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Positive Experiences as Countermeasures to Stress in Spaceflight: An Investigation of the Experiences of Astronauts

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Abstract

Title: Positive Experiences as Countermeasures to Stress in Spaceflight: An Investigation of the Experiences of Astronauts

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Long-duration space mission targets such as asteroids, the Moon and Mars in coming years will increase the need to stress management techniques to support crews on increasingly risky, autonomous missions. New stress management approaches may be found by better understanding the reported positive effects resulting from factors in these environments. This study utilized an exploratory case study approach to leverage quantitative and qualitative data to yield research questions for future correlational analysis. This study found that positive experiences and changes in environmental perspectives occurred from viewing Earth from orbit. Furthermore, this study found that personality factors such as extraversion may not effectively predict stress resilience in the astronaut population. The study suggests recommendations for future research; especially on the potential use of head-mounted virtual reality technology for providing similar immersive, relaxing experiences for crews travelling beyond Earth orbit.

Keywords: psychology in isolated and confined environments, virtual reality, spaceflight, resilience, stress

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Chapter 1

Introduction

With more efficient closed ecological life support technologies, as well as international political and financial investment, humans may visit Mars in the coming decades. Technology allows us to live and work in places that are foreign, exotic, and dangerous. These environments are often physically isolated from more habitable areas on Earth. Due to the challenges of these environments, such as launch payload size limitations, and cost of launching habitation modules, individuals are forced to live in small spaces together for long periods of time. These situations exhibit a unique paradox of being both isolated from the rest of humanity and confined with a select crew in an extreme environment. The technology now exists for humans to venture, live, and work in increasingly isolated and confined environments for long periods of time. However, the long-term success of these activities will depend on a thorough understanding of the psychology of crews interacting within these environments (Suedfeld & Steel, 2000).

Individual and group psychology in response to isolated and confined environments, such as those in submarines, Antarctic expeditions, polar stations, and spacecraft environments has been a source of study for the last 60 years. The focus of many of these studies has been on quantifying the negative impacts of the

social and physical environment on crew psychology. This focus on stress-related issues has failed to explain the voluntary return rate of participants to these environments. A growing body of anecdotal and empirical research suggests that in some cases, stressful environments directly contribute to personal growth in individuals and groups (Jenkins & Palmer, 2003). This research study aims to explore the positive aspects of being in space. A more holistic understanding of the positive aspects of spaceflight may improve stress management techniques for future long duration missions to the Moon or Mars. Improved stress management will decrease the probability for human error and may significantly improve mission safety and success.

Purpose Statement

Isolated and confined environments (ICE) provide natural laboratories to study the psychology of humans in response to stressors and socio-environmental pressures. To understand the range of effects of this type of environment on humans, it is important to determine what makes these experiences uplifting, inspirational and personally satisfying, as well as potentially stressful, difficult, and exhausting. Previous research identifying the personal growth possibilities in ICE spaceflight missions suggests that perspectives on Earth change after the experience (Suedfeld, Brcic, Johnson, & Gushin, 2012; Suedfeld, Brcic, Johnson, & Gushin, 2015). The purpose of this study was to determine the extent to which astronauts

experience: both positive and negative effects of spaceflight; including stressors, growth opportunities, and any persistent changes in perspectives or attitudes.

Problem Statement

Individuals living in dangerous, isolated, and confined places are forced to contend with constant danger, harsh environmental conditions, and life support systems of various complexity. In response to living in remote locations in small spaces with the same individuals, many people have reported increased stress, interpersonal conflict, and decreased moods (Nelson, 1962; Palinkas, 2003; Sandal, Leon, & Palinkas, 2006). Understandably, spacecraft, submarines, polar stations, and underwater habitats have served as natural laboratories for studying the psychology of living in an isolated and confined environment (Stuster, 1986). Although many individuals report increased stress living in these environments, many desire strongly to return. Still others report changes in perspective, personal growth, and increased resilience (Kjærgaard, Leon, Venables, & Fink, 2013; Palinkas, Stern, & Holbrook, 1986; Suedfeld, 1996; Wood, Hysong, Lugg, & Harm, 2000).

A growing body of qualitative and quantitative research suggests that in some cases, stressful situations contribute to the development of resilience and personal growth (Tedeschi & Calhoun, 1996). To better understand the positive effects of spaceflight, Ihle, Kanas, Ritsher, Weiss, and Marmar, (2003) developed the Positive Effects of Being in Space (PEBS) survey for assessing changes in

perspectives or values. This study proposes to increase the depth of analysis obtained from the PEBS by combining it with qualitative interviews.

Significance

Longer-duration space mission targets such as asteroids, the Moon and Mars in this century and beyond will increase the need to understand the myriad factors that influence performance of small groups in stressful, crowded conditions. As manned space missions increase in duration and distance from Earth, the effects of isolation and confinement will be increased. Risk and perceived stress will increase as distance from Earth increases. It is well known that the effects of stressful environments produce cognitive and behavioral adaptations (Zimmer, Cabral, Borges, Côco, & Hameister, 2013). However, understanding the response to stress is incomplete without addressing the reported positive effects resulting from these environments. This study will contribute to the growing body of evidence that stressful situations can produce positive outcomes, and the greater depth of this study may uncover new factors, connections, and themes. Future research can focus on the exploratory information uncovered in this analysis to establish correlational links which would inform selection and training for long duration spaceflight.

Human error represents a substantial risk to mission safety and success in spaceflight systems (Holden et al., 2013). Under stress, crew's task performance and cognition tend to decrease, leading to decreased human reliability (Boyer,

Holubec, & Whitmore, 2012). One way to increase the probability of mission success is to mitigate the levels of chronic stress experienced by crews (Manzey, Schiewe, & Fassbender, 1995).

Thus, understanding the positive aspects of spaceflight may result in improved stress remediation techniques for future Mars missions. Such positive factors uncovered in this research could ultimately improve Mars mission safety and success.

Chapter 2

Literature Review Sources

The literature reviewed was collected through keyword searches in electronic journal databases, including PsychArticles®, Pubmed, EbscoHost, and Science Direct® accessed through Florida Institute of Technology's research subscriptions. In addition, early reports from Antarctic psychological experiments conducted in the 1960's-1980's were retrieved from government technical report servers, including NASA Technical Reports Server and the Defense Technical Information Center. Keyword searches used to retrieve the literature were "Psychology of Extreme Environments," "Polar Psychology," Humans in Isolation and Confinement," "Isolation and Confinement," "Human Spaceflight," "Space Psychology," "Post Traumatic Growth" and "Psychology Antarctica." The literature was collected from 2016-2017. The selected literature included in the review comprised the most methodologically sound results concerning human factors in isolated and confined environments available.

Selected Literature Review

Future spacecraft crews on long-duration flights will be effectively isolated and confined with mission success dependent on their own abilities. This is stressful, yet many astronauts and winter-over personnel describe their experiences

as formative, and life-changing (Suedfeld, 1996; Suedfeld et al., 2012, 2015). Many individuals deliberately agree to undergo isolation and confinement for long periods of time without clear financial or interpersonal rewards (Suedfeld, 1996). Many winter-over personnel return year after year to Antarctica (Ihle, Ritsher, & Kanas, 2006; Leveton, Shea, Slack, Keeton, & Palinkas, 2009). In fact, 25% of Australian winter-over personnel return for the subsequent winter in Antarctica (Evans, Stokols, & Carrere, 1988; Ritsher, Kanas, Ihle, & Saylor, 2007) and individuals claim these stressful experiences changed their global perspectives in positive ways (Palinkas & Suedfeld, 2008). Limited research has been conducted on the growth phenomenon with astronauts. To increase the breadth of this literature review, other individuals and studies from other extreme environments on Earth will also be included. This review will identify the components of isolated and confined missions, identify perspectives on the human response to stress, and identify stressful factors in ICE missions. Finally, it concludes by covering the literature on posttraumatic growth.

The components of an isolated and confined environment

There are a limited number of astronauts who have participated in long-duration space missions, which limits the generalizability of research on this phenomenon One way to gather more valid data is to consider research on Antarctic station personnel Antarctic bases have been studied longer, and these studies often have higher sample sizes. These factors make them preferable to generating psychological research on crews in extreme environments. As a result,

from a research perspective, Antarctica as a space analog can provide more statistical data and flexibility for researchers (Kanas et al., 2009; Palinkas & Suedfeld, 2008; Palinkas, 1987). Thus, studying winter-over personnel at Antarctic bases has been the most common method for researching the psychology of extreme environments on individual and group processes (Bishop, 2013; Leveton et al., 2009).

The fidelity of a terrestrial habitat for comparison to space station life was categorized by Stuster, (1986) who collected and analyzed data comparing Antarctica to spaceflight by ranking and weighting the demands of the social, environmental, mission, task, habitat and individual factors (see Table 1 below).

Table 1
Factors Impacting the Fidelity of Earth-Based Analog ICE Missions

Social Factors	**Environmental Factors**	**Mission Characteristics**	**Work & Task Factors**	**Habitat Factors**	**Individual Factors**
Size of Group	Physical Isolation	Risk	Task Type and Duration	Physical Quality of Habitat	Motivation
Composition of Group	Psychological Isolation	Duration of Mission	Amount of Free Time	Quality of Life Support	
Social Organization Hierarchy	Hostility of Environment	Training & Preparedness for Mission			

For an analog mission to be comparable to spaceflight, it must have small, restrictive living quarters, high risk, dependence on life support technology, and a

hostile outside environment, among other socio-environmental factors (Stuster, 1986).

There are key psychological similarities between spaceflight and Antarctic station life. Stuster's (1986) systematic comparative analysis indicated that Antarctic station life was stressful and that research from this environment could be generalized to crews living in space. In lieu of having more participant data from long-duration spaceflight missions, this literature review will incorporate data from research on Antarctica.

Conceptual framework for understanding the human response to stress

The cognitive interpretation of stressful stimuli determines if the stimuli are considered positive or negative for individuals (Folkman, Schaefer, & Lazarus, (1979). Improvements have been made to model the cognitive interpretation of stressors. Geuna, Brunelli, and Perino, (1995) proposed a descriptive model for the development and cognitive interpretation of stress reactions in long duration spaceflight (see Figure 1 below). This model is more applicable for describing the dynamic nature of the causes and expressions of stress in isolated and confined environments.

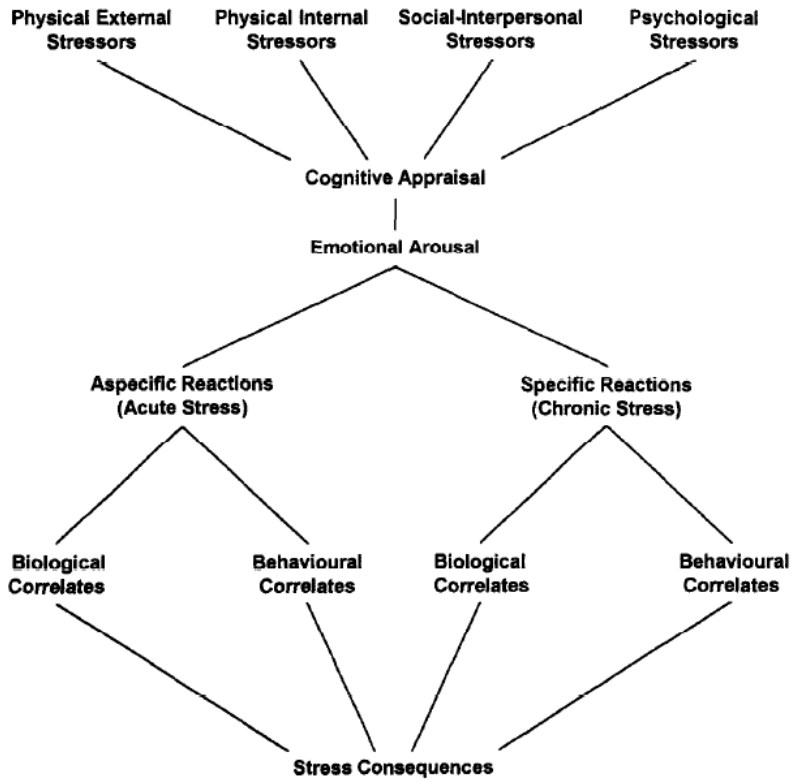

Figure 1. *Modelling cognitive appraisal and stress in extreme environments*

Cognitive appraisal of the situation is crucial for determining stress reactions and subsequent adaptations. Evaluating stress can be experimentally assessed biologically and behaviorally (Geuna, Brunelli, & Perino, 1995).

Small social factors influencing the increase of chronic stress in Antarctic, submarine and spaceflight environments represent the largest contributors to the development and expression of negative effects. These chronic stressors are heightened in these environments because the inhabitants are confined to a small space with ever-present environmental and social stressors (Suedfeld & Steel, 2000).

Chronic stress present in isolated and confined environments

The ICE research domain is a cross-context interdisciplinary field with major contributors being social scientists including anthropologists, experimental psychologists, and psychiatrists. Summarizing recent research from multiple contexts will help to shed light on the phenomena. Although no consistent meta-analytic results of psychological effects have been documented (Leveton et al., 2009), significant results concerning small group studies in ICE have been published (Sandal, Leon & Palinkas, 2006). The following discusses the major results concerning the stress of ICE situations, methods of coping with stress, and the evidence for personal growth in ICE.

Stress has been documented in the ICE research literature by direct inquiry and indirect inquiry methodologies (Evans et al., 1988). The psychological aspects comprising the crews' behavioral correlates of stress have been documented using direct measures, involving interviews, surveys, medical reports, personality assessments, and clinical observations. In addition, the length of stay in long-term isolated and confined environments has been associated with biological correlates of stress, including increases in blood pressure, adrenal hormones and negative moods (Cohen, Evans, Stokols, & Krantz, 1986). The biological correlates of stress in studies have been measured through direct hormone sampling, via blood, urine or saliva. In addition, heart rate variability, blood pressure, and sleep quality measures have been implemented to quantify dynamic physiological changes (Palinkas et al., 2001; Pavy-Le Traon, Heer, Narici, Rittweger, & Vernikos, 2007).

The extent of chronic stress symptomology present in ICE environments is dependent on station location, micro culture, interpersonal group factors, and individual personal adaptation skills (Leach, 2016). The impact of the station location and configuration has significant bearing on the amount of chronic stress reported by its inhabitants. The situation produces differential stress reactions on participants in the environment (Chen, Wu, Li, Zhang, & Xu, 2016). Although not all winter-over personnel experience the symptoms of chronic stress in the same manner, trends in human adaptation to ICE have been found (Suedfeld & Steel, 2001).

In a large study with 358 sailors, 155 civilian scientists and technicians assigned to 6 small Antarctic stations, stress was evaluated pre-and post-winter over by self-report surveys. The data indicated that stress reactions resulted in psychosocial correlates of chronic stress including depression, insomnia, hostility, and aggression. The civilian members at the 6 different stations only reported increases on measures of anxiety, and hostility (Palinkas, Gunderson, & Burr, 1989). This finding is consistent with interviews from 163 men wintering-over at 6 small stations from 1957-1958. Participants' reported universal adaptation effects that corresponded with a 3-stage presentation. In 1961, Rohrer found that anxiety increased, with a corresponding increase in work output. When the sun set and the winter began, stress reactions presented through an increase in reports of depression in most of the men. As the end of the winter-over period neared,

measures of depression decreased, however interpersonal conflicts increased (Rohrer, 1960).

This symptomology has been observed in multiple contexts, including Artic stations (Binsted, Kobrick, Griofa, Bishop, & Lapierre, 2010) the Antarctic (Palinkas, 1988) spaceflight ((Kanas et al., 2009; Stuster, 2016) submarines (Sandal, Endresen, Vaernes, & Ursin, 1999; Weybrew, 1991) and in planetary base analogs (MacCallum, Poynter, & Bearden, 2004; Rai, Foing, & Kaur, 2012). The presentation of anxiety, depression and interpersonal conflict are congruent with psychophysiological correlates of chronic stress in the isolated and confined environment. This gradual increase in chronic stressors over time further support the chronic stress model in long duration spaceflight (LDSF) or isolated and confined environments. Furthermore, the mood symptoms accompanied with stress change in presentation over time (Geuna, et al., 1995; Steel, 2005). The changes in mood states over time have been collectively termed the "Third Quarter Effect" (Bechtel & Berning, 1991).

The third quarter effect is a characterization of the third quarter being the time of greatest psychosocial distress and disturbance in the group during the mission. The third quarter effect appears to be present to some extent in most groups regardless of duration of mission (Connors, Harrison, & Akins, 1985; Palmai, 1963). However, variations in the intensity of the ICE situation and stressors present, as well as group cohesion likely play a role in the extent of the third quarter phenomenon (Suedfeld & Steel, 2000). In the vast majority of studies

addressing mood states, a general trend in anxiety, depression and hostility has increased in participants between the second and fourth quarters of the ICE mission (Palinkas, 1988). In a study of 27 winter-over personnel in an Antarctic station, doctor's observations indicated that stress reactions manifested differently over time. Evaluating the men with a 59-item observation grid each week, the mission doctor observed an increase in anxiety during summer, the beginning, an increase in social stress during the middle of the mission, and an increase in hormonal reactions toward the end of the mission (see Figure 2 below).

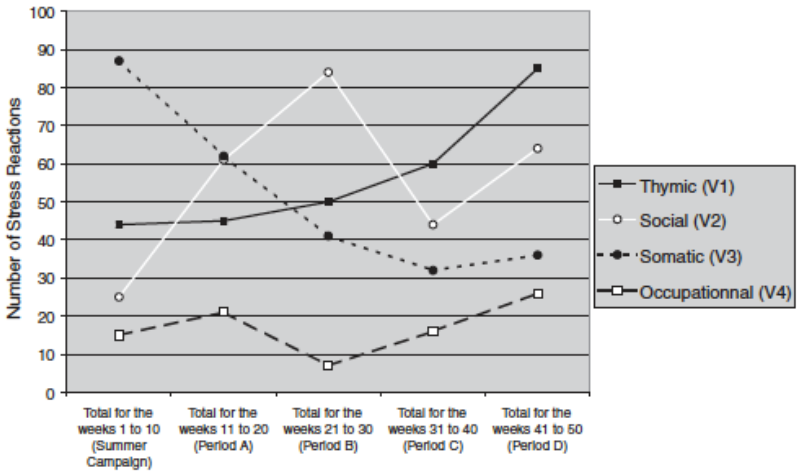

Figure 2. *Reactions to stress change over time*

Participants' self-reported stress reactions were assessed by a clinician each week. The clinician reported changes in stress reactions over time as the mission progressed (Wood et al., 2005). The results of the study confim the third quarter phenomeon. The most difficult time for crews occured toward the end of winter. The data suggest that during the third quater, particpants internalize stress reactions greater than during other periods. This study demonstartes that at the least, stress

reactions change in presentation over the duration of the ICE mission (Wood et al., 2005).

While the exact changes in mood states may differ from group to group, with some indicating greater anxiety (Palmai, 1963) and other groups exhibiting more anger and depression (Suedfeld & Steel, 2000), the nature of the trend of increased psychosocial distress has been demonstrated in Antarctic expeditions (Palinkas, Suedfeld, & Steel, 1995; Bhargava, Mukerji, & Sachdeva, 2000; Wagstaff & Weston, 2014) in polar stations (Binsted et al., 2010; Suedfeld & Steel, 2000; Wood et al., 2005; Bishop, Kobrick, Battler, & Binsted, 2010) submarines (Van Wijk & Cia, 2016) spaceflight simulations (Ushakov et al., 2014) and spaceflight (Bluth & Helppie, 1986; Mount, 2006).

In a content analysis study of 4,200 journal entries from ten astronauts on the ISS, substantial evidence of a third quarter phenomenon was found. Nine out of ten astronauts indicated changes in the net positivity/negativity analysis in the category of adjustment, during the third quarter, which was related substantially to individual morale (Stuster, 2010; 2016). In the astronaut journal study, self-report evidence of stress was found, and the greatest frequency of stress causes were centered around high workload schedules, time pressure, tedious and frustrating work, problems with procedure, and work stress. In addition, participants indicated that trivial interpersonal issues were exaggerated in isolated and confined environments in space (Stuster, 2010; Emurian & Brady, 2007; Kanas, 2015). These findings were echoed in astronauts' reports from Skylab missions, in which

time stress and scheduling significantly contributed to astronauts' perceived stress and decline in morale (Kanas et al., 2009; Kanas et al., 2001; Mount, 2006; Stuster, 2010).

Chronic stress effects in isolated and confined environments are not only limited in the presentation of mood state changes. Participants in Antarctic bases report increased physiological changes as well (Decamps & Rosnet, 2005; Evans et al., 1988; Zimmer et al., 2013). Hormone levels in ICE environments show significant variations indicating that participants experience significant physiological activation throughout the experience (Cornelius, 1991; Lugg, 2005). The effects of confinement with the same group, limited outside communication, and monotony likely contribute to an increase in perceived stress as well (Peldszus, Dalke, Pretlove, & Welch, 2014). Furthermore, in short duration planetary base analogs, commanders have higher hormone levels than other crew members suggesting even in short-duration missions individuals with more responsibility experience more stress (Rai et al., 2012). The highest hormone concentrations were exhibited before extra-vehicular activity, an activity of consequence for participants' safety. Differential adrenal hormone concentrations have been observed between short-duration and long-duration spaceflight (Stowe, Sams, & Pierson, 2011). Long-duration spaceflight participants had a greater baseline change in levels of norepinephrine upon landing than their short-duration counterparts. Although this may be evidence of chronic stress in ICE, it is likely confounded by microgravity, as Earth-based bed-rest studies and isolation

experiments have indicated similar hormone changes correlated with decreased physical exertion (Custaud et al., 2004).

Thus, changes in adrenal hormones are congruent with certain stressful contexts. It is likely that not all ICE environments are equally stressful or demanding. In a 105-day spacecraft simulation, hormone tests indicated no increase in physiological stress biomarkers throughout the experience (Gemignani et al., 2014). Yet, in a similar longer duration spacecraft isolation simulation adrenal hormone levels were found to increase above pre-mission baseline. Levels of adrenal hormones fluctuated, with highest peaks during high workload times in the simulation (Ushakov et al., 2014; Wang et al., 2014). It is likely that the comparison of the two studies, where the 105-day simulation was meant to serve as a pilot study for the longer duration simulation, participants and environmental factors were quite similar. Thus, it can be tentatively concluded that a 105-day group isolation study is not as stressful as a similar, but much longer duration study with similar groups (Gemignani et al., 2014; Wang et al., 2014).

The perception of stress and concentration of hormone biomarkers are dependent on the intensity of isolation, location of the station, and available amenities. In a comparison of two Chinese winter-over station groups, only the participants at the station farther south reported statistically significant changes in hormone levels and mood states (Chen et al., 2016). The participants were screened and selected for winter-over duty at two Chinese Antarctic stations from 2003-2004, and pre-assessments indicated no differences between the groups in

age, marital status, winter over experience, weight, BMI, systolic or diastolic blood pressure, thyroid hormones, plasma catecholamines, or the Profile of Mood States (POMS) scores. Participants at the southern Zhongshan station reported statistically significant increases in fatigue, anger, confusion, and tension compared to their baseline pre-winter over scores, and this was higher than participants at the sub polar station as well. Self-report POMS scores indicated anger, tension and confusion peaked at mid-winter, and anger was reported five times higher than participants at the lower latitude great wall station (Chen et al., 2016).

Major differences between the stations included sunlight, outside time, and social activities available. The stations had no access to TV or internet. At the sub-polar station, participants could spend 1 hour outside during the winter, where the average temp was 27.5 degrees F. Participants in the sub-polar station had a minimum of 4 hours of sunlight during the winter, they were able to have frequent celebrations, had access to more fruits and vegetables, and were able to visit other individuals at nearby research stations. They were also allowed to use the telephone at will (Chen et al., 2016).

Participants at Zhongshan station had no sunlight for 2.5 months, were limited to a maximum of 15 minutes outside, had to ration fruits and vegetables, and had only scheduled telephone access with the outside world. They did not have nearby stations to visit, and resupply was not possible during the winter. The socio-environmental characteristics of the situation likely influence the perceived stress, and the moods of the participants.

These differences in ICE intensity are confirmed in a 1988 winter over study on Palmer Station, a sub-polar island. Participants reported changes in moods on the POMS scale indicating increases in hostility and anxiety, but not depression. The participants also demonstrated increased anxiety over time, and this was correlated with changes in the sampling data which indicated norepinephrine and epinephrine levels declined. However, the results for the POMS scale are within one standard deviation, indicating changes in mood were not extreme. This lends credence to the idea that station latitude, isolation, and crew composition impact the degree of mood and hormone effects in an ICE environment (Evans et al., 1988). One further possibility for the differences in the study results is that cognitive appraisal and coping strategies used by the members in the different stations and situations prompted different physiological responses. The physiological response to stressors may change based on metacognitive factors, culture, and group social norms. Testing using urinary and salivary hormones may serve as reliable predictors for changes in group dynamics and individual stress perception (Kraft, Lyons, & Binder, 2003). Furthermore, utilizing biological and behavioral measures of stress can help to improve our understanding of the impact of an individual's cognitive interpretation of their situation. This cognitive interpretation may drastically impact the level of physiological stress experienced. Furthermore, it is likely that the cognitive interpretation of stressful stimuli in ICE missions plays an important part in the posttraumatic growth process.

Positive experiences in isolated and confined environments

Despite the difficulties and challenges coping with stress in isolation and confinement, most participants report it as a positive experience (Suedfeld, 1996; Suedfeld & Steel, 2000). In an isolated mountaineering expedition to Antarctica, participants reported that happiness was overwhelmingly reported compared to other emotions (see Table 2 below).

Table 2.
Frequency of Emotions Experienced by Participants During an Antarctic Expedition

Emotion	Frequency	Percent of total
Happiness	170	41.06
Anxiety	32	7.73
Contentment	24	5.80
Boredom	22	5.31
Anger	21	5.07
Relief	20	4.83
Pride	18	4.35
Fear	18	4.35
Sadness	15	3.6
Hurt	11	2.7
Fatigue	10	2.4
Envy	8	2.0
Frustration	7	1.7
Loneliness	6	1.4
Shame	6	1.4
Disgust	6	1.4
Disappointment	5	1.2
Worry	3	.7
Guilt	3	.7
Excitement	3	.7
Irritation	3	.7
Love	2	.5
Uneasiness	2	.5
Elation	1	.2
Discomfort	1	.2
Total	414	100.0

Although participants reported the expedition was stressful and difficult, they overwhelmingly reported a high frequency of pleasant emotions (Wagstaff &

Weston, 2014). Despite the challenging conditions of wintering-over in Antarctica, 25% of Australian Antarctic winter-over personnel return for the next year (Wood, et al., 2000). Although the list of negative symptoms from polar service is lengthy, the incidence of these negative experiences are low, and the reported frequency of positive experiences are higher (Wood et al., 2000). Even short duration sensory deprivation tanks have been used as therapeutic remedies for the treatment of phobias and addictions (Suedfeld, 1975). Astronauts indicate long-lasting positive changes in attitudes after spaceflight (Suedfeld, Brcic, Johnson, & Gushin, 2012), and even early polar explorers in the most difficult and arduous times of their voyages mention many positive experiences in their diaries (Cook, 1909; Mocellin, Suedfeld, Bernadelz, & Barbarito, 1991). The evidence supporting personal growth from living and working in an extreme environment are based on results from studies on long-term health, and evidence for attitude and perspective changes.

Understanding personal growth in stressful situations

Psychological growth following traumatic events has been receiving increased attention in the research literature in the last 15 years, and the change in perspective comes from the changing paradigm brought about by the larger positive psychology movement (Tedeschi & Calhoun, 2004). Evidence for post traumatic growth has been gaining ground in the clinical research literature, where growth following traumatic events has been reported (Jayawickreme & Blackie, 2014). These positive effects from severe life trauma have been reported in up to 70% of

trauma survivors (Linley & Joseph, 2004). Optimism and social support may increase health responses and positive adaptation to difficult life events (Tedeschi & Calhoun, 2004). In addition, these effects were not mediated by age or gender (Prati & Pietrantoni, 2009).

Stressful situations may influence individuals to develop coping strategies which facilitate personal growth by shattering schemas and values and causing them to rebuild their value hierarchies into more robust and adaptable ones (Tedeschi & Calhoun, 2004). Stressful life events may lead to personal growth when individuals cognitively appraise their situation (Dekel, Mandl, & Solomon, 2010). Individuals' perception of control (Park, Cohen, & Murch, 1996) and use of active coping strategies may aid in growth instead of post-traumatic stress disorder (PTSD) (Bellizzi & Blank, 2006).

Personal growth is more than just resilience; which is considered a return to the pre-trauma baseline (Tedeschi & Calhoun, 2004). A review of the personal growth or "benefit finding" literature indicated that an overall increase in positive well-being scores and decreased depression occurred post trauma (Helgeson, Reynolds, & Tomich, 2006). In the extreme environment, health outcomes may actually improve after stressful experiences (Palinkas, Stern, & Holbrook, 1986). Although it is not yet clear what factors separate the development of post-traumatic stress disorder from post-traumatic growth, early research suggests that aspects of the individuals' assessments of self-control may improve the probability of experiencing post traumatic growth as opposed to the former (Dekel et al., 2010). If

this is indeed the case, it helps to explain why adventurers with a high internal locus of control, and high achievement motivation may report more growth effects. In some studies, the relationship between personal growth and PTSD is curvilinear (Levine, Laufer, Stein, Hamama-Raz, & Solomon, 2009). Mental health outcomes may actually improve after stress exposure, though more empirical research needs to be done to better define the correlational relationships (Ihle et al., 2006). Future research needs to be done to quantify the factors that correlate with resilience and post traumatic growth. If these positive factors can be predicted, selection, training and habitability design may improve the reliability and success of future space missions.

Long-term beneficial health effects from isolation and confinement

In a study of 327 sailors stationed at six small Antarctic stations, living in Antarctica produced no negative long term health effects, and provided evidence that humans are capable of adapting effectively to extreme environments (Palinkas, 1985). Not only were participants able to adapt to station life, but there is evidence to indicate the harshness of the station location was inversely correlated with post traumatic growth (Palinkas, Gunderson, Johnson, & Holland, 1999). Furthermore, residence in an extreme environment may improve long-term health outcomes. In a study of sailors, 2,724 men volunteered and were eligible for Antarctic service, but only 324 were deployed to Antarctica. A longitudinal study of the two groups for 5.4 years after their duty assignment indicated that the men who served in Antarctica were found to have lower incidence of disease compared to men

stationed elsewhere (Palinkas et al., 1986). Perhaps these factors are present in submarine missions as well. Compared to matched controls, submarine personnel had lower hospitalization rates (Burr & Palinkas, 1986). Longitudinal studies of individuals who faced extreme hardship in their lives show remarkably positive adjustment later in life. This return to healthy physical and mental functioning is remarkable, and has been documented in individuals who suffered captivity as prisoners of war (Deaton, Berg, Richlin, & Litrownik, 1977; Feder et al., 2008; Suedfeld, 1996) and holocaust victims (Greene, 2010; Suedfeld, 1996).

Extreme environments engender cognitive and behavioral changes that may increase perceptions of self-efficacy and improve general health (Palinkas & Suedfeld, 2008; Suedfeld, 2001).This provides support to the notion that stressful situations may lead to positive effects, by supporting the development of effective coping strategies, increasing self-efficacy and developing participants' resilience to stressors. The psychological changes resulting from residing in a stressful environment are likely contributory factors to this change in health outcomes (Palinkas et al., 1986).

Positive psychological effects

Post traumatic growth reports involve the perception of better relations with others, new possibilities in life, enhanced personal strength, and an increased appreciation of life and spiritual growth (Tedeschi & Calhoun, 1996). In the astronaut population, similar anecdotal reports of personal growth and awe have been reported following spaceflight (Yaden et al., 2016). Empirical and anecdotal

data from studies indicate that individuals experience personal growth and positive psychological changes associated with living in the extreme environment of space (Ihle et al., 2006). The primary factors that show positive change correlated with isolation and confinement are social, personal, and environmental.

Positive social effects of living in an isolated and confined environment

The social environment was the most stressful part of living in extreme environments, and changes in personal growth related to social factors were reported by participants in the Mars 500 spaceflight simulation study (Solcova & Vinokhodova, 2015). The study indicated that participants grew from the experience in several ways related to interpersonal perspectives and perceptions of self-efficacy. The frequency of responses to the stress-related personal growth questionnaire indicated that participants developed new relationships, learned to appreciate others who have had difficulties, became more accepting of others, and learned to approach life more calmly. In addition, participants also reported positive changes in locus of control over baseline values (Solcova & Vinokhodova, 2013). Astronauts report globally that self-awareness and group harmony are major concerns (Stuster, 2010), and training for these experiences may help to improve their social skills and capabilities (Kass & Kass, 1999; Tomi, Kealey, Lange, Stefanowska, & Doyle, 2007). Interpersonal training for effective group functioning is an important part of the Japanese space program (Roach, 2010).

Positive personal growth effects

Living and effectively coping with the stressors in isolation and confinement likely boost participants' confidence, perceived self-efficacy, and belief in their own capabilities. Polar patrollers reported increases in personal strength and self-efficacy following year long-patrols in the Artic (Kjærgaard et al., 2013). Polar isolation and confinement improves participants' perceptions of self-efficacy, fortitude, perseverance, independence, self-reliance, ingenuity, and comradeship (Palinkas & Suedfeld, 2008). Astronauts reported that they were more confident and comfortable post flight as evidenced by decreases in responses to measures on self-doubt, and desire to seek isolation (Suedfeld & Brcic, 2011). In addition, perceptions of personal strength increased after spaceflight (Ihle et al., 2006). Going through adversity and successfully adapting to it likely improves participants' perceptions of their own capabilities. This may lead to more self-confidence, stress tolerance, and interpersonal awareness (Linley & Joseph, 2004).

Changes in environmental perceptions

One of the key factors living in an extreme environment is the participants' awareness and dependence on functional life support systems. In the BioSphere2 experiment, this source of stress culminated in a profound awareness, and appreciation for the interconnectedness of life on Earth (Nelson, Gray, & Allen, 2015). Polar military patrols reflected this perspective as well, with an increase in scores on "universalism", where patrollers felt an appreciation for nature's beauty (Kjærgaard, et al., 2013). Cook's diary onboard the Belgica speaks to the

appreciation for the natural beauty of the Antarctic, despite their trying ordeal trapped in the pack ice during the Antarctic winter (Cook, 1909).

Viewing Earth is often a favorite leisure activity on board the ISS (Robinson et al., 2013; Stuster, 2010, 2016). Perspectives of Earth also change considerably relative to other attitudes and perspectives after spaceflight missions (Ihle et al., 2006; Ritsher, Kanas, Ihle, & Saylor, 2007.) Spaceflight experiences changed astronauts' attitudes of Earth's beauty and fragility, and altered their behaviors after spaceflight (Ihle et al., 2006). Cosmonauts who spent a year or more in space reported higher positive changes on scores in "appreciation for life" and "relating to others" than cosmonauts with less than a year in space. In addition, comparisons of active duty cosmonauts and retired cosmonauts indicated that spaceflight experiences contributed to long-term positive changes in values and attitudes (Suedfeld et al., 2012). It is possible that spaceflight, stress, and viewing Earth from orbit are transcendental experiences that affect participants' attitudes and values. In personal memoirs, astronauts report the transcendental nature of viewing a finite Earth without geo-political borders (Eisele, 2016; Linenger, 2000). In addition, value hierarches show differences following spaceflight. Spacefarers had an increase in universality, environmental concern, and collective values regardless of nationality post-flight (Suedfeld & Brcic, 2011).

Early Apollo astronauts' memoirs showed changes in measures on spirituality after their mission phase, perhaps as a result of their experiences travelling to the Moon, and seeing Earth (Suedfeld & Weiszbeck, 2004). The awe

resulting from spaceflight may have transcendental properties for spacefarers. In a series of interviews with 30 astronauts, awe and transcendence were common themes, where the perspective of viewing Earth profoundly influenced astronauts' perspectives (White, 1998). This "overview effect" has been reported to profoundly change participants' perspectives of themselves and their humanity (White, 1998;Yaden et al., 2016). Perhaps small changes related to environmental appreciation are likely to occur as opposed to global value changes. Even though some astronauts have experienced profound, positive life-altering experiences associated with spaceflight (Yaden, et al., 2016).

Personality traits correlated with resilience

Five Factor personality traits correlate with an individual's stress resilience capabilities. In a recent study, neuroticism and extraversion were inversely correlated with resilience and life outcomes (Sarubin et al., 2015). This supports previous research linking Five Factor personality traits with resilience constructs. In Campbell-Sills, Cohan, and Stein, (2006) researchers demonstrated statistically significant correlations between personality traits and self-report scores on the Connor Davidson Resilience Scale. The results indicated strong positive correlations with extraversion and conscientiousness. Further, a strong negative relationship was identified with neuroticism and resilience. As well as a small, but statistically significant effect for openness.

Taken together, this research literature suggests that high extraversion, low neuroticism and high openness to experience may promote quick recovery from

stress. These personality traits may predispose an individual to deal with stress and negative life events in more adaptive ways.

Conclusions from the Literature Review

Spaceflight and training for it are very stressful situations, full of discomfort, uncertainty and risk (Garshnek, 1989; Roach, 2010). The social and physical environments of isolation and confinement contribute to irritability, depression, and interpersonal conflict during the period of isolation and confinement in multiple contexts (Palinkas et al., 1995; Suedfeld & Steel, 2000). In addition, the monotony of day-to-day tasks takes its toll on spacefarers (Roach, 2010; Stuster, 2010, 2016). Combined with scheduling and time pressures, spaceflight activities are highly stressful, exacting, and short on creature comforts and opportunities to relax (Baggerman, Rando, & Duvall, 2004; Kanas, et al., 2001; Kanas, 2015; Roach, 2010; Stuster, 2010). Spending long periods of time confined with the same individuals in high-risk situations causes trivial issues to become major annoyances (Bluth & Helppie, 1987; Stuster, 2010).

Selecting out individuals who won't perform well in these environments is important (Chidester, Helmreich, Gregorich, & Geis, 1991; Gunderson, 1966). "Selecting in" individuals who will adapt, and cope appropriately to these environments is increasingly important as autonomy and duration increase (Kanas, 2011, 2015a; Roach, 2010). Selecting-in individuals who are task-oriented problem solvers, who have high assertiveness, positive expressivity and interpersonal

awareness are key to future success for missions in these environments (Kanas 2015; Kass, Kass, Binder, & Kraft, 2010).

Despite the challenges of spaceflight, spacefarers report it as one of the greatest experiences of their lives. This is not just because they are elite civil servants performing their duties for their nation; participants in other extreme environments report similar growth effects, and desires to return (Wood et al., 2005, 2000). Personal growth, appreciation for nature, and group processes that occur in these situations are novel, motivating, and potentially serve as countermeasures to the stress in ICE.

Value changes by astronauts and enhanced environmental appreciation following short and long duration spaceflight are important factors that may serve as positive countermeasures to stress in spaceflight. These positive factors have only begun to be considered by researchers in the literature (Ihle et al., 2006; Ritsher et al., 2007; Solcova & Vinokhodova, 2015; Suedfeld et al., 2012; Suedfeld & Steel, 2000). This study aimed to learn more about the positive aspects that can occur during spaceflight. It utilized an exploratory case study design to further understand this phenomenon. In addition, identifying astronauts who are low on extraversion and high on resilience may provide new information to refine current resilience theory. In the next chapter the research design and methodology will be discussed. The following chapter will cover the research design, the study's research questions, as well as the research protocol.

Chapter 3

Introduction

The purpose of this chapter is to review the methodology for the study, which was designed specifically to address the research questions. The study investigated how the perceptions and values of astronauts changed after spaceflight. The study collected demographics, measures of resilience using the Brief Resilience Scale (Smith, et al., 2008). Additionally, personality data was collected utilizing the Mini-IPIP. Finally, a quantitative survey instrument was administered to identify the reported changes in astronauts' values post-flight. Following the analysis and identification of quantitative results, astronauts participated in a one-hour semi-structured qualitative interview. This chapter provides an overview of the design of the methodology. In addition, sample strategies and ethical considerations are addressed.

Research Design and Approach

This study employs an exploratory, multiple case-study design. Yin, 2017 indicates that a multiple case study design should include at least two case studies for a theoretical analysis, and this study employs three case studies. The unit of analysis for each study was at the level of the individual astronaut. All participants were provided informed consent, completed web-based survey items, and

participated in an interview in person or over the phone centered on understanding their experiences in space, and changes to their perspectives or values post-flight. transcripts were transcribed, de-identified and analyzed using thematic content analysis. Quantitative and qualitative results are presented in descriptive statistics and in three case studies along with a cross-case synthesis, respectively. Finally, these cases are discussed concerning agreement and disagreement with theory, as well as addressing rival explanations for the observed phenomenon.

Research Questions

The purpose of this research is to determine the perspective and value changes that are related to spaceflight activities, and to a limited extent, to better understand the cognitive processes astronauts use to deal with stress in spaceflight. Understanding the positive factors of spaceflight and designing systems to provide these positive factors may reduce psychological risks in long-duration spaceflight operations. This effort contributes toward the development of a more holistic understanding of human performance in extreme environments.

- RQ 1: What perceptions change post-flight in astronauts?
- RQ 2: What are the changes in values that occur post-flight in astronauts?
- RQ 3: What were the most stressful experiences in space?
- RQ 4: How did participants cope with those stressful experiences?
- RQ 5: Why did spaceflight experiences change participants' values and perspectives?

Addressing the research questions with the exploratory case study design

A case study is effective for investigating a contemporary phenomenon in depth and in its real-world context, especially when the boundaries between the context and the research phenomenon may be blurred (Yin, 2014). In answer this study's research questions, using an exploratory case study was an effective approach to understanding stress, resilience, and perspectives growth in the context of spaceflight as the context and research phenomena are highly related (Suedfeld & Steel, 2001). In addition, using the exploratory multiple-case study design enabled this study to collect a large amount of qualitative data from a small sample, and explore those experiences in depth. This design utilized interviews to gain breadth and depth in the scope of data that was gleaned from each participant. In total, over thirty pages of qualitative data was generated from three participants. Thus, the case study design was advantageous compared to use of other methodologies, especially when presenting and sharing these findings.

Furthermore, the use of the case study design to answer these research questions represents a novel addition to the research literature. The exploratory case study approach elucidated factors for future empirical research, as well as informing potential refinements for consideration in predicting resilience.

Research Setting and Sample

Population

There are 553 individuals who have orbited the Earth (Drake, 2018). Of those, 305 are active or retired NASA astronauts (Whiting, 2017a; 2017b; 2017c). The total population includes individuals from multiple nationalities, including American, Russian, Japanese, European, Chinese, and Indian. The majority of astronauts are male, with only about 10% of the total population being female. Over half of all astronauts have advanced degrees in science, technology, engineering or mathematics (STEM) fields. The definition for "astronaut" in this study was considered as an individual who flew higher than 50 miles above mean sea level and orbited the Earth.

Sample

The study included three former astronauts who flew on Shuttle missions in the 1990's and early 2000's. The sample was recruited via email using social networking platforms such as LinkedIn, or by contacting former astronauts via email. Participants were not compensated for their time.

Procedure

Participants were sent recruitment emails and given brief information about the study. They were given an informed consent form and signed and returned electronic copies of the informed consent form. Then, survey materials were presented to study participants, and participants were given about a week and a half

on average to complete the survey items at a time convenient for them. Two out of three participants completed the survey items at one time. One participant completed 75% of the survey items at one time and 25% the next day. Participants were sent four consecutive email links which brought them to the web-based survey and questionnaire items. Participants completed all the survey and questionnaires in about eight and a half minutes on average. Participants accessed the web-based items from their personal devices, either on mobile or desktop platforms. The type of platform that participants used to complete the items was up to their preference and this information was not available to the PI. Finally, participants answered customized questions in a semi-structured interview format for about an hour in person or over the phone. At the end of the interview, participants were thanked for their participation.

Research Instrumentation and Materials

Measures

This study leveraged four distinct surveys designed to answer and explore the research questions. Demographics were collected to inventory quantitative differences across participants. The brief resilience scale was used to assess participants' resilience. Personality was assessed using the Mini-IPIP to explore the predictions of resilience theory. Finally, the Positive Effects of Being in Space was utilized to provide quantitative data on participant's perspectives on the post-flight effects of spaceflight on their lives.

Personality

Personality data were collected using the Mini-International Personality Item Pool (see Appendix C). This instrument is scored on a continuum with 0-20 points possible for each factor. For example, a high score of 20 on extraversion would represent an extremely sociable and outgoing individual. Whereas a score of 0 on extroversion would represent a highly introverted individual.

Table 3.
Aggregate Personality Data

Factor	Extraversion	Agreeable-ness	Conscientious-ness	Neuroticism	Intellect/ Imagination
Mean	12	17.3	16.33	8.33	17.66
SD	3.46	3.05	1.15	1.53	2.52
Range	16-10	20-14	17-15	10-7	20-15

Brief Resilience Scale

The Brief Resilience Scale is structured on a 5-point Likert-like scale such that an individual rating a 5 indicates "strongly agree", with 3 indicating neutral and 1 indicating "strongly disagree" (see appendix A). The Brief Resilience Scale contains three questions which are phrased in the negative to attempt to counteract potential response biases. The reverse-scored items had means of 1.11 and standard deviation of .33, indicating participants "strongly disagreed" with the negatively-

phrased statements. These items were transformed into corresponding positive scores for the analysis by participant and for the combined resilience data.

Positive Effects of Being in Space

The Positive Effects of Being in Space is scored on a Likert-like scale from 0 to 5, with 5 being "I experienced this change to a very great degree from being in space." The table below presents the statements that received the highest Likert-like responses on the 36-question forced-choice portion of the instrument. Additionally, participants can indicate that being in space didn't increase their perspectives on some statements because they already agreed or believed in the statement as much as possible pre-flight. This is scored with a 0* on the assessment.

Data collection and analysis

This study sampled individuals through convenience sampling. Participants completed web-based short demographics questionnaire. The next item they completed was the Brief Resilience Scale, followed by a brief personality assessment, the Mini-IPIP. Finally, participants completed the Positive Effects of Being in Space questionnaire (see Appendix A-D). Quantitative data was analyzed using descriptive statistics. Survey and interview responses were attributed and traced to participants using an assigned alpha-numeric coded identifier.

Interview questions

Interview questions were generated for each individual based on a number of factors. These included an individual's biography, work experiences, career,

mission objectives and their responses to the survey items. Interviews were done with participants in person or over the phone at a time convenient for them.

Case study

Data for the case studies came from written articles, publicly available video footage, as well the data collected as part of this study. This information was integrated into each individual case study.

Qualitative data analysis process

Interviews were conducted in person or over the phone. In either case, transcripts were audio recorded and then transcribed. During the transcription process, data were cleaned of personally identifiable information including mission designations, names of participants, and specific years to maintain participants'' anonymity. After collecting and transcribing interview data, a recursive qualitative thematic analysis process was utilized.

Qualitative thematic analysis was performed following guidelines provided in Braun & Clark, (2006). Themes were defined as representing some level of patterned response or meaning within the data set (Braun & Clark, 2006). Thematic content analysis was performed on each interview transcript independently from the others. Then, interview transcripts were aggregated by question, considering each participant's responses in context. When all transcripts were compiled by question, another thematic analysis designed to identify themes was run on all the transcripts. Themes were recursively identified based on the transcript data and organized into a spreadsheet. Transcripts were then coded based on the identified themes, and this

evidence was compiled into a spreadsheet. In accordance with the qualitative data management suggestions of Yin (2014), a research database was maintained which provided a chain of evidence from data collection to results. Finally, the supporting evidence for the themes were refined and key quotes from each participant by theme. This parsed thematic analysis data was used to substantiate each theme in each participants' case study report. After the case study reports were written, a cross case synthesis was performed to identify differences and commonalities.

Ethical considerations

All attempts to maintain participant's anonymity were utilized in this study. Data transcripts were cleaned of identifiers, years, and mission designations. Additionally, participants were made aware of the risks and benefits of the study and were free to discontinue participation at any time.

Data security

Interviews were audio recorded to ensure that written transcripts were as accurate as possible. Specific personally identifiable indicators present in the audio files included the participant's name, responses, choice of words, voice, and intonation. The primary investigator was the only individual who had access to the audio recordings. These recordings were never transmitted on the internet or stored on any cloud service. During the study, the audio files were password protected, stored on an AES 128-bit encrypted software-locked solid state external drive capable of only physical USB access. Furthermore, the external drive was stored in

a locked safe. Access to the safe was restricted by a key which was in the PI's possession at all times. No unauthorized access or data security breach occurred at any time during the study. At the completion of the study, data containing participants' personally identifiable was securely erased.

In the following chapter, research results are presented. Including findings from both quantitative and qualitative components.

Chapter 4

This chapter details the quantitative findings collected from questionnaires and survey components. In addition, it presents the results of the explorative qualitative case studies.

Quantitative Data

This study leveraged four distinct surveys designed to answer and explore the research questions. These included demographics, personality, resilience, and the Positive Effects of Being in Space. Aggregate data for those instruments is reported in this chapter.

Demographics

Many former astronauts were contacted for this study, but only three completed the questionnaires and interviews. Of the six participants that agreed to participate, only three completed the informed consent and were eligible to participate in the study. Participants were all former NASA astronauts who flew on Space Transport System ("Space Shuttle") flights during the 1990's and early 2000's. All participants spent up to two weeks living onboard Shuttle. Participants flew on an average of 3 flights during their active duty astronaut careers, with a standard deviation of 1 flight. All participants flew in space on short duration missions. The average duration of each mission was about 12 and a half days (12.4), with a standard deviation of about 2 and half days (2.6). The longest

duration each participant spent in space on a single mission was an average of 15 and a half days, with a standard deviation of about a day (1.3).

This study sought former astronauts who had had significant time since their last flights to better understand the impact spaceflight has had on their lives. To that end, participants' median ages at the time of study participation were 62 years old with a standard deviation of 4.5 years. All participants had earned at least a master's degree in an engineering field.

Aggregate personality data

Based on the aggregate data, individuals scored in the middle of the scale on extraversion, indicating they are neither strongly extroverted nor strongly introverted. They scored highly on intellect, or desire for new knowledge and abstract ideas. Participants scored low on neuroticism, which correlates with higher resilience and is expected given the rigorous astronaut selection process. Conscientiousness was scored with a high mean and the lowest amount of standard deviation among all factors. Finally, the greatest differences between individual scores were found on extraversion and agreeableness factors.

Brief resilience survey data

Participant's responses to the Brief Resilience Survey (BRS) items were very consistent, and participants self-reported high measures on resilience. The data indicated that participants strongly agreed with the items corresponding to high resilience.

Table 4.
Summary of Responses for each question on the BRS

Participant ID	**Mean**	**SD**
TR	5*	0*
TK	4.67	0.52
PS	4.83	0.41
Aggregate	4.87	0.39

Overall, the aggregate data demonstrated that participants strongly perceived themselves as having high resilience, reporting aggregate mean 4.87, standard deviation 0.39. It is of note that one participant did not answer a question, which has been indicated with an asterisk. This omission was not scored and was omitted from the individual and aggregate analysis.

Positive effects of being in space aggregate data

The PEBS data was analyzed by each question across participants. The results are compiled in the following tables (see table 5 and 6 below).

Table 5.
Statements with which Participants' reported a Moderate Degree of Change from Being in Space

- I put more effort into relationships
- I can better appreciate each day
- I have greater appreciation for the value of my own life
- I changed my priorities about what was important in life

Table 6.
Statements with which Participants' Experienced a Great Degree of Change from Being in Space

- I learned to appreciate the fragility of the Earth
- I realized how much I treasured the Earth
- I gained a stronger appreciation for the unity of human-kind
- I gained a new appreciation for the boundlessness of the cosmos

No aggregate data indicated that participants "experienced this change to a *very great degree*". However, there was a median consensus across all participants representing "no change" on three statements. These included perceptions on extrasensory perception, the perception of arbitrary differences between political ideologies and the statement "I established a new path for my life." Although there are differences on individual responses to the last question. One participant reported a "great degree of change" and the other two reported "no change", leaving a median of 0.

Additionally, participants indicated that being in space didn't increase their perspectives on some statements because they already agreed or believed in the statement as much as possible pre-flight. These items, indicated with a "0*", were variable across items with limited agreement across participants. Of the statements answered with "0*", the only question that had two responses of "0*" was "I became more interested in space exploration".

Qualitative Data

The following three case studies were compiled from diverse sources, including the responses collected as part of this study and as publicly available written and video records. Additionally, the researcher reviewed STS mission flight footage from each participant's missions to better place their comments on stressful experiences and habitability data in context. In the interest of maintaining participant's anonymity to the best extent possible, mission designations, names, dates and details about specific events are not included in the case study reports. Additionally, participants are referred to in the data and case studies with a different first and last initial than their actual names to protect their identities.

Case Study-TR

TR was selected to the astronaut corps in the early '90s, during the Shuttle program. Their missions primarily provided research on tools and techniques in microgravity that later assisted in the construction of the International Space Station which was planned for construction near the end of that decade.

Habitability and work characteristics

They described life onboard the Shuttle as "six people living in a camper, a Winnebago, you're just all together, all the time". They described the lack of privacy as a manageable issue only because they were on-orbit for a short period of time. They also missed good, home cooked food.

For them, living aboard the Shuttle for two weeks was manageable and very enjoyable, and the "novelty of it just never wore off." However, Shuttle was a busy operational environment which routinely consisted of long, hard days. Describing a typical day on-orbit TR said "during the 16 hours you're awake, you're busy." Leaving only 8 hours in the day scheduled for sleep. During non-EVA days, the crew would be running various experiments, testing tools and techniques. They would work in teams of two or they would work alone depending on the requirements of the experiments. Then, they would regroup for meals together in the Shuttle mid-deck. Although many Shuttle astronauts worked in shift schedules, TR's missions were all single shift. On their missions, all crewmembers spent meals and waking hours together.

On days that they were scheduled to do EVA operations, efficient teamwork and concise, clear interpersonal communication were crucial for safety and success. The entire crew was involved in the safety, preparation and coordination for those activities. There were two crewmembers outside the Shuttle, an Internal Vehicular activity (IVA) crewmember coordinating tasks, and if required, the pilot would be operating the robotic arm while the commander would oversee the operation to provide an extra set of eyes. On their missions, spacewalks typically took 6 to 8 hours to complete, with additional hours spent donning and doffing the suits and completing checklists.

Successful, safe completion of complex mission tasks hinged on clear interpersonal communication which was facilitated by a top-down military-style

power dynamic. The commander was in charge, and if they said "jump, you'd say, how high?" TR stressed the importance of good crew discipline, especially during off-nominal events. They also stressed how important it was to know your crewmembers. Prior to flight, the crew worked in an office together, they lived, worked, and travelled together during the year prior to the scheduled mission launch date. This level of acquired interpersonal communication from living, travelling and eating together on Earth was important because crewmembers needed to be able to "kind of know each other beyond just the formal checklists and things like that." This ensured a successful mission on-orbit and especially, in a multi-national crew, reduced the potential for miscommunication while ensuring that the crew was able to live together in a tight space with limited privacy for two weeks.

During TK's satellite servicing EVA, the EVA required the entire crews' undivided attention. While TK and their EVA buddy were outside positioned on the Shuttle payload bay, the commander was communicating with Mission Control, the pilot was positioning the orbiter, and the IVA crewmember was engaged in procedural support tasks from the Mid-Deck.

Stressful experience

TK's most stressful experience involved an off-nominal, unanticipated, service of a satellite during EVA. Recalling that experience, they emphasized how difficult and dangerous it was. There were rough edges on the satellite, which if touched could tear a glove and cause a suit depressurization- a life-threatening

event in the vacuum of space. While preparing to service the satellite, they were hit with a sudden bout of intense vertigo. They explained how they "mentally tuned-out" an overwhelming feeling that they were falling forward. Focusing their attention on the ego-centric static movement of the satellite, they were able to stay on task, push past their vertigo, and continue the EVA to complete the mission objective. They dealt with this brief, unexpected encounter with spatial disorientation on-orbit by immediately drawing on their past experience and training.

Earth observation

Despite the intense task load and difficult mission demands they would still take the time to look out the window and admire the great orbital scenery. They recalled, "The most fun thing to do is just stare out the window". Viewing Earth on the day-side of the orbit, then viewing the stars on the night-side were positive experiences for them. The orbital perspective impacted them significantly because of the unique, beautiful perspective, and this was their most memorable factor from their whole spaceflight experience. They indicated that viewing Earth was what impacted them the most in a personal or spiritual sort of way “cause everything looks so different and so amazing up there." Their appreciation of viewing Earth's complexity and natural beauty, suspended in the cold black of space inspired an enhanced environmental perspective.

Viewing wildfires in Australia from orbit, TR stated "you could just see the pollution in the top of the atmosphere, just spreading over the Earth" and those

were acts of nature. When contrasted with a deliberate human-caused event, such as the Kuwaiti oil field fires during the Gulf War, the pollution from the oil well fires would float up into the Earth's atmosphere, and astronauts could see the soot and smoke travelling through the upper cloud layers. TR commented that:

> "When you see it from that perspective, just really rubs you the wrong way. (It) disturbs you that somebody who has no clue as to what they are doing, how they are hurting the whole planet. It's like me going to your house and setting the house on fire. Terrible. The Earth is our home."

Viewing Earth against the background of space reinforced the perceived fragility of our mutual home. Given this orbital perspective, they indicated the impact of viewing the Earth in space reinforced a clear perception of its fragility and impermanence "You realize how insignificant the Earth is on the grand scheme of things... in the total scheme of the universe it's just a speck of dust". In addition to an appreciation of the size and scale of the Earth, they emphasized the importance of their perspective from orbit, which fostered an improved sense of environmental stewardship, commenting "if we don't care for it, it'll just blow away, it'll be gone". In addition to environmental sentiments, viewing Earth from an orbital perspective helped to reinforce their perspective that humans have more in common, compared to the differences that people tend to focus on.

The orbital perspective contributed to an increased sense of universalism, because the Earth "is so beautiful and peaceful looking. You don't see any

conflict... You don't see people developing nuclear weapons and other people and politicians arguing." In addition to this sweeping orbital perspective without boundaries, TR mentioned that working with international astronauts during astronaut training reduced the perception of barriers between individuals from different countries. The intense crew training on Earth prior to flight reinforced a perspective that "the international barriers... disappear, as you get to know people really well, you don't really think about which country they are from... You find out you have more in common than you have different."

Post-flight perceptions and impacts

Table 8.
Categorical Summary of TR's Highest Responses to PEBS Statements

I experienced this change to a *moderate degree*	**I experienced this change to a *great degree***	**I experienced this change to a *very great degree***
• Increased involvement in environmental causes • Increased interpersonal effects	• Increase perspective of the fragility of Earth • New personal opportunities • increased perspective of the unity of humanity	• Increased appreciation for Earth • Improved career prospects

Spaceflight had significant career advantages for TR. They spoke at length about how their spaceflight experience positively impacted their career opportunities, as well as elevating their quality of life and standard of living. As a former astronaut, they were invited to dine with world leaders in foreign countries all over the world. They got to meet people from many cultures and levels of status and remarked that people seemed to treated them with more kindness and respect. They enjoyed getting the opportunity to meet many, many different people and the opportunity to inspire others.

Regarding their increased public presence as a former astronaut, they mentioned that "...the magnifying glass is always on you." They are careful walking the line between space advocacy and political advocacy. They are conscious of their potential for increased perception in society, the media, and must be careful with expressing their personal political beliefs. They often turn down offers to speak at political rallies. Juxtaposed with those constraints, they feel a strong sense of honor and duty, and the role they have representing NASA. As a member of an elite group of space explorers, they feel they have a responsibility to "do good things and to represent yourself, NASA, and America, in a good, positive way." In addition to the personal, and career aspects of spaceflight, they joke about how they found a picture of themselves being auctioned online, "It was just a regular picture of me, nothing fancy, a little 8x10 photograph somebody was auctioning off, worth like $25 or something.... It was funny." They have no doubt that spaceflight altered the course of their life and changed their life for the better.

They believed it significantly improved the life of their family members, as well. If given the opportunity to return to space, they would go again, provided the mission was new and novel.

Conclusions

Despite the "Jam-packed" task and workload schedule, the operational tempo was manageable "for a short period of time." This capability to execute tasks for 16 hours a day, performing dangerous work with extremely low margin for error highlights TR's adaptability, hard work and resilience. Likely, this capacity stems from a combination of their personality, and perspectives sharpened by years of training. Their remarkable performance during their EVA was indicative of significant cognitive stress management resources, and a task-oriented coping strategy. They provided us an indication of their high internal locus of control, which they believe is required before performing complex orbital operations, "you have to be prepared to handle everything. You need to have confidence in yourself that you can handle it. And if you don't, if you don't have that, you're in the wrong business."

Case Study- PS

PS flew on a number of STS missions. A few of the missions gained a good degree of public and media interest, which created competing mission demands. Additionally, they flew on a mission delivering new modules and supplies to the ISS. Regarding the different characteristics on these missions, they stated that when

"you go and dock with another spacecraft and open the hatches and work on them (as a) combined spacecraft...It's a huge difference."

Habitability and work characteristics

Their Shuttle missions featured multiple competing demands that were placed on astronauts. They were running experiments, conducting EVAs, conducting microgravity research, resupplying ISS and adding modules to the station. It was busy, with cramped quarters. They described living onboard Shuttle as "a hiking camp, where every night you pack up all your stuff again." But, living aboard Shuttle for a short period of time, typically lasting two weeks, "[was] no problem".

Concerning frustrating factors in spaceflight during their missions, they mentioned that using the bathroom was an arduous process. Humans evolved in gravity, so there are some behavioral adaptations that are required for spaceflight, some less glamorous than others.

On a different note, PS mentioned that " in space, it is really hard to maintain an organized workspace, and that really [frustrated] people... it's much more work and you never have enough hands, and it's easy to lose things." They described it as a function of adapting to the microgravity environment, that the lack of a consistent, reliable organizational framework generated a sort of "underground frustration" that they didn't recognize until their later flights. It was more of an issue managing tools and items than the inherent nature of microgravity itself, which in the confined space of Shuttle actually increased their perception of habitudinal volume.

In one example, PS detailed how having constant access to multiple surfaces was a significant benefit that the astronauts didn't fully capitalize on until they were on-orbit. On one of their missions, they had a table in the payload bay which was such a valuable piece of equipment they scheduled it "to the minute, for the whole mission." Once arriving on orbit, PS and the crew realized that they had only scheduled the use of the top of the table. They had completely neglected to consider that the bottom surface of the table. Which was an equally useful Velcro workstation. Despite significant spaceflight training, a lifetime of assumptions from living in one-G interfered with their planned utilization of space in this new environment. However, this was not their only human-machine challenge living on-orbit. They mentioned that the design of the system needed systematic design improvements.

The flight deck was incredibly complex, "designed before anyone had really thought of human factors, and it really showed... the cockpit was a nightmare". There were also aspects of the flight deck that did not afford high cognitive performance. The vehicle systems did not provide appropriate or adequate feedback for astronauts on flight. PS indicated that Shuttle "responded in a way that was really sort of mysterious." It required extensive training, repetition, checklists, and cheat sheets to "get through all the human factors challenges" to maintain the necessary level of situational awareness. These systematic human factors challenges likely increased cognitive and training demands placed on flight crews.

Stressful experience

PS's most stressful experience occurred while they were returning from performing an EVA. Climbing into the airlock after a full day in the spacesuit, "absolutely exhausted" and running out of oxygen, battery power and water, they couldn't close the airlock outer hatch. The issue is if an astronaut can't close the outer hatch, they can't safety enter the spacecraft. As an astronaut on an EVA, the airlock is a critical system that needs to work, and "you don't have a huge amount of options" to resupply your suit with life support supplies or enter the spacecraft. With a high degree of adaptability, and a task-oriented approach, PS focused on solving the mechanical problem. Along with their EVA buddy, they "wiggled and jiggled" the airlock outer hatch to get it sealed. Retelling the story, PS epitomized an extremely adaptable, resilient mindset, commenting that the situation was "not a big deal in the end. Most stressful things are that way."

Faced with the stress of performing under the weight of life-threating consequences, PS demonstrated the importance of having an adaptable, task-oriented coping strategy. Task-oriented coping, managing tiny details under pressure is likely crucial for mentally managing off-nominal events. Based on the interview with PS, these off-nominal events occur fairly often when pushing the boundaries of technology and human performance.

Earth observation

PS indicated that one of the most enjoyable experiences during one of their missions was viewing Earth. Their spaceflight missions increased their perception

of the beauty of Earth, the fragility of the environment, and the unity of humanity. During their Shuttle missions they indicated Earth observation was a positive leisure experience, and that it was the most "endlessly interesting thing to do." Travelling in low-Earth orbit at 17,500 miles per hour, astronauts view sunrises and sunsets every 45 minutes. In just minutes they travel over entire continents in new attitudes and from interesting perspectives. On Earth, we are accustomed to seeing topography from an east-west (or west -east) perspective on an aircraft, or "north-up" when viewing maps. Due to the orbital inclination of most human missions to low-Earth orbit, astronauts have the opportunity to view Earth from new, novel orientations. PS enjoyed watching the fascinating interaction of topography, weather and light on the Earth, commenting "[it's a] constantly fascinating show about your own home, you never knew so well." Yet, the beautiful, immersive and relaxing activity watching Earth was contrasted with a clear perception of its fragility.

Table 10.
Categorical Summary of PS's Highest Responses to PEBS Factors

I experienced this change to a *moderate degree*	**I experienced this change to a *great degree***
• Increased Personal Creativity	• Improved perspective of Earth's beauty and fragility • Improved understanding of the Boundlessness of the cosmos

On their first mission, PS was struck by the beautiful, yet thin and fragile nature of the atmosphere. Contrasted with this beauty was a clear perception that Earth's all-important atmosphere was tenuous and extremely fragile. Regarding their experience viewing the Earth, they stressed that their experience was not unusual, it was a common reaction among astronauts. Viewing Earth enhanced their perceived need for shared environmental stewardship. They commented, “we've got to take care of this [Planet]." The orbital perspective impacted them and helped them to recognize our shared responsibility to care for the planet that we call home.

On both survey and interview components of this study, PS indicated that Earth observation was one of the most impactful aspects of their spaceflight experience. Viewing Earth from orbit impacted their perception of humanity on a larger scale. Viewing cosmic objects, seeing the scale of the universe from orbit, PS observed "everything you see is bigger and older than we are. Not just bigger or older than each individual... but bigger and older than the entire human race." This cosmic context was supplemented with PS's extensive cross-cultural training while in the Astronaut Corps. Working with international astronauts during training, on missions, and living in other countries enhanced their cultural understanding of others.

Regardless of whether they enjoyed sharing the same space with other, very different individuals, PS mentioned that their experience enhanced their perception of the unity of humanity. On orbit, teamwork and trust were critical, "because

pretty much anybody on the crew can screw up badly enough to kill the whole bunch." Astronauts rely on each other's knowledge, skills and abilities for their shared survival. Regardless of whether they are friends or not, the reliance on each individual's strengths and skills, "...as a team, [makes] you unbeatable". PS worked with lots of individuals over their long career with NASA and stated that their experience in space enhanced their appreciation for all types of people. Summing up this perspective, they stated "whether I liked them or not, it was an incredible, amazing expression of the complexity of human-ness. I think being in space enhanced my sense of that." This expression of common heritage and human universality are not uncommon as these themes often are reflected in other astronauts' journals and memoirs (White, 1998).

Conclusion

PS operated in stressful off-nominal situations during their spaceflight experience. They had very high resilience scores on the assessments, which was validated by their remarkable performance on their EVAs. Based on those experiences, it is reasonable to infer that PS leverages significant cognitive stress management skills and is clearly capable of handling dangerous situations. Given their task-oriented approach to solving problems, they clearly maintain a cool head when faced with life-threatening risks. They were able to accomplish tasks with a high internal locus of control and significant adaptability. These characteristics were likely pre-existing throughout their life and perhaps may have contributed to their selection to the astronaut corps. Perhaps best summarizing their commitment

and dedication to spaceflight, they said, "[the] decision you have to make is it's worth your life... and you have to make that decision way before you get on that rocket."

Case Study- TK

Astronaut career

TK had a long career at NASA, where they flew on a number of Shuttle missions. The primary objectives of their missions were to collect space science data, resupply space stations, and test Shuttle repair and inspection techniques. TK's experience on Shuttle included living onboard for two weeks at a time, as well as travelling and docking with space stations. These experiences gave them a clear opinion on habitability concerns. Summarizing their experience living onboard Shuttle TK mentioned" you can kind of jokingly describe it as a camping trip in an RV with your closest friends, with hardly the ability to open the door and go outside." However, the microgravity environment attenuated the sense of confinement, increasing perceptions of habitable volume, because "you could hang out on the ceiling if you wanted to." Visiting ISS, they indicated that newer technology and increased living space integral in the design of the ISS modules combined to improve the quality of life onboard ISS.

Task characteristics

Shuttle was "a sprint" with a significant number of scheduled tasks that needed to be completed each day. TK mentioned that the pressure to complete the

highly scheduled mission timeline contributed to stress and frustration. Going into the Shuttle missions, they were aware that they were packed, short duration flights so they pushed to get the tasks done. The pressure to stay on track and on timeline were frustrating work factors, noting "if anything went a little bit wrong ...then you were immediately behind. So, that proved to be frustrating." The packed operational schedule introduced factors which proved to be chronic stressors, "feeling like there was always something else you needed to get done." This pressure increased significantly when rendezvous operations with space stations were scheduled. In addition to timeline stressors, in microgravity it was easy to lose things. TK said, "If you let go of something, it *will* float away, and then you're going to have to spend time trying to find [it]". In a high workload environment, with pre-existing timeline stressors this factor likely increased their perceived stress. Transporting huge amounts of cargo to and from spacecraft, they clearly managed these stressful and frustrating factors successfully.

TK indicated rendezvous operations were always stressful. These operations required significant cognitive resources with extremely low margin for error. Regarding cognitive factors, TK had to manage risks, figure out problems, work with ground control and solve problems. In that regard they drew upon their previous experience, and their cognitive problem-solving skills. Working in demanding situations, their prior training and experience helped them to deal with the stressors on-orbit. Addressing those factors, they commented "I don't know if it's so much resilience... [As] I have experiences that I can draw upon to help me

figure out what to do in this situation." Thus, previous experience and expertise helped them perform difficult tasks on orbit.

Positive experiences on orbit

Table 12.
Categorical Summary of TK's Highest Responses to PEBS Factors

Experienced this change to a *moderate degree*
• Increased political involvement • Greater appreciation for the value of their life • Can better appreciate each day • Strengthened spiritual/religious faith • Puts more effort into relationships and accepts needing others • More likely to try to change things that need changing • Increased perception that people are wonderful

Table 13.
Categorical Summary of TK's Highest Responses to PEBS Factors

Experienced this change to a *very great degree*
• Improved perspective of Earth's beauty and fragility • Realized how much they treasured the Earth • Became more excited about space exploration • Stronger sense of wonder about the universe • Improved understanding of human-unity

Describing their experiences on orbit, Earth observation was their favorite leisure activity. It was a stunningly beautiful view that was difficult for them to describe. On orbit, "floating in place, [you] watch the world go by, [with] sunrises and sunsets every 45 minutes or so." Understandably, this was a very impactful view. They emphasized the powerful perspective on-orbit, commenting "when you're up there, 250 some miles, looking down on the planet against the backdrop of space...That is a very powerful view. We see the world in a very different way." TK described the impact of viewing the Earth against the black void of space, and it accentuated their perspective on the fragility of the Earth. The interaction of powerful sunlight washing out the stars, leaving Earth in an intensely black void, made the Earth appear tiny, fragile. They reflected that the orbital perspective increased their perception of the necessity for environmental stewardship. Commenting " that [view] strikes you, and usually we come back and say [it] drives home, we better do a better job of taking care of this planet, the only one we know how to live on."

Post flight perceptions and changes

TK indicated that their NASA career post-flight was not impacted significantly by their spaceflight experience. Much like a civilian or corporate job, seniority on the job was rewarded with promotions and greater responsibility and "that's the way it worked at NASA as well." Career opportunities were less dependent on spaceflight experience and more on time spent at the agency. Despite being promoted to management positions, TK didn't think their spaceflight

experience had any significant bearing on these assignments, attributing it to their seniority.

Pursing jobs after their NASA career, TK indicated that for those jobs, being a former astronaut was just part of the job requirements. They viewed their spaceflight experience from a very matter-of-fact perspective. Stating, if the organization wants someone to "give presentations about what they did in space... that's going to be a former astronaut." They don't see their space experience as having a significant bearing on their post-flight career prospects. It is just another thing that they did, even though they often give talks and presentations about their spaceflight experience. Their space experience didn't fundamentally change their career prospects, for TK, that fundamental career change came when they decided to pursue a career as an astronaut.

Conclusion

Regarding their spaceflight experience, TK says "I feel very privileged that I was able to make my dream come true, which was to be an astronaut and to fly in space... more than anything I'm grateful that I had the opportunity." TK would return to space "in a heartbeat" if given the opportunity and would have liked to live on ISS for a long-duration mission. They developed the knowledge, skills and abilities to operate successfully on orbit. They performed well on orbit due to their technical proficiency, skills, and a task-oriented stress management approach.

Cross-case synthesis

Early life

All individuals pursued and attained at least a master's degree in an engineering field. All participants were selected to the astronaut corps in the '90s.

Habitability and task characteristics

All participants flew on STS missions, which at that time were tasked with testing and developing techniques for ISS construction and resupply, as well as microgravity research. All three participants were involved within NASA's decade long on-orbit development of ISS in some fashion. Participants spent brief periods of time on ISS. All participants spent at least two weeks in space onboard Shuttle. They equated life onboard Shuttle to being in an RV or on a camping trip, if not a bit jokingly. Shuttle had a fast-paced operational tempo and this was reflected in the interviews, with participants stating that it was a stress-producing factor. They indicated the fast pace was manageable for the short period of time they were on-orbit. All participants reported this operational tempo would be unmanageable on a longer-duration mission.

Task characteristics

The importance of interpersonal communication and teamwork were emphasized by all participants. Teamwork was important on-orbit as astronauts indicated that they often completed tasks in pairs together. This was not always the case, but generally the more complex the task the more crewmembers were dedicated to the task. For example, a simple task such as filling a water bag, would be done by only one individual. Completing complex IVA tasks, such as

experiments, were often done in pairs. Tasks with high complexity, such as manipulating the robotic arm, were supported by half the crew. When performing complex tasks with mission-critical ramifications, especially if an astronaut was on EVA, usually the entire six-person crew was involved. Two astronauts would be on EVA, and the remaining four crew members would be involved with communication support, coordinating procedures, piloting, or supporting robotic arm manipulation activities.

Pre-flight training

All participants indicated that pre-flight astronaut training was demanding and required all of their time. They reported that pre-flight training was comprehensive and was very effective in preparing them for their missions. When asked about their perceptions, they all believed that their training preparation for short duration life on-orbit was sufficient. It provided them with the knowledge skills and abilities needed to be successful. Interestingly, two participants were placed in off-nominal situations that they had not received training on. They reported that while these situations were stressful to them, there had essentially no issues completing the tasks with the support and training they had been provided.

As was the case in the Shuttle missions, participants lived, worked and traveled together. No participants reported that they had interpersonal issues with other crewmembers. However, they did report having disagreements and working through those disagreements with others while serving as management astronauts.

Dealing with microgravity

Participants indicated that living in microgravity was mostly fun and enjoyable. None of them experienced significant symptoms of space adaptation sickness (SAS) or spatial disorientation inside Shuttle. All individuals reported minor frustrations caused by losing objects. Despite the small living space on Shuttle, all the astronauts commented that microgravity helped to increase the perception of habitable space onboard. Of those that docked with ISS, the greater volume and locations to store items were positive affordances compared to life aboard Shuttle. On Shuttle, participants reported that they would have preferred to have more personal space. A small place for privacy or a place to store personal items would have improved their experience. While participants had no trouble managing these issues, they perceived it would be increasingly important on a long-duration mission to have private quarters.

Stressful experiences

Two participants indicated that they had off-nominal experiences on their EVAs, and that these experiences were the most stressful components of their total time on orbit. This shouldn't come as a surprise, any EVA is risky, and astronauts fully understand that life-threating situations may occur at any time. On their missions, they were placed in situations where they had to perform unplanned EVAs on-orbit using untested techniques on equipment they had never trained with. The extra stress present in any EVA was compounded by additional off-nominal interactions with space systems. These unplanned, off-nominal

interactions required cognitive and psychomotor performance which likely would have exceed the capabilities of most humans. These tasks included: servicing a satellite in low Earth orbit while experiencing vertigo; and diagnosing and manipulating the airlock outer hatch while exhausted and running out of critical life support supplies. Regardless of the specific stressful experience, all participants had to perform tasks with an extremely low margin for error, while dealing with an uncompromising mission schedule. When things went wrong, and they often did, these former astronauts focused on dealing with the task at hand. Their cognitive stress management skills allowed them to adaptively deal with the new stressor through task-oriented coping. This allowed them to maintain extremely high performance under pressure for their short-duration missions.

Earth observation

Viewing Earth was a significant, impactful leisure activity reported by all astronauts. They all enjoyed the orbital perspective, reporting that it was both immersive and relaxing. The interaction of topography, weather and light on Earth presented a constantly changing, beautiful scene that helped participants relax. Viewing Earth inevitably led to a perception of Earth's fragility, prompting participants to express increased environmental concerns. Regarding this positive experience viewing Earth, virtually every participant indicated that this was a common experience among astronauts. TK summarized this well when they said, "I think you are going to find that every astronaut would tell you that [viewing Earth]

was a remarkable experience." For two participants, viewing Earth from orbit was the most memorable experience of their spaceflight activity.

Human universality

Viewing Earth without geo-political borders increased participant's perceptions of the commonality of all humans. Additionally, training with other individuals from other countries likely enhanced participant's perception of commonalities between all people. Summarizing these perceptions, one participant commented **"**we have far more in common than we have differences, oftentimes what we say is a difference is really just perception". Thus, training and living on-orbit impacted participants significantly and contributed to these post-flight changes in perspectives and values.

Post-flight career outcomes

One participant unequivocally believed that spaceflight significantly improved their quality of life and standard of living. The other two participants did not express such a strong belief. While PS leverages their knowledge and expertise to pursue research and development of space systems, they could have pursued these activities successfully without their space experience. Many individuals with similar educational history and expertise manage research labs and garner funding for agency research contracts. It is unlikely that their spaceflight experience hinders this capability in any way, however it was likely not a pivotal, required component for their success in their current pursuits. In the same vein, TK did not believe that their spaceflight experience changed their career outcomes significantly. They

mentioned they are able to pursue jobs that require prior spaceflight experience, such as speaking to kids at STEM events related to space. Yet, they viewed this as more of a matter-of-fact situation, and they didn't mention having more opportunities because of their spaceflight experience.

TR self-reported higher on extraversion than the other two, so it is possible this personality factor may have contributed to their greater post-flight benefits. In addition, it is extremely probable that there are other factors at play. Unfortunately, this study doesn't have the sample size or methodological design to effectively speculate on the reasons one participant reported significant post-flight career benefits while others did not.

Resilience factors

All participants were highly adaptable and resilient, but this was a significant emphasis in NASA's astronaut selection criteria, so that is not necessarily surprising. The surprising factor is that individuals did not strongly report high extraversion. This was not entirely congruent with Sarubin, et. al (2015) predictions of personality factors in the resilience model. Participants' scores on extraversion were not so low as to indicate that these were highly introverted individuals, however. Due to this study's low sample size (n=3), this should only serve as an exploratory clue for future investigation.

Desire to return

Just as reported in studies with polar explorers in ICE, participants in this study emphasized a strong desire to return to space. For PS and TK, this statement

is not particularly surprising, given that they worked the majority of their lives to fly in space. For TR, however, it is particularly interesting. They indicated that they had no desire to fly on ISS while they were an astronaut. Yet, they stated that they would quickly return to space if they were given an opportunity to go on a new or novel mission. While the reasons for this were not conclusively explored in this study, it is possible that TK would score higher on measures on sensation-seeking compared to the other two participants. During the interview, they mentioned that they preferred when things went wrong because it was exciting. They also briefly mentioned they prefer activities that are "short and intense." Higher ratings on sensation seeking would suggest a propensity to engage in new, novel and intense activities. Long duration flights are monotonous, but the novelty, excitement and prestige accompanied with going to a new place perhaps are motivating factors that inspired TK to respond the way that they did.

Chapter 5

Overview

This study's main objectives were to better understand the interaction between personality, resilience factors and experiences on orbit. Additionally, this study was designed to explore positive factors in spaceflight that could alleviate stress on orbit. In line with those objectives, this study utilized a novel case-study approach to better understand these underlying factors. This chapter will discuss the findings and place them in the research context. The data is discussed in quantitative and qualitative sections.

Quantitative Data

Personality

Broadly speaking, that participants had high conscientiousness, high agreeableness, and low neuroticism were not surprising results. These former astronauts are organized, high-achievers. They work well on teams and possess low emotional reactivity. They complete their tasks in a timely manner and deal with disagreements in an assertive way. These personality factors map closely to previous analysis of astronaut personality trait clusters as found in Musson, Sandal, and Helmreich (2004). In which, factors essentially measuring high achievement, task competence and positive interpersonal skills were defined. Taken together,

these personality traits suggest that these individuals get along well with others, but are driven, competitive, and possess high emotional stability.

Brief resilience survey

Participants' self-report data indicated that they perceived themselves as highly resilient. When viewed in the context of their experiences on orbit, it is clear that these participants are highly resilient, or highly adaptable. In this sample, the BRS data exhibited a clear ceiling effect.

Positive effects of being in space survey

The study replicated previous findings indicating Earth observation was a favorite leisure activity and is an immersive, relaxing activity (Stuster, 2012). Another major finding was that astronauts felt the need for increased environmental stewardship. Additionally, they felt enhanced commonality, or universality between humans. These findings served to replicate the research findings of Suedfeld, Brcic, Johnson, and Gushin, (2012) using a different self-report instrument. While one participant reported important career effects post-flight, this was not the consensus. PEBS results did not indicate changes to new opportunities or increases in self efficacy, this is an interesting result as participants in long-duration spacecraft simulations report changes on these factors (Solcova, & Vinokhodova, 2015). Perhaps this difference is due to the self-selection of individuals choosing to participate in short or long-duration flights or simulations.

Limitations

This study only leveraged the perspectives of astronauts from short-duration missions. While their perspectives are extremely important, they may not fully reflect factors that would exist on long-duration missions.

The study did not test hypotheses, so it was unable to determine causality or correlational relationships between the observed items in the study. The study only was an exploratory descriptive study attempting to better understand the phenomena and to determine its occurrence with the population of interest. This study aimed to provide directions for future research to explore, in a more rigorous methodological capacity, the relationships between spaceflight, stress and resilience.

This study was only able to query astronauts post-flight, which relied solely on their perceptions of change over time. There are some notable limitations in this post-test only design. Changes in values and perceptions cannot be compared to pre-flight baseline levels. This study was not be able to identify factors that may account for changes in values or perspectives in a rigorous casual design, as multiple correlational factors may co-vary with, values changes related to spaceflight.

Rival explanations

The impact spaceflight has on post-flight values may simply be a memory bias, where the recollection of the experience is different than the experience may have been at the time (Kahneman, 2011). Furthermore, it is possible that

participants' self-reported perceptions of change are not associated with how they have really changed (Henry, Moffitt, Caspi, Langley & Silva, 1994). As a possibility, the self-report data may have been unreliable. Finally, it must be noted that this study did not fully determine if astronauts positively adapted to spaceflight. There were was no data suggesting that participants failed to adapt to spaceflight, but the absence of evidence is not necessarily evidence of absence. Especially given the amount of time that passed since last spaceflight and the data collection for this study.

Conclusion

Earth viewing, and cognitive stress management factors are important considerations that assisted in the success of these crewmembers on their respective missions. Furthermore, these astronauts reported that they had very high confidence and self-efficacy prior to spaceflight and that spaceflight did not change these factors. This result differed from other ICE domains that typically involve longer-duration habitation. Providing future astronauts with a substitute for the relaxing, immersive experience of viewing Earth needs to researched in order to support astronaut psychological health in LDEM.

Recommendations

Future research should investigate the impact of resilience and personality predictions within the astronaut population. There may be significant differences between optimal personality characteristics for short or long duration astronauts. In

this study, astronauts did not report high extraversion, but reported very high resilience. It is unclear how this finding generalizes to any population given the case study methodology and the small sample size. Additionally, the personality and resilience data collected and analyzed in Sarubin et al, (2015) had a significantly higher sample size and more methodological rigor than this study. At best, this study provides an exploratory clue that more research is needed concerning resilience and personality within the astronaut (or similar) population if these factors are important for selection in the future. Furthermore, future research should target operational differences between resilience constructs and adaptability constructs. Astronauts in this study reported that they considered themselves to be very adaptable individuals. While they scored high on resilience, perhaps adaptability and cognitive flexibility will be more important for a long duration space mission. Given the occurrence of off-nominal events in participants' missions, a LDEM may be significantly more risky and dangerous. Astronauts will be more or less on their own for long periods of time, and will need discipline, adaptability to address system failures and interpersonal skills. To address future selection for these missions, optimal team composition factors for ICE should remain a research priority

Future research should be conducted using virtual reality or similar simulation technology to identify elements that provide positive, relaxing and immersive experiences. Disrupting the monotony and isolation expected on LDEM and providing relaxing experiences should be a focus for future research. Such

research has applications for distributed operations in ICE on Earth, as well. VR systems should be given full usability evaluations concerning orientation preferences in microgravity. User preferences should be taken into account concerning optimal optic flow and frame of reference considering the microgravity environment.

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Appendix A: Brief Resilience Scale

Brief Resilience Scale

Instructions: Use the following scale and **circle** one number for each statement to indicate how much you disagree or agree with each of the statements.

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

1. I tend to bounce back quickly after hard times..	1	2	3	4	5
2. I have a hard time making it through stressful events……..	1	2	3	4	5
3. It does not take me long to recover from a stressful event……..	1	2	3	4	5
4. It is hard for me to snap back when something bad happens……..	1	2	3	4	5
5. I usually come through difficult times with little trouble..……	1	2	3	4	5
6. I tend to take a long time to get over set-backs in my life……..	1	2	3	4	5

This scale is used with permission from Smith, et al., 2008. Highly resilient individuals are able to "bounce back" from stress faster. They are then able to perform well and maintain psycho-social function despite experiencing significant stress. Reliability was assessed using Cronbach's alpha, and the results indicated alpha was above .80. The researchers demonstrated the BRS to have adequate test-retest reliability as well. On 4 different study samples, the BRS demonstrated convergent, and discriminate validity (Smith, et al., 2008).

Appendix B: Demographics

Demographics Questions

1. What is your current age?
2. What is your gender?
3. What was the longest time you spent in space on a single mission (in days)?
4. Please report your approximate time since last spaceflight (in years).
5. Please describe your background or occupation prior to your spaceflight assignment.
6. What was your primary habitation vehicle while in space?
7. Please indicate your highest level of education attained.

Appendix C: Personality Assessment

20-Item Mini-IPIP

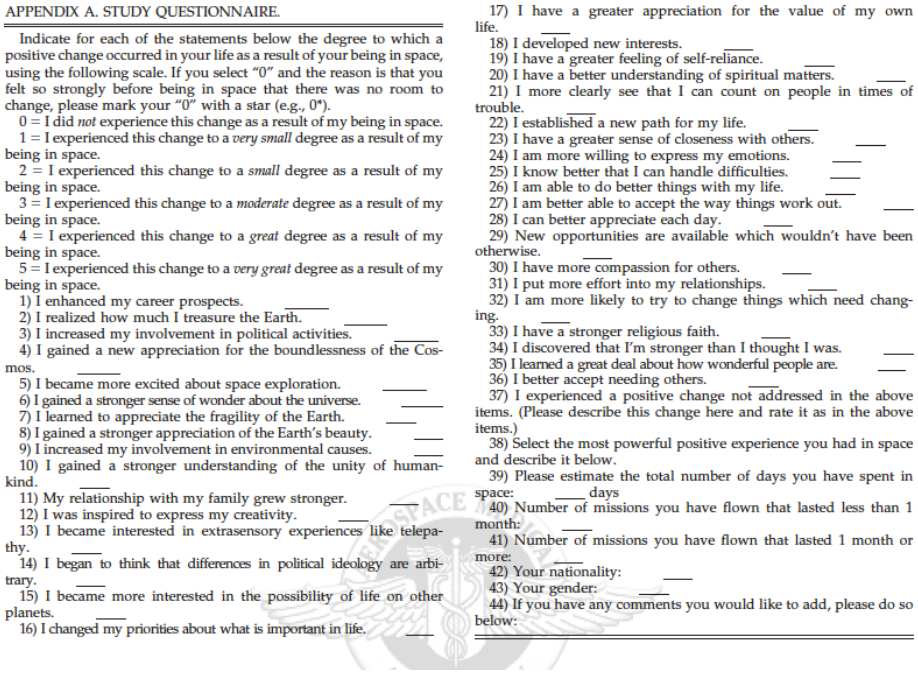
Item	Factor	Text	Original Item Number
1	E	Am the life of the party.	1
2	A	Sympathize with others' feelings	17
3	C	Get chores done right away.	23
4	N	Have frequent mood swings.	39
5	I	Have a vivid imagination.	15
6	E	Don't talk a lot. (R)	6
7	A	Am not interested in other people's problems. (R)	22
8	C	Often forget to put things back in their proper place. (R)	28
9	N	Am relaxed most of the time. (R)	9
10	I	Am not interested in abstract ideas. (R)	20
11	E	Talk to a lot of different people at parties.	31
12	A	Feel others' emotions.	42
13	C	Like order.	33
14	N	Get upset easily.	29
15	I	Have difficulty understanding abstract ideas. (R)	10
16	E	Keep in the background. (R)	16
17	A	Am not really interested in others. (R)	32
18	C	Make a mess of things. (R)	18
19	N	Seldom feel blue. (R)	19
20	I	Do not have a good imagination. (R)	30

Note. E = Extraversion; A = Agreeableness; C = Conscientiousness; N = Neuroticism; I = Intellect/Imagination; (R) = Reverse Scored Item. Original 50-item IPIP-FFM available at http://ipip.ori.org/newQform50b5.htm.

The Mini-IPIP consists of four items corresponding to each Big Five factor. It has internal consistency measured with Cronbach's alpha at or above .60. The scale has test-retest correlations which closely approximate the test-retest correlations of the parent measure. The scale has comparative convergent, discriminant and criterion-related validity with other Big Five assessments. Thus, the Mini-IPIP is a short, effective and psychometrically acceptable measure for quickly assessing personality characteristics (Donnellan, Oswald, Baird, & Lucas, 2006).

Appendix D: Positive Effects of Being in Space

PEBS Survey Questions



APPENDIX A. STUDY QUESTIONNAIRE.

Indicate for each of the statements below the degree to which a positive change occurred in your life as a result of your being in space, using the following scale. If you select "0" and the reason is that you felt so strongly before being in space that there was no room to change, please mark your "0" with a star (e.g., 0*).

0 = I did *not* experience this change as a result of my being in space.
1 = I experienced this change to a *very small* degree as a result of my being in space.
2 = I experienced this change to a *small* degree as a result of my being in space.
3 = I experienced this change to a *moderate* degree as a result of my being in space.
4 = I experienced this change to a *great* degree as a result of my being in space.
5 = I experienced this change to a *very great* degree as a result of my being in space.

1) I enhanced my career prospects. ____
2) I realized how much I treasure the Earth. ____
3) I increased my involvement in political activities. ____
4) I gained a new appreciation for the boundlessness of the Cosmos. ____
5) I became more excited about space exploration. ____
6) I gained a stronger sense of wonder about the universe. ____
7) I learned to appreciate the fragility of the Earth. ____
8) I gained a stronger appreciation of the Earth's beauty. ____
9) I increased my involvement in environmental causes. ____
10) I gained a stronger understanding of the unity of humankind. ____
11) My relationship with my family grew stronger. ____
12) I was inspired to express my creativity. ____
13) I became interested in extrasensory experiences like telepathy. ____
14) I began to think that differences in political ideology are arbitrary. ____
15) I became more interested in the possibility of life on other planets. ____
16) I changed my priorities about what is important in life. ____
17) I have a greater appreciation for the value of my own life. ____
18) I developed new interests. ____
19) I have a greater feeling of self-reliance. ____
20) I have a better understanding of spiritual matters. ____
21) I more clearly see that I can count on people in times of trouble. ____
22) I established a new path for my life. ____
23) I have a greater sense of closeness with others. ____
24) I am more willing to express my emotions. ____
25) I know better that I can handle difficulties. ____
26) I am able to do better things with my life. ____
27) I am better able to accept the way things work out. ____
28) I can better appreciate each day. ____
29) New opportunities are available which wouldn't have been otherwise. ____
30) I have more compassion for others. ____
31) I put more effort into my relationships. ____
32) I am more likely to try to change things which need changing. ____
33) I have a stronger religious faith. ____
34) I discovered that I'm stronger than I thought I was. ____
35) I learned a great deal about how wonderful people are. ____
36) I better accept needing others. ____
37) I experienced a positive change not addressed in the above items. (Please describe this change here and rate it as in the above items.)
38) Select the most powerful positive experience you had in space and describe it below.
39) Please estimate the total number of days you have spent in space: ____ days
40) Number of missions you have flown that lasted less than 1 month: ____
41) Number of missions you have flown that lasted 1 month or more: ____
42) Your nationality: ____
43) Your gender: ____
44) If you have any comments you would like to add, please do so below:

The questionnaire is used with permission from Ihle, et al (2006). This questionnaire has the advantage of being developed specifically for inventorying changes resulting from spaceflight. Note that only the Likert-like 36 items on the assessment were used, omitting the free response questions. The questionnaire has been screened for validity and reliability. This survey questionnaire has high internal consistency reliability at a= 0.96 for the complete PEBS. The instrument's validity was assessed through an inter-item analysis which was reported to be 0.64 (Ihle, et al., 2006)