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30 Day Lunar/Martian Planetary Habitation Analog: Subjective Crew Analysis Of Behavioral Health

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30 DAY LUNAR/MARTIAN PLANETARY HABITATION ANALOG: SUBJECTIVE CREW ANALYSIS OF BEHAVIORAL HEALTH

by

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This thesis, submitted by Travis Nelson in partial fulfillment of the requirements for the Degree of Master of Science in Space Studies from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done is hereby approved.

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PERMISSION

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Travis M. Nelson
May 1, 2015

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Dedicated to Aubrey Luna Nelson.

ABSTRACT

Long duration spaceflight poses risks to astronauts from stressors including challenging living environments, rigorous workloads, physical and mental fatigue, interpersonal conflict, mission uncertainty, emergencies, isolation and confinement. Analog space exploration simulations on Earth provide researchers with controlled environments to train and study human spaceflight operations. The findings of this study provided data on self-assessed metrics from an analog crew (N=3) who independently completed subjective reports of sleep quality, stress, anxiety, fatigue, mental exertion, and also provided objectively assessed sleep quality data by biometric watches. The daily mean reports from subjects were compared across time in order to ascertain possible quarterly phase changes during a 30 day simulated Lunar/Martian analog habitation mission. A 12x3x3 meter living habitat, detachable electric planetary rover and space suits were used as life support. Results confirmed the initial hypotheses that the autonomous, isolated and confined environment was associated with consistent third quarter effects. Furthermore, a noticeable increased first quarter phase effect in numerous measurements was evident.

CHAPTER I

INTRODUCTION

Astronaut Performance

Stress has been well known to negatively affect human performance in many hostile environments. Specifically during space operations, stressful situations can occur rapidly in many circumstances without warning. As durations of exploratory missions into space become longer, general astronaut stress levels may increase accordingly while living in isolation inside of a confining space craft or habitat upon a planetary surface. Astronaut functionality and performance can be significantly affected by the severity of simultaneous multiple stressors present (Kanas, 2009). Previously completed research (Anthes, 2010) within the scope of stressful and emergency spaceflight, indicated that middle to third quarter changes are occurring independent of mission durations. Research of quarterly phase effects regarding crew performance may lead to patterns of behavior that could better train astronauts and give general expectations of habitation conditions far away from Earth. With anticipation of quarterly effects from environment adaptation and early stressor onset, it is feasible to consider the first quarter of a mission also critical in terms of maintaining astronaut mental health and operational performance.

Future research in space physiology will undoubtedly continue to study extended radiation exposure, muscle atrophy, bone demineralization, upward fluid shifts, ocular changes and sensory changes (Wickman, 2005). By continuing this research in parallel with psychology and human behavioral health effects in space; habitation in extreme space environments will become more habitable. The principle characteristics of space environments are the fact that they possess extremely hostile physical conditions and require sophisticated engineering systems to support human life (Santy, 1994). Earth based analog simulations have been found to be acceptable alternatives to on-orbit research and include a lessened risk to human life, improved access for extended behavioral research than with flight crews (e.g. Mars 500) and are more cost effective, all while maintaining many environmental parameters with real space missions.

Distress in Space

There are varying types of stressors that have been shown to negatively impact astronauts and cosmonauts over the years of space exploration. According to Morphew, et al, (2001), there are multiple categories of stressors that can be separated into psychological, habitability/environmental, physiological, and human factors groups. For the purposes of this literature review and intended research, psychological and habitability/environmental based stressors were the main area of concentration.

Psychological stressors of both short duration spaceflight (SDSF) and long duration spaceflight (LDSF) (Whitmore, 1997) can be shown as similar in stress types but different in severity. Critical psychological stressors of long duration manned spaceflight (Manzey, 1995, Stuster, 1990, Morphew, 1999, Christensen & Talbot, 1986, Leonev & Lebedev, 1975), have included isolation, confinement, alterations/deprivation in sensory and/or perceptual stimuli, knowledge of limited possibility for abort/rescue, high risk conditions and potential loss of life, system and mission complexity, habitation in hostile environments with absence of time parameters and sleep disruptions.

Environmental stressors associated with space habitation in particular can result in significant challenges during spaceflight of any duration. According to a recent presentation by Dr. Jonathan Clark (2014) from the National Space Biomedical Research Institute, cognitive changes have been reported in hostile space environments include information processing problems such as space fog, perception, memory and learning difficulties. Realistic space analog simulation missions have previously reported time/space distortions, decreased task performance ability, difficulty concentrating and mild fatigue states in these types of environments (Sandal, et al., 1995). Other challenging aspects of analog environments seen have included fatigue, sleep disruptions, irritability, depression, anxiety, social withdrawal, interpersonal conflict (Kanas, et al., 2000) and adaptation problems. These challenges associated with analog space environment simulations are expected to occur during actual missions far from Earth, where in flight support is delayed or difficult.

Consideration of astronaut and cosmonaut stress data (Sandal, et al., 1995; Connors, et al, 1985) collected post mission, indicated that the time of stressor onset of increased group stress varies the most during the midpoint than beginning phases within crew (N=68) participant responses. In similar post mission surveys, the time of stress onset occurred after the midpoint phase rather than the beginning phases of adaptation (Charles, 2011). The second most common complaint cluster from this post mission survey was psychological issues, thus emphasizing a need for increased discussion and research of human habitation and psychology of space research as LDSF becomes more common.

Other important psychological stressors include limited communication with people on Earth, helplessness to events occurring on Earth, cultural and familial isolation (Kanas et al., 2009, 2006), high autonomy and monotonous daily activities. These psychological stressors are theorized to become increasingly more probable the longer an astronaut spends in space. Important and challenging tasks requiring critical performance during high pressure situations such as spacecraft docking maneuvers, (e.g. Mir M-34), life support system failures, fire, medical emergencies and meteorite impacts are important and can cause serious problems with little prior warning.

Disagreements between crew and/or ground support and leadership clashing are aspects of behavior that may also occur at any time, but most likely will occur after adaptation phase on a long mission where autonomy is high. When stressors begin to compound, this can result in a situation that is extremely dangerous for crew cohesion, functionality and overall performance. Other limitations of long term space habitability include low and boring workload levels, food restrictions, technology interface challenges, operations equipment in partial or micro-gravity, limited equipment, supplies and hygiene facilities.

Psychological stressors in space have caused disturbances ranging from sensory illusions, short term depressive reactions, neurotic disorders, and a syndrome Soviet and Russian investigators termed asthenia, with associated feelings with fatigue, exhaustion, reduced mental and physical fitness, and elevated irritability (Kanas, 1985). Asthenia, possibly a result of chronic stress, is generally characterized by abnormal fatigue, weakness, emotional liability, irritability, and minor disorders of attention and memory (Myasnikov, 1996). Although these symptoms rarely reach clinical levels, they have resulted in instances of impaired performance capacity, significant conflict among crew members, and errors in performing operational tasks (Nechayev, 1991 & Shaposhnikov, 1991). According to Russian reports, the effects of psychological stress generally appear after six weeks in space when the initial adaptation is complete and activities seem routine.

The many adverse effects of stress in space, in turn may amplify feelings of isolation, confinement and monotony of crew members (Manzey, 1995). Further elaboration of major categories pertinent to human spaceflight stressors are indicated below in Table 1. These demonstrate but a few of the many stressors that can potentially affect performance and wellbeing of LDSF crews.

Table 1 – Categorized Spaceflight Stressors (Morphew, 2001).

Psychological	Physiological	Human Factors
Isolation	Cardiovascular Deconditioning	High/Low workload levels
Confinement	Space Adaptation Sickness	Limited external communication
Alterations to Sensory Stimuli	Sensory deprivation	Limited equipment and supplies
Limited possibility for rescue	Upward Fluid Shifts	Food restrictions and limitations
High risk and death conditions	Sleep disturbance	Technology-interface challenges
Hostile External Environment	Muscular deconditioning	Using equipment in micro gravity conditions
Reduced sensory stimulation	Skeletal deconditioning	Individual Control
Mission/System Complexity	General adaptation syndrome	Psychosocial factors
Monotonous activities	HPA axis	Habitability with crew members
Radiation Exposure	Immune and Nervous System changes -	Interpersonal conflicts

Feelings of stress, anxiety and fatigue have been well documented to negatively affect human performance in extreme environments (Jensen & Biegelski, 1989). There has been considerable evidence that psychosocial stressors are among the most important impediments to optimal crew morale and performance (Suedfeld, et al, 2007, Torre, et al, 2012, Geuna, 1995). This was conveyed by Valery Ryumin, a Russian cosmonaut, who expressed in a journal entry during Salyut 6: "All the conditions necessary for murder are met if you shut two men in an 18 by 20 cabin for two months". Common sources of stress in early American missions included maintaining high performance under public scrutiny, as well as isolation from peers and family. The latter is still often seen in ISS operations (Suedfeld, 2007), such as when the mother of astronaut Daniel Tani died in a car accident and when astronaut Michael Fincke was forced to miss the birth of his child.

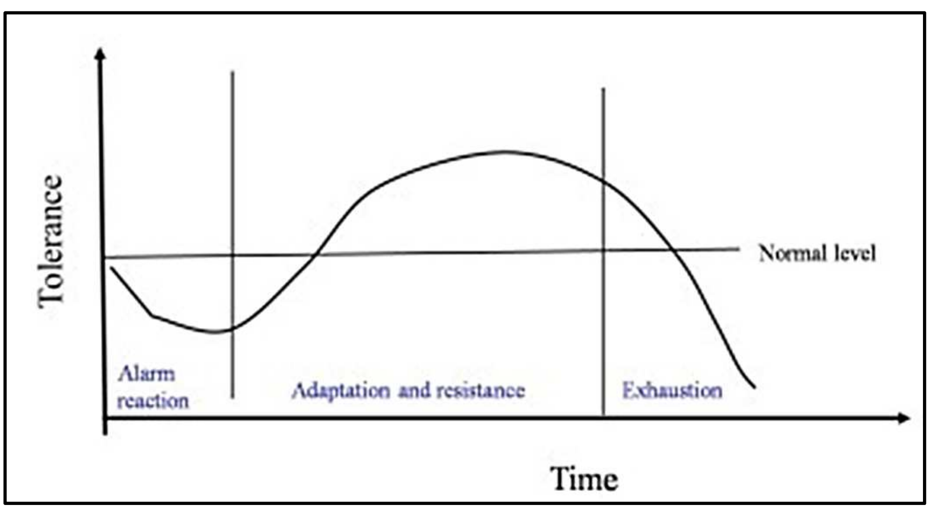
Pre mission training scenarios, crew/ground control transparency and emergency procedure development will be a major means for humans to counteract negative effects of extended space flight. Thus, systematic work in the area of analog missions can provide a model for training astronauts about what to expect psychologically within LDSF missions. Focusing on the positive events and milestones of the mission will also serve as important countermeasures to battle negative or challenging events in space.

General Adaptation Syndrome

Hans Selye conceptualized the physiology of stress as having two components: a set of responses which he called the "general adaptation syndrome" or GAS (see figure 1), and the development of a pathological state from ongoing, unrelieved stress. Pioneering research of general stressor responses has indicated that most individuals follow a performance curve congruent with the Hans Selye's (1974) GAS. The GAS system functions whereby the body copes with stress through activation of the hypothalamic-pituitary-adrenal axis (HPA axis) consisting of chemical glandular secretion release, initiating an alarm state. Selye first described the GAS in 1955 within the article “Stress and Distress”. Since then, Selye and many others have observed distress symptoms and varying reactions that typically follow a graphical curve of performance and time consisting of an “alarm state”, a “resistance state”, followed by an “exhaustion state”. These phases of general adaptation syndrome occur in relationship to glandular secretion and situational awareness. Selye called negative stress "distress" and positive stress "eustress" as a result of how a person copes with an event.

A critical phase of the GAS curve is the point of exhaustion whereby chemical secretions are expended. Running out of these stress fighting hormones is in itself a stress factor often resulting in difficultly to remain positively functioning. If such were to occur in a situation already affected by moderate to chronic stress levels, mistakes or errors may happen even more and therefore impact survival and performance of the crew.

Figure 1. Hans Selye’s Stress Tolerance Response - The curve of Selye’s stress phases demonstrates a typical response as chemical secretions are released in order to mitigate negative human body impacts of a stressor (Selye, 1995).



Human Performance

As seen in Selye's Stress curve, performance during stress onset increases quickly but diminishes after numerous stressors or one stressor is present past the adaptation stage. Manzey (1995) found that "working efficiency during the acclimation/alarm phase is jeopardized by the body's adaptive reactions to the changing environment and weightlessness (p. 351)." This clearly has implications to performance as crew members are less able to complete work accurately after this phase has passed. Circumstances where human operational error was found to be fatal have occurred in many aviation accidents, often due to stressors leading to diminished performance (Shayler, 2000). Multiple stressors occurring at once may simultaneously compound in severity with increasing amounts of time in-flight or upon another planet.

Previously completed research (Anthes, 2010) within the scope of LDSF indicated that the third quarter stage of a mission timeframe is a critical phase, often associated with lowered crew performance and behavioral health. Third quarter effects are therefore increasingly interesting in terms of serious incidences and accidents occurring and more importantly, the crew member's ability to react to these difficult times. Long duration missions beyond low Earth orbit (LEO) are currently in a forward moving stage of development from an engineering standpoint. The issue of mental health in stressful, dangerous and extreme environments is regarded as an important factor while moving forward with planning for human integration into complex systems.

For the purposes of this research, long duration (LD) is considered as consecutive spaceflight for six months or beyond. Beyond this point, coping and adaptation to habitation in extreme environments becomes more difficult, leaving more time for interpersonal conflict, personal issues and operational error (Shayler, 2000). Historically from MIR Space Station research, three behavior and coping stages over 6 months reliably occurred and share similarities with the work of Hans Selye. Stage one includes adaptation where the crew is busy adapting to the foreign environment and too busy to be highly affected by stress up to three months (Grigoriev, Kozerenko, and Myasnikov, (1985). Stage two includes signs of fatigue and low motivation between months three and six. Stage three happens beyond six months and includes asthenia. Asthenia is known to demonstrate symptoms such as hypersensitivity, nervousness and irritability. There appears to be no time to develop asthenia in missions under six months, unless unforeseen circumstances arise leading to sustained stress, exertion and/or fatigue.

Studies of the longest spaceflights concluded that the first three weeks represent a critical period where attention is adversely affected because of the demand to adjust to the change of environment (Manzey, D.; Lorenz, B.; Polyakov, V., 1998). Future ISS, lunar and Mars directed missions must prepare crews for the initial and prolonged strain of adaptation by carefully examining past astronaut and cosmonaut experiences. The top 6 holding LD spaceflight records occurred with Cosmonauts Polyakov (438 days), Avdeynev (379.6 days), Titov (365 days) Manarov (365 days), Romanenko (327 days), Krikalev (312 days). These achievements further demonstrate that it is possible, yet very challenging to live in space for extended durations. Until now, few humans have spent more than six months in space, making long term assessment of performance under distress challenging to evaluate and extrapolate for longer missions. Longer durations beyond six months will be increasingly challenging for even the most psychologically qualified astronauts. As of March 2015, two humans will board the ISS for a 1 year mission, emphasizing yearlong human habitation upon the ISS for the first time. As of March 23, 2015 the ISS has been continuously occupied for 5967 person days, most often consisting of 6 month missions or less. Skylab ended with 504 person days and Mir with 849 person inhabited days.

Analog Space Simulations

Changes and assessment of future astronaut mental health may be analogous to living in Earth based environments such as Antarctica, submarines, and dedicated ground habitats designed to perform human research. These types of environments share similarities with space habitation and can therefore offer possible avenues for psychological research, but with more control. Analogous space environments enable missions to be pushed for longer periods of time because the Earth based crews are typically in less danger.

Years of training must be integrated prior to multi-billion dollar missions to the Moon and Mars. Space analog exploration simulations on Earth provide researchers a cheaper means to train, rehearse, and prepare astronauts for long term interplanetary transfer and planetary or capsule-based habitation. Ground based studies are useful because they enable the determination of effects due mostly to confinement and isolation, without the influences of microgravity and eminent danger from actually residing in space. Anecdotal reports from studies conducted in space analog environments on Earth (e.g., Antarctic, submarines, & simulation habitats) have isolated a number of psychological, psychiatric, and interpersonal issues that can affect the safety, functionality, performance and well-being of crewmembers working in ISS or other space operations (Kanas and Feddersen 1971; Kanas 1985, 1987, 1990, 2004; Connors et al.

1985; Harrison et al. 1991; Sandal et al. 1995; Palinkas et al. 2000; Sandal 2000; Stuster et al. 2000; Kanas and Manzey 2008). These space analog missions have focused on specific factors by closely replicating the operations, autonomy, habitat, vital preparations, training and mission planning. Major differences between analog and actual space operations include the enormous distance away from Earth, more danger and longer missions. A major benefit of space analog simulations is the training for an astronaut to make critical self-assessments concerning both their physical and mental reactions to model situations. Reasoning for self-assessment of mental and physical health and performance would be needed when communication to mission control is delayed, ineffective or impossible and crews are functioning completely alone.

The future of LDSF beyond the relative safety of current LEO will continue to be benefitted by cost effective simulated analog space habitation studies completed on Earth. Examples of planetary lunar and Martian analogs on Earth include NASA's Desert RATS and NEEMO, Russia's Mars 500, Devon Island, Hi-Seas, the Mars Desert Research Station and the University of North Dakota Lunar/Martian habitat. Other related locations with isolated and confined parameters include but are not limited to the oceans, Meteor Crater, the Atacama Desert and Antarctic missions at Concordia station and the McMurdo dry valley.

Many early analog investigations (Flaherty, et al, 1960) for NASA missions Mercury, Gemini and Apollo were aimed primarily at determining effects of stress due to isolation, confinement, fatigue, and altered work-rest cycles on proficiency, interpersonal communication, and crew performance capabilities. With future proposed capsule based habitation again in the near future, similar research may be again beneficial to resurrect.

Important research gaining knowledge about how participant subjects respond to small challenging environments where isolation, confinement and lack of communication are evident will be discussed in the following. Research and data collection by analog environments will be shown to provide valuable insights and data, while yielding new methods for crew training and selection. Dr. Oleg Ganzenko from Moscow's Institute for Biomedical Problems (IBMP) indicated that studying cosmonaut applicants in isolation and confined environments yielded much better results than written or oral psychological assessments (Santy, 1994). Presently, the NASA Human Research Program has designated psychological and team adaptation/cohesion among the list of critical risk factors that need to be addressed for future LDSF. The future of human missions beyond the relative safety of LEO will continue to be benefitted by cost effective simulated analog space habitation studies completed on Earth.

Crew Selection

NASA crew members are carefully selected for space missions and typically train together for years to improve operational task performance, group cohesion and teamwork. Psychological training is a systematic process aimed at developing specific job and team related skills, knowledge, attitudes, and behavior (Manzey, et al, 1995, Cooper, 1987). In accordance with crew selection, during a presentation by Dr. Johnathan Clark (2014), it was concluded that typical astronaut qualities include individuals who are extremely self-sufficient, hard-working and success-driven. These qualities are a tremendous benefit to completing mission objectives in adverse conditions. Additionally, astronauts have a strong desire to avoid appearing "less than optimal". As seen in the early NASA Mercury program, psychological selection had four basic, but distinct tasks:

determination of job requirements, determination of personal characters requirements, determination of assessment methods, and validation of selection criteria (Santy, 1994). Criteria for selecting crew members for LD missions must include a variety of other professional skills: expert medical doctors, geologists, pilots, engineers, botanists, etc. compared to the previous "right stuff", comprised of mostly military test pilots.

In order to mitigate the chances of negative interactions among diverse crews, suggested crew selection parameters include participants who have trained together for an extended period of time, have similar goals, ambitions and drive to succeed. Crew selection criteria should also include crew compatibility and cohesion selection by choosing less extroverted people who do not need a lot of external stimulation from others. Team oriented crew members who are conscientious, positive, and have good self-control are regarded as important personality criteria for future LD crew selection.

Problem Statement

Normal training exercises for astronaut's take years of preparation that often occurs in realistic simulation mock-up environments. These training exercises are highly controlled and lacking real time LD exposure. Applying 30-60 day space analog training missions prior to actual LDSF would be beneficial to prepare astronauts about what challenges to expect while isolated and confined. On Earth bound analog habitation missions, human subjects have a choice to simply leave the mission and go home if too much stress arises, leaving a lowered degree of reality and heightened degree of comfort. However, there is a continued need for space analog enclosure studies that simulate actual spaceflight stressors of confined and isolated conditions to provide motivation for subjects to complete goals regardless of negative or stressful events. Given that analog participants have the option to leave the study, a major question to be answered includes whether the persistence to complete Earth based missions would be similar to the motivation astronauts have to complete ISS missions. Since two subjects seldom perceive environmental stimuli in the same manner, data on individual differences is helpful, but difficult to generalize across a population. Furthermore, since interpretation of autonomous behavior is limited and the patterns of crew response are similarly limited (Burns, Chambers and Hendler, 1963). Through continued and refined autonomous analog research, certain patterns of human behavioral responses may be more easily detected and subsequently implemented into future crew selection, training and operations.

Hypotheses

By assessing available data collections and literature concerning human distress levels during analog spaceflight operations, it was hypothesized that the confined and isolated Lunar Martian Analog Habitat (LMAH) facility at the University of North Dakota (UND), would have increasingly negative and stressful effects upon self-assessed behavioral and environmental/habitation questionnaires. Specifically, this research examined stress, anxiety, mental exertion, physical fatigue, affect and sleep habits of a crew (N=3) during a fall 2014 study. The primary researcher hypothesized that crew members of the 30 day LMAH study would experience the highest amounts of subjectively perceived stress, anxiety, exertion and fatigue during the third quarter phase of the mission (approximately days 17-23) compared to all other quarterly phases. It was also hypothesized that sleep quality would deteriorate until mission completion, possibly due to lack of natural sunlight and environmental cues.

Close evaluation of the third quarter effect theory using this highly autonomous lunar/Martian analog simulation with environmental parameters similar to confined, isolated and long distance planetary surfaces, also provided crews with self-assessment measures that could be used in the future. Questions potentially answered by this research include: do stress, anxiety, mental fatigue, and physical exertion levels increase as confinement and isolation persist throughout a mission? Does sleep become better or deteriorate? Stressors over quarterly phase measurements were statistically compared to understand the severity of different stressors and changing behavior during simulated human planetary habitation. This type of analog habitation research potentially reinforces the notion that astronaut training must include increased psychological training and use of analog habitation as preventive training measures in the pre-flight stages. This research was aimed at autonomous self-assessment and analysis of stress, anxiety, fatigue, exertion, anxiety and sleep responses of the individuals in anticipation to benefit actual future spaceflight mission operations.

Model Development

Research and data collection from realistic analog spaceflight scenarios utilizing UND Space Studies spaceflight infrastructure (habitat, electric rover and 2 space suits) was aimed at providing valuable insight and data that can be used to benefit new focuses of crew training and selection methodology based on differences in mission type and duration. The first human data points using this facility were collected over a prior 10 day mission by monitoring 3 participants during the October (2013) UND Lunar Mars Analog Habitation I (LMAH I). The primary investigator participated in LMAH I as mission commander and had firsthand knowledge of the infrastructure and experience within the habitat.

During LMAH II, investigators aimed at confirming that simply placing human subjects in such a closed environment, in which they can leave only in space suits creates elevated stress to the individuals and future astronauts using similar systems. Contemplating how stressors can be numerically presented was a challenge, but overcome by both subjective and objective crew measurements. Self-assessed crew measurements were recorded to develop profiles in accordance with 4-phase quarterly curves of stress development, where the third quarter timeframe was considered as a most critical phase where reports fluctuations would be most significant.

The basic research model of the LMAH II project aimed at creating self-reported astronaut assessments that could be used to both keep their thoughts private while still assessing many levels of the experience, their own behavior, emotions and feelings. It is possible that future LD missions will have a completely autonomous self-assessed psychological survey or computer interface that may be helpful when ground control support is limited and no longer can they relate to the astronauts experience. Self-assessment will be an important tool during such situations.

CHAPTER II

METHODS

Infrastructure

Data was obtained by subjective questionnaire reports and objective Basis© fitness and sleep tracking watches. The aim of the study was to evaluate the crew members by recording 24/7 watch measurements in order to collect quantitative sleep data that may be associated with previously experienced stressors. Watch data was then compared to subjective nightly questionnaire reports. The research at hand was aimed at assessing quarterly phases of fluctuating stress, anxiety, mental exertion, physical fatigue and sleep quality of three analog crew participants during a 30 day duration Lunar/Martian analog habitation simulation.

The habitation infrastructure used for this analog planetary simulation study consisted of a 12 x 3 x 3 meter living habitat module, two air locks, and an undocking electric planetary rover housing two detachable space suits used for extravehicular activity (EVA) and simulated emergency evacuation. The total habitation area of the living module was 34.1 m^2 and was designed to support up to four crew members (see Figure 2). The mission took place on an isolated grass field at the University of North Dakota John D. Odegard School of Aerospace campus.

Figure 2. Lunar/Martian Analog Habitat living quarters.

NEO-FFI

As a supplement to interviews, the NEO-Five Factor Inventory (NEO-FFI, McCrae and Costa, 2010) was administered to top 4 selected applicants for the 30 day analog mission. The five personality traits/dimensions assessed were neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness. This inventory was used to assess personality dynamics (see Table 2 for further facets) as an effort to screen for subjects who may be prone to adverse reaction to the challenging, confined and isolated environment at hand.

Table 2 - NEO-FFI personality facets

Neuroticism	Extraversion	Open to Experience	Agreeableness	Conscientious
Anxiety	Positive emotion	Feelings	Trust	Self-Discipline
Hostility	Assertiveness	Actions	Straightforward	Competence
Depression	Activity	Ideas	Altruistic	Order
Stress Vulnerability	Gregarious	Values	Compliance	Achievement Striving

Participants

Researchers chose the three most qualified applicants in combination with interviews, flight physicals, education levels and experience. Age and gender differences can potentially be a negative factor for between-person variance statistics in small group studies. For this study 3 white males, age 25, 27, and 27 (Md = 26.33) were selected as qualified candidates. The educational background of the three participants included two students enrolled in Master of Science degrees at the time of the mission and one participant having completed their M.S. degree. All had relevant backgrounds and graduate education of space, including individual focuses on: engineering, astronomy and biology. Before the 30 day mission, one participant had previous experience the 10 day LMAH I mission the UND facility.

No leadership hierarchy was implemented and all participants held the same crew rank of flight engineer. Institutional Review Board approval, consent forms, pre-mission safety training and study disclosure meetings were completed as required. Subjects were informed they had the opportunity to leave the study without prejudice at any time and any data collected would remain anonymous. No monetary compensation was given to the subjects for participation in the study. Risks associated with this research included possible personal intrusion from self-administered questionnaire reports aimed at assessing psychological and behavioral health factors in relation to the environment.

Participants were instructed that they are free to refuse participation in any way and withdraw from participation at any time without consequence. Also conveyed to the participants, any refusals or withdrawals would in no way affect their relationship with the college or study affiliates. If in the de-briefing interview or mission operations, if a participant indicated psychological difficulties as a result of participation in the study, he would be referred for psychological counseling, if they so desire, in their most convenient community, time and location.

Questionnaires

Participants were assessed by completing self-administered questionnaires (see appendices A & B) that subjectively measuring perceived: feelings, emotions, stress, anxiety, exertion, fatigue, positive affect (PA) and negative affect (NA) levels experienced that particular day. Subjects were asked to complete these assessments independently each night after daily operations over the course of the 30 day mission. The environment where the questionnaires were completed consisted of their personal crew sleeping quarters or research desks using computer laptops. A similar version of this 70 item rating form has been used in previous studies (Leon, Kanfer, Hoffman, & Dupre, 1991; Kahn & Leon, 1994; Leon, Atlis, Ones, & Magor, 2002; Leon et al., 2011), and was modified as needed for the circumstances of this simulated planetary/space environment.

PA and NA measurements (Watson, Clark & Tellegen, 1988, PANAS measure) consisted of self-reported responses on a 1-5 Likert scale aimed at assessing both positive and negative emotional/feeling responses to the environment. Defined vocabulary (appendix B) of the PANAS measures was given to the participants for universal understanding of the emotions and feelings being reported. Stress, anxiety, fatigue, exertion, self-rated sleep measurements were rated on a 1-10 Likert scale while objective sleep scores were obtained by a biometric wrist watch.

Biometric watches.

During pre-mission protocol training, participants were asked to complete daily sleep pattern/quality analysis via wearing an activity/fitness watch over the course the mission. The subjects simply wore the watch and charged/synched it periodically with the MyBasis website interface (See appendix C). The watch continuously assessed and recorded general health biometrics, sleep and fitness habits/patterns. The instantaneously available watch data was also streamed via Bluetooth to hidden by-standing researchers during EVA to monitor them safely yet still give a sense of mission autonomy. The ability to assess real time biometrics was an advantage to crew safety as researchers could be quickly aware of physical performance limits such as overexertion by monitoring heart rate, skin temperature and sweat rate from a distance. The main purpose of the watch was for sleep quality assessment by measuring sleep pattern stages throughout the night, including: amount of REM, light sleep, deep sleep, tosses/turns and interruptions. Changes in these crew sleep patterns recorded by the watch were used for comparison of self-assessed sleep quality of the questionnaire.

Statistical Analysis

A series of non-parametric repeated measures Friedman tests of variance were conducted to test for statistically significant changes between the quarterly phase timeframe conditions of group means for: exertion, stress, anxiety, fatigue, watch-rated sleep quality and self-rated sleep quality scores. These measures were compared on a quarterly basis to test for rank order, visible trends and mean comparison with third quarter effect expectations. The reason for non-parametric group testing was to gain optimal statistical power, given the small crew (N=3), and because the data were not normally distributed. To be considered statistically significant, specified mean group reports of the mission must have had mean changes with a significance p value $<.05$ in comparison to previous quarterly based mission phases. The design of this research was not to hypothesize whether stress, anxiety, fatigue and exertion increases would be evident, but rather that increased reports in these areas would undoubtedly occur and fluctuate during respectively hypothesized first and third quarter mission phases.

CHAPTER III

RESULTS

NEO-FFI

The three crew members scored as follows concerning the NEO-FFI personality inventory of below (See Table 3) measured personality dimensions.

Table 3. NEO-FFI t-scores.

N	Neurotic	Extraverted	Openness to Experience	Agreeable	Conscientious
1	37 low	58 high	69 very high	58 high	46 average
2	38 low	67 high	62 high	64 high	67 very high
3	34 low	74 very high	57 high	54 average	58 high

The subject's scores within these 5 dimensions were compared to the original t-distribution control population, N=1539, for the NEO-FFI (McCrae & Costa (2010). Neuroticism t-scores were overall considered low for all three subjects. Extraversion t-scores were considered high for subjects one and two, and very high for subject three. Openness to experience t-scores were considered high for subjects two and three, while very high for subject one. Agreeableness t-scores were considered average, for subject three and high for subjects one and two. Conscientiousness t-scores indicated subject one exhibiting average, subject three exhibiting high and subject two exhibiting very high measurements.

Quarterly Phase Results for Exertion - Questionnaire

The quarterly exertion comparison analyses using the Friedman test for repeated measures rejected the null hypothesis, suggesting there was significant differences between the quarterly exertion means (p = .037). Further post hoc analysis did not indicate which specific quarter was significant in comparison to the other quarterly exertion means. There was overall significance with exertion means consistently decreasing over each quarter. Post-hoc analyses showed this as a trend with p=.083, but did not reach statistical significance. See Figure 3 for visual presentation of the crew data and Table 4 for statistical representations. Notice consistently decreasing exertion trends for each crew member.

Figure 3. 30 Day Group Exertion Reports. Notice decreasing trend across subjects.

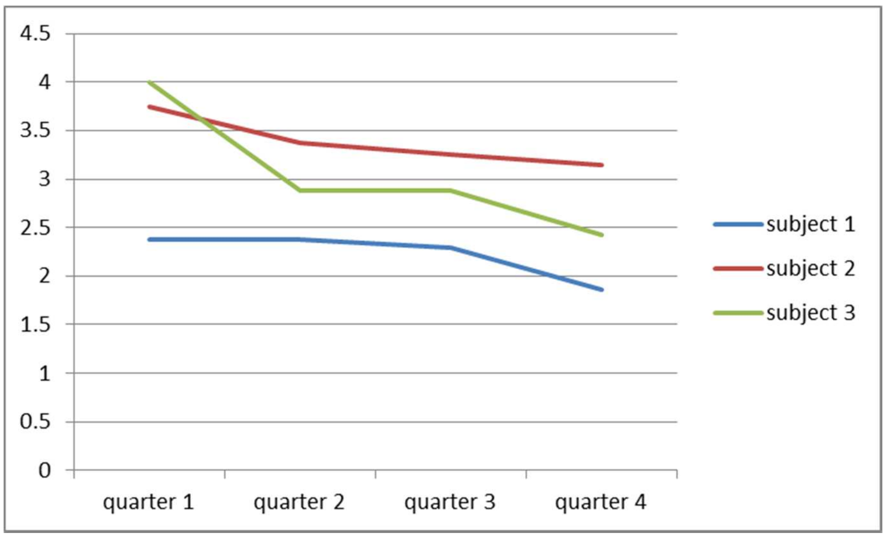


Table 4. Quarterly Friedman test and Post Hoc tests for exertion.

	N	Mean	Std. Deviation	Minimum	Maximum	Mean Rank
qrt1 exertion	3	3.37	.88	2.3750	4.0000	3.83
qrt2 exertion	3	2.88	.50	2.3750	3.3750	3.00
qrt3 exertion	3	2.80	.49	2.2857	3.2500	2.17
qrt4 exertion	3	2.48	.64	1.8571	3.1429	1.00

Asymp. Sig.	.037

Quarterly Phase Results for Positive Affect (PA) - Questionnaire

The quarterly comparison analysis of PA using the Friedman test for repeated measures failed to reject the null hypothesis. There was not a significant difference between the quarterly PA means (p = .072), see Table 5. There was an overall consistently decreasing trend of positive affect over quarters 1-3 with quarter 3 yielding the lowest reports of PA, but did not reach statistical significance. Friedman analysis demonstrated a trend at .07, but since the study population was only N=3, statistical power was therefore not high. See Figure 4 for a visual representation of consistently decreasing PA levels with low levels evident in quarter 3 for all three crew members.

Figure 4 – Visual representation of quarterly positive affect levels.

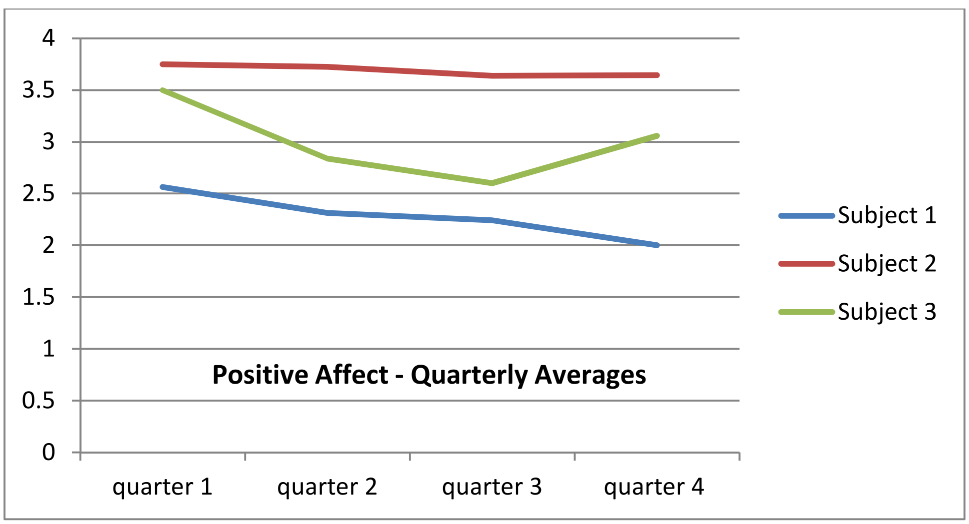


Table 5– Friedman Positive Affect Output.

	N	Mean	Std. Deviation	Minimum	Maximum	Mean Rank
qrt1posaffect	3	3.27	.63	2.5625	3.7500	4.00
qrt2posaffect	3	2.96	.72	2.3125	3.7250	2.67
qrt3posaffect	3	2.83	.72	2.2428	3.6375	1.33
qrt4posaffect	3	2.90	.83	2.0000	3.6429	2.00

Asymp. Sig.	.072

Quarterly Phase Results for Negative Affect (NA) - Questionnaire

The quarterly comparison analysis of NA using the Friedman test for repeated measures failed to reject the null hypothesis. There was not a significant difference between the quarterly PA means (p = .086). There was an overall consistently increasing trend at .086 over each quarter 1-3 (quarter 3 was highest) for NA, but not reaching statistical significance. Notice the decrease during quarter 4 to below previous quarterly baseline levels. See Figure 5 for visual illustration of the increasing NA trend through quarter 3. These reports suggest that quarter 3 was perceived as the most challenging quarter phase before returning home.

Figure 5 - Visual representation of quarterly negative affect means.

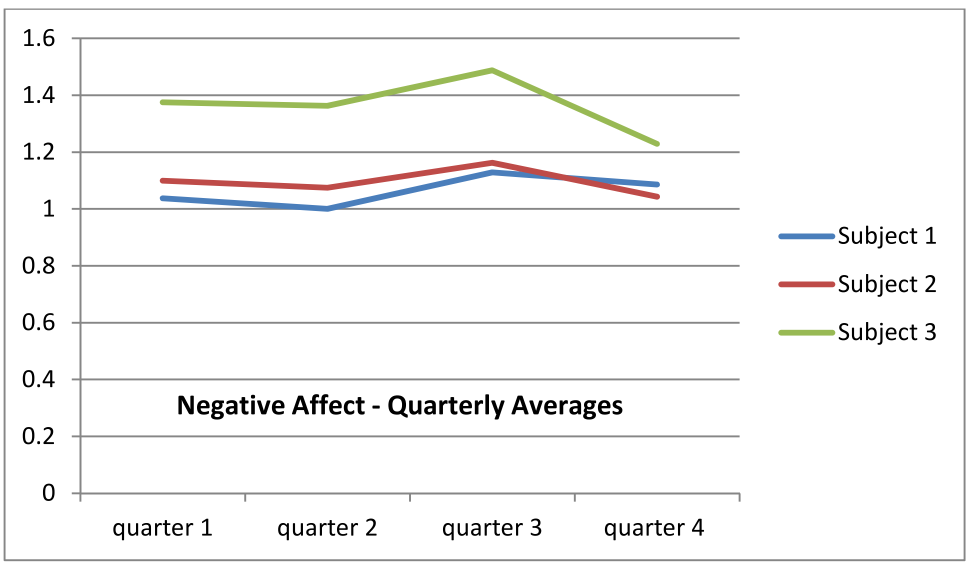


Table 6 – Freidman Negative Affect Output.

	N	Mean	Std. Deviation	Minimum	Maximum	Mean Rank
qrt1negaffect	3	1.17	.18	1.0375	1.3750	2.67
qrt2negaffect	3	1.15	.19	1.0000	1.3625	1.67
qrt3negaffect	3	1.26	.20	1.1285	1.4875	4.00
qrt4negaffect	3	1.12	.10	1.0429	1.2286	1.67

Asympt. Sig	.086

Quarterly Phase Results for Stress - Questionnaire

The quarterly comparison analysis of stress assessment averages using the Friedman test for repeated measures failed to reject the null hypothesis. There was not a significant difference between the quarterly PA means ($p = .532$). There was an overall consistently increasing stress trend throughout the mission, but not reaching statistical significance. Notice comparisons (see Table 7) of group mean quarterly stress reports, particularly quarter 3 increases. Large individual differences between the standard deviations assisted in a non-significant overall main effect. However, the fact is that there was evidence of elevated stress level up until quarter 3, as initially hypothesized. Figures 6, 7, & 8 indicate important visual representation of individual stress levels over the mission. Notice first and third quarter changes, especially in figure 7 and 8. Figure 9 illustrates the stress comparisons as a group.

Table 7. Statistical representation of quarter phase mean reports for stress.

	N	Mean	Std. Deviation	Minimum	Maximum	Mean Rank
qrt1 stress	3	1.33	.31	1.000	1.625	2.33
qrt2 stress	3	1.46	.26	1.250	1.750	3.00
qrt3 stress	3	1.58	.62	0.875	2.000	3.00
qrt4 stress	3	1.19	.08	1.143	1.286	1.67

Asympt. Sig	.532

Figure 6. Subject 1 – daily stress levels.

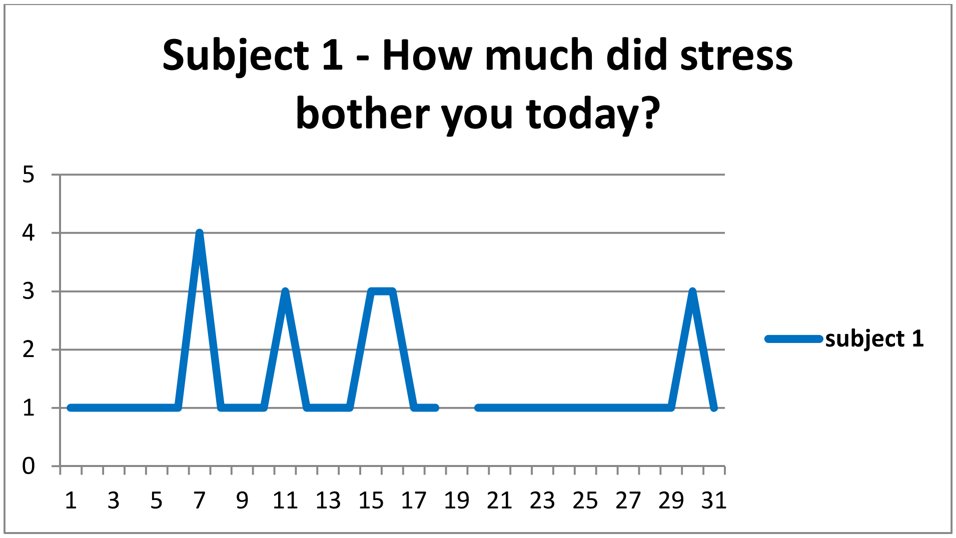


Figure 7. Subject 2 – daily stress levels.

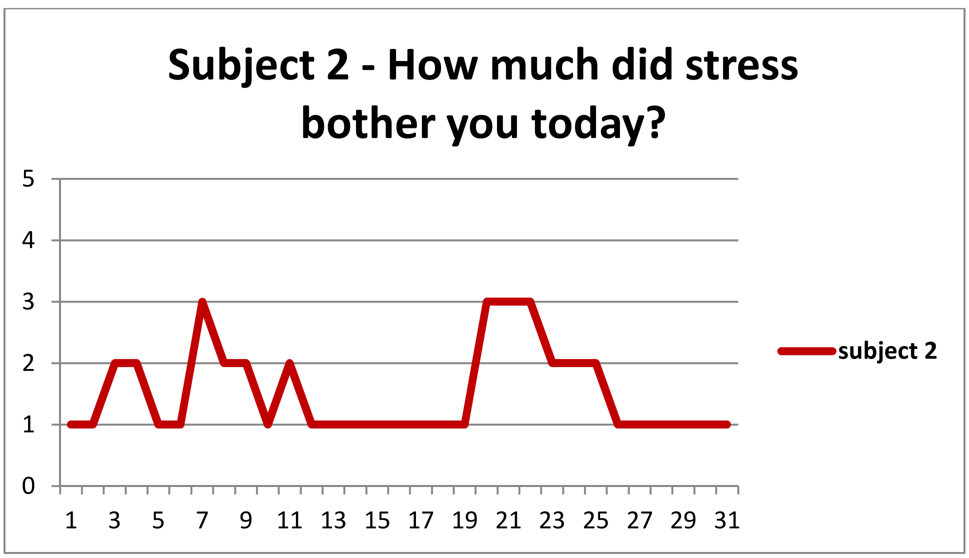


Figure 8. Subject 3 – daily stress levels.

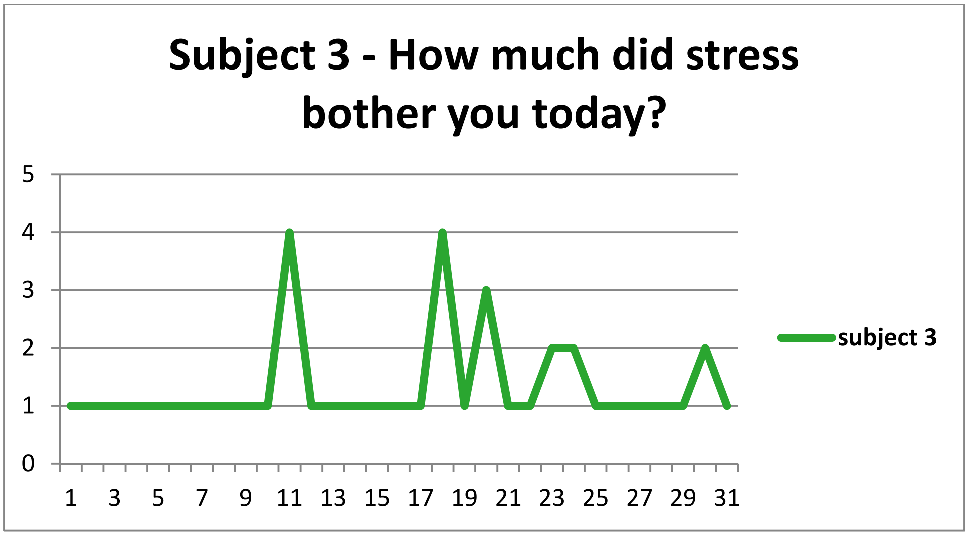
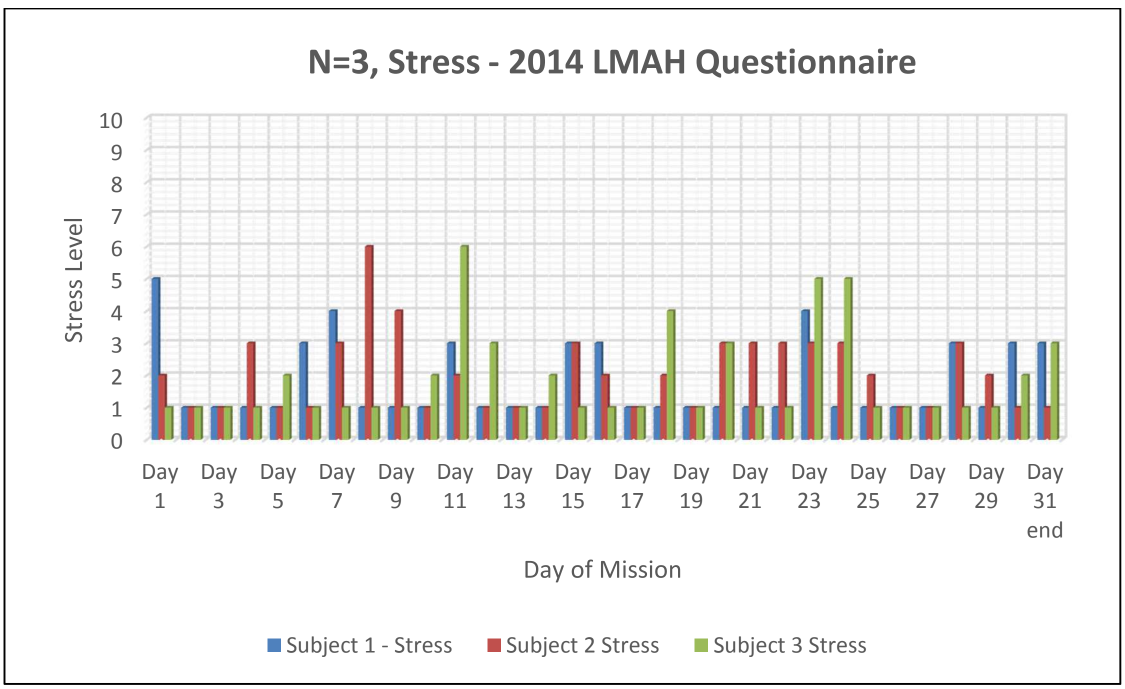


Figure 9 – 30 day group stress reports.



Quarterly Phase Results for Anxiety - Questionnaire

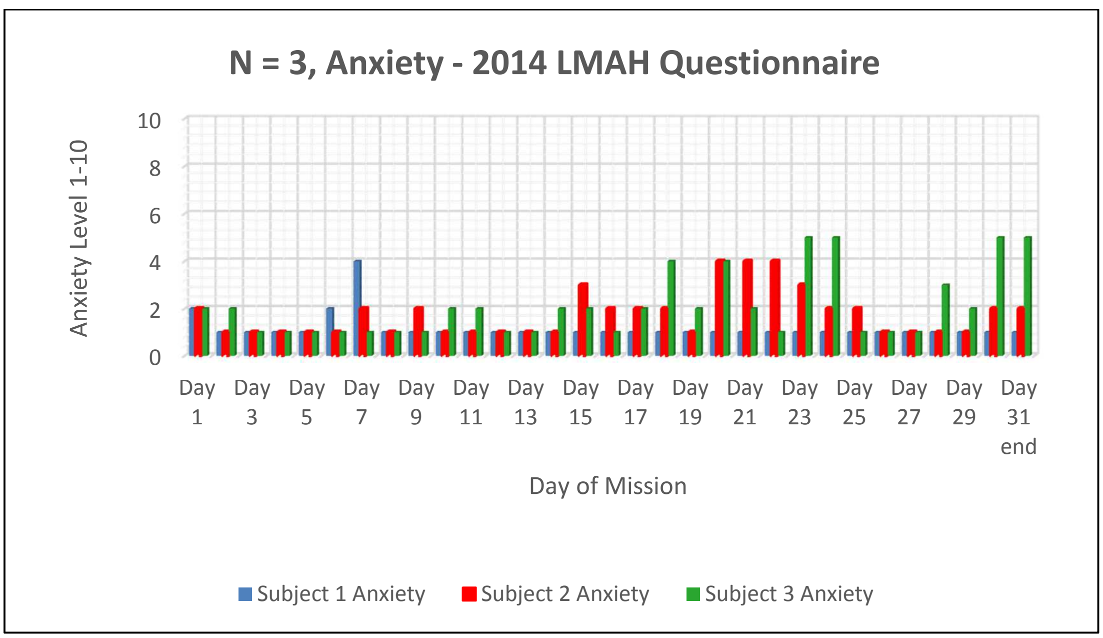
The quarterly phase mean results of the anxiety assessments using the Friedman test for repeated measures failed to reject the null hypothesis. There was not a significant difference between the quarterly anxiety means (p = .557) (see Table 8). There was not an overall consistent positive or negative trend throughout the mission, and not enough to reach statistical significance. There were large observed individual differences (standard deviation) which results in a non-significance for anxiety overall effect. Certainly the quarter 3 mean is well above the other quarterly phases and due to the SD and low crew, non-significance occurred, indicating individual differences between participants. See figure 10 for group anxiety comparisons over the mission duration.

Table 8. Friedman Anxiety Output

	N	Mean	Std. Deviation	Minimum	Maximum	Mean Rank
qrt1 anxiety	3	1.38	.22	1.2500	1.625	2.
qrt2 anxiety	3	1.34	.29	1.2500	1.500	2.33
qrt3 anxiety	3	2.30	1.13	0.8750	3.130	3.33
qrt4 anxiety	3	1.66	.81	1.1430	2.570	2.33

Asympt. Sig	.557

Figure 10 –Group Anxiety Reports. Notice overall quarter 3 increases in subjects 2 and 3..



Quarterly Phase Results for Fatigue - Questionnaire

The quarterly phase mean results of the reported fatigue assessments using the Friedman test for repeated measures failed to reject the null hypothesis. There was not a significant quarterly difference between the reported fatigue means (p = .334) There was not an overall consistent positive or negative trend throughout the mission, and therefore not enough evidence to reach statistical significance or make generalized conclusions. There were large observed individual differences in the SD, reinforcing non-significance for quarterly fatigue overall main effect. As seen in Figures 11, 12 and 13, there is certainly the quarter 3 peak well above the other quarterly phase means, however due to the SD and few subjects (N=3), non-significance occurred. See Table 9 below for numerical representation of these results.

Table 9. Friedman Fatigue Output.

	N	Mean	Std. Deviation	Minimum	Maximum	Mean Rank
qrt1 fatigue	3	2.17	.63	1.50000	2.75000	2.00
qrt2 fatigue	3	3.17	1.38	1.75000	4.50000	3.00
qrt3 fatigue	3	3.38	1.51	2.00000	5.00000	3.33
qrt4 fatigue	3	2.24	.44	1.85714	2.71429	1.67

Asymp. Sig	.334

Figure 11. Subject 1 – Daily fatigue levels. Notice mid to quarter 3 peaks.

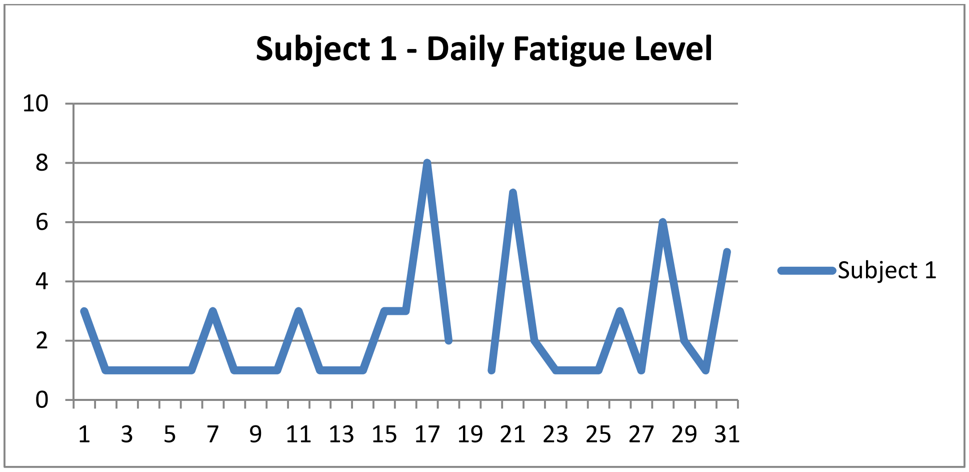


Figure 12. Subject 2 – Daily fatigue levels. Notice quarter 2 peaks.

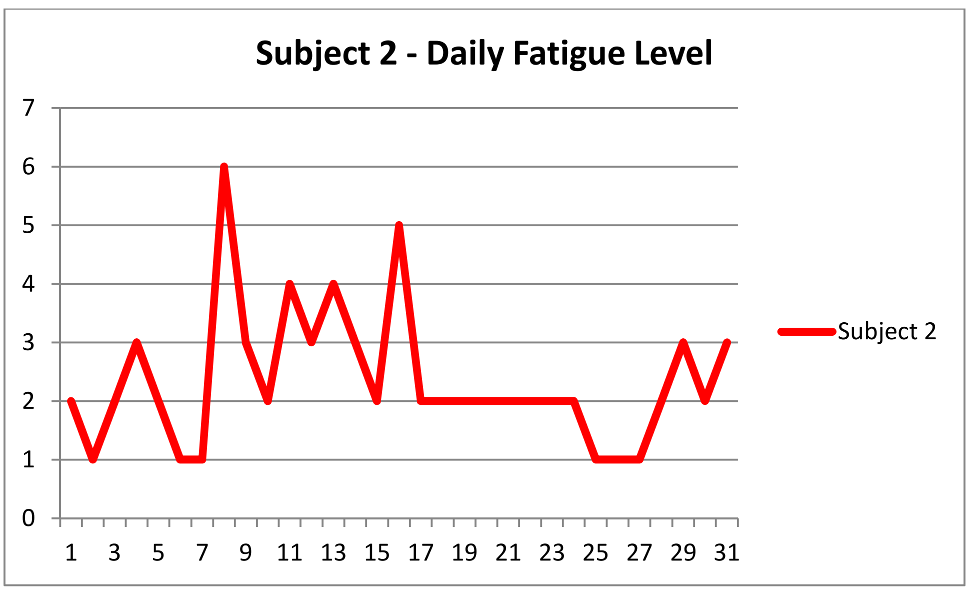
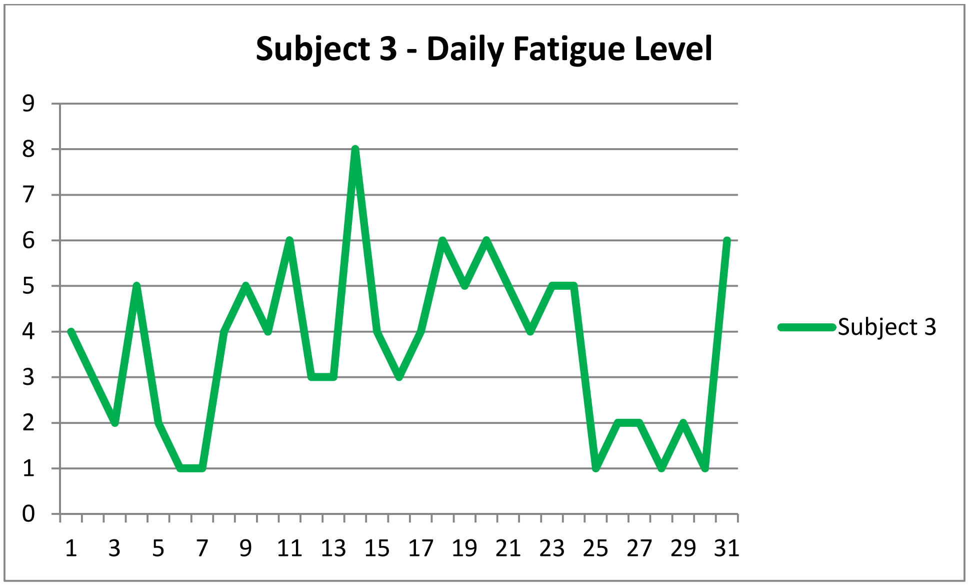


Figure 13. Subject 3 – Daily fatigue levels. Notice mid quarter peaks and overall fluctuation.



Quarterly Phase Results for Self Assessed Sleep Quality - Questionnaire

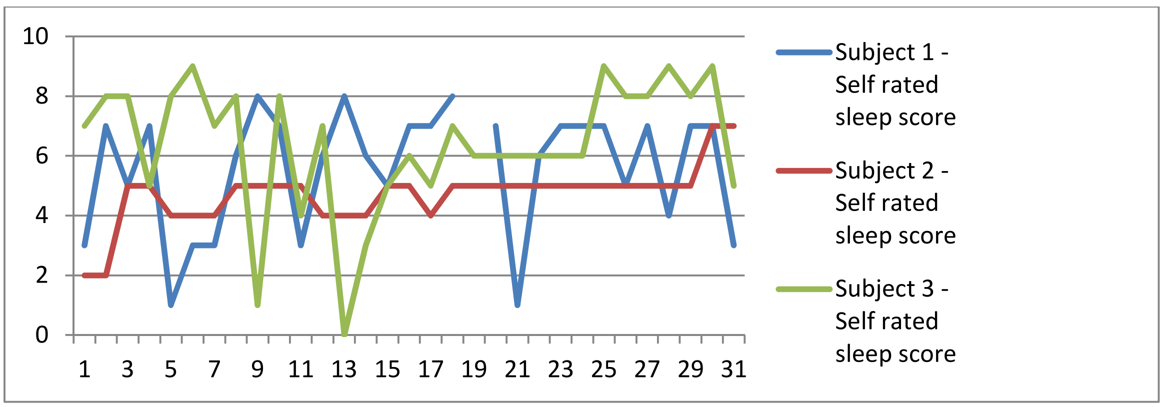
The quarterly phase mean results of the reported self-assessed sleep quality assessments using the Friedman test for repeated measures failed to reject the null hypothesis. There was not a significant difference between the self-reported sleep quality means, $p = .801$. There was not an overall consistent trend throughout the mission and therefore not enough evidence to reach statistical significance. There were large observed individual differences in the SD and only three participants in the study so again, non-significance occurred. Individual differences between participants may exist and contribute to non-significance, but more evidence would be needed to sufficiently support this claim. See figure 14 for visual representation of daily self-reported sleep scores. These results suggest that the lowest (worse) self-rated sleep score reports were evident during the quarter 2 of the mission whereas the quarter 3 and 4 demonstrated increased self-rated sleep quality. This is seen as inverse to the biometrically derived sleep scores data (see Table 10 for comparison).

Table 10. Quarterly Friedman test for Self Assessed Sleep Quality

	N	Mean	Std. Deviation	Minimum	Maximum	Mean Rank
qrt1 self sleep	3	6.42	1.77	4.375	7.500	2.67
qrt2 self sleep	3	5.33	1.01	4.250	6.250	2.00
qrt3 self sleep	3	6.21	.95	5.375	7.250	2.33
qrt4 self sleep	3	6.95	1.15	5.714	8.000	3.00

Asymp. Sig.	.801

Figure 14. Visual Representation of Group Self-Rated Sleep Quality.



Quarterly Watch Assessed Sleep Quality Score

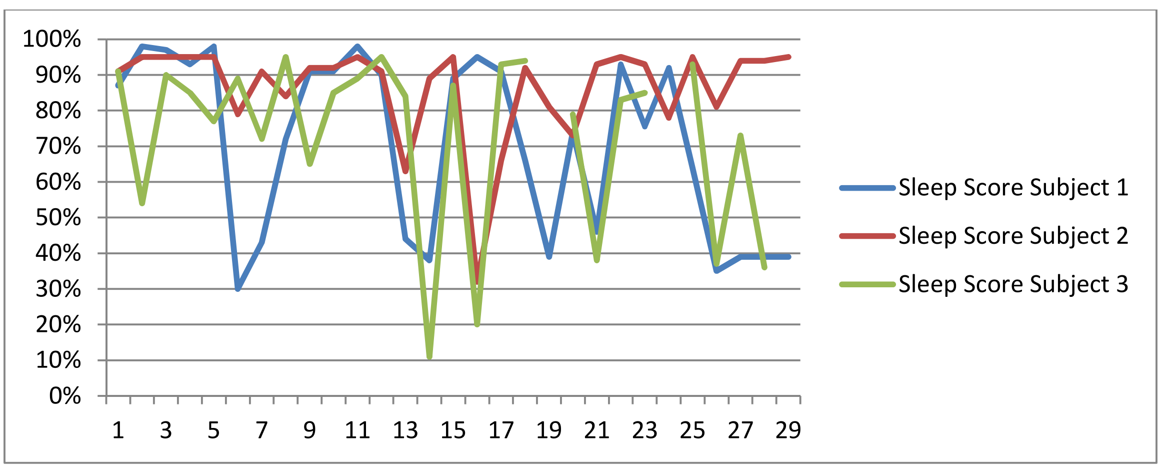
The results of the quarterly phase comparison of the watch-assessed sleep quality reports using the Friedman test for repeated measures failed to reject the null hypothesis. There was not a significant difference between the quarterly watch-sleep means, $p = .241$ (see Table 11). However, there was an overall consistent decreasing trend throughout the mission, but not enough to reach statistical significance. There were large observed individual differences in the SD, assisting in non-significance for a quarterly watch-sleep overall main effect. Even though overall decreases were visually evident, individual differences between participants exist and therefore may contribute to non-significance. See figure 15 for visual representation of individual watch-assessed sleep score means. These findings suggest that the biometrically obtained watch data indicated that the worst sleep quality for the entire crew occurred during quarters 3 and 4.

Table 11. Quarterly Friedman test for Watch Derived Sleep Quality.

	N	Mean	Std. Deviation	Minimum	Maximum	Mean Rank
qrt1 sleepscore	3	86.96	4.82	81.500	90.625	3.67
qrt2 sleepscore	3	78.11	3.90	73.714	81.125	2.67
qrt3 sleepscore	3	69.29	10.57	59.000	80.125	**1.67**
qrt4 sleepscore	3	65.49	21.98	50.714	90.750	2.00

Asypm. Sig.	.241

Figure 15. Visual Representation of Group Biometric Watch Sleep Quality



CHAPTER IV

DISCUSSION

NEO-FFI

For the three NEO-FFI score reports in comparison to the control population (N=1539, McCrae & Costa, 2010) T-scores, the crew yielded overall low neuroticism and overall high levels on all of the positively regarded personality characteristics pertinent to this mission, including agreeableness, extraversion, openness to experience and conscientiousness. These measurements of crew personality dimensions were found to be a valued supplement to other crew selection criteria previously mentioned, in terms of selecting psychologically adapted subjects for this study.

Persistent efforts by the crew to complete the mission goals regardless of personal or interpersonal stressors may be regarded as a viable connection to what would hopefully occur in future LDSF missions during phases of stress. The NEO-FFI measures for characteristics that would be regarded as important personality characteristics for future LDSF crew selection.

Quarterly Phase Discussion Part I

Since two subjects seldom perceive environmental stimuli in the same manner, data on individual differences may be quite valuable. However, since interpretation of autonomous crew behavior is limited, the patterns of response are similarly limited. Through continued research with in-flight monitoring, certain styles of response may be detected and scoring systems can be devised for future model development (Burns, Chambers and Hendler, 1963). Results from the 30 day LMAH II reports provided both subjective and objective quarterly phase data indicating that participants of this habitation analog underwent specific periods of adaptation, difficulties and/or challenges. As hypothesized previously, the data yielded both first and third quarter effect fluctuations in the majority of reported measures. These measures will now be acknowledged individually for discussion of study results and future research.

Exertion

The quarterly phase exertion comparison analysis using the Friedman test for repeated measures rejected the null hypothesis, indicating that there was a significant difference between the quarterly reported exertion group means ($p=.037$). Levels of exertion in all the crew members decreased consistently over each quarter as the mission progressed. Post-hoc analyses showed this as a negative trend ($p=.083$), but did not yield statistical quarterly significance ($p<.05$). There were clear visual and mean rank differences in the quarterly group means that indicated the lowest exertion reports were evident during quarter 4 and highest during quarter 1. It is assumed that immediate onset of adaptation to the foreign analog environment contributed to higher exertion levels overall during the beginning phase, similar to previously mentioned Hans Selye's (1974) general adaptation syndrome where the alarm phase typically occurs during early phases of adaptation. A decreasing trend in exertion reports may be correlated with increasing quality of self-assessed sleep reports as indicated by the crew. Lowered workloads and routine activities may have also affected perceived decreased exertion as crews worked more efficiently with increasing amounts of boredom and downtime. Based on exertion reports, the space analog environment was not shown to be demanding to the point of extreme or unhealthy exertion.

Negative Affect

Results indicated that the average group NA scores were highest during quarter 3 of the mission. This was found to be in support of initial hypotheses stating that quarter 3 would be the biggest challenge where struggles were most likely to arise. This increase of NA may have been due to heightened stress, anxiety, boredom or simply emotional low points when compared with other quarterly timeframes while in that environment. These findings therefore suggest that heightened NA reports during quarter 3 may be due to extended habitation in the LMAH environment, which again was isolated, confined, had very limited outside communication, and with close quarters habitation with two other people. Strong NA decreases during quarter 4 were seen by all and may be attributed with a possible "going-home effect" (Raghabir, 2011), in which group cohesion and morale increases as a result of nearing mission and goal completion. Anticipation of readapting to normal life by seeing friends and family and partaking in normal activity would serve as a morale booster during final mission phases and return to "Earth".

Positive Affect

Results indicated that PA scores decreased from the beginning of the mission and were lowest during the quarter 3. During the quarter 3 timeframe, there were recorded journal entries and email correspondence with the primary investigator indicating interpersonal conflict and power struggles. Within these archives, crew members often mentioned occurring arguments, outbursts, and clashing among primarily two of the subjects. The low PA during these challenging times may be attributed to personality differences or social behavioral over extended stays in a challenging and foreign analog environment. See table 12 for all mean values for PA and NA reports, noticing specifically quarter 3 reports in comparison to previous phases.

Table 12. Quarterly & Monthly Mean Values for PA and NA.

(+) & (-) Affect	Subject1 + affect	Subject 1 - affect	Subject 2 + affect	Subject 2 - affect	Subject 3 + affect	Subject 3 - affect
quarter 1mean	2.563	1.038	3.75	1.1	3.5	1.38
quarter 2 mean	2.313	1	3.73	1.075	2.84	1.36
quarter 3 mean	**2.243**	**1.129**	**3.64**	**1.1625**	**2.6**	**1.49**
quarter 4 mean	2	1.086	3.64	1.0429	3.06	1.23
30 day mean	2.216	1.026	3.69	1.0968	3.00	1.37

Analogous with the achievement, success and thrill of space exploration of the past, there were many positive events that were endorsed in reports from the 30 day LMAH questionnaires. These positive events particularly were reported during quarter 1 during the adaptation phase when the sense of mission drive, awareness and positive group interaction was likely higher.

Stress Levels

Friedman analysis of group quarterly stress means was not significant. However, when examining the individual graphical representation of the individual data (Figures 6, 7, and 8), both 1st and 3rd quarter phase peaks are clearly visible. Although not significant due to low subject count or standard deviations, these individualized metrics illustrate interesting patterns congruent with the previously hypothesized third quarter effect increases and first quarter adaptation effects. These results further strengthen the argument suggesting that isolated and confined environmental conditions result in third quarter increases as initially hypothesized. Further research with more participants should be carried out to gain more subjective reports from analog participants using this facility to understand more about quarterly phase effects. Future LMAH missions indicating quarter 3 effect reports will further strengthen the argument for pre-flight training and extra in-flight support/monitoring during this critical mission phase. It is also important to note that stressors evident in this study may not be the same as real spaceflight operations; there could likely be more stressors evident in LDSF, as mentioned previously or possibly less.

Anxiety Levels

Two subjects reported increasing anxiety levels consistently throughout the mission duration. All crew had slight first quarter increases in anxiety, especially subject 1. Subjects 2 and 3 reported strong third quarter increases in anxiety. However, according to the Friedman test, there were no significant differences found in the quarterly mean anxiety ratings across the 30 day mission. These results suggest that large differences in the SD and low N=3 values hindered the demonstration of statistically significant quarter phase effects for anxiety. The questionnaire illustrated slightly increased anxiety trends from quarter one to quarter two, followed by a much more pronounced third quarter increase overall. For both stress and anxiety, this was of interest because crew members all seemed to go through similar environmental stages of adaptation in accordance with hypothesized third quarter effects and are visually evident in figure 10.

Fatigue

Overall, there were not consistent positive or negative trends throughout the mission regarding physical fatigue, and therefore not enough differences to reach statistical significance between quarter phases. Certainly, as seen in previous fatigue report graphs, the quarter 3 means are well above the other quarterly means in the mission. However, general fatigue responses were low with large observed individual differences in the SD between the subjects, which resulted in non-significant findings.

Based on physical fatigue results, the space analog environment was not shown to be physically demanding to the point of physical fatigue. Each weekday during EVA in the space suits and planetary rover, two subjects were able to exit the habitat to explore the large grass field surroundings for exercise. This was the only exercise the crew was required to complete. There were reports of light exercising within the habitat, but not evident in strong questionnaire fluctuations of physical fatigue or watch data. This suggested that workload levels were considered low overall. Future representative LDSF missions would require a much more rigorous exercise routine to combat the negative physiological changes associated with confinement and actual microgravity.

Self-assessed Sleep Quality

Altered sleep patterns are often associated with situational stress, physical exertion and mental fatigue (Burns, Chambers and Hendler, 1963). Measuring patterns and quality of sleep provides a method to infer indications of physical and mental stressors associated with exertion, anxiety and fatigue of these interconnected psycho-physiological systems. Concerning self-assessed sleep quality for LMAH II, there was an overall consistent negative trend throughout the mission, but not great enough to reach statistical significance. There were large observed individual differences in the crew SD for self-assessed sleep reports, which influenced the lack of significant findings for quarterly effects of these reports. The rank mean analysis indicated quarter 3 and 4 were rated as the highest quality of sleep for the group overall. This was evident and similar to crew accounts reporting increasingly better sleep once they were acclimated to their environment. Both subjects 2 and 3 had worse sleep quality reports and less sleep length in their nightly sleep cycles during quarter 2 of the mission. Crew members were asked to report on their previous night sleep quality after they participated in the subsequent daily operations as a gauge of their performance relative to their previous sleep period. This served as a personal reference to their quality of sleep, a measure that must be highly regarded during future LDSF missions where there will be no sunrise or sunsets for extended periods of travel time. While self-assessed sleep quality reports indicated better sleep quality, watch derived sleep measurements indicated quite the opposite, as discussed in the next section.

Watch-Assessed Sleep Quality

The watch reports of sleep quality were found to relate inversely when compared with self-assessed sleep quality. The watch sleep quality reports indicated that crews got overall worse sleep in a decreasing trend across the entire mission. Circadian rhythm changes due to natural light deficiency and lack of environmental time cues could have been factors for why watch sleep quality data decreased. However, it appears that the inverse relationship between the two sleep measures is due to the watch sleep scores being derived by an autonomous algorithm, taking into account the time each individual went to bed for the evening. This is important because the crew went to bed at increasingly later times as the mission progressed. Specifically, 03:00-04:00 was the mean sleep start time after day 20 until the end of the mission, compared to sleep start times of 23:00-24:00 during early phases. These patterns of late sleep start times began after the first quarter of the mission and continued to be reported at later times until the end of the mission.

These findings suggest that there may not have been the ability to positively maintain 24 hour biological sleep cycles, possibly affected by the environmental and habitation conditions, boredom and lack of natural biological clock cues. Such biological clock changes are currently being investigated on ISS missions, of which have 15 sunrises and 15 sunsets per day. Changes in ISS and analog based biological clocks and circadian rhythms can provide research opportunities to evaluate future sun and season changes on Mars. A well-controlled sleep/wake cycle schedule may mitigate negative or disrupted circadian rhythm changes during instances of interplanetary transit where there are no sunsets.

Subject 1's sleep score improved overall while wearing the watch. The watch was designed as an exercise training device, which may have assisted in creating better sleeping habits if fully utilized. Subject 3 had many fluctuations in terms of sleep time, consistency and quality of sleep according to the biometrically derived watch measurements. Subject 2 had a slight decreasing sleep quality score but had most consistent sleep patterns overall with near perfect levels until after 7-9 days into the mission. This was likely the time of any circadian rhythm changes due to less natural sunlight (Morphew, 2001). Adapting to monotonous and sometimes boring activity could have result in feelings of more energy at the end of the day, therefore going to sleep at increasingly later times, as was seen in this study.

These findings indicate that the biometrically obtained watch data was different in comparison with the personal accounts the day after a sleep period, leaving the validity of the real time recording vs. post assessment up for further research and discussion. The changing sleep start time likely influenced a decreasing trend in watch-assessed sleep quality; therefore the crew's personal accounts were regarded as more reliable. If changes in sleep quality were a schedule-based effect, it is suggested that future crews wear watches for one month while training prior to a mission to understand their sleep cycles, train their bodies and show proficiency with the watches before starting an analog simulation. Developing a consistent sleep schedule prior to the mission would serve as valuable training to maintain biological schedules when environmental cues are reduced.

Quarterly Phase Effects Part II

The third quarter effect has not been replicated during 20 years of ISS operations (Kanas, 2009). Why is this so? The simple answer is that typical ISS missions last less than 6 months and may not be long enough to obtain distress levels hypothesized to present quarterly phase changes in well trained, professional, healthy and educated astronauts. Another possible alternative answer, while difficult to prove, may simply be that astronauts are not disclosing distress or performance decreases for fear of being grounded for future missions or perceived as inferior (Macho effect, Leon, G.R. 1999). This could be due to a high degree of astronaut professionalism or desire to be perceived as mentally tough while under the global microscope.

Historically, early missions aboard the MIR space station have shown indications of stressed cosmonauts (Myasnikov, 1996), raising the question as to whether current NASA astronauts may be experiencing stressors but choose not to disclose evidence of such. In future LDSF missions, lack of transparency or disclosure could prove to be dangerous to astronaut performance and overall functionality in such a high risk environment over long periods of time. Either way, evidence of distress in first and third quarter effects of on Earth simulation missions can be important to develop training models for future missions leaving the safety of LEO.

There appears to be a lesser need for using countermeasures during the last quarterly phase of a mission. A slight positive trajectory of the human performance curve most commonly is associated with the “going home effect”. According to a six month travel study (N=96) concerning transit to home versus transit to another destination, (Raghubir, et al, 2011) found that travelers feel that they are “almost there” when they are simply in transit to their final home destination. Given the larger perimeter of the home vs. non-home area in space, space voyagers may feel that their journey is coming to completion sooner when they travel from a non-home location to home destination, than when they travel from home to a non-home destination. Implications of this travel study indicate that the last leg of most missions (<15%) is the least stressful time and thus less likely for crew members to experience negative stressors. The “going home effect” can therefore be used as a timeframe period in space habitation whereby there is a lesser need for stress countermeasure implementation.

Future Recommendations

For future studies, salivary cortisol testing would provide more objective data on acute stressors to compare with subjective self-assessed crew reports. Stressors via simulated emergency could be induced during future LMAH missions, including emergency event scenarios such as atmospheric decompression from meteorite impact, habitat fire, power failure, carbon monoxide and medical problems. These scenarios would provide realistic research opportunities for individual performance and group cohesion. Neurobehavioral and psychosocial crew selection factors such as leadership style, crew personality composition, crew cohesion, organization, and adequate communication will be criteria used for selecting participants of future LMAH missions. Selection methods are recommended to be more rigorous in order to optimize crew effectiveness and mission success as demonstrated in an actual NASA mission with many stages of recruitment and training. In addition to meeting countermeasure development needs of future astronauts, this research can also potentially benefit workers in safety-sensitive, extreme and remote locations here on Earth such as winters in Antarctica and submarine habitation.

Future long-duration missions (beyond 6 weeks) in this analog simulation and other remote setting simulations have to be provided, with participants rigorously trained to work under those conditions to increase awareness level about hardships of confinement and isolation. Future astronaut training for remote deep space missions would benefit by augmented confinement, isolation and briefing sessions clarifying and understanding future anticipated stressors. A Mars mission of 500-1000 days will be of greater duration compared to past and present flights and may not follow the Selye (1974) preconceived curve of adaptation. Stress may increase more rapidly; with unknown implications for mission success and when stress peak levels will occur and decrease. Future research on stages of LD adaptation and stages of coping will continue to be regarded as important when moving further into the solar system for longer periods.

Effects of personality types on performance profiles in confined remote settings seem to be under-researched as reflected in limited amount of bibliography resources. Research on the effects of confinement and isolation on different personality types has to be specifically studied more in special design facilities or challenging remote settings, further emphasizing the beneficial cost vs. risk relationship of these endeavors compared to space. Self-assessment and self-analysis of stressors and psychosocial behavioral health would enable a more rapid acknowledgment and treatment within differing crews on autonomous LDSF missions.

CHAPTER V

CONCLUSIONS

The findings of this study quantified both positive and negative effects of isolation and confinement by analyzing quarterly phase changes in the group mean reports. This research aimed to provide human data that anticipated, recorded and assessed behavioral health profiles of crews. Potential benefits from this research include providing more evidence to strengthen the case for space psychology research and the importance of quarterly phase effects during any extreme environment habitation. Space analog exploration simulations on Earth have provided researchers a controlled means to train, rehearse, and prepare astronauts for space. In particular, these missions can access specific elements and factors by closely replicating the environment, conditions and scenarios needed to inform many research topics.

Administering moderate stressors on the ground in controlled space analog simulations may provide valuable training concerning what astronauts can expect on a 500-1000 day Mars mission, asteroid capture/mining and lunar base development. The current study was the first to address psychological crew assessment for UND LMAH space analog research. The findings provided valuable data that could result in new focuses for crew training in stressor mitigation, selection methodology, and maintaining in-flight performance for the well-being of astronauts and space analog participants. Overall, this study addressed future space environmental habitation considerations for manned missions on the surface of the moon and Mars.

This research confirmed the existence of fluctuating quarterly phases of psychological status within a 30 day habitation analog. Results were found to be in support of the initial hypotheses concluding that the environmental conditions resulted in lowered exertion, heightened stress, anxiety, less consistent sleep patterns, fatigue, and lowered operational performance levels primarily during the third quarter timeframe of the mission (~days 17-23). Results indicated that negative affect was most evident during the third quarter while positive affect was simultaneously the lowest during the same time period. Other research questions not hypothesized, but important include are that acclimation to the unique LMAH environment resulted in highest positive affect levels and perceived exertion levels during the first quarter timeframe of the mission.

This research gained valuable data that offers new insights applicable to lunar/Martian analog habitation, benefiting crew training, selection methodology, and in-flight stress assessment and mitigation. Such insights could further develop the safety, performance and well-being of astronauts leaving Earth on a planetary mission. As a result of this research, it is believed that future self-assessment and self-reinforced coping mechanisms will reduce the effect of negative stressors to nominal conditions without continued ground crew support from Earth. Future missions to the Moon, asteroids and Martian environments will require increasingly comprehensive countermeasure development and training in order to mitigate potential or anticipated problems and challenges. Future lunar missions will answer questions derived from the Apollo moon landings and also serve as engineering stepping stones towards Mars. Space analog research can therefore be of valuable assistance to a broader understanding of human habitation and operations as we advance further in exploration of the solar system.

APPENDICES

Appendix A

LMAH Daily Crew Member Evening Questionnaire

Subject Code No._____ Date: _____

Please complete this measurement after you daily activity but before going to sleep.
This section consists of a number of words that describe different feelings and emotions. Indicate to what extent you felt that way **today:**

1 = very slightly, not at all; 2 = a little; 3 = moderately; 4 = quite a bit; 5 = extremely

interested _P___	guilty _N___	irritable _N___	determined _P___
distressed _N___	scared _N___	alert _P___	attentive _P___
excited _P___	hostile _N___	ashamed _N___	jittery _N___
upset _N___	enthusiastic _P___	inspired _P___	active _P___
strong _P___	proud_P___	nervous _N___	afraid _N___

(Highlight your rating below on a scale ranging from 1 (not at all) to 10 (the most possible)

How much did stress bother you today while completing mission objectives?	1 2 3 4 5 6 7 8 9 10
The level of stress you experienced today.	1 2 3 4 5 6 7 8 9 10
The level of anxiety you experienced today.	1 2 3 4 5 6 7 8 9 10
How fatigued do you feel today?	1 2 3 4 5 6 7 8 9 10
Your level of exertion over the course of the day.	1 2 3 4 5 6 7 8 9 10
Your level of exertion over the course of the mission.	1 2 3 4 5 6 7 8 9 10
How restful was your sleep in the last major sleep period?	1 2 3 4 5 6 7 8 9 10
How many total hours of sleep did you get in your last major sleep period?	Hours

Do you feel that you got enough sleep during your last major sleep period? __ If Yes, please elaborate here:
List any problems or issues that you think might interfere with the success of the mission :
Enter on the line: "1" for each event/situation you experienced today. Enter "0" for events/situations you did not experience today.

___Problems with infrastructure (habitat, rover or space suit), technology, or equipment
___Feeling of camaraderie/closeness with teammate
___Concern about the well-being of my other crew members
___Enjoyment of the analog space environment
___Concern about how effective my crew members and I are working together
___Feeling down/low or stressed out because my crew members are feeling that way
___Tension or argument with other crew members
___Satisfaction in making good progress today
___Satisfaction that equipment and infrastructure is working properly
___Satisfaction that I am able to cope with the challenges
___Concerns about the effectiveness or safety of decisions I made today
___Concerns about the effectiveness or safety of decisions my crew members made today
___Enjoyment of being currently located in a simulated space environment
___Worried about family, friends
___Loneliness, homesickness
___Personal hygiene (wanting to be cleaner)
___Lack of privacy or personal time
___Headache
___Injury Location on body:

Other significant events today? Please describe:

Did any particularly positive or pleasant events occur today? ___Yes ___No
If yes, indicate what occurred here:

Did any particularly negative or not pleasant events occur today? ___Yes ___No
If yes, indicate what occurred here:

Enter "1" for each coping method you used <u>today</u>. Enter "0" for methods you did not use <u>today</u>.
___Told myself, "take it one day at a time. Live with it, accept it".
___Kept my feelings to myself.
___Discussed task concerns with teammate.
___Discussed personal/emotional concerns with teammate.
___Wrote home or in a diary/journal
___Tried harder. Pushed myself to do my best, told myself I can do it.
___Prayer.
___Saw way, the situation in a very positive what I'm learning and getting out of it.
___Kept a positive attitude. Humor, joking around, having fun.
___Relaxed, meditated, listened to music, daydreamed.
___Kept the goal in sight. Thought about finishing the mission and why I'm here.
___Thought of something pleasant such as good times to come.
___Tried to figure out how to solve the situation that's bothering me.
___Negative feelings about myself
___Negative feelings about others.
___Yelled, stomped, threw things around
___Other (explain here)

Did you encounter a situation today in which you and your teammate had different opinions as to how it should be resolved (specific route to take, when to stop for the day, etc.)? ___Yes ___No
If yes, describe the situation and how you resolved the difference of opinion here:

APPENDIX B

Vocabulary for the 30 day LMAH questionnaire – PANAS measure

Use: for consistent group interpretation

Interested - Having the attention engaged. <interested listeners>
- Being affected or involved. <interested parties>

Distressed - Feeling or showing high levels of unhappiness or pain.

Excited - To cause feelings of enthusiasm in (someone).

Upset - Be made unhappy, worried, angry etc. due to others or yourself.

Strong - Having great physical power and ability, or having a lot of strength.

Guilty - Feeling bad because you have done or think you have done something wrong.

Scared - Thrown into or being in a state of fear, fright, or panic.

Hostile - Of or relating to an enemy: not friendly: having or showing unfriendly feelings: unpleasant or harsh to another.

Enthusiastic - Feeling or showing strong excitement about something:

Proud - Very happy and pleased because of something you or others have done.

Irritable - Becoming angry, short tempered or annoyed easily by events or other people.

Alert - Watchful and prompt to meet danger or emergency: quick to perceive and act.

Ashamed - Feeling shame or guilt: not wanting to do something due to shame or embarrassment.

Inspired -Very good or clever: having a particular cause or influence you stand behind.

Nervous - Having or showing feelings of being worried or afraid about what might happen.

Determined - Having a strong feeling that you are going to do something and that you will not allow anyone or anything to stop you.

Attentive - Thinking about, paying close attention to or watching something carefully.

Jittery - Very nervous, marked by jittering movements or anxiety.

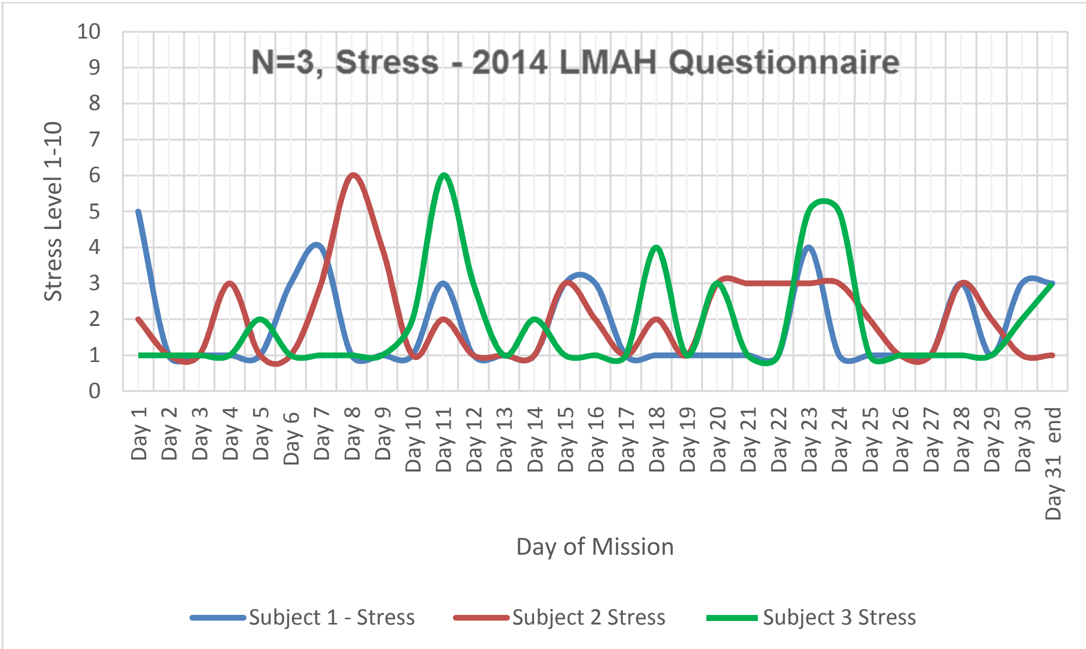
Active - Doing things that require physical movement and energy, involving action or participation in body conditioning.

Afraid - Filled with fear or apprehension: Filled with concern or regret over an unwanted situation.

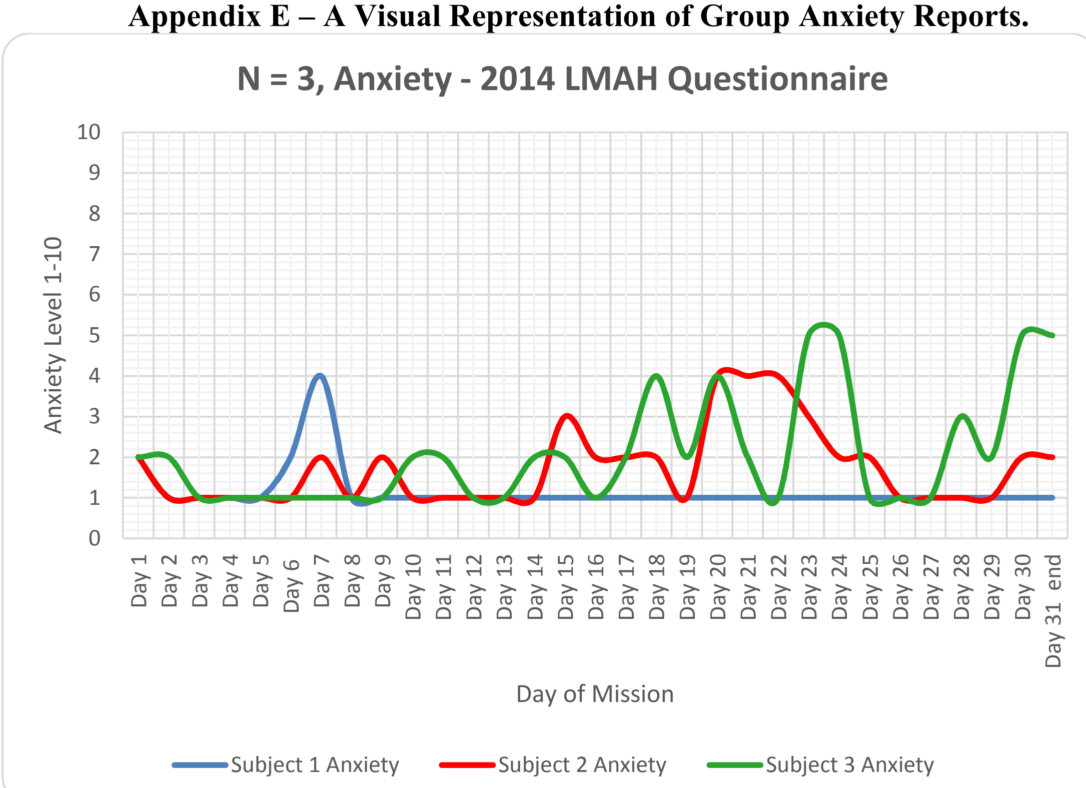
Please contact the primary researcher if you need any further assistance interpreting these definitions or with any other questions you may have. Thank you.

Appendix C – Actiwatch Sleep Data Interface

Appendix D - A Visual Representation of Group Stress Reports.



Appendix E – A Visual Representation of Group Anxiety Reports.



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