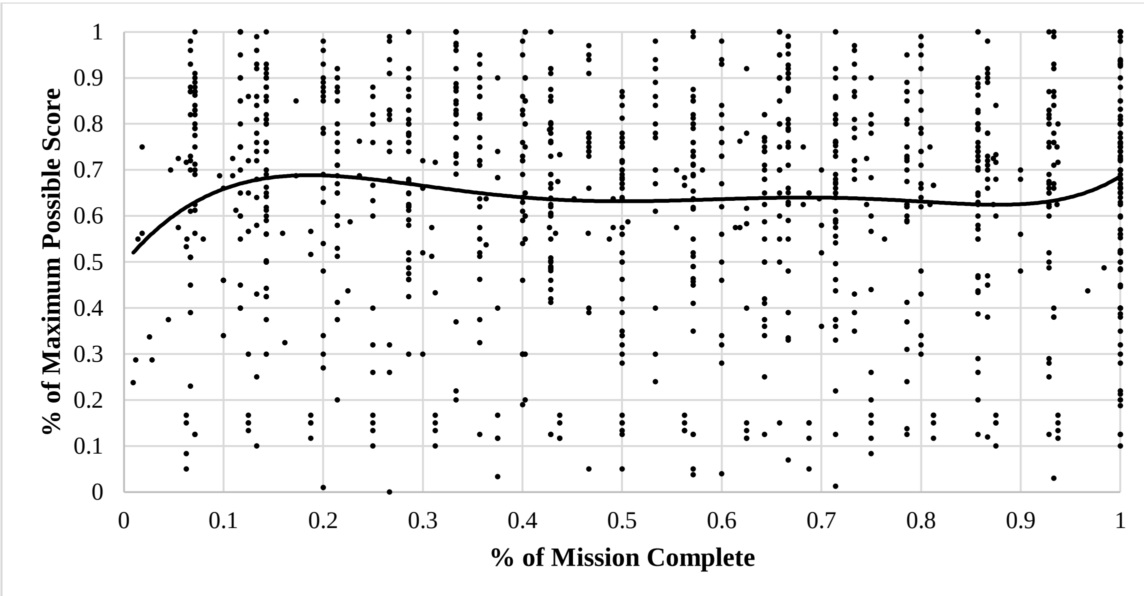
Temporal Change in Psychosocial Factors Sample Descriptions

Individual-level Temporal Change. Appendix B depicts the characteristics of studies included in these analyses. In total, there were 15 studies reporting individual-level temporal change data (k = 15). The majority of these studies were conducted among crews either in simulation settings (k = 7) or during Arctic expeditions (k = 6). Data were also reported from an Antarctic winter-over (k = 1) and a spaceflight (k = 1). As described above, the total sample size was N = 67 across the 15 studies (M = 4.47, SD = 2.90). The average mission length across samples was 142.73 days (SD = 155.83 days). Just over half of the studies examined crews that were exclusively male (k = 8). Five studies examined crews of heterogeneous sex (k = 5), and two studies examined exclusively female crews (k = 2). Just under half of the studied crews were multi-national (k = 7), six were homogeneous (k = 6), and crew nationality was not reported for k =2. Among homogeneous crews, three were American (k = 3), while one crew each was reported to be British (k = 1), Russian (k = 1), and Australian (k = 1).

With regard to the frequency with which temporal trends were reported for positive and negative indicators of psychosocial functioning, 13 of the 15 studies reported evidence regarding positive indicators (30 positive indicators total) and 12 of the 15 studies reported evidence regarding negative psychosocial functioning (20 negative indicators total). The results of these analyses are presented in Figures 1 and 2, respectively. Both figures depict psychosocial functioning (both positive and negative) to be slightly above the middle possible score on response scales from which data were gathered (0.5 to 0.6; or between 50% and 60% of maximum possible score).

Overall, Figure 1 (positive psychosocial functioning, k =13, N = 48) suggests that individuals reported near average positive psychosocial functioning throughout the duration of the mission. However, some trends are worth noting. Least subtle is the trend over the first 15-20% of the mission during which positive psychosocial functioning increases by approximately 20%. From there and for the much of the remainder of the mission mean positive psychosocial functioning appears to regress back towards the beginning level, reaching a low point of just over 60% of the maximum possible score, before the mean score then increases again shortly after 90% of the mission is complete, reaching nearly 70% of the maximum possible score by the end of the mission.

Figure 1. *Individual-level Temporal Change: Indicators of Positive Psychosocial Functioning (Top: scatterplot of data points; Bottom: confidence intervals aggregated at each 5% mission complete interval)*



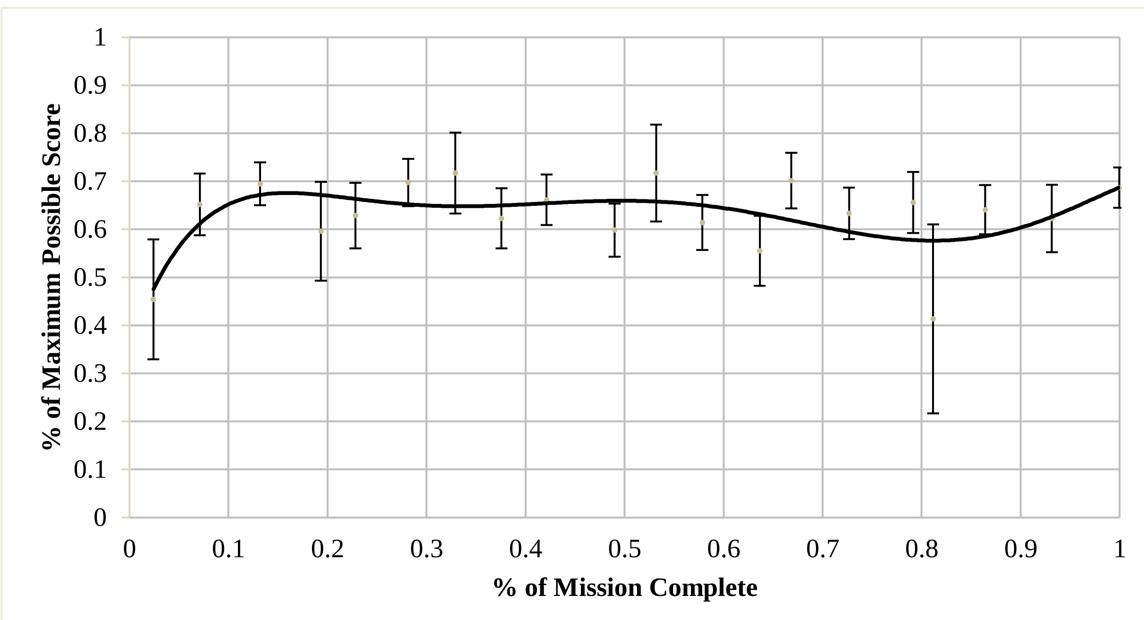
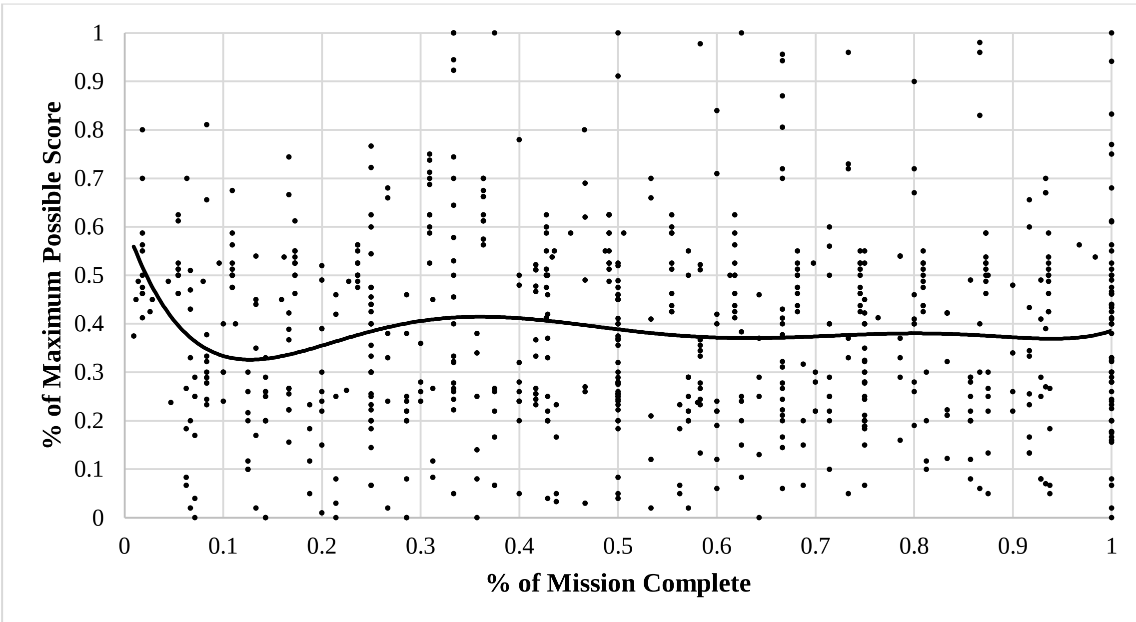


Figure 2. *Individual-level Temporal Change: Indicators of Negative Psychosocial Functioning (Top: scatterplot of data points; Bottom: confidence intervals aggregated at each 5% mission complete interval)*



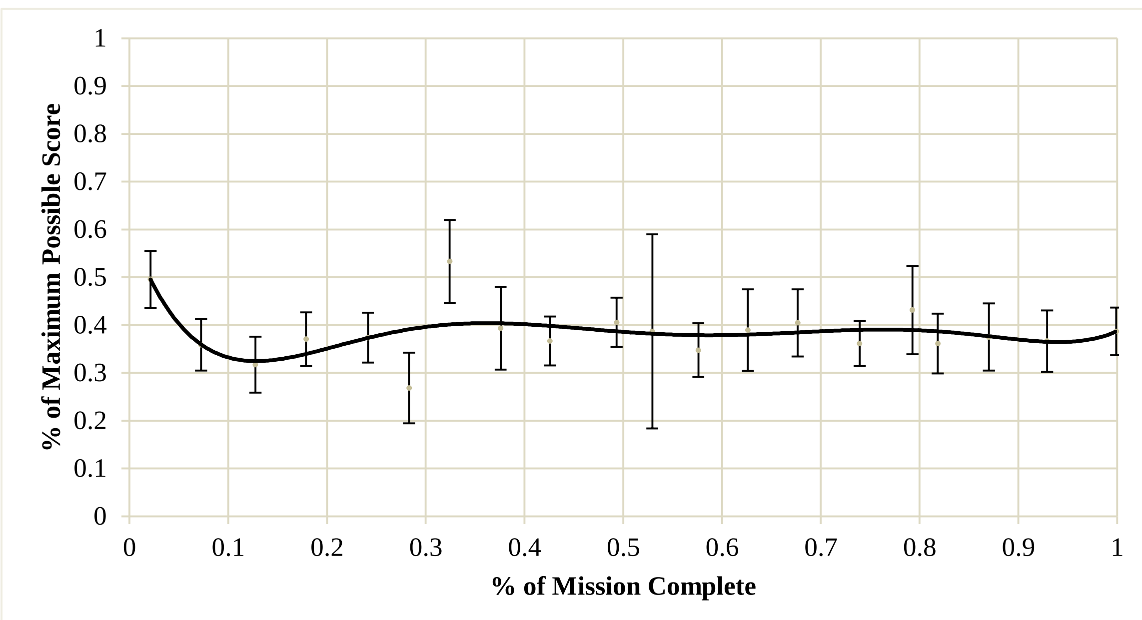


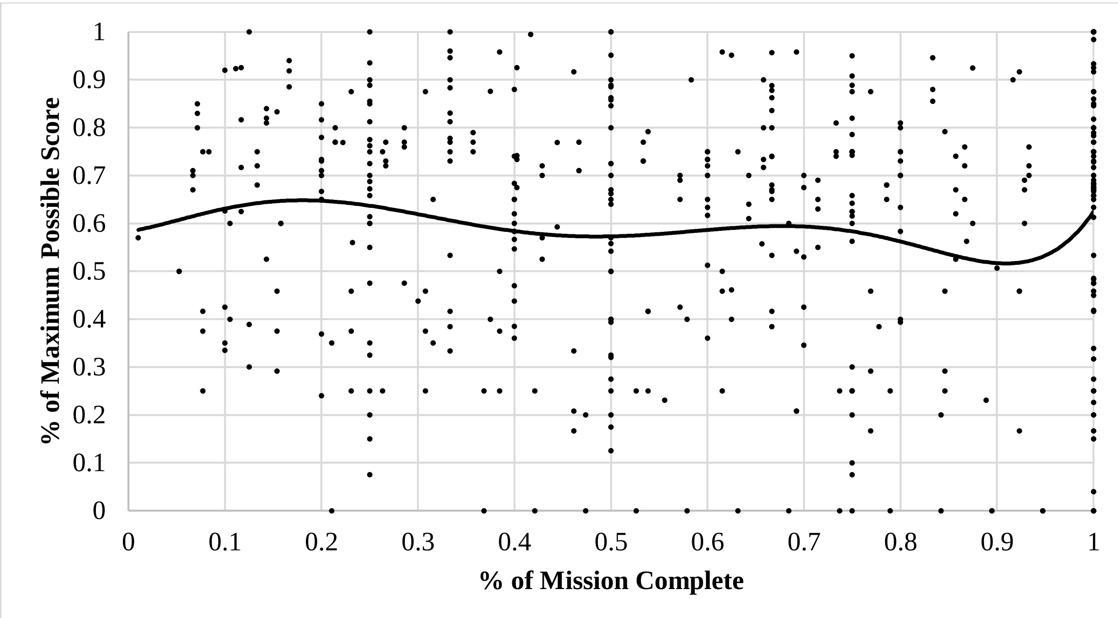
Figure 2 (negative psychosocial functioning, k = 12, N = 52) depicts an almost mirror image of Figure 1, wherein scores on negative functioning drop by approximately 25% of maximum possible by the time just over 10% of the mission is complete. Negative psychosocial functioning then shows a slight increase leveling out at approximately 40% of the maximum score possible. This suggests that individuals reported mid-to-low levels of psychosocial functioning throughout the remainder of the mission.

Group-level Temporal Change. The characteristics of studies included in these analyses are presented in Appendix C. As described above, 32 studies containing 41 independent samples were included in these analyses (k = 41, N = 686). The mean sample size across studies was n = 16.59 (SD = 17.45). The most common study setting was Antarctic stations (k = 17), followed by simulations/hyperbaric chambers (k = 14), and Arctic expeditions (k = 6). An additional two samples each were drawn from submarine/diving (k = 2) and spaceflight settings (k = 2). Average mission length across samples was 174.06 days (SD = 134.60 days). The majority of crews were exclusively male (k = 23). Twelve crews included both males and females (k = 12), one crew was exclusively female (k = 1), and crew sex was not reported for the remaining k = 5. Most crews were nationally homogeneous (k =24), k = 11 crews were multi-national, and crew nationality was not reported for k = 7. Among crews of homogeneous nationality, nine were American (k = 9), five were French (k = 5), three were Russian (k = 3), two were Australian (k = 2), two were British (k = 2), one was Indian (k = 1), and one was Norwegian (k = 1).

Indicators of positive psychosocial functioning were reported among 29 of the 41 samples (52 total positive indicators; N = 421). Indicators of negative psychosocial functioning were reported among 33 of the 41 samples (57 total negative indicators; N = 616). Results of group-level temporal trend analyses are presented in Figures 3 and 4, respectively. Contrary to the almost mirror-image trends in positive and negative psychosocial functioning observed through the individual-level analysis, the group-level trends presented in Figures 3 and 4 suggest positive and negative indicators function somewhat differently. Mean trend levels in Figure 3 suggest that individuals reported above-average positive psychosocial functioning across mission duration. Moreover, the trend remains fairly flat throughout the first 90% of mission duration. At mission start, scores are slightly above average (approximately 60% of the maximum possible score). Positive functioning scores then show a small (approximately 5%) increase over the course of the first 20% of the mission. Mean scores then regress back to initial levels by the half-way point of the mission. At 70% of mission completion positive functioning scores show a downward trend, dropping nearly 10% by the time 90% of mission duration is complete. However, the most acute change in positive psychosocial functioning appears during the final 10% of mission duration during which scores increase by approximately 10%, to the approximate level of positive functioning reported at the beginning of the mission.

Moving next to examine mean trends in negative psychosocial functioning, Figure 4 shows negative psychosocial functioning to be well below average at mission start (approximately 25% of maximum possible), suggesting a general lack of psychosocial problems among crewmembers. However, over the course of the first mission quarter, the mean trend in negative psychosocial functioning scores saw an increase of over 30%. During the second mission quarter, Figure 4 depicts a reduction in negative functioning scores to approximately 50% of that maximally possible (i.e., the middle point on the response scales for which the data were originally reported). From there, mean trends suggest that negative functioning scores remained largely stable throughout the remainder of mission duration.

Figure 3: *Group-level Temporal Change: Indicators of Positive Psychosocial Functioning (Top: scatterplot of data points; Bottom: confidence intervals aggregated at each 5% mission complete interval)*



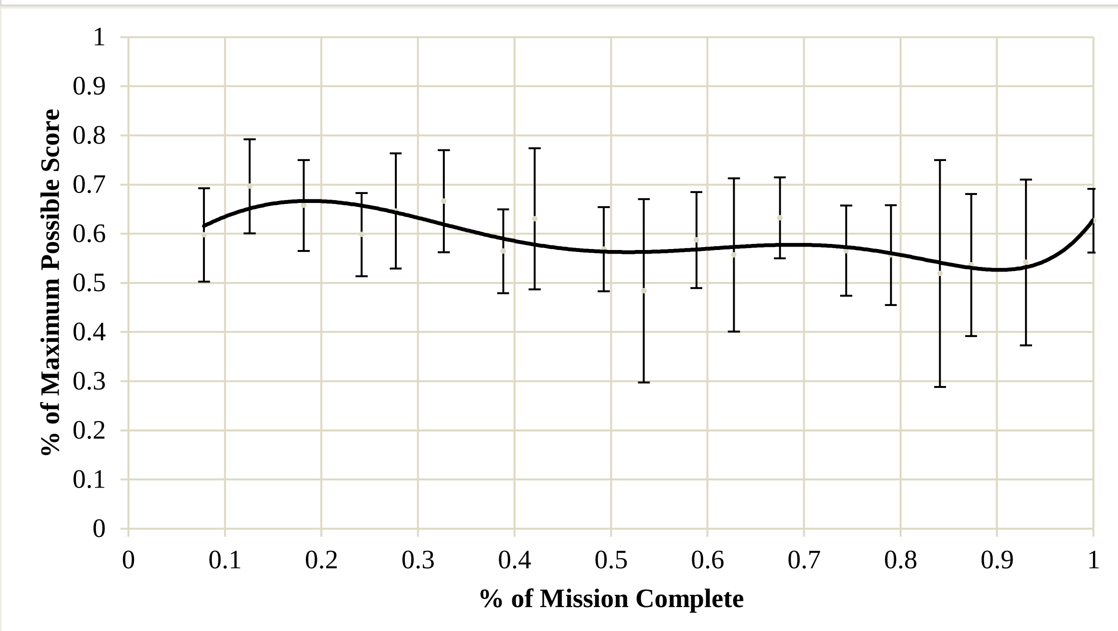
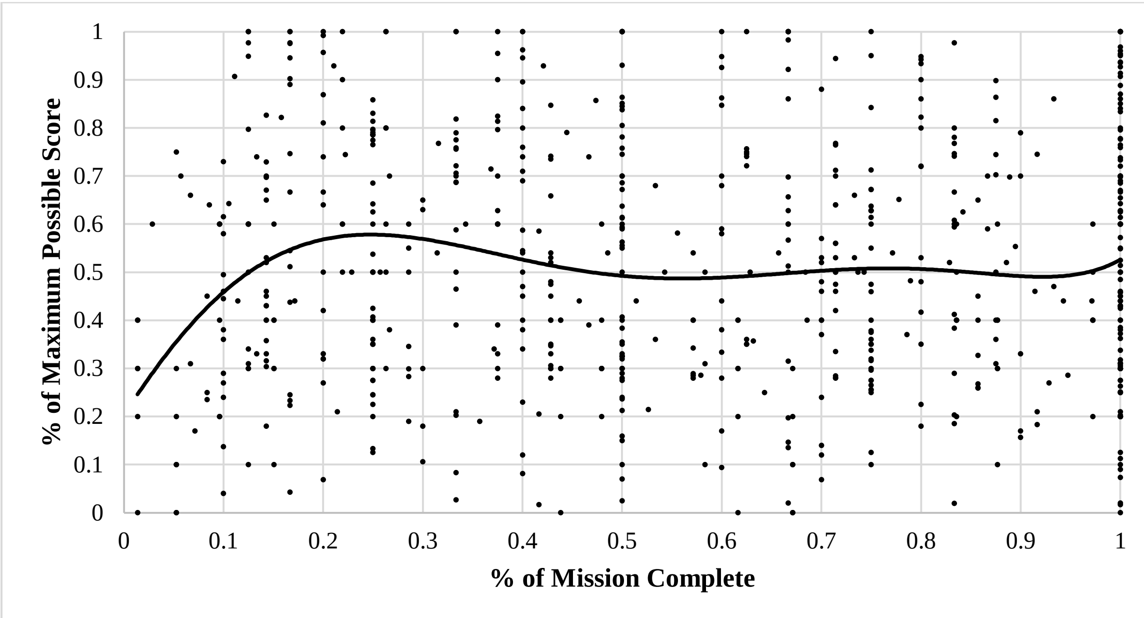
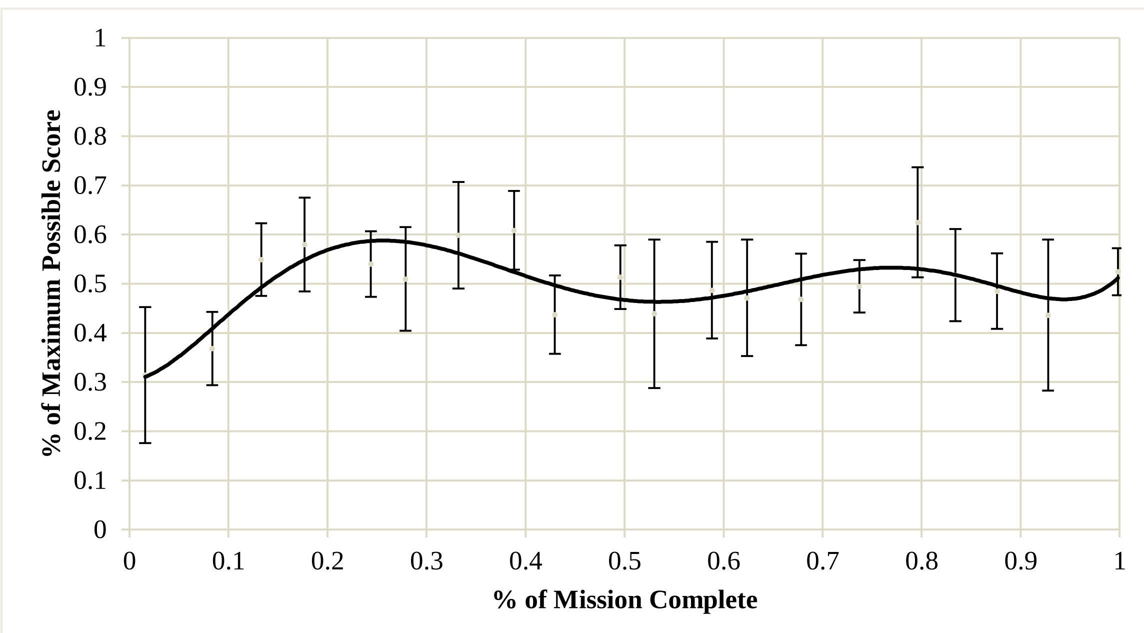


Figure 4: *Group-level Temporal Change: Indicators of Negative Psychosocial Functioning (Top: scatterplot of data points; Bottom: error bars aggregated at each 5% mission complete interval)*





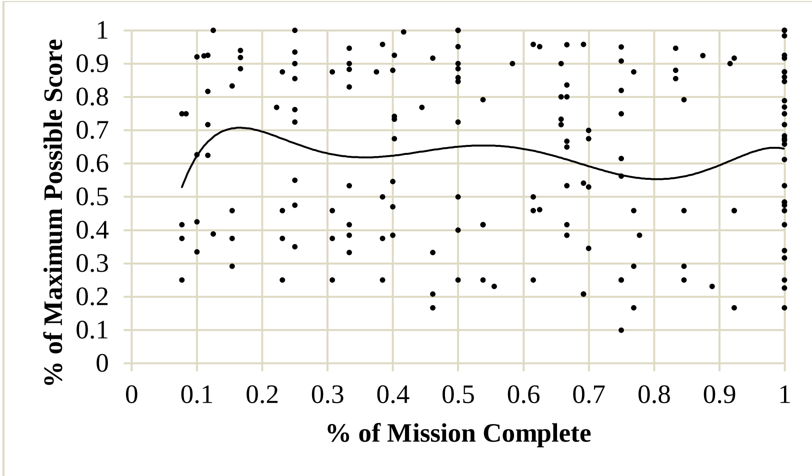
In addition to examining main effect positive and negative psychosocial functioning trends across studies we sought to examine whether study characteristics moderated these trends. The potential moderating variables we examined were: mission duration (short = 1-90 days; intermediate = 91-180 days; long = 181+ days), crew nationality (multinational, homogeneous-

American, homogeneous-other nationality), and crew gender (heterogeneous crew, male crew). Given the small number of studies reporting individual-level temporal trends and concern over spurious findings due to further partitioning these data, we restricted our analyses to group-level data. First, we assessed whether temporal effects differed due to mission duration (Figures 5a and 5b). The temporal trends among crews taking part in long- and short-duration missions were very similar, although the temporal trends observed among crews taking part in intermediate missions differed. With respect to positive psychosocial functioning, intermediate trends appear be inverted in comparison to the trends observed across long- and short-duration missions. Moreover, while the greatest change in positive functioning during long- and short-duration missions can be observed during the earliest stage of the mission (initial 20% of mission duration), the greatest change during intermediate-duration missions can be observed during the final 10% of mission duration. With respect to negative psychosocial functioning, the trend observed for intermediate-duration missions appears to actually be similar to long- and short-duration trends, save an initial 10% decrease in negative psychosocial functioning scores. Importantly, few studies evaluated temporal trends in intermediate-duration missions, which raises concern over whether these trends truly differ from the trends observed across long- and short-duration missions. Given the similar findings among shorter- and longer-duration missions, for which considerably more evidence exists, observed intermediate-duration mission temporal trends may represent spurious effects.

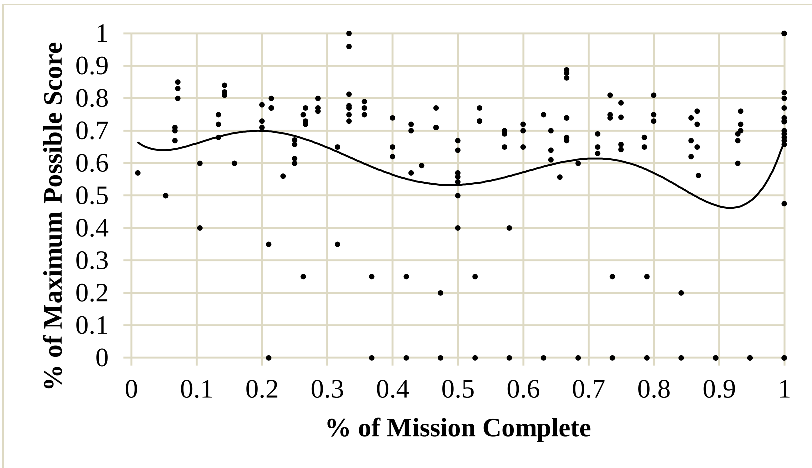
Next we examined crew nationality as a potential moderator. Specifically we conducted separate analyses of temporal effects on positive and negative psychosocial functioning among multi-national crews, homogeneous American crews, and homogeneous crews of other nationalities (Figures 6a and 6b). Considerable variation across crew make-up was observed across these categories. Examining positive psychosocial functioning, the observed trend among multi-national crews was highly similar to the overall temporal trend found across all group-level data reporting positive psychosocial functioning, wherein the greatest fluctuation in scores was a 10-15% increase during the final 10% of mission duration. Among homogeneous American crews Figure 6a shows a similar trend in the fluctuation in scores as was observed among multi-national crews. However, American crew data also demonstrates a clear downward trend in positive psychosocial functioning scores over the course of the mission. Importantly, these trends are based on only three studies (N = 13), which is likely too few upon which to draw any reliable conclusions. Finally, evidence indicates positive psychosocial functioning scores were highest among non-American homogeneous crews (approximately 60-70% of maximum possible responses) and the trend remained remarkably stable across the entirety of mission duration.

Figure 5a. *Group-level Temporal Change: Indicators of Positive Psychosocial Functioning by Mission Duration*

Long-duration (181+ days; *k* = 15, *N* = 241)



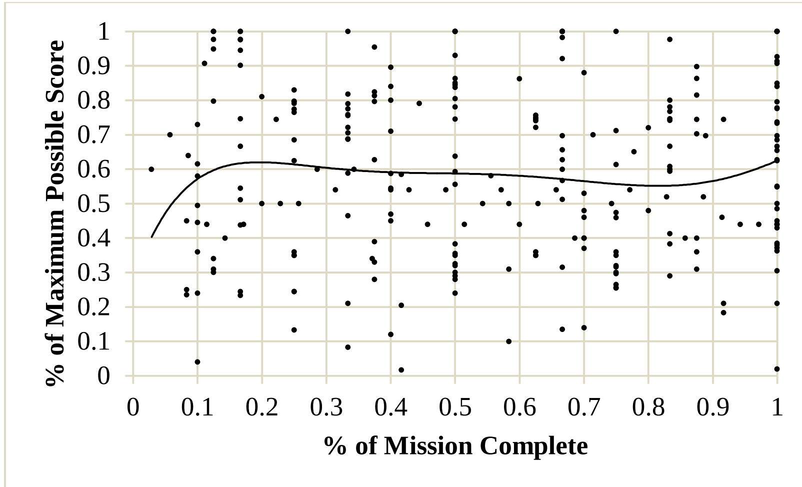
Intermediate-duration (91-180 days; *k* = 6, *N* = 35)



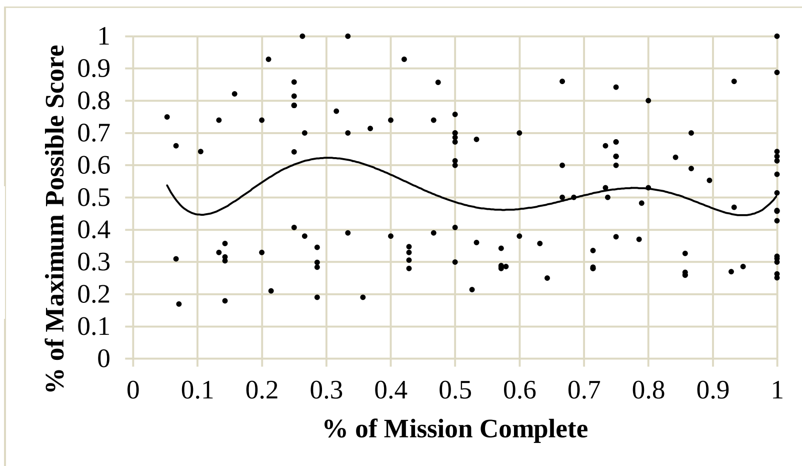
Short-duration (1-90 days; *k* = 8, *N* = 73)

Figure 5b. *Group-level Temporal Change: Indicators of Negative Psychosocial Functioning by Mission Duration*

Long-duration (181+ days; *k* = 12, *N* = 225)



Intermediate-duration (91-180 days; *k* = 5, *N* = 31)



Short-duration (1-90 days; *k* = 14, *N* = 235)

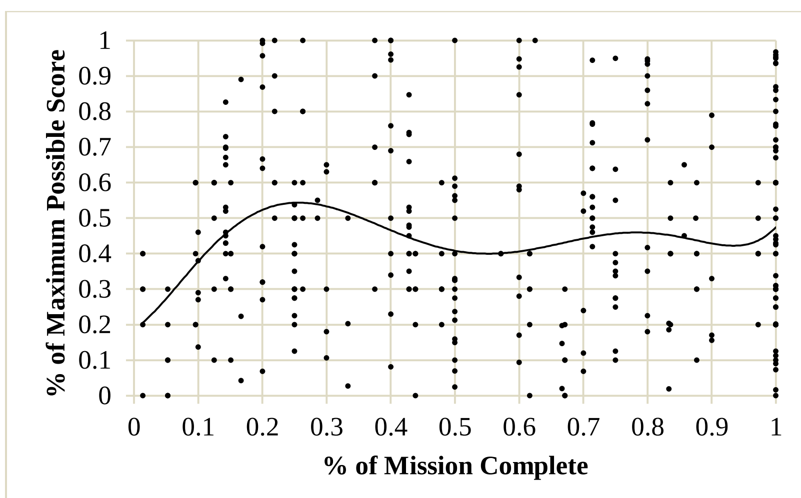
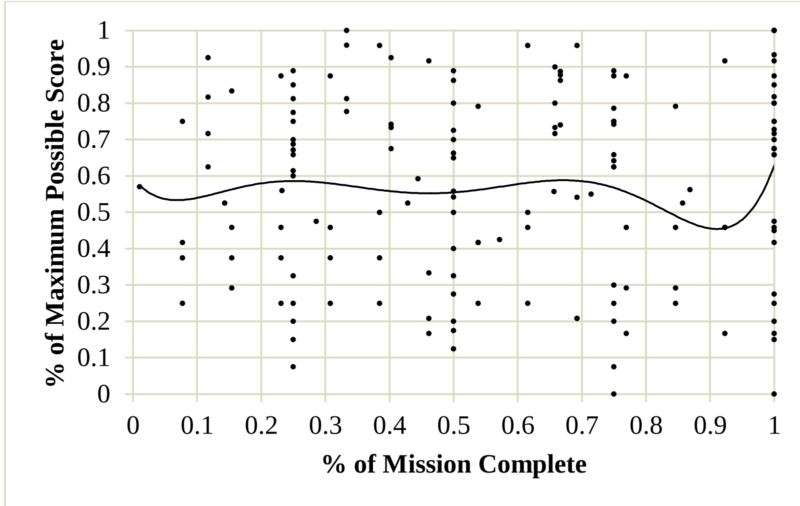
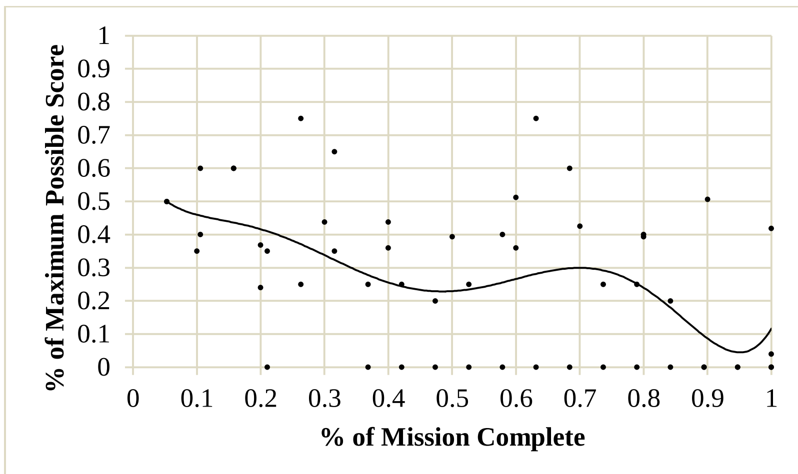


Figure 6a. *Group-level Temporal Change: Indicators of Positive Psychosocial Functioning by Crew Nationality*

Multi-national crew (k = 10, N = 98)



Homogeneous American crew (k = 3, N = 13)



Other nationality homogeneous crew (k = 10, N = 122)

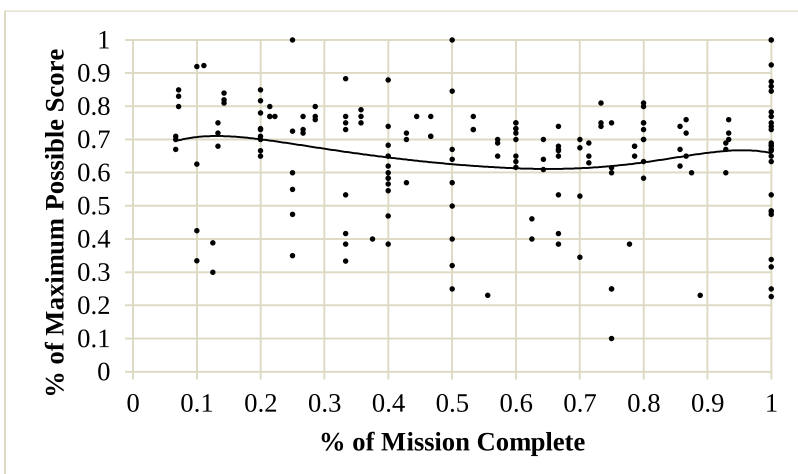
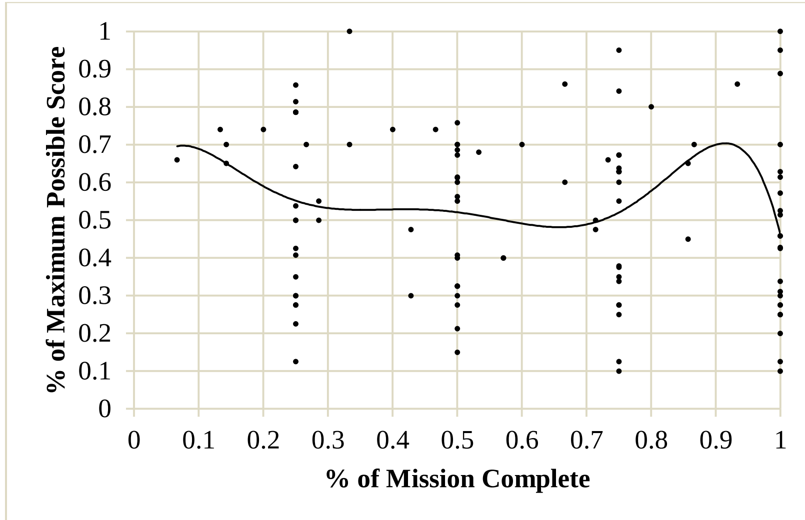
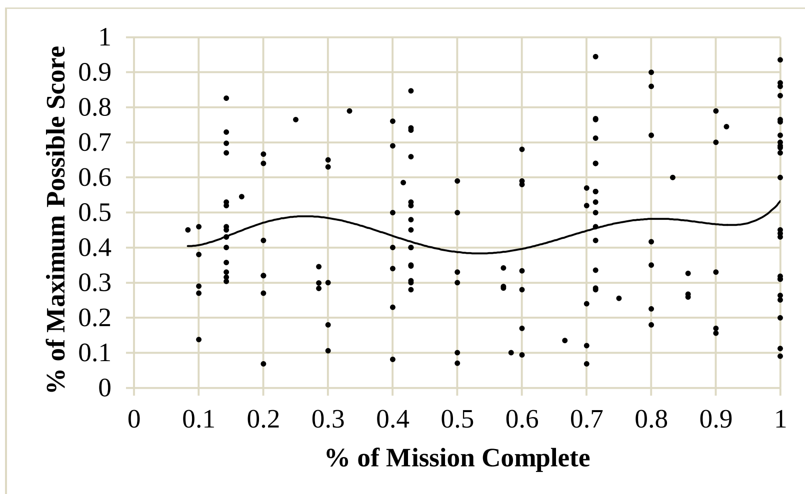


Figure 6b. *Group-level Temporal Change: Indicators of Negative Psychosocial Functioning by Crew Nationality*

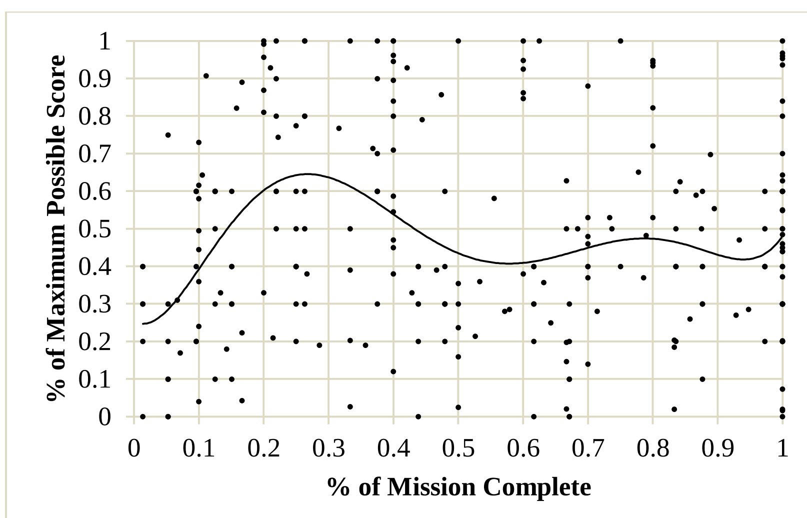
Multi-national crew (k = 8, N = 81)



Homogeneous American crew (k = 8, N = 195)



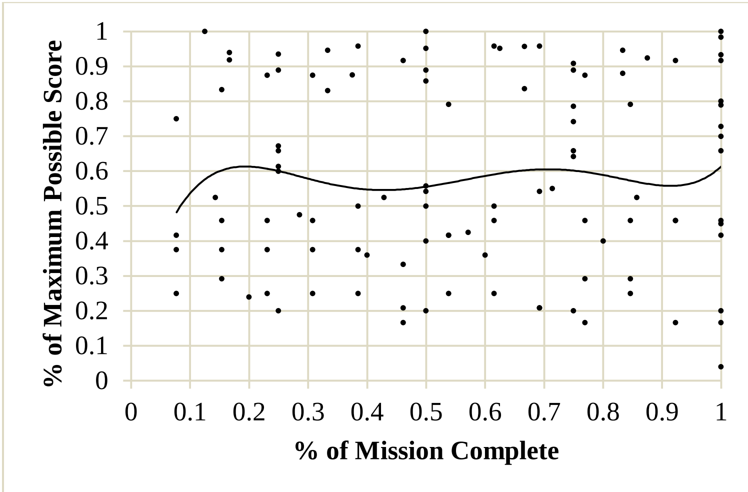
Other nationality homogeneous crew (k = 10, N = 148)



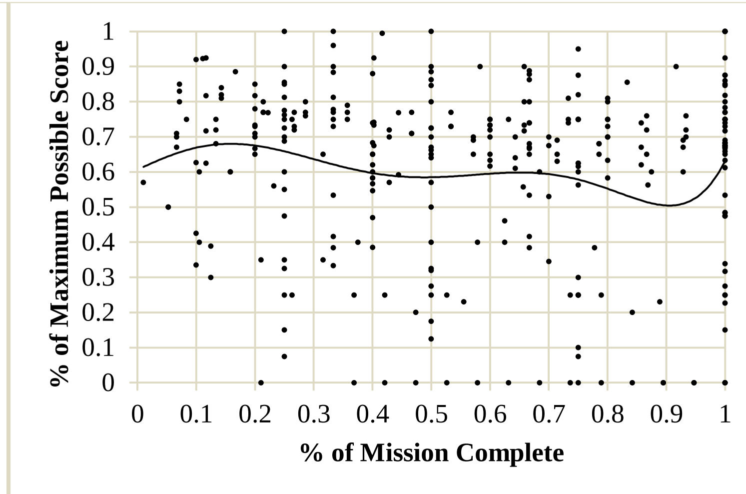
Multi-national crews showed a 20% drop in scores between 10% and 30% of mission completion on negative psychosocial functioning. Additionally, multi-national crews showed a sharp, 20% increase in scores between 70-95% of mission duration, followed by an even sharper 20% decrease during the final 5% of the mission. Despite the downward trend in positive psychosocial functioning scores observed in the underpowered analyses conducted among homogeneous American crews, the trend in negative psychosocial functioning scores among these crews remained largely stable throughout mission duration at an approximately average level (50% of maximum score possible). The lowest negative psychosocial functioning scores at mission outset were observed among non-American homogeneous crews (approximately 25% of maximum score possible), suggesting few psychosocial issues. However, these scores increased dramatically (an approximate 40% increase to 65% of the maximum possible score) prior to 30% mission completion, which then decreased to near average (i.e., 40% maximum possible score) just over halfway through the mission and remained fairly stable thereafter.

The final potential moderator examined was crew gender (multi-gender versus male-only). The temporal trends for positive psychosocial functioning scores associated with multi-gender (k = 9, N =221) and male-only crews (k = 14, N = 146) are highly similar (see Figure 7: top). Conversely, the negative psychosocial functioning scores appear to be higher overall and fluctuate more among multi-gender crews (k = 11, N = 237), as compared to male-only crews (k = 17, N = 312), suggesting that the multi-gender crew context may be a source of increased stress among crewmembers (see Figure 7: bottom). Importantly, the positive psychosocial trend among multi-gender crews appears to be bimodal. That is, individuals appeared to score particularly high or particularly low in multi-gender crews. This finding is discussed in greater depth in the discussion section.

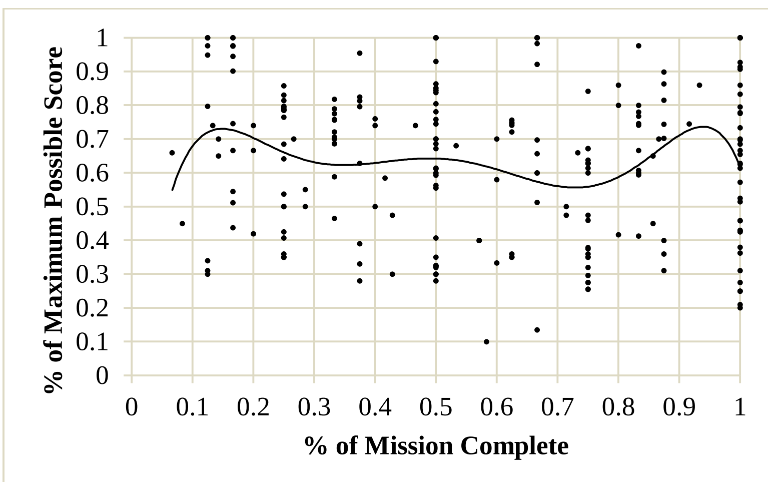
Figure 7. *Group-level Temporal Change as a Function of Crew Gender*



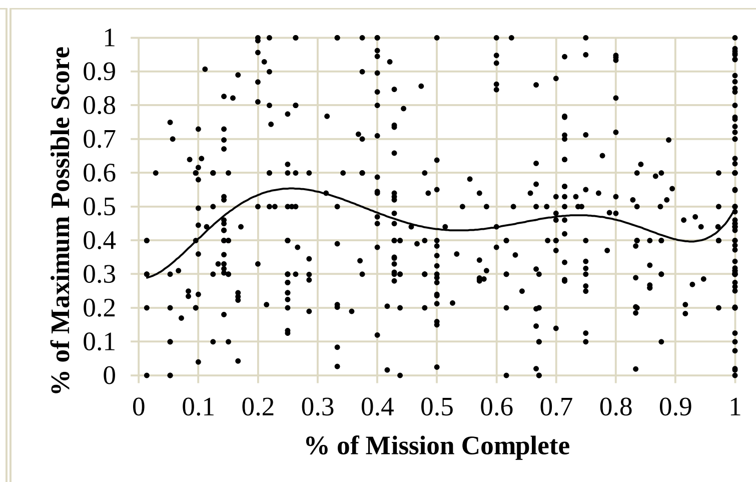
Positive Psychosocial Functioning/Multi-gender crews



Positive Psychosocial Functioning/Male crews



Negative Psychosocial Functioning/Multi-gender crews



Negative Psychosocial Functioning/Male crews

Summary of Individual- and Group-level Temporal Change. With few exceptions, mean trends for both positive and negative psychosocial functioning remained largely stable across individual-level and group-level analyses. The first exception is during the initial stage of missions. For example, individual-level analyses suggest both an increase in positive functioning and a decrease in negative functioning during this period. To a lesser extent, group-level analyses also show an increase in positive functioning during this period. Taken together, these trends may reflect individuals' and crews' initial excitement regarding their missions. Conversely, the group-level analysis of negative functioning shows a sharp increase in negative psychosocial functioning, which suggests crews experienced an initially stressful adjustment period. Moreover, this initial increase receded only slightly indicating crews reported average levels of negative psychosocial functioning throughout the remainder of the mission, rather than returning to their initial level. The second possible exception is during the final phase of mission. This stage was marked by an increase in positive psychosocial functioning in the group-level analysis, and to a lesser extent in the individual-level analysis. This likely reflects crews' and crewmembers' excitement over the prospect of returning to normal, non-ICE environments.

Moderator analyses indicate that both positive and negative psychosocial functioning follows a similar trend across short- and long-duration missions. Somewhat different trends were observed among intermediate-duration missions, but those findings were based on a limited number of studies and a relatively small sample size. Moreover, there exists no theoretical rationale for this difference, suggesting that intermediate-duration trends were spurious. Greater heterogeneity was observed among trends based on crew nationality. Taking this evidence together, it appears that homogeneous crews' functioning may be more stable across mission duration, but evidence also suggests that multi-national crews are not particularly dysfunctional. Finally, somewhat mixed evidence was observed through crew gender trend analyses. First, multi-gender and male-only crews did not appear to differ in temporal effects on positive psychosocial functioning, but it does appear slightly higher and more volatile levels of negative psychosocial functioning was associated with multi-gender crews.

Discussion

The current report meets three specific aims. First, it provides a framework for studying well-being in ICE settings (Aim 1). Second, it summarizes existing primary evidence regarding the relationship between indicators of well-being and measures reflecting or related to performance in ICE settings (Aim 2). Third, it summarizes evidence regarding the manner in which indicators of positive and negative psychosocial functioning have been observed to change over the course of ICE missions (Aim 3).

Well-being-Performance Relationship (Aim 2)

Although there has been an increased focus on well-being in the ICE literature in recent decades (e.g., Mocellin & Suedfeld, 1991; Palinkas & Suedfeld, 2008; Suedfeld & Steel, 2000), the amount of research examining any specific relationship (e.g., between positive affect and task performance) remains limited. Thus, we presented a theoretically-consistent way of classifying well-being indicators and performance-related measures into a parsimonious framework and provided an initial qualitative review of existing evidence linking hedonic well-being, eudaimonic well-being, and PsyCap with measures of performance/work attitudes and stress and psychosocial symptomatology.

The evidence included in this review suggests that eudaimonic well-being indicators have been those most commonly studied in relation to performance-related measures in the empirical

ICE literature. However, eudaimonic indicators have typically not had the strongest effects on performance-related outcomes. For example, PsyCap indicators showed the strongest and most consistent positive relationship with direct measures of performance (i.e., objective and subjective measures of task performance). Weaker relationships were consistently found between indicators of hedonic (positive) and eudaimonic well-being (negative) and direct measures of performance. In interpreting these findings, it is important for readers to consider that direct measures of performance have been almost completely absent from research in ICE settings beyond that of Antarctic stations. This may be due to the comparatively large crews that take part in these missions, and their organizations' need to use formal performance appraisal systems as a means of effectively managing performance in these larger units. Additionally, multiple reviews have sought to compare and contrast the characteristics of long-duration spaceflight and various analogue settings (e.g., Bishop, 2004; Manzey, 2004), and although winter-overs typically represent one of the most similar analogues to long-duration spaceflight in terms of mission duration, it could also be argued that Antarctic wintering crews are less confined and dependent upon each other than long-duration spaceflight crews. Introducing peer or leader appraisals of performance in small and highly co-dependent crews may actually be deleterious to individual and crew performance, as well as interpersonal relations and trust. Taken together, it may be difficult for future research to obtain direct evidence of performance, short of establishing unobtrusive and objective measures.

With this in mind, we sought to expand our criteria to indirect measures of performance. Examining indirect measures of performance, we found that indicators of all three factors showed positive relationships with individuals' perceptions of group functioning and cohesion. Moreover, this evidence appears to be robust across a wide range of specific well-being indicators and ICE settings. Some evidence also exists regarding the indicators of hedonic and eudaimonic well-being and individuals' retrospective perceptions of their ICE experiences. Among this evidence, well-being indicators have been consistently (positively) related to retrospective "attitude" criteria. However, the magnitude of these effects has been relatively weak. Taken together, existing research is fairly definitive in demonstrating the importance of the relationship between well-being and broader group functioning, as compared to evidence linking well-being to direct measures of performance. As such, this subgroup of performance/work attitude outcomes may be those to which well-being holds the greatest utility.

In this report, we also examined the relationship between indicators of well-being and measures of stress and symptomatology. The most consistent evidence relating well-being to stress has come from positive affect (hedonic well-being), while the evidence relating stress to eudaimonic well-being and PsyCap indicators has been inconsistent, but generally weak. Much of the evidence examining hedonic indicators and symptomatology has come through the use of positive and (the absence of) negative affect, with findings typically being weak. However, one study employing another indicator of hedonic well-being, satisfaction with social support (Palinkas & Browner, 1995), showed a moderate relationship with subsequently-measured depression. A range of eudaimonic well-being indicators have been linked to symptomatology, and the evidence generally suggests that these indicators may have practical utility with regard to a range of symptoms. We identified only four studies linking PsyCap indicators to symptomatology measures. Among these, the strongest evidence was found for hardiness and self-efficacy, while inconsistent evidence was found for resilience.

In sum, the reviewed evidence suggests each of the three facets of well-being to differentially relate to performance-related criteria. Based on our findings we conclude that

PsyCap is the factor that has been most strongly related to direct measures of performance, though all three factors have been consistently related to group cohesion and functioning. Hedonic well-being, and more specifically positive affect, has been most consistently (negatively) related to perceptions of stress. The strongest relationships with symptomatology outcomes were observed across a number of eudaimonic indicators. Less robust evidence was found across hedonic and PsyCap indicators in relation to symptomatology outcomes. However, we found evidence of negative relationships with symptomatology for satisfaction with social support (hedonic), self-efficacy (PsyCap), and hardiness (PsyCap).

There are multiple considerations the reader must make when interpreting the evidence reviewed in this report. First, much of the evidence reviewed here represents concurrently-measured well-being and performance-related variables. Therefore, the reviewed evidence cannot be interpreted as causal in nature. Effective performance, positive interpersonal relationships, and the absence of stress may be just as likely to influence individuals' well-being, as well-being is to influence these factors. In fact, the relationship is likely cyclical (e.g. Fredrickson, 2003). Nonetheless, the link between well-being and performance-related measures remains important in understanding how to optimize both, while minimizing the likelihood and magnitude of negative psychosocial functioning among individual crewmembers. Related, it is clear from the findings reviewed here that those based on concurrently-measured, same-source data consistently showed stronger effects than did evidence based on multi-source and/or prospective data. The problems associated with common method bias have been well-documented (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003), and readers must strongly consider research design when interpreting the practical significance of primary evidence reviewed here.

Second, although a reasonable amount of evidence exists regarding the well-being-performance relationship, the research on relationships between specific indicators of well-being and specific indicators of performance is quite limited. This creates difficulty in attempting to conduct summary analyses. Integrating the wide range of well-being and performance indicators into a more parsimonious set of well-being factors and performance-relevant categories provides greater opportunity to summarize existing evidence and draw general conclusions. However, it is also important to note that the conclusions presented here are just that, general. There were a number of instances within this review in which specific well-being indicators representing any one broader factor showed differential relationships with particular performance-relevant categories of outcomes. For example, among eudaimonic well-being indicators, evidence indicates autonomy to be strongly (negatively) related to depressive symptoms (Nicolas et al., 2013), but locus of control to be weakly (positively) related to depressive symptoms (Palinkas & Browner, 1995). This highlights the fact that, although many of the well-being constructs included in this report may show commonality and be expected to covary to some extent, theory suggests that these indicators are also somewhat unique (e.g., see, for example, Crawford & Henry, 2004 for a discussion of the theoretical conceptualization of positive and negative affect as related but different constructs). Moreover, there are also instances in which multiple studies evidencing the effects of a specific well-being indicator showed different relationships across performance-relevant outcomes, even those categorized under the same general performance factor. For example, job satisfaction was significantly and moderately related to group cohesion but only weakly and non-significantly to intentions to return for a subsequent ICE mission (Sarris & Kirby, 2005). Making this issue even more complex is the fact that study characteristics (e.g., crew size, ICE setting, mission duration) varied greatly across the studies reviewed. This likely further affected the magnitude (and possibly directionality) of the well-being-performance relationships observed across primary studies. However, given that few specific well-being-performance relationships (e.g., life satisfaction-depression, optimism-stress) have been assessed in multiple studies, the extent to which study characteristics influenced observed effects remains largely unknown.

The conclusions drawn from this review provide a foundation for which future research can develop more targeted studies regarding relationships between specific well-being indicators and performance criteria. As described above, there was often only a single study (and a single performance or symptomatological criterion) that examined the effects of any one of these indicators, and it is unclear the extent to which the effects of these well-being indicators possess criterion-related validity across a broader range of relevant criteria. Thus, future research should aim to determine which well-being indicators demonstrate the most robust effects across performance and psychosocial health criteria. Developing a greater understanding of the extent to which specific indicators of well-being predict a wider range of performance and symptomatological criteria will be important in establishing the validity of such measures for use in long-duration spaceflight selection and training procedures.

Moreover, additional research is needed to examine the effects of multiple indicators simultaneously in order to further identify which indicators are most effective in predicting specific outcomes deemed most vital to long-duration mission success (e.g., task performance, group functioning, stress resistance). For example, a range of eudaimonic, hedonic, and PsyCap indicators have been shown to positively affect group functioning and cohesion, but it remains unclear from the existing evidence which indicators most effectively predict these outcomes when tested simultaneously. Based on the present evidence, it appears that, broadly, PsyCap indicators may have the greatest utility in predicting performance and eudaimonic well-being indicators in predicting symptoms. However, beyond the effects of positive affect on perceived stress, there is little definitive evidence regarding which specific well-being indicators (e.g., resilience, autonomy) best predict specific outcomes (e.g., task performance, depressive symptoms). Such research has important implications for predictive efficiency in selection, training, and monitoring procedures. For selection-related efforts, there exists a considerable restriction of range among astronaut candidates, as most candidates are highly qualified from a knowledge, skills, and abilities standpoint. Indicators of psychosocial health may provide a viable means for differentiating these individuals, especially in the context of long-duration missions in which resistance to stress may be as important to mission success as will be technical proficiency. Given the high stakes of such selection decisions, however, it is vitally important that indicators of psychosocial health chosen to be included as part of selection are actually those which will best predict effective and healthy functioning among crewmembers.

Consequently, such research will inform future efforts toward the development of any well-being measures created specifically for NASA's purposes. That is, identifying which well-being indicators have the most robust effects across outcomes, as well as which provide the greatest incremental validity in predicting specific outcomes deemed as most crucial to mission success, will guide decisions regarding which indicators are most important to capture in order for such a scale to be effective.

This review provides a foundation for identifying these more specific indicators. For example, PsyCap indicators demonstrated arguably the most consistent relationship across categories of performance-relevant outcomes. This is not particularly surprising given the psychological, social, and environmental stressors that have been associated with ICE missions (e.g., Geuna et al., 1996) and the research demonstrating the protective power of these constructs against maladaptive stress responses in high-risk and extreme contexts (e.g., Bartone, 2006; Lamp, 2013; Lester et al., 2011a). However, PsyCap indicators have been those least studied within the context of ICE environments. It remains unclear which PsyCap indicators have the strongest effects with various relevant outcomes, as well as whether the whole of these related constructs is greater than the sum of their parts. Thus, an important direction for future research may be to further explore the potential preventive and salutogenic effects of resilience and resilience-based protective factors during long-duration ICE missions.

In addition, this review identified a number of eudaimonic indicators, as well as one or more hedonic and PsyCap indicators that related to a wide range of symptomatology criteria. However, given the lack of consistency with which well-being and symptomatological measures have been employed, this literature is currently underdeveloped. An important future research need is surely to better understand these various relationships. As a more immediate focus, future research may seek to identify the symptomatological criteria most crucial to long-duration mission success (e.g., aggression/hostility, depression) and assess the incremental validity of indicators identified through this review as potentially most relevant (e.g., altruism, instrumentality, mindfulness, resilience, satisfaction with social support, self-efficacy) in predicting these criteria.

Finally, the emphasis of the present review was on ICE crewmembers, an emphasis that is reflective of the broader ICE literature (for exceptions see Kanas, 2004; Kanas et al., 2002; Kanas, Weiss, & Marmar, 1996; Leon & Scheib, 2007). However, it has been pointed out that mission control personnel and crewmembers' families also play an important role in the well-being and performance of crewmembers (Brady, 2005; Buckley & Mortimer, 2004), and the deleterious effects of a lack of well-being and positive relations has been documented within the empirical ICE literature (e.g., Bergan et al., 1993; Kanas et al., 1996). This suggests that greater well-being among these secondary units may well have positive effects on the performance and psychosocial functioning of crews. Support for such a relationship can be seen in the military psychology literature, where interventions have been developed targeting not just soldiers, but also those individuals central in soldiers' lives, in attempts to maximize these individuals' contribution to soldiers' health and performance (e.g., Park, 2011; Prevail Health Solutions, 2011). Thus, future research should aim to expand its focus to the effects of maintaining and enhancing well-being among mission controllers on crew-mission control communication effectiveness and crewmember performance, as well as the effects of crewmember family well-being on crewmembers' psychosocial functioning and performance.

Temporal Effects on Well-being

Overall, the summary evidence presented here does not support the third-quarter phenomenon, which has been commonly theorized to exist during ICE missions (Bechtel & Berning, 1991). Instead, the meta-analytic evidence reported here strongly suggests that the critical points of fluctuation across the broad categories of positive and negative psychosocial functioning appear at the outset and final phase of missions. As described above, research has argued for a number of trends in addition to the third-quarter phenomenon, including the trend observed here (see Bergan et al., 1993; see also Mocellin & Suedfeld, 1991; and Sandal, 2001). One plausible explanation for the trends is that both positive and negative indicators of "arousal" are highest at the beginning and end points of the mission. For example, ICE researchers have commonly discussed the presence of a "novelty" effect among crewmembers during the initial acclimation phase (e.g., Kanas et al., 2001a), wherein crewmembers experience a mix of excitement and anxiety, as well as increased stress while initially adapting to ICE environments. When nearing mission completion, crewmembers may experience similarly mixed emotions reflecting increased arousal as they prepare to return and readjust to normal life, while also potentially experiencing negative emotions due to the understanding that they will be leaving the environment and individuals to which they have grown accustomed.

One shortcoming of the present analyses and the subsequent conclusions that can be drawn from them is the broad nature with which the temporal trends of variables could be assessed. That is, the relative lack of continuity in the specific indicators used in examining temporal trends in the ICE literature made partitioning these indicators into specific categories of psychosocial functioning unfeasible; instead we used the very broad categories of positive and negative aspects of psychosocial functioning. The lack of consensus in the ICE literature over the temporal changes experienced by ICE crewmembers may well be a function of the more specific psychosocial indicators being tested. That is, negative indicators of "arousal" and "depression" may show different trends. For example, Bhargava et al. (2000) showed reports of sleep difficulty to peak relatively early in an Antarctic winter-over and subsequently recede, suggesting that individuals experienced initial difficulty adjusting to their ICE environment, while dissatisfaction slowly grew and peaked during the third quarter of the mission before receding during the final phase. Using alternative frameworks in conceptualizing psychosocial health indicators, such as that based on arousal/depression, may provide greater continuity to existing theories of temporal change across ICE missions. Further, better understanding how time differentially affects more specific aspects of psychosocial health may also have important implications for determining the specific countermeasures most important during different phases of long-duration missions.

The moderator analyses presented above provide additional and potentially important information. First, despite the somewhat divergent trends associated with intermediate-duration missions, the meta-analytic evidence presented in this report suggests striking consistency in the temporal trends in both positive and negative psychosocial functioning across short- and long-duration missions. The demonstration of highly similar temporal effects among crews taking part in 1-90 day and 181+ day (typically ranging to upwards of one year in duration) missions alike has potentially important practical implications because it suggests that similar effects may appear in even longer-duration missions (two-plus years) for which evidence is either non-existent or highly limited. From a theoretical standpoint, these findings also suggest that existing explanations of temporal change (e.g., early/final phase arousal) likely generalize to missions of a wide range of durations.

Second, moderator analyses controlling for crew characteristics (nationality and gender) indicate potential differences between homogeneous and heterogeneous crews. Existing theory from the broader literature suggests that homogeneous teams tend to function better interpersonally (Haleblian & Finkelstein, 1993; Jackson et al., 1991). This phenomenon is reflected in the temporal trends reported here, and existing primary research has documented problems associated with heterogeneous crews (e.g., Inoue et al., 2004). This presents a particularly important issue, given that long-duration spaceflights will most likely involve multi-national initiatives and crews will likely be heterogeneous in both cultural and gender make up. However, multiple points warrant further mention. First, this evidence does not suggest heterogeneous crews have been particularly dysfunctional, and research within the ICE literature has described the possible greater importance of crew personality characteristics to long-duration mission success (Bishop, 2004; Palinkas et al., 2001). Second, analyses depict that while some within multi-gender crews showed relatively low scores on positive psychosocial functioning throughout mission duration, others appeared to thrive in these social contexts, with high positive functioning scores throughout mission duration. ICE researchers have provided recommendations for maximizing functioning in gender-heterogeneous ICE crews (Rosnet, Jurion, Cazes, & Bachelard, 2004), but an important future research need will be to identify and possibly select on the characteristics possessed by those who respond positively to heterogeneous crew make-up. More generally, crew compatibility should be taken into consideration in order to optimize psychosocial functioning throughout mission duration.

It should be noted that many of the findings stemming from the moderator analyses were based on relatively small numbers of studies and primary sample sizes. Moderator analyses were not conducted on the individual-level data available, given a clear lack of power. In addition, we cannot be sure the reported temporal trends associated with many of the group-level moderator categories reflect stable estimates. For example, the confidence bands reported for the main effect temporal trends among positive and negative psychosocial functioning scores are not reported for moderator analyses. This decision was made to aid readers in comparing and contrasting the trends observed across multiple categories within each moderator analysis. However, in all cases the unreported confidence bands were very wide, given the data combined in the main effect analyses were partitioned into 2-3 categories for each moderator analysis. Thus, moderator analyses should be interpreted with considerable caution.

Finally, analyses reported here were constrained to temporal changes during ICE missions. A considerable amount of research in the military psychology literature suggests that pre- and post-mission temporal trends are also important to comprehensively understanding individuals' psychosocial health in extreme environments (e.g., Bliese et al., 2007). As such, future research should expand the time frame with which psychosocial health indicators are monitored. Doing so may prove important in predicting crewmembers ability to initially adapt to ICE environments. In addition, pre-mission monitoring may help identify the need for more careful monitoring of specific crewmembers and potentially improve NASA's ability to identify specific crewmember's countermeasure needs throughout the mission phases.

With regard to expanding measurement time points to the post-mission phase, very high rates of former ICE crewmembers surveyed have reported intending not to return for subsequent missions (e.g., Sarris & Kirby, 2007). It is unclear why such high rates have been observed, but it may be due, at least partially, to the stressors associated with such missions. There exists a complete absence of research within the literature assessing the longer-term (e.g., six-months-to-one-year post-mission) effects of ICE mission participation on crewmembers' psychosocial health. First and foremost, research is needed in order to assess whether ICE missions have lasting negative effects on crewmembers and ensure that post-mission support and countermeasures are provided, if necessary. This is particularly important in the context of long-duration missions, when crews will experience unprecedented levels of isolation and confinement. Moving forward, this may represent a major concern regarding the potential effects of long-duration missions. Second, identifying those who maintained healthy psychosocial functioning post-mission or even demonstrated post-mission growth (Tedeschi, Park, & Calhoun, 1998) may prove useful to informing crew selection for future long-duration missions.

Conclusion

This report had three purposes: to identify a model of well-being factors within the ICE literature (Aim 1), to systematically summarize existing evidence from the ICE literature regarding the well-being-performance relationship (Aim 2), and to summarize temporal effects on crewmember well-being over the course of ICE mission duration (Aim 3). Although sufficient primary evidence from ICE settings exists in order to systematically summarize the well-being-performance relationship and temporal effects on psychosocial functioning over mission duration, attempts to do so have not previously been made. With respect to the well-being-performance relationship, this may be a result of the absence of a theoretically-supported organizing framework of the broad set of well-being indicators that have been, individually, infrequently studied in ICE environments and/or the absence of evidence linking well-being indicators to measures directly reflecting performance. By organizing well-being indicators into three distinct factors (hedonic well-being, eudaimonic well-being, and PsyCap) and qualitatively reviewing the effects of each in relation to a broad set of performance-related criteria we were able to draw a number of conclusions to guide future research on this topic:

- Eudaimonic well-being indicators have been those most commonly studied in relation to performance-related measures in the empirical ICE literature, while evidence regarding the relationships between indicators of hedonic well-being and PsyCap and performance-related measures have appeared in the ICE literature relatively less frequently.
- PsyCap indicators have most consistently shown the strongest, positive relationships with direct measures of performance (e.g., objectively measured task performance, peer/supervisor performance ratings). This suggests that selecting on and developing characteristics such as optimism, resilience, and self-esteem may have the greatest effects on individual-level task-related performance.
- Relatively consistent and moderate (positive) effects were found for indicators of all three well-being factors on indirect measures of performance, namely self-reported perceptions

of group functioning and cohesion. In addition, a consistently positive, but generally weak, relationship was found between indicators of hedonic and eudaimonic well-being and retrospective measures of individuals' positive attitudes towards their ICE experience. Thus, although hedonic and eudaimonic well-being may not strongly influence individual-level task performance, these factors may play an important role in crew functioning and individuals' perceptions of ICE experiences.

- Evidence suggests that positive affect, an indicator of hedonic well-being, is the most consistently (negatively) related to perceptions of stress.
- In general, eudaimonic well-being has been most consistently (negatively) related to symptomatological outcomes. Less consistent is evidence regarding hedonic well-being and PsyCap, although evidence suggesting practically significant effects has been observed with regard to satisfaction with social support (hedonic), self-efficacy (PsyCap), and hardiness (PsyCap).

Our analyses provided evidence with both theoretical and practical implications regarding the temporal effects on indicators of both positive (i.e., well-being) and negative psychosocial functioning (i.e., stress/symptomatology):

- Meta-analytic evidence reported here suggests the beginning, and to a lesser extent the end, of missions to be marked by the greatest changes in both positive (i.e., well-being) and negative indicators of psychosocial functioning (i.e., stress/symptomatology), with relatively stable trends during the interim stages of mission duration.
- Across mission duration, individuals and crews have reported slightly above average levels of positive psychosocial functioning and average levels of negative psychosocial functioning.

- Evidence among short- (1-90 days) and long-duration (181+ days) missions shows highly similar temporal trends, suggesting temporal effects to be largely robust.
- Evidence regarding crew characteristics (crew nationality and gender) suggests that homogeneous crews may experience somewhat greater and more stable psychosocial health throughout mission duration. However, evidence does not suggest that heterogeneous crews will typically be detrimental to crew psychosocial health. In addition, there appears to be a clear difference between those who do and do not thrive, at least, in multi-gender crews.

Based on the results of this study, the following recommendations are offered for the future study of well-being in ICE settings, with a specific eye toward preparations for a long-duration mission to Mars:

1. The validation of well-being measures specific to ICE settings is needed:
   - The present research has shown that indicators of well-being are statistically related to measures of performance. Better understanding the role of well-being in ICE settings can inform health surveillance efforts in long-duration spaceflight settings and can contribute to long-duration spaceflight selection and training procedures.
   - Using the hedonic well-being, eudaimonic well-being, and PsyCap framework, future research should aim to determine which specific well-being indicators demonstrate significant relationships with performance and psychosocial health criteria in ICE settings.
   - Next, specific well-being predictors should simultaneously be examined using a regression framework to determine the incremental effects of each on outcomes of interest. Doing so will identify which factors are most efficient in predicting specific

outcomes deemed most vital to long-duration mission success (e.g., task performance, group functioning, stress resistance).

- Indicators of PsyCap are more strongly related to direct measures of performance than either hedonic well-being or eudaimonic well-being. Findings suggest that emphasis should be placed on these indicators of well-being in order to explore the potential preventive and salutogenic effects of resilience and resilience-based protective factors during long-duration ICE missions.
- HRP is currently undertaking health surveillance efforts to identify the signs, symptoms, and diagnoses of neurobehavioral health in ICE and spaceflight settings. HRP would benefit by supplementing this effort or similar future efforts with an examination of the relationship between indicators of well-being and neurobehavioral health in such settings. Doing so would provide a comprehensive study assessing the ability of well-being indicators to predict adverse health and behavioral outcomes.
- The research presented in this report suggests that specific indicators of positive and negative behavioral health likely follow different temporal trends over the course of ICE missions. Assessing how specific indicators of well-being and symptomatology covary and/or differ over the course of a mission can be used to develop countermeasures to enhance specific aspects of well-being, to counteract the negative effects of stress and symptomatology, or both, at various points during a mission.
- Studies to validate ICE-specific measures of well-being can be conducted in a variety of settings. Earth-based analogs provide the most efficient settings for validation studies to take place initially. These studies could be carried out among individuals and teams in analog settings such as Polar expeditions; submerged settings such as NASA Extreme

Environment Mission Operations (NEEMO); and analogous Mars settings such as the Hawai'i Space Exploration Analog and Simulation (HI-SEAS).

- Ultimately, low earth orbit settings such as the International Space Station (ISS) will provide the most suitable analog for inquiries related to long-duration exploration-class missions. Examining the relationships between well-being and performance, and well-being and health in this context will allow researchers to validate a comprehensive measure of well-being for use in a long-duration mission to Mars.

2. NASA should focus on the well-being of ground support and family members:
   - NASA is currently investigating the applicability of resilience training for ground crews. It is recommended that NASA continues this effort and also assesses the effects of maintaining and enhancing well-being among mission controllers. Understanding and enhancing the well-being of crew-mission control may increase the communication effectiveness of ground crews, which may ultimately serve to enhance crewmember performance.
   - Families serve as a critical point of support for individuals in ICE settings. To date, very little research has examined the well-being of crew-members' families. Even less research has examined how family well-being can impact the well-being and performance of crew members. Work should be done to examine the effects of crewmember family well-being on crewmembers' psychosocial functioning and performance.
3. NASA should continue to assess well-being of crew members after the mission has ended:

- Research is needed to assess lasting effects of ICE missions on crewmember well-being. This information can be used to inform and develop post-mission support procedures, if necessary.
- Research is needed to identify post-mission factors of healthy psychosocial functioning and growth to inform crew selection for future long-duration missions.
- Assessing the post-mission well-being of astronauts and individuals in ICE settings will be especially critical to understanding the potential impacts of multiple flights/ICE missions on well-being.

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*indicates study was included in well-being-performance analyses

†indicates study was included in temporal effects analyses

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Appendix A. *Characteristics of Studies included in Systematic Review of Well-being-Performance Relationship in ICE Settings.*

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	GWB	H	E	PC	S	P
Bishop et al. (2010)	7	Y	B	Simulation	FMARS (2007)	120		x			x	
Brasher et al. (2010)	219	N (UK)	M	Archival (submarine)	NR	NA		x	x		x	
Doll & Gunderson (1969) Civilan Scientists	66	N (US)	M	Antarctic Winter-over	NR	365			x			x
Doll & Gunderson (1969) Navy enlisted	129	N (US)	M	Antarctic Winter-over	NR	365			x			x
Doll & Gunderson (1970) Civilians	125	N (US)	M	Antarctic Winter-over	Multiple US Naval Antarctic stations and across multiple years (1963-1968)	365	x					x
Doll & Gunderson (1970) Seabees	121	N (US)	M	Antarctic Winter-over	Multiple US Naval Antarctic stations and across multiple years (1963-1968)	365	x					x

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	GWB	H	E	PC	S	P
Doll & Gunderson (1970) Technical Administrator	93	N (US)	M	Antarctic Winter-over	Multiple US Naval Antarctic stations and across multiple years (1963-1968)	365	x					x
Doll et al. (1969) Civilians	5	N (US)	M	Antarctic Winter-over	NR	365				x		
Doll et al. (1969) Navy Seabees	5	N (US)	M	Antarctic Winter-over	NR	365				x		
Doll et al. (1969) Navy technical-administrative	5	N (US)	M	Antarctic Winter-over	NR	365				x		
Eid et al. (2004)	18	N (NOR)	M	Submarine	NR	6				x	x	X
Grant et al. (2007)	140	N (UK)	B	Antarctic Winter-over	1999-2003 British Antarctic stationers	270		x		x		X
Kanas et al. (2008)	6	Y	NR	Space	ISS	NR		x				X

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	GWB	H	E	PC	S	P
Kanas et al. (2010) Neemo	25	NR	NR	Submarine	Neemo 12 and 13	12			x		x	
Krins (2009) Study 1	25	NR	B	Simulation	Expedition 2	14.5		x	x	x	x	X
Krins (2009) Study 2	12	NR	B	Simulation	Mars Desert Research Station	14			x			X
Krins (2009) Study 5	9	Y	B	Antarctic Winter-over	Concordia Antarctic Station	215			x			X
Leon et al. (1994)	11	Y	M	Arctic expedition	Soviet-American Bering Strait Expedition	61		x	x			X
Musson et al. (2004)	147	N (US)	B	Archival (space)	1990, 1992, and 1994 NASA applicant pools	NA	x					X
Nicolas et al. (2013)/Kanas et al. (2010) Mars 105/ Kanas et al. (2011)	6	Y	M	Simulation	Mars105 (March-July 2009)	105		x	x		x	

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	GWB	H	E	PC	S	P
Palinkas & Browner (1995)	121	N (US)	NR	Antarctic Winter-over	U.S. Antarctic Program 1988-1989	360		x	x	x	x	X
Palinkas et al. (2000) Operation Deep Freeze (1963-1974)	657	N (US)	M	Antarctic Winter-over	Operation Deep Freeze (1963-1974)	NR			x	x		X
Rose et al. (1994)	65	N (US)	B	Archival (space)	1990 NASA astronaut corps supervisory assessment	NA	x	x	x			X
Rosnet et al. (2000)	16	N (FRA)	M	Antarctic Winter-over	Dumont-d'Urville Station	210			x			X
Sandal et al. (2003)	50	Y	M	Submarine	10-d NATO exercise	21.4			x		x	X
Sarris & Kirby (2005, 2007)	117	NR	B	Archival (Antarctic station)	Australian Antarctic stations (1950-2000)	NR		x	x			X
van Baarson (2013)	6	Y	M	Simulation	Mars500	520			x			X

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	GWB	H	E	PC	S	P
Weiss et al. (2000)	107	N (JAP)	M	Antarctic Winter-over	JARE 1991-1993	330			x	x	x	X
Zuckerman et al. (1968) sensory deprivation	12	N (US)	B	Simulation (bed rest)	NR	1				x	x	X
Zuckerman et al. (1968) social confinement	12	N (US)	B	Simulation (bed rest)	NR	1				x	x	X
Zuckerman et al. (1968) social isolation	12	N (US)	B	Simulation (bed rest)	NR	1				x	x	X

*Notes***:** *N* = total sample size; M = male only crew; B = male and female crew; NR = not reported; GWB = general well-being; H = hedonic; E = eudaimonic; PC = PsyCap; S = stress/psychosocial symptomatology; P = performance.

Appendix B. *Characteristics of Studies included in Individual-level Temporal Change Analyses.*

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Atlis et al. (2004)	2	Y	F	Arctic expedition	NR	97	Confidence; Energy; Positive affect;	Negative affect; Stress
Bell & Garthwaite (1987)	12	N (UK)	M	Antarctic Winter-over	Rothera Base (April 1983-March 1984)	330	NA	General health symptoms;
Bergan et al. (1993)	6	Y	M	Simulation	EMSI (Aug.-Oct 1993)	25	Cheerfulness; Energy; Feeling toward others; Personal/team mood; Team closeness; Team harmony	Complaints of physical conditions; Problems outside team control; Tenseness
Bishop et al. (2010)	7	Y	B	Simulation	FMARS (2007)	120	NA	Stress;
Cleveland et al. (1963)	4	N (US)	B	Underground shelter	NR	14	Positive mood; Relief (Mood);	NA
Gushin et al. (1996)	1	NR	M	Simulation	EXEMSI	60	Joking;	Negative statements;
Gushin et al. (2012)	6	Y	M	Simulation	Mars105 (March-July 2009)	105	Activity; Health; Mood;	Negation;

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Inoue et al. (2004)	2	Y	B	Simulation	SFINCSS-99	110	Vigor-activity;	Anger-hostility; Confusion-bewilderment; Depression-dejection; Fatigue-interia; Tension-anxiety;
Kahn & Leon (1994)	4	N (US)	F	Arctic expedition	1986 North Pole expedition	67	Positive affect;	Negative affect;
Leon et al. (2004)	3	Y	B	Arctic expedition	Otto Sverdrup Centennial Expedition (late 2000)	46	Positive affect; Satisfaction	Negative affect; Tension/conflict
Leon et al. (2011)	2	N (US)	M	Arctic expedition		55	Positive affect;	Negative affect;
Manzey et al. (1998)	1	N (RUS)	M	Space	MIR (Jan 1994-March 1995)	438	Emotional balance/alertness;	Sadness;
Steel & Suedfeld (1991)	5	NR	B	Arctic station (short)	Isachsen decommissioned weather station	49	Arousal; Pleasure;	NA

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
van Baarson (2013)	6	Y	M	Simulation	Mars500	520	Experienced challenge as encouragement; Freedom of choice; Perceived voluntariness; Willingness to sacrifice;	NA
Wood et al. (1999)	6	N (AUS)	M	Arctic expedition	1993-1994/1994-1995 Lambert Glacier Basin traverse	105	Cognitive Readiness; Emotional State; Personal Morale;	Group tension;

*Notes***:** *N* = total sample size; M = male only crew; B = male and female crew; NR = not reported; NA = not applicable.

Appendix C. *Characteristics of Studies included in Group-level Temporal Change Analyses.*

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Abaini et al. (1998)	16	N (FRA)	M	Diving	Hydra V Hydra VIII Hydra IX	43	NA	Anxiety; Apprehension; Emotional instability; Low self-control; Suspicion; Tension;
Bergan et al. (1993)	6	Y	M	Simulation	EMSI (Aug.-Oct 1993)	25	Cheerfulness; Energy; Feelings toward others; Personal/team mood; Team closeness; Team harmony;	Complaints of physical conditions; Problems outside team control; Tenseness;
Bhargava et al. (2000)	25	N (IND)	M	Antarctic Winter-over	11th Indian Expedition	330	Rapport; Satisfaction with work/life;	Alcohol intake; Interpersonal hypersensitivity; Sleep difficulty; Smoking;
Bishop et al. (2010)	7	Y	B	Simulation	FMARS (2007)	120	Positive mood;	Negative mood;
Décamps & Rosnet (2005)	27	N (FRA)	NR	Antarctic Winter-over	Dumont-d'Urville Station (1997-1998)	350	NA	Stress reactions;

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Eid et al. (2004)	18	N (NOR)	M	Submarine	NR	6	NA	General health complaints; Negative impact of event; PTSD symptoms;
Evans et al. (1987)	9	N (US)	M	Antarctic Winter-over	Palmer station	180	NA	Anxiety; Depression; Hostility;
Gushin et al. (1996)	1	N (RUS)	M	Simulation	EXEMSI	60	Joking;	Negative statements;
Gushin et al. (2012)	6	Y	M	Simulation	Mars105 (March-July 2009)	105	Activity; Health; Mood;	Negation;
Kahn & Leon (1994)	4	N (US)	F	Arctic expedition	1986 North Pole expedition	67	Positive affect;	Negative affect; Stress
Kanas et al. (1996)	3	N (RUS)	M	Simulation	MIR simulation	135	NA	Mood disturbance;
Kanas et al. (2001a) US astronauts	5	N (US)	NR	Space	Shuttle/Mir	120	Cohesion; Self-discovery;	NA
Kelly et al. (2005)	4	N (US)	B	Space	STS-89	10	Arousal;	Fatigue;

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Koscheyev et al. (1994) Russian	6	N (RUS)	M	Arctic expedition	Soviet-American Bering Strait Expedition	61	Activity; Positive mood; Well-being;	Anxiety;
Krins (2009) Study 5	9	Y	B	Antarctic Winter-over	Concordia Antarctic Station	215	Cooperation; Friendship; Group identification; Socialization;	NA
Leon et al. (2002)	6	Y	B	Arctic expedition	NR	365	Positive affect;	Negative affect; Negative events
Mocellin & Suedfeld (1991) Antarctic	7	N (UK)	M	Antarctic Winter-over	19th-20th explorer early explorers	240	Arousal; Pleasure;	NA
Mocellin & Suedfeld (1991) Arctic	6	N (UK)	M	Arctic expedition	19th-20th explorer early explorers	240	Arousal; Pleasure;	NA
Nicolas et al. (2013)	6	Y	M	Simulation	Mars105 (March-July 2009)	105	Positive emotions;	NA
Palinkas & Houseal (2000) McMurdo	63	NR	B	Antarctic Winter-over	1991 McMurdo Station	360	Vigor;	Mood disturbance;

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Palinkas & Houseal (2000) Palmer station	7	NR	B	Antarctic Winter-over	1991 Palmer Station	360	Vigor;	Mood disturbance;
Palinkas & Houseal (2000) South Pole station	18	NR	B	Antarctic Winter-over	1991 South Pole Station	360	Vigor;	Mood disturbance;
Palinkas et al. (2000) South Pole Station (1991-1994)	83	NR	B	Antarctic Winter-over	South Pole Station (1991-1994)	NR	Vigor;	Mood disturbance;
Palinkas et al. (2001)	12	N (US)	B	Antarctic Winter-over	McMurdo Station (1997-1998)	300	NA	Mood disturbance;
Palmai (1963)	14	N (AUS)	M	Antarctic Winter-over	Australian National Research Expedition (1960)	330	Positive emotional response;	Negative emotional response;
Rosnet et al. (2000)	16	N (FRA)	M	Antarctic Winter-over	Dumont-d'Urville Station	210	Harmonic self-image;	NA
Sandal (2000) land base	19	Y	NR	Antarctic Winter-over	Dronning Maud's land	90	Optimism; Well-being;	Aggression; Stress;
Sandal (2004) Group 1	4	NR	M	Simulation	SFINCSS-99	240	NA	Problems outside of individual control;

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Sandal (2004) Group 3	4	Y	B	Simulation	SFINCSS-99	110	NA	Problems outside of individual control;
Sandal et al. (1996) hyperbaric chambers	18	Y	B	Hyperbaric chambers	ISEMSI; EXEMSI; O2 dive	39	Positive instrumentality;	Aggression; Anxiety; Homesickness;
Sandal et al. (1996) polar expeditions	15	Y	B	Arctic expeditions	Polaremsi; Norwegian South Pole expedition; Greenland North-South expedition; MIE Arctic expedition	80.5	Positive instrumentality;	Anxiety; Depression
Steel (2001) Study 1	8	NR	NR	Antarctic Winter-over	Scott Base	240	Arousal; Vigor	Mood disturbance;
Steel (2001) Study 2	9	NR	NR	Antarctic Winter-over	Scott Base	330	Vigor;	Mood disturbance;
Stuster et al. (2000)	9	N (FRA)	M	Antarctic Winter-over	French remote stations (1993-1994)	193	Positivity;	NA

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Taylor et al. (1968) 20d No privacy	41	N (US)	M	Simulation	Great Lakes Naval Training graduates	20	NA	Anxiety; Stress
Taylor et al. (1968) 20d Privacy	40	N (US)	M	Simulation	Great Lakes Naval Training graduates	20	NA	Anxiety; Stress
Taylor et al. (1968) 4d No privacy	43	N (US)	M	Simulation	Great Lakes Naval Training graduates	4	NA	Anxiety; Stress
Taylor et al. (1968) 4d Privacy	42	N (US)	M	Simulation	Great Lakes Naval Training graduates	4	NA	Anxiety; Stress
van Baarson (2013)	6	Y	M	Simulation	Mars500	520	Experienced challenge as encouragement; Freedom of choice; Perceived voluntariness; Willingness to sacrifice;	NA
Weiss & Gaud (2004)	32	N (FRA)	M	Antarctic Winter-over		270	Positive occurrences;	Negative occurrences;

(*Table continues*)

Study	N	Mixed Cultural	Crewmember Sex	Setting	Mission	Mission Length	Positive	Negative
Wood et al. (1999)	6	N (AUS)	M	Arctic expedition	1993-1994/1994-1995 Lambert Glacier Basin traverse	105	Cognitive Readiness; Emotional State; Personal Morale;	Group tension;

Notes: *N* = total sample size; M = male only crew; B = male and female crew; NR = not reported; NA = not applicable.

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The purpose of this report is to: 1) provide a systematic review of the literature characterizing the well-being performance relationship in isolated, confined, and extreme (ICE) contexts, and 2) to examine temporal trends in well-being in ICE environments. Using a three-dimensional framework (hedonic well-being, eudaimonic well-being, and psychological capital) the report first summarizes the existing literature examining the relationship between these three domains of well-being and performance and health outcomes. Results show that psychological capital had the strongest and most consistent (positive) relationship with task performance, hedonic well-being the most consistent (negative) relationship with perceptions of stress, and eudaimonic well-being the most consistent (negative) relationship with psychosocial symptomatology. All three types of well-being showed consistent (positive) relationships with indirect performance correlates. The analysis of temporal trends in indicators of behavioral health yielded several notable findings, including: a) greater change in health scores at the beginning and end of missions, b) similar trends in health scores for both short- and long-duration missions, and c) heterogeneous crew composition (in nationality and gender) may not be detrimental to crew behavioral health. Implications for future research are discussed within.</td></tr>
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