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Identification Of Psychological Stressors For Long Duration Space Missions: Psychological Stressors Among Five Astronauts And Cosmonauts

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IDENTIFICATION OF PSYCHOLOGICAL STRESSORS FOR LONG DURATION SPACE MISSIONS: PSYCHOLOGICAL STRESSORS AMONG FIVE ASTRONAUTS AND COSMONAUTS

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This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

As humans continue to experience space missions of longer and longer duration, more and more high intensity stressors are going to be experienced. Although physiological stressors have been studied, there have been few studies on the psychological stressors. Those that are present primarily focused on the polar environment as a space analogue. In order to answer the question of how stressors may affect future astronauts and cosmonauts, the evolutionary reasons behind stress must be considered not only the type and intensity of the stressors.

Five astronauts and cosmonauts representing three space agencies were surveyed regarding their experiences with ten types of general stressors and eight types of interpersonal conflict related stressors. These stressors were analysed as to their perceived frequency, intensity, and the risk to mission success of both short-term and long-term missions. Subjects who had experienced longer duration spaceflight tended to experience more stressors at a higher intensity.

CHAPTER I

INTRODUCTION

Several million years ago, a human ancestor, visibly resembling her ape ancestors more than her future human descendents, surveys the wide-open space of the savannah. All she can think about is staying alive one more day in this environment not only hostile with predators, but also fraught with intra- and intergroup competition for food and water. The savannah can be a dangerous place and creatures like her do not last long if they are careless. The only real hope that she has to survive was to remain in her group and always have an escape route in case the predators come. If separated from the group and cornered by predators, she is likely to be killed. At least in her group, while she might not be the most dominant member, she can reduce her chances of a predator attack and increase her chances of defending group resources. Her primary concern relates to the stress that comes with being part of a group; hierarchy, threat displays, miscommunication, and intragroup competition, etc. Although it is best if they all stay together, the small group she lives with is always changing. If a fight breaks out there is always the option to leave regardless of the danger. Thus some old members would leave and new members would come, leading to new difficulties. This group protection is one of many aspects of their behaviour that allows them to survive to reproduce and pass down their genes to the next generation.

Several million years later, some of her descendents are confined in a small spacecraft. The trip to Mars will take several months each way and it will take several years to complete the mission and return to Earth. Even though the crew trained together from the beginning, the stresses and strains of their new life in space eventually started to get to them. Tempers frayed and the crewmembers started to snap at each other. Communication began to cease and hostility was thick in the air. The commander secretly starts to worry, surely if his crew kept up this hostility towards each other, they could all end up dead.

Some might ask how or in what way these two situations are related.[1] At first glance, there might be more differences than similarities. However, both the savannah dweller and the astronaut have a lot in common, both psychologically and physiologically. The environmental pressures selected for certain behavioural traits, which have been passed down from generation to generation. These behavioural traits, which affected our ancestors, are still in play even though different environments have torn away their advantage and provide a disadvantage to our present and future astronauts. All of the evolutionary traits programmed into us from millions of years of evolution need to be considered when designing human spaceflight missions, particularly those of medium to long duration when an emergency trip back home is simply unfeasible. Stressors that can be reduced should be reduced as much as possible in order to avoid jeopardizing mission success.

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[1] Apparently, both of these have the additional similarity as they are both mentioned in the opening scenes of the movie *2001: A Space Odyssey*. Unfortunately, I have not seen this movie and so cannot comment on this aspect.

The Problem

Although many space scientists have studied the physiological stressors of microgravity, there have been very few studies on psychological stressors of space flight. The problem that exists is not simply the identification of psychological stressors, but instead of a truer understanding of the stressors present and why they occur. Few, if any, space and polar psychology studies have reported on why stressors occur. The literature only reports that stressors do occur and the often-negative reactions that go along with them, such as feelings of personal failing. Thoughts of personal failing in highly ambitious and motivated groups can cause further tension as self-confidence begins to decrease and motivation drops.

While individuals might want to wish their stress away, it is important to realize that stress in certain circumstances is a natural occurrence which has been passed down genetically for millions of years because it offered a survival advantage to the individual. While human ancestors evolved in an environment very different from the environments were we currently find ourselves, those evolved traits are still present even though they might not be needed or wanted. Under certain circumstances, such as long duration mission to Mars, an overly negative reaction to stress might offer a survival disadvantage and compromise the safety of the mission. This is why understanding the proximate and ultimate causes of stressors are so important. Only by understanding the stressors' roots can we hope to reduce their occurrences and reduce the severity of the incidents that do occur. Stressors can be reduced and mission success can be increased by providing better pre-flight training to allow better coping skills and increase communication skills.

While many of the space stressors found in Geuna et al (1995) can be traced back to our evolutionary roots, the one interpersonal conflict stressor seems to occur the most frequently and is linked to many other stressors. This is the stressor that should be the easiest to identify, understand, and reduce as well as being one of the more dangerous of the stressors. Interpersonal conflict in isolated and confined systems occurs in several ways. These ways are easily divided into two major topics: mission control/crew conflicts and intracrew conflicts. Those intracrew conflicts that occur can be for any number of reasons including personality conflicts, hierarchical conflicts both in mission and in their career, cultural miscommunication, and differences in experience. Unlike on Earth, when one has a conflict in space, it can be very difficult to remove oneself from the situation as spacecrafts are often crowded and cramped further escalating any difficulties that are present.

The purpose of this project is to survey astronauts and cosmonauts in order to assess the frequency, intensity, and perceived threat to mission success of 10 stressor categories modified from Geuna et al (1995) as well as gauge the current effectiveness of preflight training for interpersonal conflict reduction and prevention. This project is the first to look at space stressors, particularly interpersonal conflict, through the tools of biological anthropology and evolutionary psychology. This allows us to understand the biological basis for these behaviours and suggest ways to reduce stressors during a long duration, extremely isolated mission to Mars.

A Brief Overview of Previous Research

The field of space psychology is a relatively new area and is primarily studied using analogue environments such as submarines, arctic, and antarctic environments.

Psychological stressors and reactions to the extreme environment have been recorded among the polar expedition crews and have been extensively reported in the literature. These reports give some indication of the circumstances under which astronauts and cosmonauts must work.

While stressors in polar environments have been the primary focus for space psychologists, there have also been experiments of short to medium duration in a closed ecological system, such as the Russian BIOS projects, the American Biosphere-2 project, and the upcoming long duration project by the European Space Agency. These experiments were primarily focused on human survival in a closed ecological system although interesting psychological reactions were recorded and published. Although these situations are not the exact same set of circumstances as those in space, this information is still being applied to the space program.

Unfortunately, very few studies have been performed on astronauts and cosmonauts themselves. An exhaustive search of the literature turned up less than a dozen articles regarding space psychology, only a few of which included astronaut/cosmonaut experiences. Kelly et al. (1992; 1993) focused on communication issues, while Kanas (1998; 2000; 2001) primarily reported on general social and psychological issues which arose on short to medium duration Shuttle/Mir missions. The others focused on theoretical aspects, but had little or no data to support their ideas. All articles mentioned the need for further research in this area.

Importance to the Field

An exhaustive study of the underlying causes of social and psychological issues is necessary for the well-being of the crew and the success of a Mars mission. While other studies have primarily focused either on a few theoretical aspects of long duration spaceflight, simply stating that there are going to be social and psychological issues that will develop, there was minimal input by those who would be selected to go on such a trip. Other projects only studied a single aspect (miscommunication issues) among astronauts and cosmonauts in low Earth orbit (LEO). While this is something, it is hardly enough. This project seeks to fill in the gaps between our present knowledge and ability to deal with psychological stressors and the knowledge which will be needed in future missions to Mars.

CHAPTER II

LITERATURE REVIEW

Human Factors and Closed Life Support System Stability

From 1957 until 1996, there was a tremendous interest in small and large scale closed ecological systems leading to a wide scope of theoretical works and experiments which took place in the USA, Western Europe, and Russia. While scientists have been concerned with the mechanics of creating an efficient system, few research groups have been concerned with designing a system which reduces the amount of physiological and psychological stressors. Human psychological, motivational, cultural, sociological, and physiological factors have to be considered in the design and the development of any closed ecological system for long-term Life Support (LS) applications.

The consideration of psychological and cultural factors must be considered when the mission is initially designed and created. Stressors may affect a member of one culture, or of one sex, and might not stress a member of another. For example, there might be members of a certain culture who must have a particular food in order to feel complete; this might be difficult to accommodate. The crew must also be aware that they would have to get along, evenly divide the work, and be free of psychological disorders.

There are also psychological factors that may develop as a result of the confinement. Being in a closed space can cause stress, often leading to psychological instability and acute mental stress. While physiological stress can cause mental stress, the reverse, mental stress can cause physiological stress, is also true. Mental stress can be just as powerful as physiological stress, both of which interact to increase the hormone cortisol, which impacts the body physiologically. While there are many ways to control stress, only a few, such as maintaining a private cabin or to having some form of hobby, would be possible in a closed system. Other stress reduction techniques, such as the keeping of pets, would have to be adapted or removed from consideration.

Human Factors and Complex System Stability

There are three interacting blocks, which need to be balanced in order to create and maintain a stable closed ecological system (CES) or a controlled ecological life support system (CELSS). The first block includes the physical limits of internal CES stability. Important features of this area include the interaction of material recycling and In Situ Resource Utilization (ISRU), the use of material already present at the site. These issues regarding material have been a primary concern of those studying CES (Sridhar, Finn et al. 2000; Accettura, Bruno et al. 2004; Czupalla, Aponte et al. 2004). Another important feature is human/machine interaction, how the crew is able to interact with the computer interface, such as via speech or handwriting recognition, in an efficient and hopefully entertaining manner in order to increase and maintain safety (Johannsen 1997; Dybkjaer, Bernsen et al. 1998; Agah 2000; Noyes 2001). The importance of a well-designed computer control system is paramount in several industries such as nuclear power plants (Nelson 1989; Chang, Choi et al. 1999; Xiaoming, Zhiwei et al. 2005b) and manufacturing (Stahre 1995).

The second interacting block is that of external stability issues. Important features of this block include the idea that a system can be completely closed to neither energy exchange nor information exchange. The inability of the CES to be closed to energy exchange is due to the Clausius Theorem and Inequality, which states that in every non-reversible reaction energy is lost. Doing work transfers energy from an area of high energy to that of low energy. The energy ends up in an energy sink and is unusable.

The third block is going to be explored the most in this paper. While the first two blocks have been explored though Russian (Salisbury, Gitelson et al. 1997) and US ground based experiments (Marino and Odum 1999) as well as through the International Space Station (ISS) and Mir, there have been few experiments whose primary focus is on the human factors aspect of CES (Sauer 2004). The area of human factors includes such diverse areas as physiology, individual psychology, spirituality, and social psychological group interactions including personal, sex/gender, leadership, stress, cultural, and sociological phenomena. Human factors have only rarely been considered as there is a dearth of literature as it applies to CES.

Potential Areas of Instability

There are many potential sources of instability in the human factors area which can be divided into seven categories: technical/engineering, physiology, psychology, social psychology, human ecology, human/machine interaction and the dynamics over time.

Technical/Engineering

The technical and engineering stressors have been studied most in depth (Bartsev, Mezhevikin et al. 1996; Morowitz, Allen et al. 2005). Instability can refer to problems with the ecosystem leading to its collapse of failure. Any instability in these areas can lead to collapse of the ecosystem. Since smaller scale life support systems would be too small to sustain a natural stability, technology such as CO2 scrubbers, oxygen generation systems, contaminant removal systems, and waste management must be employed in order to create stability and balance (Crump 1997). Increased instability can lead to death of a life support system's residents, so the prevention of technical breakdown is paramount.

Physiology

Physiological stresses can be in several forms. The physical limits of what we can stand would be four to five minutes without Oxygen, about a month without food, and several days without water. Humans can suffer temperature and humidity extremes for a brief amount of time, while radiation, toxicity, and pressure depends on the severity of exposure. As physiological stress can impact mental performance, it can also affect the mental limits of what we can stand. This could possibly allow an earlier "breaking point" as well as altering individual and group interactions.

Psychology

There are psychological limits which also need to be considered. Factors that can affect the mental limits of the crew can be the lack of privacy (Klitzman and Stellman 1989; Johnson and Suedfeld 1996; Wilson 2000), claustrophobia (Connors, Harrison et al. 1985), overcrowding of crew (Fuller, Edwards et al. 1993; Brown and Grunberg 1995), appetite for certain foods, being far from home in a hostile environment (Taylor 1991), absence of friends and family (Taylor 1991; Kass, Kass et al. 1995; Johnson and Suedfeld 1996; Rosnet, Cazes et al. 1998), possible lack of motivation (Cleveland, Boyd et al. 1963; Earls 1969; Connors, Harrison et al. 1985; Stuster 1996; Santy 1997), possible time delay in communication, and even boredom (Kishida 1973; Connors, Harrison et al. 1985; Taylor 1991; Buck and Lamonde 1993; Stuster 1996; Sagberg 1999; Thiffault and Bergeron 2003; McLeod, Walker et al. 2005). There are also more spiritual limits. Everyone has a need for some form of ritual. Although religiously based rituals are the more commonly thought of, rituals can include a variety of behaviours such as having a morning coup of coffee taken a certain way, doing one's morning routine (shower, shave, brushing one's teeth, etc) a certain way, etc. If these rituals are disrupted, aggressive behaviour can occur (Murphy, Macdonald et al. 2000). There could also be problems with technological interaction, for example, a user being unable to get the desired results out of the computer leading to frustration and distress. Any one of these factors can cause someone to be pushed to their mental breaking point.

Social Psychology

Social psychology contains many limits as well. There can be problems with internal group interaction (Kelly and Kanas 1992; Kanas, Salnitskiy et al. 2000), crew/mission control interaction (Kelly and Kanas 1993; Kanas, Salnitskiy et al. 2000), sex/gender issues (Taylor 1991; Sandal, Vaernes et al. 1995; Bishop, Grobler et al. 2001), cultural and sociological differences (Santy, Holland et al. 1993; Kanas, Salnitskiy et al. 2000), occupational differences, leadership (Leon and Sandal 2003), and egalitarianism (Woodburn 1982). Some of these limits can be overcome by the proper selection and training of a crew, although it is highly unlikely that a very large crew would work together in perfect harmony.

Human Ecology

In the realm of human ecology, there are several environments that need to be considered. In the Earth environment, there is the presence of a Nitrogen/Oxygen atmosphere with a pressure of 101 kPa, a 24-hour day, gravity (1 g), a relatively consistent temperature, and protection from most radiation. The open space environment can have a 400-degree or more temperature variation, no atmosphere or pressure, high radiation, and altered gravity. A planetary environment can provide different levels of radiation protection, pressure, gravity, temperature, and atmospheric composition depending on the planet. In the space cabin environment, it has enclosed space, increased amounts of microbes, microgravity, increased toxic chemicals due to material recycling, as well as other problems such as the reduction in diversity of food. The three latter environments are not optimal for the human physiological or psychological well-being as they are very different from the conditions in which we evolved.

Human/Machine Interaction

Stressors regarding human-machine interaction are very widely experienced and should be familiar to anyone who uses a computer on a regular basis. Stressors relating to the difficulties with user interface (Xiaoming, Zhiwei et al. 2005a) and software (Paradowski and Fletcher 2004) all fall under this category. Difficulties with machine use impact the amount of mental workload (a psychological stressor) as well as compromising safety and stability of the system (Xiaoming, Zhiwei et al. 2005a; Nachreiner, Nickel et al. 2006).

Evolution of Dynamics

As with anything that involves living things, various dynamics will change over time. The human body is constantly adapting to the nutrients it receives as well as the hormones it secretes. Mentally speaking, we are constantly adapting to new stressors. Extended periods of time can lead to changes in mental processing, possibly leading to an unforeseen mental breakdown (Taylor 1991). Group interactions are also in a constant state of change. All of this leads to eventual changes over time and evolution of human factors. These eventual changes have to be considered previous to any CELSS creation.

Human Factors and Sociobiology

What is Behavioural Biology?

The field of behavioural biology is defined as the "scientific study of all aspects of behaviour, including neurophysiology, ethology, comparative psychology, sociobiology, and behavioural ecology" (Wilson 2000). While there are many fields that make up behavioural biology, much of what I will be discussing comes from the field of ethology, sociobiology, and evolutionary psychology, a field closely related to sociobiology.

Ethology was the first field which used evolution in order to explain often innate species-specific behaviour in animals or, in other words, species specific instincts (Baldwin and Baldwin 1980; Pope 2000). Although Darwin's Expression of the Emotions in Man and Animals (1872) was the first to connect innate behaviour as a consequence of evolution, it was not until the early 20th century when ethology came into its own (Baldwin and Baldwin 1980). However, it took until 1973 for a Nobel Prize to be awarded to ethologists Konrad Lorenz, Karl von Frisch, and Nikolaas Tinbergen for their work on social behaviour.[2] The most influential of these works was the four

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[2] Konrad Lorenz was honoured due to his work on imprinting and fixed action patterns. Karl von Frisch was honoured due to his work on the honeybee's "waggle" dance. Nikolaas Tinbergen was able to create experiments that would help test theories on

questions Tinbergen (1965) set forth. These questions, which should be asked of all behavioural responses, included:

1) What does the behaviour do to help reproduction?

2) What caused the behaviour?

3) How does the behaviour change with age?

4) How does the behaviour compare across species?

Ethology lost most of its dominance in the field of behavioural biology as E.O. Wilson's Sociobiology: the New Synthesis, first published in 1975 and later reprinted as a 25th anniversary edition in 2000, began to rise in importance. Sociobiology explains animal and human social behaviour as being advantageous from an evolutionary standpoint. This new concept of sociobiology, which combined both psychology and biology, led Wilson to predict that ethology and comparative psychology were "destined to be cannibalized by neurophysiology and sensory physiology from one end and sociobiology and behavioural ecology from the other" (Wilson 2000).

Wilson was correct and ethology has been on the decline in favour of sociobiology in the animal behaviour textbooks (Alcock 2003). Evolutionary Psychology, a related field of sociobiology, looks for evidence of past natural selection for behaviour (Barrett, Dunbar et al. 2002). In order to fully approach the problem of human psychological issues, it is important to not only understand how behaviour can be selected for genetically, but also to understand the environment in which those behaviours might have evolved and how they can come into play when one is in a new

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animal behaviour as well as for development of his four questions. Detailed information on the award and the honourees can be found in Dewsbury (2003).

environment. Now that a brief overview of behavioural biology has been provided, we can proceed.

Natural Selection and Behaviour

In order to continue our discussion on human psychological factors in space, we need to continue with the discussion of natural selection and how instinctive (non-learned) behaviours became so widespread. In Chapter 4 of On the Origin of Species, Darwin (1860) laid out the basics of natural selection. Since there are always going to be more individuals produced than are able to survive, many individuals will not be able to survive. Darwin suggested that an individual's expressed difference in phenotypic variation could have an effect on the individual's reproductive success. Reproductive success would be measured by how many offspring and grandoffspring one would produce. Those with higher reproductive success will pass more of their expressed traits to the next generation. However, natural selection moves slowly and it could take many generations before a positive trait is prevalent in a population.

Behavioural traits are traits which also could be passed down until all members of a species have this trait. Tinbergen (1965) stated that the causes for behaviour could be divided into "ultimate" and "proximate" causes. The ultimate causes were those causes selected for via natural selection over time, while the proximate causes were those that were the immediate cause of the behaviour. For example, the ultimate cause of aggression in mice is due to past selective pressures on males to defend their territory from other males, while the proximate cause would be change in hormonal levels which caused the behaviour (Parmigiani, Francesco Ferrari et al. 1998).

The Environment of Evolutionary Adaptedness

Ultimate causes of a species' behaviour evolved in what Bowlby (1969; 1973) called the Environment of Evolutionary Adaptedness or EEA. The EEA provided the selection pressures during the period of evolution responsible for producing the trait. The period of evolution is the period during which the behaviour develops and can spread throughout the species until it is possessed by every member of the species (Tooby and Cosmides 1992). Due to the slow rate at which evolution takes place, this makes it likely that past traits are usually ill adapted to the present environment (Cosmides and Tooby 1987). If a trait has spread through a species and has been present for generations, the traits would likely be adapted to a past environment, which might be very different from the current environment. For example, one trait advantageous in the EEA but ill-adapted to the present environment are the cravings humans have for fat and sugar, which while beneficial to survival in an area where food is scarce, can lead to obesity problems when fat is plentiful and past selective pressures are still triggering us to crave, and eat, the now plentiful fat (Eaton, Konner et al. 1988).

For *Homo sapiens*, the EEA is considered to have occurred between 2.5 million years ago to 10,000 years ago in the plio-pleistocene era (Eaton, Konner et al. 1988; Cosmides and Tooby 2000). Over these 2 million years, our ancestors went through significant change, evolving from *Australopithecus* (4.2 million to 2 million years ago) to *Homo habilis* (2.5 to 2.0 million years ago) to *Homo erectus* (1.8 to 0.07 million years ago) to *Homo sapiens* (200,000 to present). As a result, our bodies and brains still reflect adaptations to this past environment and even though humans are constantly creating new environments, we are stuck with the "behavioural repertoire of our ancestors," though "our intelligence makes it possible for us to shape our behaviour to new circumstances" (Cronk 1992).

Life on the Savannah

The savannah is a large seasonably variable grassland with few trees, which is quite a different environment than the forests where primates originally evolved. By 2.5 million years ago, forests were starting to shrink as the environment became cooler and drier favouring the expansion of the savannah (Vrba 1988; Reed 1997) . While habitat reconstruction is open to interpretation, all evidence shows that this change in habitat happened gradually and likely influenced human evolution by encouraging the evolution of *Homo erectus* with its larger size and larger brain capacity than its ancestors (Bobe and Behrensmeyer 2004). By *Homo erectus*, the species was highly adapted to life on the savannah (Stanley 1992). Although *Homo erectus* spread throughout the world in the first out of Africa migration, some of the descendents of those who stayed behind on the savannah evolved into modern *Homo sapiens* (Cann 1988).

Group-Living

Since anthropologists are unable to time travel in order to observe the social behaviour of our human ancestors, they need to speculate using primate models and savannah-dwelling hunter-gather cultures such as the !Kung-San Bushmen.[3] While some anthropologists might disagree, primate models and studying hunter-gather cultures

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[3] Information on primate models is provided extensively in Kinzey (1987). Extensive use of hunter gather cultures as models of human behaviour are provided by Cronk (1992; 2000).

can give tremendous insight into the behaviours of the past. Primate models are the closest anthropologists can get to our more apelike ancestors such as Australopithecus.

For ancestors who were modern *Homo sapiens* or close enough to it and lived before the development of farming, hunter-gatherers are appropriate models as they have yet to have the problems that arose after the discovery of farming. After the development of farming, cities developed with long-term permanent social stratification as well as nutritional deficiencies due to reduced food diversity. This led to an overall increase in stress level as humans were forced into an unnatural arrangement so different from life on the savannah. One aspect of living on the savannah that most evidence, including archaeological excavations, primate models, and cultural evidence agrees upon is the issue of living in small groups.

The basic principles of animal group interactions take several forms. In every group, there is some form of hierarchy in which certain individuals are higher than other individuals. Even amongst the most egalitarian of groups, there are certain individuals who are given more prestige than others due to difference in skills, such as having better hunting ability. Higher ranked individuals generally have better access to food sources, more mating opportunities, and other things that generally reward. The structure of many groups is fairly fluid and individuals are able to slip up and down the hierarchy. Most of this fluidity is variable across species and can be dependent on age or other factors. One of these factors and one way for an individual to rise in status would be to display aggressive behaviour.

Aggression is defined as "a physical act or threat by one individual that reduces the freedom or genetic fitness of another" (Wilson 2000). Aggressive behaviour can quickly lead to domination of a group although it may or may not lead to becoming the most dominant animal over a long term. Not every animal may acquiesce to increased aggression, some other individuals may respond aggressively in turn preventing further dominance of the individual who first showed aggression. However, one other way for individuals to reduce the domination of the higher-ranking individual would be through cooperation and the forming of alliances. Alliances can allow several lower-ranked members to protect their resources from the higher ranking members. A real world example common in the business world could be the development and prevention of a hostile takeover. If investors realize what is occurring, they can individually or together become aggressive towards the "hostile" individual and stop the behaviour before more damage is done.

Our ancestors likely travelled in small groups long before they moved from the forests and onto the savannah. Since trees, and the relative safety they provide, are very sparse in the savannah, it was even more important for our ancestors to remain in small groups in order to reduce their chances of predator attack. Living in a group meant that more eyes were looking out for predators so each individual could spend more time foraging (Lima 1995; Roberts 1996; Barta, Liker et al. 2004). This provides a tremendous evolutionary advantage for those who were naturally social and preferred to work in small groups.

Living in groups also provided increased food foraging abilities (Ranta, Peuhkuri et al. 1998; di Bitetti and Janson 2001), which was particularly important to life on the dry savannah. The savannah does not provide as much food as the forest due to the differences in rainfall leading to more scattered food and water. A small group would do better than an individual in the search for food and water. Since the savannah is filled with predators and scavengers, it is likely that human ancestors were able to acquire meat first by scavenging and then by opportunistic hunting of small game, later made easier by collaborative hunting efforts (Bunn and Ezzo 1993; Milo 1998; Gaudzinski and Roebroeks 2000; Villa, Soto et al. 2005). Collaborative hunting allowed hunters to take on larger game than they would otherwise be able to take on alone. Hunting gradually became a bigger part of life and the increased amount of protein in the diet and the use of weapons are thought to have encouraged brain development (Calvin 1982; Broadhurst, Wang et al. 2002; Flinn, Geary et al. 2005).

Cooperation in Group living

Since there can be only one dominant individual, most individuals in the group need to rely on alliances based on favour exchange and reciprocal altruism. Reciprocal altruism is the idea that one will help another now in exchange for help in the future. This was first described by Robert Trivers (1971; 1974) and has been expanded by others over the past few decades (Axelrod 1984; Cosmides and Tooby 1992). Reciprocal altruism is vital in order to assure access to resources (Gompper, Gittleman et al. 1997; Silk, Alberts et al. 2004) or to make a bid for greater dominance (Altmann 1962; Hall and DeVore 1965; O'Brien 1993; Allman 1999). Since reciprocal altruism depends on favour exchange and the "I'll scratch your back now if you'll scratch mine later" mentality, there is often a delay from the time the favour is given to the time it is repaid. Since there is this delay, this gives cheating individuals the opportunity to take advantage of their more altruistic counterparts and never return the favour (Cosmides and Tooby

1992). This would benefit the "free-rider" because he or she would take all the advantages (including possible reproductive benefits), but would not share in the costs.

Individuals are, for the most part, aware of the possibility of free-riders. If there is little chance that the individuals would continue to interact in the future, cooperation is less likely. For individuals who would interact again in the future, it would behove them to work together to assure the best outcome for the both of them. This is further extensively detailed in studies of the Prisoner's dilemma game (Rapoport and Dale 1966; Moore and Mack 1972; McNeel 1973; Roth and Murnighan 1978; Benoit 1988; Boyd 1988; Raub 1988; Farrell and Ware 1989; Hirshlifer and Rassmusen 1989; Peyton Young and Foster 1991; Ockenfels 1993; Moller 2005; Hruschka and Henrich 2006; Noe 2006; Oliveira dos Santos Soares and Martinez 2006).

In order to not be taken advantage of by freeloaders, each individual has to be able to remember past interactions with other individuals in order to keep a mental tally of past favours that have been provided and have been received. For example, it would be better to provide help to those who have helped you in the past and is likely to offer help in the future than to offer help to someone who has never offered help in the past and probably will not offer help in the future. Those individuals who have a long history of working together are often said to form alliances. As the size of the group increases, the more alliances are usually necessary in order to benefit the individual (Dunbar 1984). Often these alliances are between same sex siblings or half-siblings who share the same mother (Wilson 2000) or between females who provided allomaternal care to each other's infants (O'Brien 1993). Since the brain can only remember so much information about social relationships, there comes a point where the group becomes unstable and the risk of free-riding may increase (Dunbar 1992). The maximum cognitive group size, or the maximum amount of individual relationships one can remember, has been linked to an increase in the neocortex size (Dunbar 1992; Dunbar 1995; Kudo and Dunbar 2001) with baboons maximum group size being around 100 individuals (Cohen 1969), while a human social group can go up to about 150 individuals (Dunbar 1998).

There are times when only one person benefits and the other person continues to provide things without expecting an equal favour in return. Nearly all of this non-reciprocal altruism involves individuals providing benefits to their kin such as a parent providing to their child. This is also called kin directed altruism. Although this appears to be altruism, the parent invests energy into assuring the children's survival in order to assure their genes are passed down in the future. While it can seem at first as if it is selfless behaviour, it is selfish behaviour at the level of the gene. If an individual helps assure a relative's survival, more of the altruist's genes are passed down indirectly. Those individuals who are more genetically related are more likely to be helped by relatives than those who are less related (Hamilton 1964). This is more beneficial from an evolutionary standpoint then helping non-kin.

Aggression

Aggression, defined earlier as "a physical act or threat by one individual that reduces the freedom or genetic fitness of another," was extensively reviewed in Wilson (2000) and continues to be a primary reason behind conflict. Wilson identified eight types of aggression: sexual, parental disciplinary, weaning, moralistic, predatory, anti-predatory, territorial, and dominance. Sexual aggression occurs when males threaten or attack females in order to mate with them. Parental disciplinary aggression occurs when the parent directs aggression towards the offspring. Weaning aggression occurs when the parents and the infants have a conflict of interest over continual weaning, this conflict of interest is called the parent-offspring conflict. Moralistic aggression occurs in order to keep the parties involved in reciprocal altruism honest. Predatory aggression occurs when one animal is hunting another. Anti-predatory aggression is a move by prey in order to attack the predator and defend itself. Territorial aggression occurs when an individual is trying to repel intruders from their territory. Dominance aggression is similar to territorial aggression, but it refers to a dominant individual preventing subordinates from accessing resources.

Causes of Aggression

There are several possible reasons for aggression to have become an important behavioural adaptation. However, at a certain point, aggression is constrained due to the increased chance of hurting relatives (decreasing the individual's fitness) and spending so much time in aggression that one is not reproducing (lowering an individual's direct fitness). At that point, being overly aggressive would become a liability. The following causes of aggression were reviewed by Wilson (2000) and Buss & Shackelford (1997) and are vital for understanding the conflicts that aggression can cause.

Strangers. Sensing an unfamiliar individual in one's territory causes the strongest aggressive response due to the possible threat that the stranger may pose. Intragroup aggression may even be put on hiatus in order to defend the group territory from strangers. . Reaction to strange individuals has been studied in lizards (Husak and Fox 2003), pupfish (Leiser 2003), dogs (Podberscek and Serpell 1996; Vas, Topal et al. 2005), cows (Boe and Faerevik 2003), hens (Maier 1964; Guhl 1968; Cloutier and

Newberry 2002), frogs (Bee and Gerhardt 2001b; Bee and Gerhardt 2001a), mice (O'Donnell, Blanchard et al. 1981), insects (Scott 2006), marmosets (Schaffner and French 1997), vervet monkeys (Fairbanks, Newman et al. 2004), and tamarins (Epple 1981). This type of aggression has also been seen in space crews when they are exposed to previously unknown members of the ground crew (Scott 2006).

Food Resources. Aggression can also increase when food is clumped into a few areas rather than being spread out over a large space leading to increased territorial aggression (McGlone 1986; Robb and Grant 1998; Andersen, Andenaes et al. 2000; Gray, Jensen et al. 2002; Kim, Brown et al. 2004; Jensen, Gray et al. 2005). These smaller territories are easy for individuals or small groups of allied individuals to defend from intruders (Hixon 1980; Grant 1993; Noel, Grant et al. 2005). Aggression related to food resources starts to decline as interaction between the animals spread out. Males are particularly more likely to act aggressively towards clumps of food resources (Grenier, Barrette et al. 1999). Recent sociobiologists have expanded this aggressive behaviour to include co-opting any resource of value, such as jewellery, money, etc by criminals and bullies (Buss and Shackelford 1997; Cherek, Moeller et al. 1997a; Cherek, Moeller et al. 1997b).

Density gradients, effects, and dependencies. Aggressive behaviour can also be density dependent, although results for non-human primates show tremendous variation on whether the aggression and stress increased or decreased as a result of density (de Waal, Aureli et al. 2000). In one study, macaques showed a decrease in male/male and male/female aggression as a result of increased density, though an increase in female/female aggression was noticed (Judge and de Waal 1997; de Waal, Aureli et al.

2000) and in another only slightly increased aggression was observed (Judge and de Waal 1993). Another study using Japanese macaques showed a large increase in male aggression (Alexander and Roth 1971). Leaving primates alone for a second, overcrowding has also been linked to aggression in gerbils (Hull, Chapin et al. 1974), birds (Nephew and Romero 2003), rats (Brown and Grunberg 1995), and mice (Van Loo, Mol et al. 2001). Interestingly, pregnant mice who are stressed by overcrowding in the third trimester causes any resulting male offspring to be less confrontational and less aggressive in similar situations (Harvey and Chevins 1985). In studies with rats, it was found that it is the amount of overall space that stresses males making them fight for territory, while females are more concerned with the amount of individuals in an area and less the overall space (Brown and Grunberg 1995).

While the majority of studies have focused on crowding, there have also been experiments in isolation, which can also lead to excessive aggression. This isolation caused aggression has been studied in macaques (Honess and Marin 2006), mice (O'Donnell, Blanchard et al. 1981; Swanson and Schuster 1987; Schneider, Hoffmann et al. 1992; Rodgers and Cole 1993; Sanchez and Hyttel 1994; Sandnabba 1995; Van Loo, Kruitwagen et al. 2002), fish (Hannes and Franck 1983; Franck, Hannes et al. 1985; Halperin and Dunham 1993), pigs (Moore, Gonyou et al. 1993), and humans (Rubin and Mills 1988).

The excessive crowding creates aggression because it interferes with the individual's "social distance", the minimum space that an animal usually keeps between himself and another member of the same species. Not only is this dependent on the individual's species, but in humans it can also be based on one's culture. This study of the variation in culture's social distance is called "proxemics" and was extensively discussed in Hall (1966) and reviewed by Wilson (2000). While Wilson (2000) discussed how this was common among many animals species and not just humans, Hall (1966) discussed some of the differences in how cultures view personal space. For example, the French and the Italians are able to tolerate much more cramped conditions than the Germans or the English. Further, Eastern cultures need less personal space than the Western cultures (Pope 2000).

Breeding Purposes. Both intersexual and intrasexual aggression increases when females are in estrus. Intrasexual aggression occurs between members of the same sex in order to access a higher amount of mates such as male/male, a better quality of mate as in female/female aggression, or access to more resources. When a male does not have access to willing females, such as due to lack of resources, "the mate deprivation hypothesis" states there should be an increase in aggression and sexual coercion towards females (Lalumiere, Chalmers et al. 1996; Thornhill and Palmer 2000). Varies forms of breeding season related aggression has been studied in baboons (Plowman, Jordan et al. 2005), rats (Melchior, Ho et al. 2004), lemurs (Cavigelli and Pereira 2000), birds (McKeegan and Deeming 1997; Moore, Wada et al. 2004; Schwabl, Flinks et al. 2005; Sperry, Moore et al. 2005; Jawor, Young et al.), iguanas (Rubenstein and Wikelski 2005), dogs (Pal, Ghosh et al. 1998), mice (Hyde and Sawyer 1977), and hamsters (Wise 1974).

Deterrent. Aggression could also deter rivals from future aggression (Aureli, Cozzolino et al. 1992; Buss and Shackelford 1997), theft of resources (Adams and Johnson 1995), or to give an advantage in bargaining (Hornstein 1965). Male aggression and violence could also be used scare females in order to prevent them from joining with a new partner (Buss and Shackelford 1997). This sexual aggression has been studied in salamanders (Jaeger, Gillette et al. 2002), macaques (Rilling, Winslow et al. 2004), and humans (Daly, Wilson et al. 1982; Serran and Firestone 2004; Gage 2005; Wilkinson and Hamerschlag 2005). In addition and related to the use of aggression as a deterrent, aggression can further be increased by pain (Fortuna and Gandelman 1972; Schilder and van der Borg 2004), sleep deprivation (Peder, Elomaa et al. 1986), artificially forced groupings regardless of density (Wilson 2000), and chemical dependency (Avis and Peeke 1979).

Jealousy. A common emotion that results in aggression is jealousy. What is jealousy? Jealousy is a "perceived threat to a valued relationship or to its quality" (Malakh-Pines 1998) and can felt towards an object, a person, or even something imaginary (Mathes 1992) and can be even considered a form of paranoia (Breitenberg 1993). While this is often confused for envy, they are different emotions. Envy is when one wants something that belongs to another, while jealousy is just the worry of the potential loss of the object (Mathes 1992; Malakh-Pines 1998). There are two types of jealousy, sexual and romantic jealousy. The sexual jealousy, caused by the fear of sexual infidelity, is likely the result of selective pressures to prevent against investing in unrelated children (Buss, Larsen et al. 1992), it should come as little surprise that this is the form of jealousy most males experience with the most intensity (Buss, Larsen et al. 1992; Afifi and Reichert 1996). Romantic jealousy is likely due to the fear of potential loss of investment in future or current offspring (Buss, Larsen et al. 1992), women tend to find this form the most distressing (Buss 2000).

Jealousy is a very dangerous emotion and the stigma of jealousy could lead it being underreported by Westerners (Buunk, Angleitner et al. 1996). However, the reactions and dangerous situations caused by jealousy is very prominent even if it is underreported. Jealousy is a leading cause of spousal murder in the United States and, among some cultures, it is the leading cause of spousal homicide (Buss 1994). Even for those couples who have not reached the level of murder, married or dating couples in which there is domestic violence, jealousy was found to be the main cause (Buss 1994; Gard 1999; Schumacher, Feldbau-Kohn et al. 2001). Individuals who experience a high amount of jealousy tend to have higher levels of vengeance (Sommers and Vodanovich 2000).

Continuous Aggression Accumulation and Coping Strategies

Individual reactions to stress vary, often due to the status of the animal (Bartolomucci, Pederzani et al. 2004; Clement, Parikh et al. 2005). Although short-term stress serves to increase aggression (Tsuda, Tanaka et al. 1988; Bartolomucci, Pederzani et al. 2004), long-term stress can reduce general aggression although other forms of aggression may continue (Albonetti and Farabollini 1994). In many species, subordinate animals are under chronic long-term stress and will tend to show more stress when dominant animals show more aggression (Bjorkqvist 2001). This stress continues to accumulate over time and remains high unless social stressors can be reduced (Abbott, Keverne et al. 2003) or by use of coping strategies. Some of these coping strategies include handling (Waiblinger, Menke et al. 2004), grooming (Call, Aureli et al. 2002), calling (Cross and Rogers 2006), exercise (Albonetti and Farabollini 1994), or redirection of stress-induced aggression such as to the opponent's less aggressive kin (Aureli, Cozzolino et al. 1992) or redirection towards a lower ranking individual in the group (Greenberg 1946; Wilson 2000). The lowest ranking individuals have no further place to displace their aggression and can suffer from any number of problems. Symptoms of excessive stress can include depression (Bjorkqvist 2001; van Praag 2004), weight loss (Michel, Duclos et al. 2005), lack of motivation (Rygula, Abumaria et al. 2005), altered risk of cardiovascular disease (Farah, Joaquim et al. 2004), and impaired learning (Touyarot, Venero et al. 2004). In extreme cases where the individual can not escape, the body may shut itself down in a suicidal gesture in order to escape the stress (Liu, Tein et al. 2005).

Ritualized and Escalated Fighting

Many of these displays of aggressiveness do not have to be physical, they can also be psychological in origin. Humans, in particular, have mastered the art of psychological warfare such as through mimicry and pretending to take on the characteristics of an animal (Roze 1985), temporary and permanent body modification (Macdonald 1890; Sinclair 1909; Witton 1941), body movement and changes in posture (Barrett, Todd et al. 2005), and alterations in speech (Slaby and Crowley 1977). These types of psychological fighting, which the humans use are learned and not genetic in origin. Some other species have a more genetic basis for some of these psychological warfare items. Psychological warfare is one part of ritualized fighting.

The goal for this psychological or ritualized fight is to make the individual's opponent accept a lower rank without expending excessive energy or putting either's lives in danger. In the event that an opponent does not accept the lower rank and attempts to fight back, then the fight becomes escalated. During a ritualized fight, the combatants may only attack areas that are heavily defended such as in mantis shrimp which use their maxillipeds to hit the heavily armored tail of their opponent (Wilson 2000) or in venomous spiders who will avoid biting (deCarvalho, Watson et al. 2004). The fighting is over when one of the combatants signals that he or she is ready to leave. In an escalated fight, which carries the risk of higher energetic costs (deCarvalho, Watson et al. 2004) and increased predation risk (Jakobsson, Brick et al. 1995), it can be a fight to the death if neither animal flees.

Many animals, particularly those that are highly dangerous such as those with very powerful natural weapons like venomous snakes, rarely escalate their fighting to this level (Maynard Smith and Price 1973). Allowing an opponent to retreat and live to fight another day is a common tactic. This is beneficial to the loser, since it is likely that they have a second chance and it would not benefit the winner to waste energy going after the loser who could be related even slightly (Wilson 2000). Maynard Smith & Price (1973) suggested that animals who are too quick to move to escalated fighting using their natural weaponry would be selected against in evolution. Animals who do not have a strong natural weapon (such as venom or poison) are more likely to attempt to kill their enemies. Only ants, humans, and chimpanzees regularly kill adult members of their own species in escalated fighting (Wilson 2000).

Intra and Intergroup Aggression

Dominance hierarchies not only have intragroup aggression, but also intergroup aggression and xenophobia, fear of strangers. This fear of strangers and newcomers is possibly due to fear of loss of resources, such as in areas where food is scarce. Individuals in stable groups tend to not like newcomers and, as previously stated, will unite under outside threat or show increased aggression when the current hierarchy is forcibly disrupted or threatened (Wilson 2000). Many newcomers to a group's territory can be met with resistance and aggression. This aggression offers the new animal a few choices: 1) it can stay as part of the group as the omega animal and be used as an "aggression sink" (Greenberg 1946) until a new omega comes along as in sunfish, 2) leave the group and migrate elsewhere, 3) die from excessive stress accumulation, or 4) leave the old group and start a new group with itself as the new alpha, a common tactic in canine species (Wilson 2000).

As previously stated, hostility and aggression is further dependent on available resources. When resources are plentiful, there is less hostility between the groups. When resources are scarce, there is more of a reason to be hostile towards other groups, particularly large groups, in order to assure survival of intragroup members (Barrett, Dunbar et al. 2002). There have been many documented cases of group size dependent hostility, such as lessened hostility when two medium sized groups met at a food site versus when two large groups met at the same sized food site (Wilson 2000). In the event that one is in an area where there are even fewer resources, such as in an extreme environment, there could be increased aggression and hostility, particularly if there is difficulty in sustaining enough food production.

"Political xenophobia," fear of others whose politics or culture is different from yours, can easily be seen in the Middle East where there has been a lot of fighting over land and resources (Barrett, Dunbar et al. 2002; Canetti-Nisim and Pedahzur 2003). Most of the resources that are vital to survival (food, water, etc) are not easily found in that part of the world. In addition, the Western countries' need for oil, a resource commonly found in areas of the Middle East, as well as the cultural differences present also further differentiates between "us" and "them." Although we are aware of the reasons for the fighting and have tried to use our mind to overpower the natural tendency to separate ourselves, it is a battle that will likely continue to be fought until everybody has the resources they need.

Hierarchies and Subordinations

Since much of aggression is based on resources and hierarchy, it might be best to further discuss hierarchy. As population density increases and resources become scarcer, populations make the transition from individual territoriality (one individual competing with all other conspecifics) to dominance hierarchies (Altmann and Altmann 1979). It only takes two to make a simple hierarchy (Wilson 2000), though there are usually many more individuals. The most dominant member likely fought or otherwise dominated the other members in order to be at the top of the hierarchical structure. A dominant member should be assertive or aggressive enough to have the respect or fear of the group, should be resistant to the stress of leadership without the stress taking its toll, and have fast recovery from conflicts. These factors are partially determined by genetics and would indicate good genetic potential.

Although in some species hierarchies are stable and rigid, in other species it might be fluid or might depend on the individual group. For example, different human cultures have different hierarchical structures and some cultures allow an easier rise in status.. The !Kung-San Bushmen of the Kalahari Desert have no permanent leader and, like other hunter-gather groups, the individuals who make up the group tends to change seasonally (Pope 2000). In this and other egalitarian groups, individuals are recognized as leaders in their individual area of interest such as war, peace, hunting, medicine, etc. Their status in the group and the respect given to them would increase once they proved competences (Pope 2000). For those individuals not considered to be competent or successful in an area, it was much more difficult for them to acquire resources and likely had to resort to additional more aggressive ways to get what they need such as rape or theft.. Society provides ways to remove these overly aggressive people from the hierarchy such as through banishment or murder in small-scale societies (Barrett, Dunbar et al. 2002) or jail in large scale societies.

How Life Has Changed Since the Savannah

Modern Society's Life Characteristics

Modern western society's life characteristics and the impact these changes have had on our physical and psychological health was reviewed extensively in Smith (2002). The advent of agriculture and domestication of animals approximately 10,000 years ago led to alterations in culture. For the first time, individuals had a regular supply of food and did not have to migrate from place to place over the year. However, because one could only tend to so many different food types, food cultivation led to a decrease in dietary diversity. Instead of being able to hunt and gather the naturally diverse food that the area provides, one had to rely on the harvest be it good or bad. This led to a decrease in overall health quality due to poor nutrition.[4] The health would continue to be compromised due to working close with domestic animals.

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[4] (For more information on this please see: Newman 1962; Stini 1971; Ulijaszek 1991; Larsen 1995)

In addition, the rise of agriculture allowed culture to become stratified allowing a few individuals to provide for the whole group. The non-farmers were able to increase their population density by moving into higher density towns and small cities. These individuals, free from being responsible to search for their own food, were able to specialize and hierarchy became more permanent. The increased population density decreased personal space, increased stress and, when combined with being in close contact with other humans and their waste products, further reduced health (Swedlund and Armelagos 1990).

Eventually, the increased technology that was developed started to further increase stress. Certain aspects of technology, such as the overdependence on cars or horses, allowed decreased physical exertion leading to a decrease in physical and psychological health. Technology has allowed for a tremendous increase in mobility, which has allowed a wider dispersal of individuals and increased "neolocal" accommodations. Neolocal families are far from extended family. This leads to a decrease in the familial support system that was present for most of our heritage. Increased workload, increased demands on time, and decreased social support further lead to increased chronic stress and increased aggressiveness.

Life Characteristics in Closed Environments

As a closed system is dependent only on itself for survival, the crewmembers have a more unique and more stressful life than a more traditional open system. While a decrease in dietary diversity has lead to decreased overall health in the past, only a small portion of our modern diet is being researched for use in the space program (Ailing, Nelson et al. 2002) likely leading to further deterioration of health. Being in an enclosed environment has also led to psychological instability and acute mental stress, as several experiments in polar psychology have shown (Connors, Harrison et al. 1985; Pesavento 2000). Stress and its effect on health are also increased due to increased isolation (Taylor 1991; Pesavento 2000), decreased ability to escape (Connors, Harrison et al. 1985), increased responsibility for the CES, and decreased privacy and personal space (Klitzman and Stellman 1989; Pesavento 2000). Increased stress has led to psychological incidents including increased aggression, disturbing fantasies, anxiety, depression, hallucinations, near loss of a crewmember, and withdrawing from the group (Connors, Harrison et al. 1985; Pesavento 2000). These psychological incidences if severe enough could result in loss of the craft or crew.

Stressors: What Are They and Why Do They Affect Us?

Stress

Ever since man started to move out of familiar territory and started to delve into new frontiers, stressors, both new and old, have plagued him. These stressors affect the physiological and psychological state of the individual possibly leading to further complications if he is in a group situation. While groups can handle the disturbances caused by minor stressors, as those stressors increase in duration and intensity, their effects on the group also increase. In a worst-case scenario, increased stressors can run the risk of leading to death of one or more individuals. In the event this situation occurs during space travel, total mission failure can result. As this is a worst-case scenario caused by the accumulation of small stressors, it is imperative to understand why these stressors occur and how to prevent them from becoming risks to mission stability.

Before we delve into the different stressors and their risks to long duration spaceflight missions, it would be important to define stress and stressor. What is stress? Dougall and Baum (2003) provide several definitions of stress including a "non-specific series of biological and psychological changes that support coping and adaptation to threat, harm, danger, or demand posed by the environment" as well as "a general state of arousal that prompts and supports action directed toward dealing with the stimulus." Stressors are defined as the stimuli which the body or mind is reacting to.

Stress is broken down into several categories including human body stress, cell stress, psychological stress, physiological stress, eustress, and distress (Yamaguchi, Kanemori et al. 2004). Eustress is caused by positive stressors such as laughter (Atsumi, Fujisawa et al. 2004), exercise (Kingston and Hoffman-Goetz 1996; Beedie and Hudson 2003), and challenge-related stress (Blonna 2000; Beedie and Hudson 2003; Boswell, Olson-Buchanan et al. 2004). This is the form of stress which encourages immune system response (Kingston and Hoffman-Goetz 1996) and esteem (Edwards and Cooper 1988) as well as increase motivation (Jensen and Toates 1997; Boswell, Olson-Buchanan et al. 2004), job satisfaction (Boswell, Olson-Buchanan et al. 2004), loyalty (Boswell, Olson-Buchanan et al. 2004), and coping responses (Edwards and Cooper 1988).

Distress is caused by negative stressors such as performance anxiety (Fehm and Schmidt 2006), injuries (Victorson, Farmer et al. 2005), and traumatic events (Bonne, Grillon et al. 2004). This type of stress causes activation of the sympathetic nervous system (Dougall and Baum 2003), release of hormones such as epinephrine and norepinephrine in preparation for "fight or flight" (Dougall and Baum 2003), increase in stress hormones (Vedhara, Miles et al. 2003; Zimmermann and Stansbury 2004), reduced wound healing (Vedhara, Tallon et al. 2004), and disease-specific mortality (Rasul, Stansfeld et al. 2004). This is often called negative stress, while eustress is often called positive stress.

There are also different levels of stress called "acute stress" and "chronic stress" (Olff 1999). Acute stress is a high-level, short-term stressor such as anticipation or examination stress. Although this is the most intense form of stress, it is also the form of stress which can have the best effect on the body when the stressor is present. The stressor encourages the body to produce a large amount of short term energy as it prepares for the fight or flight response. When the stressor is removed, the body is fatigued from being in a state of high-stress for so long (Blonna 2000). Chronic stress occurs over a long term and can include marital stress (Olff 1999), being in a high risk or dangerous environments (Connors, Harrison et al. 1985), being social disadvantaged (Goodman, McEwen et al. 2005), and burnout (Sandstrom, Rhodin et al. 2005). Stressors can build up and cause psychological reactions by means of cortisol.

Physiological and psychological stress leads to the production of hormones such as cortisol. The presence of cortisol in the bloodstream leads to the breakdown of muscle protein in order to release the amino acids. The liver then synthesizes glucose via gluconeogenesis from the released amino acids and the blood sugar level is raised (Munck and Koritz 1962; Henning, Huth et al. 1964; Seubert, Henning et al. 1968). Over an extended period of time, elevated cortisol levels can produce Cushing's disease causing muscle atrophy and excessive weight gain (Crowley 1992; Blakemore and Jennett 2001). Increased cortisol has also been shown to have an adverse effect on delayed memory recall of emotionally charged word from a word list (Kuhlmann, Kirschbaum et al. 2005), impaired verbal memory (Domes, Rothfischer et al. 2005), depression (van Praag 2004), and a decrease in the ability to control behaviour (Lyons, Lopez et al. 2000). This can lead to inefficiency in work performance and disruptions during group interactions.

Development of Psychological Disorders

Unfortunately, since there has been a lack of research into psychological distress due to a variety of reasons, there hasn't been extensive work on the effects of physiological changes on the development of psychological disorders. A few incidences have been reported from astronauts writing about their experiences. These reports seem to focus on the physiological adaptation to microgravity in the first few days of spaceflight as an additional psychological stressor possibly due to the changes in the neurovestibular system (Lichtenberg 1997; Santy 1997; National Research Council 1998).

The issues of space motion sickness and difficulties with sleeping have been the primary causes of psychological difficulties in the early part of the mission. Although space motion sickness affects around 70% of first-time astronauts, some astronauts were convinced that they would not get nausea. When space motion sickness reared its ugly head, this provided an additional stressor which they were not prepared to deal with (Lichtenberg 1997). Even among those who were more prepared mentally for the possibility of space motion sickness, the fact that their bodies were adapting did provide some minor psychological disturbances (National Research Council 1998).

Sleep disturbances due to microgravity physiologic changes can be due to space motion sickness, perception difficulties, or redistribution of bodily fluids causing various forms of pain (Santy 1997). These factors can make it difficult to sleep properly, leading to additional physiological or psychological difficulties with stress. This area will be covered more in depth later. During the later part of the mission, there could be stresses about what is going to happen on reentry such as Orthostatic intolerance or other problems.

Effect of Psychological Stressors on Mission Failure

Although humanity has not attempted a truly long duration (1+ year) spaceflight mission, it is possible to use the polar analogue studies, the biosphere 2 experiments, the Russian Closed Ecological System (CES) BIOS experiments, and short to medium duration spaceflights in order to get an idea of potential space stressors.[5] Extensive research by Geuna et al (1995) listed these potential stressors as career motivation, confinement, isolation, separation from friends and family, separation from Earth, transcendental experiences, fear of danger, inability to escape, exaggerated workload, alternation between high activity and monotony, boredom, sleep disturbances, time sense disturbances, interpersonal conflicts, and psychiatric diseases. Although Geuna et al (1995) listed these stressors, they did not go into detail about these stressors and how they could affect mission success.

Motivation

Although Geuna et al (1995) specifically mentions career motivation as a stressor, decreases in all types of motivation can equally be a stressor (Connors, Harrison et al.

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[5] At the time of this writing, the European Space Agency has just announced a call for volunteers in order to do several medium to long duration space analogue missions in order to primarily study psychological issues.

1985; Brunelli 1997; Churchill 1999). Although highly motivated crewmembers are often selected for high risk missions, this could influence them to set "unrealistically high performance standards" for themselves (Connors, Harrison et al. 1985). Often individuals plan to use their time productively, but shortly after beginning their mission they start deviating from their plans. This can lead to loss of self-esteem and morale if they are unable to keep up with their impossibly high standards.

Difficulties with loss of motivation has occurred in polar explorers (Stuster 1996), submarines (Earls 1969), fallout shelter confinees (Cleveland, Boyd et al. 1963), and space crew (Connors, Harrison et al. 1985; Stuster 1996; Santy 1997; Pesavento 2000) although different professions, such as scientists versus non scientists, are often affected differently (Kanas 1998). Scientists tended to fare better than non-scientists in the Antarctic because of their different job priorities. They spent much of their off-duty time continuing to work on their experiments and write up their data. They kept busy and maximized their productive time which kept them motivated (Kanas 1998).

As the mission approaches its end, there is a tendency to want to work less and less. Since astronauts reported on the need for meaningful work in order to prevent boredom (Kanas 1998), if this is provided, individuals should remain motivated to do their job of preparing for their journey home. Since individuals will continue their work, the mission should continue to go on as planned and the risk of mission failure is low. However, the lack of personal motivation can remain a problem and can affect morale and relations with other crewmembers although whether the lack of personal motivation will or will not cause mission failure is dependent on the individual and if this extends to continuing to help run the life support system..

Confinement and Inability to Escape

In order to prevent instability and restlessness, it is important to provide enough distractions that the crew forgets they are in a confined space. Some distractions can be making primitive calendars (Taylor 1991), taking up hobbies (Ailing, Nelson et al. 2002), or even dealing with emergency situations. Skylab 3 had so many repairs to make early in their mission that not only did they not notice the confinement, but they also did not get motion sickness (Freeman 2000). Even when the crew can leave the confines of camp or wherever they were confined, there is still the risk of anxiety attacks or reduced immunological functioning (Taylor 1991; Schmitt, Peres et al. 1995; Lugg and Shepanek 1999).

For those who are unable to leave their habitat, it would be for the best if architectural elements to alleviate feelings of confinement were considered. Some considerations of space habitat design included using a variety of colours, shapes, and textures such as on Mir, paying close attention to volume proportions, and maximizing storage (Bedini and Perino 1999). Studies show that larger windows in relation to room size can help reduce the feelings of confinement and the psychological problems that go with them (Butler and Steuerwald 1991). Even in Biosphere 2, a very large closed ecological system, there were occasionally bouts of "cabin fever" causing tension among the crew (Ailing, Nelson et al. 2002).

The stressor of confinement is not just due to the enclosed space, though that can certainly play a role in the stress. Confinement can also mean a lack of privacy and having no real way to escape a stressful situation when it develops or to avoid someone that is not liked (Klitzman and Stellman 1989; Johnson and Suedfeld 1996). Putting individuals in an enclosed space encourages fighting over resources and increased aggression due to lack of maintenance over the proper social distance (Wilson 2000). This stressor has primarily been studied in Antarctic crews (Biersner and Hogan 1984; Connors, Harrison et al. 1985; Palinkas 1992; Stuster 1996) and can lead to increased boredom, depression, negative feelings, and reduced social relationships (Biersner and Hogan 1984; Palinkas 1992; Pesavento 2000) due to an increased need for more personal space (Palinkas 1992; Tafforin 2004). While minor incidences may not pose a risk to mission success, a major incident such as a crewmember putting his life in danger can increase chances of mission failure (Connors, Harrison et al. 1985). Out in space, for example, cosmonauts have even wished to leave the space capsule and doing that would have meant certain death if one was not wearing an appropriate spacesuit (Kass, Kass et al. 1995).

Isolation and Separation from Friends and Family

While Geuna et al (1995) listed isolation and separation from friends and family as separate stressors, they are related and so can be considered one stressor. All short term space analogue missions involving close confinement and isolation showed an increase in psychological disturbances (Pesavento 2000). In order to understand why these are stressors, it is important to understand where the need for friends and family came from. As was previously mentioned, humans evolved as a social species on the savannah of Africa. Being in isolation for an extended period of time in this environment meant possible death by predation, a reduced chance of finding food and water, increased attacks by other groups, as well as an increased chance of illness from external parasites.[6]

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[6] Please see "Group Living" for more details.

Being part of a social structure, including friends and family, reduces stress and can boost the immune system.

In many studies, isolation itself was not the stressor; absence from loved ones was (Taylor 1991; Kass, Kass et al. 1995; Johnson and Suedfeld 1996; Rosnet, Cazes et al. 1998). When an individual is taken from away from their family, often they worry about their absent members (Johnson and Suedfeld 1996). This worry can be reduced by communication between the individual and his or her family. Unfortunately for individuals in isolated environments, communication often goes through a third party in order to filter out bad news. This occurred during a Soviet spaceflight when a cosmonaut lost his father (Santy 1997) as well as during missions on Earth such as trips to Antarctica and on submarine missions (Stuster 1996). Knowing that there could be negative news, which they are not being told about, could provide additional stress on crewmembers. The risk to mission failure could vary depending on the individual and the severity of the isolation (Pesavento 2000).

Separation from Earth and Transcendental Experiences

These are two stressors which can easily be discussed in one subsection since they are often closely related. Transcendental experiences, or alterations in the state of consciousness, was reviewed in Connors et al (1985). These experiences have been known for decades and have been experienced in pilots as "breakoff" phenomena, sailors as answering the "call of the sea," scuba divers as "nitrogen narcosis," and may have been experienced on Soyuz 26 when a cosmonaut made an unauthorized spacewalk and nearly floated off into space. These situations can prove a general feeling either of euphoria or of uneasiness and always provides a different sense of reality. The reasons behind these phenomena are not well understood although it does not appear to occur on land at either sea level or at altitude.

The big problem with this stressor is due to the problems that could happen when one is experiencing these states. In some respects, the experiences are very similar to hallucinations in regards to the non-participant. However, to the participant or participants involved, the hallucination could take the form of feelings of enlightenment. While an experience that only lasts a few seconds might be harmless, it is also possible that it could destroy the entire mission depending on what an individual is doing when the feeling strikes. Since the experiences are unpredictable in their severity, as well as whether or not an individual is going to drag the other crewmembers into his or her fantasies, these experiences are experiences to avoid if at all possible. A few wrong moves and the crewmember could jeopardize his or her life as well as the rest of the crew. Previous experiences suggest that this is a high-risk stressor.

Fear of danger

During every high-risk mission, it can safely be assumed that the possibility of danger would be a stressor (Pesavento 2000). This natural response is more likely to assure that all systems are functional rather than being designed to cause problems. Those with an excessive fear of danger would most likely not be volunteering for the mission in the first place nor would they likely pass the psychological testing. Fear would likely be experienced by most people at one point or another and should serve to notify the individual of potential problems so the crew can put effort into minimizing the danger.

Work: Overloading, Underloading, and Changes in loading.

Due to the high cost of space missions and the relatively short amount of time crews are able to remain in space, often times excessive work, or overloading, occurs. Connors et al (1985) defines overloading as the "increase in the task demand beyond the individual's optimum level." The opposite effect is underloading and it too can occur on a mission and can deteriorate performance. Both of these loadings, as well as sudden changes in activity levels, were reviewed in Connors et al (1985) and Stuster (1996).

Problems of maintaining either excessively high or low amounts of workload can be detrimental to mission success. Overloading cannot be sustained for a long period of time without rest breaks or else fatigue begins to occur. The constant stress can lead to mistakes (Connors, Harrison et al. 1985). This was seen in the Skylab 4 mission of 1973 to 1974.

Skylab 4's three-person crew had an extensive schedule with a high workload. Since their schedule was so strict, they were constantly making mistakes and having to work through their rest days in order to catch up. Since they were unable to get rest, they remained very tired and more problems occurred putting them further behind schedule. At one point, the astronauts mutinied and protested the high workload and demanded the schedule become less strict. Finally, Mission Control agreed. When the astronauts' schedule was less strict and they could do many of the experiments at their leisure, they not only finished all of their scheduled tasks, but also did a few additional experiments (Belew and George C. Marshall Space Flight Center 1977; Stuster 1996). If astronauts are constantly overworked, then loss of morale and loss of ability to respond effectively to mission duties could occur. Fatigue, due to overloading, commonly occurs in the Russian Space program (Sauer, Wastell et al. 1996).

On the other hand, there is underloading. When one is underloaded, the crewmember may get so bored that signals are missed and performance declines leading to the mission being compromised (Kishida 1973; Connors, Harrison et al. 1985; Brunelli 1997). Underloading is well documented in polar expeditions and in submersibles where crewmembers have been known to fall asleep on the job during periods of low activity (Stuster 1996). Closer to home, it has also been noticed in train engineers (Buck and Lamonde 1993; McLeod, Walker et al. 2005) and is related to the accident-causing "highway hypnosis" of automobile drivers (Sagberg 1999; Thiffault and Bergeron 2003). Since this also reduces work performance, there are many ways to reduce these problems such as rotating activities among the crew, not overtraining on non-critical functions, providing busy work, and letting astronauts develop their own schedule (Connors, Harrison et al. 1985; Stuster 1996).

There are also some worries about the sudden changes from underloading to overloading, particularly since these tend to occur in emergency situations. This can cause over focussing of attention on just one problem, degradation of memory, problems with communication and decision making (Stuster 1996). Any of these problems could cause a large risk to the success of the mission.

Sleep disturbances /Time sense disturbances

Disturbances in sleep and altered circadian rhythms can be a major problem during space missions (National Academy of Sciences 1972; Santy 1997; Pesavento 2000) and are the primary complaint during analogue studies (National Academy of

Sciences 1972; Connors, Harrison et al. 1985; Stuster 1996). In space, however, the problems regarding sleep are often dependent upon the individual and the mission itself. While some astronauts have reported being able to fall asleep easily, others, such as the Apollo crews, had tremendous difficulty due to cramped spaces, cold space suits, strange noises, pain, difficulties with time, and concern about mission requirements (Santy 1997; Stampi 1997; Pesavento 2000). Often times, only a very light sleep is reached and the body is not able to recover from the stress of the day leading to fatigue and performance decline (Connors, Harrison et al. 1985).[7]

Difficulties with time disturbances often come about when one is on a different light/dark schedule than the standard 24-hour cycle as review by Stampi (1997). This is called "external desynchronization." Removed from external signals, the body may drift further and further on its sleep/wake cycle to the point where a day or more may be lost. Alternatively, increasing the rate of dark/light cycle or artificially extending the light/dark cycle can also cause days to become extended and leads to time and sleep disturbances. Since sleep disturbances can affect performance tremendously, it is important to reduce disturbances and improve the quality of sleep in order to assure good performance on vital tasks.

Inter-personal Conflicts

There are two main types of conflict during a mission, that of conflict between members of the space crew and that of conflict between members of the space crew and the ground crew. While conflict is likely to be the biggest source of stress on the mission, it is also the one that is most easily researched as evidenced by the large amount

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[7] See the previous section for more information on fatigue.

of space dedicated to the subject in the literature (Connors, Harrison et al. 1985; Leon, McNally et al. 1989; Palinkas 1992; Leon, Kanfer et al. 1994; Stuster 1996; Santy 1997; Kanas 1998; Kanas, Salnitskiy et al. 2000; Pesavento 2000; Kanas, Salnitskiy et al. 2001; Leon and Sandal 2003).

The increase in group conflict can be due to overcrowding and the inability to escape other people leading to increased stress (Fuller, Edwards et al. 1993; Brown and Grunberg 1995; Johnson and Suedfeld 1996). In nature, an animal keeps a certain distance between itself and other members of the species (Wilson 2000). When this social distance is constantly breached, stress occurs and patterns of aggression are altered (Alexander and Roth 1971; Hull, Chapin et al. 1974; Harvey and Chevins 1985; Judge and de Waal 1993; Judge and de Waal 1997; de Waal, Aureli et al. 2000; Van Loo, Mol et al. 2001; Nephew and Romero 2003).

Crews under isolated and overcrowded conditions will often have conflicts over trivial issues, for example, over unwashed coffee cups and dining room behaviour as was reported in the antarctic (Stuster 1996). There are also conflicts over multicultural differences (Santy, Holland et al. 1993; Leon, Kanfer et al. 1994; Santy 1997; Kanas, Salnitskiy et al. 2000), personal backgrounds, mission role (Connors, Harrison et al. 1985), and sex/gender issues (Taylor 1991; Leon, Kanfer et al. 1994; Pesavento 2000; Leon and Sandal 2003). In mixed crews, conflict has also occurred over women (Stuster 1996; Leon and Sandal 2003) although usually women are able to reduce the amount of conflict (Taylor 1991; Kahn and Leon 1994; Sandal, Vaernes et al. 1995; Sandal, Bergan et al. 1996; Stuster 1996; Pesavento 2000; Leon and Sandal 2003) although not the amount of overall stress (Leon, McNally et al. 1989). In some situations, sexual stereotyping added to the stress experienced by women, possibly offering some additional stress for women in an isolated and confined situation (Burrough 1998; National Research Council 1998).

Not all conflicts are due to problems between crewmembers in the closed system. Primarily, there have been difficulties between the crew and ground control (Connors, Harrison et al. 1985; Kass, Kass et al. 1995; Manzey, Schiewe et al. 1995; Stuster 1996; Santy 1997; Pesavento 2000; Manzey 2004), primarily relating to difficulties in communication. This has even occurred in simulated missions (Stuster 1996; Brady, Hienz et al. 2004). Stuster (1996) reviewed several conflicts which were due to differences in priorities such as research versus public relations (potentially a very important factor), unclear communications, irritability from sleep, extreme emotional reactions, or even being told something that the crew did not want to hear. The Russian space program has several recorded incidents of communication difficulties between the ground crew and the space crew, such as occurred during the Salyut 7 mission, and another time when cosmonaut Krikalev broke off communications with the ground crew for two orbits due to bad news from home (Stuster 1996).

Difficulties with the ground crew could serve as a way to transfer aggression to a safer source so that it would be less likely to blow up between the confined crewmembers (Stuster 1996). Since clear communication of technical details is very important and the ground crew may not understand the stressors which the space crew is working under, it has been suggested to use other members of the astronaut corps to aid in ground crew/space crew communications (Stuster 1996) or to use more two way communication (Connors, Harrison et al. 1985). The communication between the two groups should not make the space crew feel as if they are being constantly intruded upon, which would decrease job satisfaction, increase hostility, and reduce privacy (Connors, Harrison et al. 1985). Constant conflicts between the ground crew and the space crew can be a very severe risk to any mission success (Santy, 1997) and should be considered one of the most important stressors to consider.

Although conflict is known for being a bad thing, there are good things that can come out of conflict. Connors et al (1985) lists the positive sides of conflict as 1) it lessens depression, 2) helps identify a better solution to a problem, 3) draws attention to a problem, and 4) helps the crew to reach important goals. It would be best for the crew to, instead of eliminating all sources of conflict, to simply lessen the degree of negative conflict to a point where it will be less likely to be destructive to the mission.

Psychiatric diseases

One stressor that is worth worrying about is the development of psychiatric diseases. Since having a psychologically disturbed crewmember is inadvisable when going to a remote environment or even in general, crew selection tries to remove individuals from consideration who have a tendency to develop these disorders (Stuster 1996; Lichtenberg 1997; Santy 1997). However, additional stressors can allow the development of psychological disturbances in those who were previously physiologically and psychologically healthy (Connors, Harrison et al. 1985; Stuster 1996; Stampi 1997; Chambers and Chambers 2006). This development could lead to early termination of the mission or else risk the success of the mission depending on the individual psychological disturbance and if it can be brought under control. Several space missions, Soyuz 21, Soyuz T-14, and Soyuz TM-2, have been terminated early due to this stressor (Pesavento

2000). Further, ground tests for Skylab showed additional psychological problems occurring at the 56th day of the 90-day test. By the end of the Skylab ground experiment, three of the four crew members showed significant personality changes (Chambers and Chambers 2006).

Crew Composition

The success of a CELSS is directly dependent on the selection and training of an appropriate crew. Currently, crewmember personalities are taken into account when planning a space mission, in order for the team members to work together as efficiently as possible during their time together. The importance of crew selection can be seen most clearly in the ISS or Mir, where crews train together for approximately 18 months before they embark on their six-month flight (Burrough 1998; Canadian Space Agency 2003). It is much easier to find a two or three person crew which can get along for six months at a time, then it is to find a larger crew which will remain harmonious. Longer-term missions, such as a trip to Mars, would require a larger crew, which might have to work together in a CES for several years with a minimum of problems. As the crew size increases, the ability to create a perfectly harmonious crew decreases and more problems are likely to occur affecting the stability of the CES and the success of the mission. The selection of the appropriate crewmembers can be difficult because there are many variables that need to be considered such as gender, personality, diversity, and leadership abilities.

Gender Composition of the Crew

Throughout history, there has been a tendency for crew composition to be primarily male. This is partly due to the role of women throughout history as the "weaker" sex. The discussion of gender composition has only rarely been considered in the discussion of long duration missions. The differences between unisexed crews and coed crews have been researched and each has been found to have its own advantages and disadvantages (Leon and Sandal 2003).

While all male crews were the norm through most of history, previous research showed an alarming tendency towards excessive competition and inability to share their feelings causing additional stress (Bishop, Grobler et al. 2001; Leon and Sandal 2003). The opposite effect is found in all female crews, which showed a greater tendency towards harmony, cooperation, mutual decision-making, respect, and egalitarianism (Kahn and Leon 1994; Sandal, Bergan et al. 1996; Leon and Sandal 2003). All female crews did report an increase of stress, due to excessive caring about their fellow crewmembers, but it was not enough to create failure of the mission (Rothblum, Weinstock et al. 1998).

There appears to be inconsistent data on the status of coed crews. Females in mixed crews reported greater interpersonal stress due to non-reciprocal sharing with the male crew (Leon, McNally et al. 1989). There have also been reports of unwanted sexual advances (Leon and Sandal 2003) as well as problems regarding the cultural assumptions about women's roles (Leon, Kanfer et al. 1994; Burrough 1998; National Research Council 1998; Pesavento 2000). While there have been negatives in some studies, other studies have showed an increase in "civilized behaviour at base camps" in Antarctica (Taylor 1991). There is also the role of women as "peacemakers" soothing over tensions in stressful situations (Sandal, Vaernes et al. 1995; Pesavento 2000). During an Antarctic study of married couples over long duration, the mission was highly successful and the presence of a partner allowed better coping strategies (Leon and Sandal 2003).

Multicultural Diversity

Antarctic analogue studies and space studies showed several interesting results relating to multicultural crews. The crewmembers of Biosphere 2 represented three countries, the United States, the United Kingdom, and Belgium. This diverse crew showed few problems relating to their multicultural makeup (Ailing, Nelson et al. 2002). In the Antarctic couple studies, there was a Russian who didn't speak English. While this caused problems at first, the crew found other ways to communicate and were able to include the non-English speaking crewmember (Leon and Sandal 2003). However, in space, there was a situation such as the American astronaut Dr. Thagard in a predominantly Russian crew (Pesavento 2000; Kanas, Salnitskiy et al. 2001). The crewmember was ignored and showed psychological distress throughout a large portion of the mission. Unlike the previous two crews just mentioned, this third crew was given multicultural training, but yet there were still problems. This might suggest the multicultural training provided by NASA and RSA is less effective than previously thought. Cultural difficulties with multinational space crews were also reported in Burrough (1998) and were also personally experienced by another astronaut Dr. Linenger (2000; 2003).

Leadership and Egalitarianism

In a crew cooped up for a long period of time, there can be tremendous problems relating to leadership. Previous to going into Biosphere 2, the selected crew had worked with each other for six years and trusted each other's judgment and knew each other's weaknesses (Ailing, Nelson et al. 2002). During the Biosphere 2 experiment, there were two captains, a science director, and a medical doctor; four overall leaders out of a crew of eight and each of the total crewmembers were the head of their own section. In the event of an emergency, there was always a leader for the situation who all crewmembers would listen to. While they did not say how the leaders were chosen, this could have easily led to "too many chefs spoiling the broth" or even mutiny if the captain or leader made a bad judgment call. While Biosphere 2 offered a seemingly ideal situation, it is not the most likely one that will occur. In the Antarctic experiments (Leon and Sandal 2003), there was one leader for six crewmembers and the crew had not previously been trained with each other. As the crew did not know each other very well, the leader served as a consultant and provided his opinion on the problem at hand though his opinion on the situation did not have to be taken.

While the importance of leadership can not be denied, it is very important to allow everyone to have a say in what occurs with the group. In a situation where a crew will be locked up for an extended period of time, it would make the most sense if the crew were as egalitarian as possible. Egalitarianism is an equality among all crewmembers leading to flexibility of social roles, such as if one person knows more than another in a certain area, his opinion will be sought out more (Kent 1993; Ehin 1995). This allows plenty of chances for everyone to be a leader (Begler 1978). Most importantly, the status of leader or consultant is not something just handed to someone, instead it has to be earned (Begler 1978). In the event that a person does not like what someone is doing or what someone is suggesting in a normal unconfined situation, they do not have to remain in that area (Woodburn 1982). The freedom to escape conflict is one that is taken away from us in the CES which makes it very important to choose leaders carefully.

Stresses Related to Food Concerns

There are several types of food concerns that need to be considered in a closed ecological system. The first relates to the difference between appetite and hunger. Appetite is the psychological craving for a substance while hunger is the physiological need. While all the crewmember's hunger can easily be satisfied in a CES, it would be much more difficult in to satisfy everyone's appetite, especially if they come from diverse backgrounds. For example, in Chinese culture and presumably in other cultures from the area, a meal is not considered a meal without some food item made from rice and if rice is not provided, the Chinese tend to complain that they are starving as if they haven't had a meal (Cooper 1986). This has, on occasion, nearly turned into an international incident. If the desired food item is not served for an extended period of time, this can cause psychological distress as was seen in Biosphere 2 (Ailing, Nelson et al. 2002).

For a long duration mission in a CES, the crew may have to become comfortable with becoming mostly vegetarian.[8] The raising of animals would take up more time and space where the crew could otherwise plant more crops. As plants are the lowest tropic level, they would provide more energy to the crew than then if the plants were fed to

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[8] A possible alternative protein source could be the eating of insects and other small creatures not normally present in a non-hunter-gather diet. Insects would be easy to "grow" in a closed ecological system as they can eat the waste and could provide a valuable recycling service.

animals first and the animals were fed to the crew. In the Biosphere 2 experiment, the diet was primarily vegetarian with some chickens, pigs, and goats being raised for meat and other products (Silverstone and Nelson 1996). The crew did report some problems getting used to their new diet in the first six months of the experiment but they adapted (Silverstone and Nelson 1996; Ailing, Nelson et al. 2002). The only dietary problems that Biosphere 2 suffered were Vitamin D and B12 deficiencies caused by a lack of dietary diversity (Silverstone and Nelson 1996). These deficiencies could have been possibly been reduced if better planning was made in regards to the diet.

In our evolutionary past, we have already undergone a reduction in food items. During the Neolithic Agricultural Revolution, approximately 10,000 years ago, the shift from hunting and gathering to a reliance on farmed foodstuffs led to increased nutritional deficiency and distress (Newman 1962; Stini 1971; Ulijaszek 1991; Larsen 1995). Of the reduced amount of food items, NASA is currently researching how to grow only a few of those in CES (Ailing, Nelson et al. 2002). Likely, this reduced dietary diversity will continue to lead to additional nutritional stress on the crew as seen in Biosphere 2.

Other Psychological Stresses

There could also be psychological difficulties such as those relating to things that one must do that is uncommon in a normal situation. Specifically, one issue, which could be difficult to handle psychologically, would be urine recycling. Urine provides high levels of nitrogen and other nutrients in a form that can easily be utilized by plants as fertilizer. Currently in Sweden, human wastewater is being used as fertilizer and approximately 23% of Swedish people surveyed were either neutral or against the use of human urine as fertilizer (Berndtsson 2006), with only one being so opposed that he said he would never eat anything grown in it. In greenhouses, diluted urine has been used to grow microalgae (Adamsson 2000). The plants and the algae remove the nutrients from the urine and act as a natural purifying agent and can create purified drinking water (Saulmon, Reardon et al. 1996). While many crewmembers may try to ignore the fact they are drinking recycled urine, it is likely that someone at some point may have difficulties with it. There could be any number of additional stressors that could add to these difficulties.

Ways to Prevent Stress

Physical Limitations for Human/Man-made and Controlled Environment Interactions

In order to understand how to prevent stress in a closed ecological system, one must be able to understand more details about the system itself and how humans are able to deal with the limitations of living in a controlled and closed environment. A few of these physical limitations may include the limitations of how often something can be recycled in the various life support (Eckart 1996) and plant growth systems (Tibbitts and Wheeler 1987), the nutrients required as a minimum for plant growth (Dy and Yap 2001; Litaor, Seastedt et al. 2005; Grant, Curran et al. 2007), additional payload space required for storage if space is at a premium, habitat design (Connors, Harrison et al. 1985; National Aeronautics and Space Administration 1995), and ergonomically designed furniture and other equipment to maximize comfort (National Aeronautics and Space Administration 1995) as well as other difficulties that may arise due to being dependent on machines and other artificially created and enhanced situations. The bare minimums of what humans need to survive for short periods of time is understood, however, knowledge of longer term survival is less known. Further, the difficulties with human-machine interaction and the stress provided by dealing with and repairing such machines can be both mentally and physically taxing. In order to reduce stress, not only do we need to more fully understand what the human body is able to deal with for an extended period of time in a closed system. If we could tell the absolute physical limitations of the human body, we have a greater chance of understanding the various forms of human-machine interactions, then we could find further ways of reducing the physical stressors, such as by improving the ergonomics of the equipment which makes the computers and other related technology more user-friendly and easier to deal with. Any reduction of physiological stress should help reduce the psychological stress present in the system.

Continuous training

One way to reduce stress would be to overtrain or to continuously train on mission critical tasks in order to increase efficiency when the task is needed. Overtraining and continuous training is currently provided for tasks such as spacecraft landing, docking, and other mission critical tasks (Connors, Harrison et al. 1985; Lichtenberg 1997; Burrough 1998; Chambers and Chambers 2006). Overtraining on certain areas increases the odds of completing the task with minimal difficulties as well as reducing the overall stress experienced in the situation (Connors, Harrison et al. 1985). While overtraining or continuous training on the ground can lead to eventual boredom, it can also help reduce the stress present when the task is finally performed. However there is difficulty in knowing how much is too much before the possibility of boredom outweighs additional benefits.

Pets

Another way to lower stress (and its instability) is through the presence of pets. Studies have shown that the presence of pets in the workplace can reduce stress and improve employee performance (Wells and Perrine 2001). Additional studies have shown a variety of positive effects that pets have on psychological and physiological stress. Pets increase the health of the community by fostering increasing social bonds between neighbours (Wood, Giles-Corti et al.). In hospitals, visiting companion animals have also been known to increase morale, reduce stress, and speed up healing time (Wu, Niedra et al. 2002; Millhouse-Flourie 2004). Interestingly, there are also different levels of attachments to companion animals, dog owners tend to be more attached to their pets than cat or bird owners (Zasloff 1996). This might be significant in the long term.

Unfortunately, the reduced space of a CES allows very little room for anything extra that does not serve a purpose. While Biosphere 2 did keep animals, the chickens, goats, and pigs were to be bred and raised as food. While the chicken and the goats had few problems reproducing, the pigs only produced one litter (Ailing, Nelson et al. 2002). Although the animals were present, it is important to note they were not pets and were not treated as such. It is unlikely crewmembers would reap the full advantages of animal companionship and pet ownership, if he or she knows it will be dinner. There is no literature showing the benefits or drawbacks of the following as surrogate pets: plants, pet rocks (a pet in name only), small animals such as rodents, or virtual pets, though these smaller and less labour intensive pets would be much more appropriate for a long duration spaceflight or CES, unless a larger and intelligent animal (such as a non-human primate) could be trained to have an additional job and function as a crewmember.

Private cabins

Studies have shown that high levels of crowding cause stress (Alexander and Roth 1971; Hull, Chapin et al. 1974; Fuller, Edwards et al. 1993; Judge and de Waal 1993; Judge and de Waal 1997) and lack of privacy can affect the occupational stress (Klitzman and Stellman 1989). Occupational stress, like any other stress, leads to physiological problems with the heart, lungs, muscles, and stomach. Mental problems such as changes in moods, attitude, and motivation can lead to alterations in social interaction such as withdrawal from contact, decreased work efficiency, and unsocial behaviour (Taylor 1991).

In order to be fair, it would be best if every member had his or her own equal private space, such as a personal cabin. In the closed ecological system Biosphere 2, all crewmembers had their own private cabin and a bathroom shared with only one other person (Ailing, Nelson et al. 2002). On the Russian space station Mir, each crewmember had a private cabin with windows overlooking the Earth (Bedini and Perino 1999). However, in the Antarctic studies, there were no private cabins and every man had to share a two-man tent which seemed to lead to additional stressors (Taylor 1991).

Hobbies and other distractions

Since food processing and related activities required only 45% of the Biosphere 2 crew's time (Silverstone and Nelson 1996), they had to find other things to do with the rest of their day. These distractions and hobbies were reviewed by Ailing et al (2002). Biosphere 2 provided its crew with a fully equipped kitchen, a TV room for watching films, a video conferencing room, a one thousand book library, a gymnasium, and an open space for theatre and dance performance. The majority of the crew participated in weekly events that encouraged social bonding, such as theatre, yoga, music, dance, storytelling, filmmaking, and writing as well as parties on their days off. The crew also participated in music, video, and poetry exchanges with local artists, shared notes with an Antarctic crew via telephone and ham radio, and participated in several teleconferences as well as being in constant contact with family. All this served to increased morale and community spirit and decrease isolation and loneliness.

Cooking (Silverstone and Nelson 1996) and gardening (Ailing, Nelson et al. 2002) were two of the most popular distractions in Biosphere 2. The crew enjoyed working in the fields and claimed to feel a deep connection to their crops (Ailing, Nelson et al. 2002). Each crewmember was required to spend one full day as chef (providing three meals that day) every eight days (Silverstone and Nelson 1996). There was a bit of a competition between crewmembers as they were constantly trying to outdo each other and provide a the best meal for their crewmembers (Silverstone and Nelson 1996).

One distraction unmentioned in the Biosphere literature is that of various forms of games, such as card games, board games, and video games. As each crewmember had access to a computer, it is likely they had access to the primitive games that come standard on any Windows PC such as Solitaire, Hearts, Freecell, and Minesweeper. They may have also had access to board games (such as Monopoly, Life, etc), a deck of cards, or puzzles.

While work on Biosphere 2 automatically provided its crew with large amounts of exercise, they still had a fully functional gymnasium that they could use. In the event of a CES in microgravity, additional exercise beyond that required for agricultural maintenance would have to be used as a distraction. Large amounts of exercise would slow bone or muscle loss, reduce orthostatic intolerance, and improve morale. Astronauts and cosmonauts exercise in microgravity in preparation for their return to Earth. On the Mir space station, 2.5 hours of daily resistance exercises were required (Convertino 2002). The US has slowly increased from 30 minutes a day in the early flights to around 2 hours each day in 2004 (Convertino 2002).

There is also the possibility of using recreational sex as a distraction also providing much needed exercise. There are problems with this distraction, mostly due to how each person perceives the sexual activity. If not all of the crewmembers are on the same page then it is possible that sexual tensions, such as jealousy, will develop. On the ground, sexual tensions between astronauts have already occurred and led to a near disastrous outcome such as in the recent development of Captain Nowak, an astronaut being charged with the attempted murder of her romantic rival. Selecting for already committed couples in the crew selection process could prevent some problems regarding recreational sex. However, another problem comes up regarding controlled reproduction, as closed systems do not have the buffer capacity to support an additional mouth. Additional difficulties and unknowns regarding pregnancy in microgravity would further encourage preventing reproduction.

In order to prevent conception, it would be wise to grow some plants that can be used as a natural form of birth control or that can be used to induce miscarriage in the event the mission is going to be so long that bringing years worth of birth control for each female crewmember is unfeasible. There are several plants used in antiquity, as well as in modern times, which are used to prevent or terminate a pregnancy (Riddle and Estes 1992). A type of giant fennel (*Ferula* genus) known as silphion was used as far back as

600 BCE. While silphion is now extinct, many of its relatives are still used as anti-fertility drugs including *Ferula assa-foetida*, *F. orientalis*, and *Ferula jaeschkaena*. Other abortatives include pennyroyal (*Mentha pelegium*), a relative of kudzu (*Pueraria mirific*), squirting cucumber (*Ecballium elaterium*), *Pilocarpus jabrandindi*, wormwood (*Artemisia absinthium*), *Murraya paniculata*, Queen Anne's lace / wild carrot seeds (*Daucus carota*), the woody herb rue (*Rue graveolens*) and possibly relatives of myrrh (*Commiphora* genus). Some of these plants produce toxic chemicals that abort the fetus, while other plants such as willow (*Salix exigua*), a type of clover (*Trifolium subterraneum*), date palm (*Phoenix dactylifera*), and pomegranate (*Punica granatum*) produce a chemical that is very similar to estrogen and this functions as a natural birth control. As many of these plants are small it could be possible to grow these in a CES without adding undue stress on the system.

Further Ways to Prevent or Reduce Stress in Orbit

Since there are so many stressors, there are a lot of things that would have to be considered in order to reduce the stress in orbit. The stress of motivation loss could be reduced by making the crewmembers aware of its likelihood, or by choosing individuals who would put less stress on themselves if they do not use their leisure time productively. However, this would prove difficult as those highly motivated individuals tend to be the most selected for during initial selection. Providing additional communication with the outside world could reduce the stresses of isolation as well as the feeling of separation from friends and family (Kass, Kass et al. 1995; Brunelli 1997; Rosnet, Cazes et al. 1998; Ailing, Nelson et al. 2002), while alterations in habitat design could reduce feelings of confinement and increase feelings of privacy (Stuster 1996; Brunelli 1997; Bedini and

Perino 1999) although more information on these factors still needs to be understood. Misloading work can be a very important problem and some of the problems could be reduced by allowing astronauts to develop their own schedule, rotate some tasks among the crew, and not overtraining on most tasks (Belew and George C. Marshall Space Flight Center 1977; Connors, Harrison et al. 1985; Stuster 1996). Disturbances in circadian rhythms might be adjusted by use of a bright light to stimulate appropriate rhythms, while sleep disturbances could be slightly reduced by reducing cabin noise and providing more appropriate sleeping quarters (Stampi 1997), although these would not completely eliminate the problems due to stress and microgravity. It has been suggested that the difficulties in personal conflict, both of intracrew conflict as well as space/ground crew conflicts, could be reduced by increased communication and multicultural training (Santy 1997), increasing the amount of women onboard (Taylor 1991; Kahn and Leon 1994; Sandal, Vaernes et al. 1995; Sandal, Bergan et al. 1996; Stuster 1996; Leon and Sandal 2003), using astronaut corps members for communication between ground and space crew (Stuster 1996), and use of more-two way communication between ground and space (Connors, Harrison et al. 1985). Of the other two stressors previously mentioned, transcendental experiences and psychiatric disorders, more data would needed in order to reduce the likelihood of occurring.

Maintaining Productive Hierarchies

Since humans have many hierarchies such as military, familial, academic, etc, there are many ways humans could attempt to express and establish dominance and respect. Discussions on individual's skills and how that can affect an individual's status in an hierarchy has already been mentioned. In a closed system, there are four options for human interaction. A crewmember can participate in 1) only one hierarchy, 2) several hierarchies at different levels depending on their skills (which would be typical for most societies), 3) no hierarchies, or 4) he can form his own (often seen in wolves). The first would not be efficient in a small-scale society where there needs to be cross training in the discipline area. The second option encourages cross training and cooperation between the crewmembers regardless of their primary training. The third encourages separation from the group, which can lead to depression and further group breakdown. The fourth would likely cause group fission. Of these hierarchies, the second is the most likely to be stable and would give everyone the chance to both lead and follow.

Practical Recommendations for Long Duration Space Missions

As the crews begin to experience longer and longer duration missions in physical isolation, it would be best to consider the evolutionary heritage of humans during crew selection and mission design in order to reduce the chances of stress. Our craft and crew should replicate the EEA as close as reasonably possible. For crew selection, ideally a family group would be best. Since humans travel in family groups, it might be reasonable to consider a crew that lives in a family group, such as a mother/father with their adult children plus the children's spouses. This would provide a natural hierarchy that all crewmembers respect because either they sorted this out among themselves long ago or were born into it. They were not thrown together as strangers and should know their own and each other's flaws well enough that they are less likely to show annoyance at each other. Also, crewmembers would not feel the loss of social structure or isolation from family since they will be on the same craft.

However, one difficulty with using a family crew would be difficulty in assuring the correct skill set. This might require extensive retraining in the appropriate areas or using additional family members such as cousins to add in the appropriate skills needed such as pilot, engineer, scientist, medical personnel, etc. While it might be difficult to find this perfect family crew who naturally went into these appropriate areas, it should be noted that it might be easier to teach the appropriate skills to a group who knows each other well than to throw a group of complete strangers together for a number of years.

In addition, it is important to realize that, regardless if the group is kin or not, assuming they return to Earth safely, the crew will be the objects of tremendous admiration by many and may even be the objects of jealousy by some. The crew will become instant celebrities and would have to be prepared for the social responsibility fame tends to bring. The crew will have to be extroverted and friendly to reporters and realize they are going to be used as role models. Everything they say and do will be front-page news and they may never lead a normal life again. All these things and more have to be considered when and if long duration spaceflight becomes a reality.

CHAPTER III

METHODOLOGY

Point of the Study

The point of this study is to analyze the reported stressors of astronauts and cosmonauts as natural responses, which had been previously provided an evolutionary advantage and were selected for and passed down from generation to generation. Stressor responses tend to be more frequent and more intense the further humans get from natural surroundings such as the environment in which we evolved. Outer space is the most extreme environment humans have been exposed to and it should not be surprising that stressors of some type are frequently reported. Unfortunately, stressors in the astronaut and cosmonaut corps have rarely been studied, as much of the literature focuses on physiologic and not psychological stress, and certainly never from an evolutionary point of view. Even the more commonly studied polar crew have not had their stressors considered from an evolutionary point of view. Without understanding the reasons for these stressors, how can one effectively implement solutions to reduce them?

The study was designed in order to 1) assess the frequency of stressors reported by Geuna, Brunelli et al (1995), 2) learn which stressors astronauts and cosmonauts considered the more troublesome both in LEO missions as well as for long duration (1+ year) mission, such as a mission to Mars, 3) gather first hand experiences of social conflict while the participants were in orbit, and 4) make recommendations for improvement of all the stressors, but primarily those related to social conflict. Although Geuna, Brunelli et al (1995) originally reported 15 categories of psychological stressors, in this study most were condensed down to 10 categories while one category, social conflict, was expanded as interpersonal conflict was a focus of this study.

Criteria for Selecting Study Participants

The criterion for selecting participants was that they must have gone through astronaut or cosmonaut training. While the study has as its primary focus astronauts and cosmonauts who have experienced stressors in microgravity, those who have not flown will be asked to finish the survey in the event they have difference expectations over stressor priority than the veterans. They also might be able to make valuable suggestions for long duration spaceflight and on preflight training. Astronauts and cosmonauts who have had EVAs or have commanded a mission received additional questions in order to gather specific information about these experiences.

Invitation to Participate in the Study

The invitation to participate in the survey was distributed by email to astronauts and cosmonauts, using personal contacts known to either the PI or the PI's advisor from late December 2006 through to the end of February 2007. The crewmembers were provided with the URL to the survey and some were provided with an equivalent Word document version in the event the online survey had technical problems. The astronauts and cosmonauts were asked to encourage their fellow astronauts and cosmonauts to complete the survey. The internet version was hosted by Websurveyor, a leader in on-line surveys, which provided security encryption as well as assuring the anonymity of the subjects. Astronauts and cosmonauts were informed that their answers will be anonymous and identified only by a self-chosen identifier. They were told they could remove their data from the study at any time.

Distributing the survey through personal contacts instead of through the space agencies was, unfortunately, necessary due to the bureaucratic difficulties present in the system. During August and September 2006, initial letters were sent to NASA's Astronaut Office in order to make them aware of the project and to ask for help in distribution once IRB approval was granted. The letters remained unanswered. One of the personal contacts who assisted in data collection, Dr. Bishop of University of Texas Medical Branch, provided an additional nudge to NASA finally allowing a response to a third letter in January 2007. While waiting for NASA's response, Dr. Bishop distributed it to astronauts she had worked with in the past. The project was given initial consideration by NASA's Committee for the Protection of Human Subjects, with unofficial support from the Astronaut Office. In part due to sudden news developments regarding Captain Nowak and other concerns preventing an expedited review, the survey was rejected for distribution. Although it was rejected for official distribution, it did reach approximately 75 astronauts and cosmonauts through personal contacts.

Participant's Descriptions

Three of the five respondents were from the Russian Space Agency (RSA), one from the European Space Agency (ESA), and one from Japan's National Space Development Agency (NASDA), which is now part of the Japan Aerospace Exploration Agency (JAXA). All described their job to be mission specialists although one additionally selected pilot and another additionally selected engineer. All subjects were male and married or otherwise partnered. Amount of children ranged from zero to two, although ages were not asked. All subjects rated themselves as being either close to their family or very close to their family. This is probably due to the selection criteria an astronaut or cosmonaut which often inquires about the family relationships. Religious views ranged from not at all religious to religious. The three subjects from the Russian Space Agency spent a minimum of several months in space, the subject from ESA spent days in space, and the representative from NASDA/JAXA spent only a few weeks in space. All but the JAXA subject were part of a space station mission of some duration. Given the time spent on the station, all three Russians were there to stay (two on Mir and one on the ISS), while the representative from ESA just visited Mir for a few days.

The Survey

The survey (see Appendix A) consisted of 36 total available questions with several questions having multiple parts. The survey included both quantitative and qualitative questions. Qualitative questions included scaled questions (four and ten point graphic rating scale), multiple-choice questions, and several free-response questions. The scaled questions focused on the amount of stress experienced in several situations by ranking them on a four-point scale as well as ten-point scale on the perceived risk of stressors on mission failure both in LEO and in long duration. Multiple-choice questions asked for the subjective experience of which was the primary psychological stressor experienced as well as expectations of future stressors. The majority of questions were free-response questions allowing the subjects to provide as much or as little information about their experience.

The survey can be divided into several sections. The first section consisting of questions one through four, asked about experienced stressors in LEO missions as both four-point questions and multiple choice. The first two questions asked about the frequency of 18 categories of stressors (ten categories of general stressors and eight categories of interpersonal conflicts) experienced by astronauts in LEO. The following two questions inquired as to which stressor was the most troublesome and, in the event interpersonal conflict was selected, which of those subtype was the most stressing.

Section two related to the subject's perceived risk of the stressor on mission success. Questions five and six were on a ten point scale with one being not a threat at all to mission success and ten being the biggest threat to mission success. Questions seven asked about whether the subject believed the risk to mission success would be the same for Mars as it would be in a LEO mission. If no was selected, question eight asked specifically how the threats would change and it was open-ended.

The questions in section three were all related to stressor reduction. Question nine asked the subjects to suggest potential ways to reduce stressors of all types. Question ten and eleven inquired as to the causes of any interpersonal conflict and, if present, how they reduced the conflict.

Pre-flight training was the subject of section four (survey questions 12 through 15). Question 12 was a ten-point question relating to the perceived effectiveness of pre-flight training by the subjects. Questions 13 and 14 were open-ended questions on the most and least effective parts of pre-flight training, while question 15 asked for suggestions on how to improve pre-flight training.

Section five (questions 16-20) and section six (questions 21-24) related to EVA stressors and command stressors respectively. Subjects who had not performed an EVA did not get questions 17 through 20, which were free response questions regarding how long they had spent in EVA, if any interpersonal conflicts were witnessed, what type of conflicts were present, and suggest ways to reduce EVA stress. No subject had been in command of a mission and thus there were no responses to section six although the questions were very similar to the EVA questions. The final section, section seven (questions 25 through 35) included demographic questions and number 36 included a data identification code for data removal.

Duration of the Survey

Data collection occurred over a two and a half month period from late December 2006 to February 2007. However, due to the inherent difficulties in securing astronaut and cosmonaut participation in psychological testing, the survey will remain open to the subjects until August 2007 in the event any additional subjects wish to volunteer their time. Latecomers to the project will attempt to be added to the analysis if possible and time permits. As of mid-February 2007, five astronauts/cosmonauts representing three space agencies have provided their data. While this may sound problematic, given the nature of the analysis and the generally low response rate of astronauts and cosmonauts, four is perfectly acceptable. As approximately 75 astronauts/cosmonauts were provided with the URL, the survey had an above average response rate of approximately 5%.

CHAPTER IV

RESULTS AND ANALYSIS

Executive Summary

The following chapter contains results of the Spaceflight Stressors survey offered from December 31, 2006 to February 19, 2007. Although this survey was offered as a Word document in both Russian and English, all participants opted to use the internet version. A total of five responses were gathered from astronauts and cosmonauts from three space agencies. Three of the five respondents were from the Russian Space Agency (RSA), one from the European Space Agency (ESA), and one from Japan's National Space Development Agency (NASDA), which is now part of the Japan Aerospace Exploration Agency (JAXA). The three subjects from the Russian Space Agency spent a minimum of several months in space, the subject from ESA spent days in space, and the representative from NASDA/JAXA spent only a few weeks in space. The responses have been compared as a whole as well as divided by duration of spaceflight medium to long duration (3 months and longer) versus short duration (days to weeks.) The subjects' demographic information, their agencies, and details about their space experience are found in Table 1. In the several tables that follow in this analysis, there were several minor obvious spelling mistakes present in the data. These typos were corrected for readability, but did not alter the voice or meaning of the words. In the event a possible correction could alter the meaning, the original spelling was left.

Table 1: Subject Demographics.

Note: "XXXXX" represents information which would have made it very easy to identify the subject. In the interests of confidentiality, this information was removed from the results.

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Sex	Male	Male	Male	Male	Male
Marital Status	Married/ Partnered	Married/ Partnered	Married/ Partnered	Married/ Partnered	Married/ Partnered
No. of Children	2	0	0	0	2
Family Relationship	close to your family	very close to your family	close to your family	close to your family	very close to your family
Religious Relationship	not at all religious	Religious	somewhat religious	not at all religious	somewhat religious
Space Agency	Russian Space Agency, and in partnership for NASA	NASDA	ESA	RSA	RSA
Job	Mission Specialist	Pilot/Mission Specialist	Mission Specialist	Mission Specialist	Mission Specialist/ Engineer
Time spent in space	Approximately 3 months	2 weeks	Few Days	XXXXX	Few months
Part of a Space Station Mission	Yes	No	Yes	Yes	Yes
Which space station	International Space Station	-	Mir	Mir	Mir
Length of Space Station mission	-	-	Few Days	XXXXX	Few months

Questions Regarding Experienced Space Stressors in LEO

This section related to the subject's experiences with space stressors and their complete responses are found in Table 2. The first question in this part of the survey asked about the frequency of stressors experienced by astronauts in LEO. This stressor list was the condensed version of stressors taken from Geuna et al (1995) and included changes in motivation, feelings of confinement, isolation from friends and family, transcendental experiences, fear of danger, workload, sleep disturbances, time sense disturbances, personal conflicts, and development of unforeseen psychiatric diseases. The options available for selection were extensively experienced, experienced, somewhat experienced, not at all experienced. Table 3 averaged out the scaled responses (1 = Not experienced, 2 = Somewhat Experienced, 3 = Experienced, and 4 = Extensively experienced) by duration subgroup and overall responses. Those who experienced longer duration spaceflight unsurprisingly had a higher degree of reported stressors in nine of the ten general categories, although this could also be the result of cultural differences (Bishop 2007, personal communication). The remaining category, development of psychological disorders, was not experienced by either group, although since admission of psychiatric disorders can result in being grounded from further spaceflight, this fear for their future careers could have resulted in insincere answers to the question.

Table 2: Experienced Space Stressors in LEO

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Frequency of General Stressors	-	-	-	-	-
Changes in motivation	Somewhat Experienced	Somewhat Experienced	Somewhat Experienced	Experienced	Experienced
Feelings of confinement	Experienced	Not at all Experienced	Somewhat Experienced	Experienced	Somewhat Experienced
Isolation friends/family	Experienced	Somewhat Experienced	Somewhat Experienced	Extensively Experienced	Experienced
Transcendental experiences	Somewhat Experienced	Not at all Experienced	Not at all Experienced	Somewhat Experienced	Not at all Experienced
Fear of danger	Experienced	Not at all Experienced	Not at all Experienced	Somewhat Experienced	Experienced
Workload	Experienced	Somewhat Experienced	Somewhat Experienced	Experienced	Experienced
Sleep disturbances	Experienced	Somewhat Experienced	Somewhat Experienced	Experienced	Experienced
Time sense disturbances	Somewhat Experienced	Somewhat Experienced	Somewhat Experienced	Experienced	Experienced
Interpersonal conflicts	Experienced	Not at all Experienced	Not at all Experienced	Experienced	Somewhat Experienced
Psychiatric diseases	Not at all Experienced	Not at all Experienced	Not at all Experienced	Not at all Experienced	Not at all Experienced
Frequency of Interpersonal Conflicts	-	-	-	-	-
Mission control	Experienced	Not at all Experienced	Not at all Experienced	Experienced	Somewhat Experienced
Professional differences	Experienced	Somewhat Experienced	Somewhat Experienced	Experienced	Somewhat Experienced
Personality conflicts	Experienced	Somewhat Experienced	Not at all Experienced	Experienced	Somewhat Experienced
Rookies	Somewhat Experienced	Not at all Experienced	Not at all Experienced	Somewhat Experienced	Not at all Experienced
Veterans	Experienced	Not at all Experienced	Somewhat Experienced	Experienced	Not at all Experienced
Rank/status	Experienced	Not at all Experienced	Somewhat Experienced	Experienced	Somewhat Experienced
Aggression	Experienced	Not at all Experienced	Not at all Experienced	Experienced	Not at all Experienced
Cultural differences	Somewhat Experienced	Somewhat Experienced	Not at all Experienced	Somewhat Experienced	Somewhat Experienced
Most affected stressor	personal conflicts	sleep disturbances	Sleep disturbances	isolation from friends and family	fear of danger
If conflicts, most affected	Aggression	-	-	-	-

Table 3: Averages for Question 1 Scaled Responses

Stressors and frequency as compared to duration	Overall	Medium to long Duration	Short duration
changes in motivation	2.4	2.7	2
feelings of confinement	2.0	2.3	1.5
Isolation from friends and family	2.8	3.3	2
transcendental experiences (ie "Superman Syndrome")	1.4	1.7	1
fear of danger	2	2.7	1
workload (too much, too little, etc)	2.6	3	2
Sleep disturbances	2.6	3	2
time sense disturbances	2.4	2.7	2
Personal conflicts (either intracrew and/or intercrew)	2	2.7	1
development of unforeseen psychiatric diseases	1	1	1

The second question was very similar to the first question although stressors were subdivided into types of personal stressors that one might experience. Again the subset of participants who experienced longer duration missions reported more experiences with the various personal stressors. Since the subjects flying on short duration missions might have an additional pressure on them to avoid conflict, then this could explain the lower amount of experienced conflicts or it could also be due to the lack of time that one would have to develop the conflicts in the first place. See Table 4.

Table 4: Averages for Question 2 Scaled Responses

Personal Stressors and frequency as compared to duration	Overall	Medium to long Duration	Short duration
Mission Control	2	2.7	1
Professional Differences	2.4	2.7	2
Personality Conflicts	2.2	2.7	1.5
Rookies	1.4	1.7	1
Veterans	2	2.3	1.5
Rank/status	2.2	2.7	1.5
Aggression	1.8	2.3	1
Cultural Differences	1.8	2	1.5

Questions three and four involved which stressor affected each subject the most. This is beneficial as in many cases, multiple stressors were experienced at approximately the same frequency. Both the shortest duration flyers reported sleep disturbances to be their primary stressor, perhaps because they were not in space long enough to get used to the sounds of the space environment. The other three subjects reported isolation from friends and family (from the longest duration spaceflight participant), fear of danger, and personal conflicts due to aggression as their primary stressors. Since many people are unlikely to be happy at the prospect of spending an extensive amount of time away from their families, it may be that honest answering of these questions may not affect their careers as extensively than if a shorter spaceflight participant had answered in a similar manner.

Questions Regarding Perceived Risk to a Mission

The fifth and sixth questions asked about the perceived risk on mission failure in LEO due to the various stressors (See Table 5 for all answers). The subjects were asked to rate each stressor on a scale of 1 to 10 scale with 10 having the most likely chance of mission failure. In most categories, there was a large spread between the lowest and highest rating per stressor (See Table 6 and 7). Like the previous questions regarding experienced stressors, the medium to long duration spaceflight Russians rated each of the stressors higher than their shorter duration counterparts from ESA and JAXA. Psychiatric disorders and transcendental experiences were the lowest concerns across all subjects, possibly an inaccurate portrait of their perceived risk due to possible risk to the subject's careers if they worried about their fellow crewmates' psychiatric state.

Table 5: Perceived Risk to a Mission

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Perceived risk to LEO mission	-	-	-	-	-
Changes in motivation	4	5	3	6	8
Feelings of confinement	3	1	2	7	8
Isolation friends/family	3	1	2	8	7
Transcendental experiences	2	1	1	3	3
Fear of danger	5	2	1	6	8
Workload	6	3	3	6	8
Sleep disturbances	4	4	3	7	8
Time sense disturbances	3	4	3	7	8
Interpersonal conflicts	7	2	1	8	4
Psychiatric diseases	1	1	1	2	2
Perceived risk in LEO - conflicts	-	-	-	-	-
Mission control	3	1	2	6	2
Professional differences	5	2	2	8	4
Personality conflicts	6	1	1	7	4
Rookies	3	1	1	4	2
Veterans	2	1	2	7	2
Rank/status	5	1	2	8	4
Aggression	7	1	1	7	3
Cultural differences	2	2	1	5	2
Same for Mars mission ?	No	No	No	Yes	Yes
Changes	The values would shift closer to the grade 10. Fear of dependence on artificial life support technologies will become acute	Isolation (5), Confinement (6), Transcendental Experiences (5), Fear of danger (3), Workload (2), Sleep disturbances (4), Time sense disturbances (5), Personal conflicts (2), Psychiatric diseases (5)	Motivation (6), Isolation (6), Confinement (6) Transcendental Experiences (5), Fear of Danger (5), Workload (2), Sleep disturbances (2), Time Sense Disturbances (2), Personal Conflicts (4), Psychiatric Diseases (3)	-	-

Table 6: Perceived Risk in LEO of General Stressors.

General Stressors	Lowest	Highest	Mean	Median	Standard Deviation
Changes in motivation	3	8	5.2	5	1.92
Feelings of confinement	1	8	4.2	3	3.11
Isolation from friends and family	1	8	4.2	3	3.11
Transcendental experiences	1	3	2	2	1
Fear of danger	1	8	4.4	5	2.88
Workload (too much, too little, etc)	3	8	5.2	6	2.17
Sleep disturbances	3	8	5.2	4	2.17
Time sense disturbances	3	8	5	4	2.35
Personal conflicts	1	8	4.4	4	3.05
Development of unforeseen psychiatric diseases	1	2	1.4	1	0.55

Table 7: Perceived Risk in LEO of Personal Stressors.

Personal Stressors	Lowest	Highest	Mean	Median	Standard Deviation
Mission Control	1	6	2.8	2	1.92
Professional Differences	2	8	4.2	4	2.49
Personality Conflicts	1	7	3.8	4	2.77
Rookies	1	4	2.2	2	1.30
Veterans	1	7	2.8	2	2.39
Rank/status	1	8	4	4	2.74
Aggression	1	7	3.8	3	3.03
Cultural Differences	1	5	2.4	2	1.52

The next questions in the survey, questions seven and eight, asked the subject if they believed the values they assigned for questions five and six would be the same on a Mars mission and, if not, how would they change. Of the five responses, three believed the responses would change although they varied somewhat on the changes. One of the Russian respondents said "the values would shift closer to the grade 10," but did not give specifics as to the changes in their numbers. He also made mention that "fear of dependence on artificial life support technologies will become acute." Both the two non-Russian respondents provided details regarding their concerns over the general stressor category, but did not suggest any alterations about the different forms of personal conflicts. Additionally, both suggested the "workload" stressor would decrease slightly from three to two. Further, one believed that the time sense disturbances and sleep disturbances would also decrease from three to two, all other stressors would increase between two to four points on the scale. The other respondent suggested personal conflicts and sleep disturbances would hold steady on the scale at two and four respectively, all other stressors would increase between one and five points on the scale bringing them more in line with the higher values reported by the longer duration Russian subjects.

The two other subjects, those who believed the values would be the same for a longer duration mission, were those subjects who consistently ranked their stressors the most severe. Nearly all of those were the top two of two although for personal conflicts they represented two of the top three on each stressor.

Questions Regarding Reduction of Stressors

The next set of questions asked about the causes of past stressors as well as suggested ways to reduce stressors. Question nine asked for suggestions as to reduce stressors, four suggested some form of increased pre-flight training (such as communication, psychological training, social sensory deprivation, etc) or more rigorous crew selection. The fifth suggested virtual reality games and exercises, although he did not specify if this was to be on-orbit or as part of pre-flight training. Other suggestions that were suggested included increased support from ground crew and more reliable life support systems.

When specifically asked about the causes of any personal conflicts experienced (question 10), two of the five subjects reported that they did not experience personal conflicts during their time in training or on-orbit, again these were the representatives from JAXA and ESA. Two of the three remaining subjects reported similar reasons for the personal conflicts namely differences in personality types. The third cited natural aggression accumulation as a possible cause of personal conflicts.

Although two of the five claimed they did not experience personal conflicts, one of them answered the question as to the steps taken to reduce personal conflicts. This in combination with the three other responses gave a total of four responses to this question. The response offered by the subject who did not experience personal conflicts, claimed it was due to a "subordination protocol." The three cosmonauts reported various steps taken to reduce the conflicts. The cosmonaut who reported being the most stressed by personal conflicts in question three, reported that "attempts to find a consensus… [but] conflicts were never resolved completely." The other two cosmonauts indicated pre-flight training relating to understanding the risks of conflict escalation and dependency on one another during spaceflight as the primary reasons to end the conflicts. All answers shown in Table 8.

Table 8: Reduction of Stressors

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Ways to reduce stressors	Rigorous pre-flight training: professional, intra-crew communication and interaction, psychological training (relaxation techniques, etc.)	Virtual reality electronic games, Exercises (physical & mental)	More emphasis on pre-flight training: cross-professional; social sensory deprivation	More rigorous selection and pre-flight training related to crew cohesiveness and stability. Mission Control support during space mission	Reliable Life Support Technologies development. Crew Selection and Training, Support from the Earth
Causes of personal conflicts if present	Personality type: extravertive or intravertive, and others	Have not experienced personal conflicts	There were not personal conflicts	Personal Conflicts could arise from nothing due to natural aggression accumulation	Different personality types
Steps taken to stop conflicts	Attempts to find a consensus. Success was very flexible Conflicts were never resolved completely: consensus were never complete	There were not conflicts	In cross-professional training it was subordination protocol	Clear understanding (pre-flight training) of high risk sequences of conflicts helped to terminate them	Mutual desire to terminate conflict due to high dependence on each other in prolonged space flight

Questions Regarding Pre-flight Training

Questions twelve through fifteen had as their focus pre-flight training. Question twelve asked the subjects to rate on a scale of 1 to 10 (10 being most effective) how effective they believed their pre-light training was. The lowest score was a four offered by a cosmonaut, next was a five by JAXA, and the remaining three rated their pre-flight training as a seven. This can lead to the conclusion that the subjects consider their training to be at least effective for the most part in preparing them for missions in LEO. However, there could be some concern about dishonesty as space agencies might not be pleased if the subjects rated their pre-flight training lower.

When asked about the most effective parts of pre-flight training in conflict reduction, one simply answered that there were no conflicts although that did not quite answer the question. The other four offered specific examples of how pre-flight training reduced conflicts. These included establishment of a hierarchy, socialization/intercultural training, cross-professional training, and problem solving.

When asked about the least effective methods to reduce conflicts, one said there were no conflicts (it is interesting to note this was not the same person who said the same answer for the previous question), one could not recognize, and one believed everything was effective but "lack of time does not allow to develop effective interaction deeper". The two remaining believed the least effective methods were different types of social interactions.

When asked about suggestions for improvement of pre-flight training, a variety of answers were received and it did not seem to have any consistency regarding the space agency the subject worked for. Two subjects wanted to increase the duration of training, two believed selection needed to be improved, one wanted to increase socialization, and another wanted "more developed training protocol on resolution of formulated problems in pre-flight phase of mission." All answers are shown in Table 9.

Table 9: Effectiveness of Pre-flight Training

Questions	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Effectiveness of pre-flight training	4	5	7	7	7
Most effective part of pre-flight training in conflict reduction	Professional and personal hierarchy establishment	Socialization and Intercultural training	There were not conflicts	Cross-professional training	Work together in resolving problems
Least effective part of pre-flight training in conflict reduction	Can not recognize	There were not conflicts.	Social Interactions	Spending just time together	Everything actually was effective; lack of time does not allow to develop effective interaction deeper
Ways to Improve pre-flight training	Selection process can be improved. Pre-flight training is sufficient	Extend time for socialization and acquaintance with each other in different situations	To increase duration of pre-flight training	More developed selection protocols. More developed training protocol on resolution of formulated problems in pre-flight phase of mission	Increase time of pre-flight preparations and training

Questions Regarding EVA Stressors

Questions 16 through 20 asked about EVA stressors. Of the five subjects, four had performed EVAs and the time spent in EVA ranged from 3 hours to 12 hours. No personal conflicts were reported as being witnessed during an EVA, with one cosmonaut reporting that "there is no chance to develop conflict." Suggested ways to reduce EVA stressors were divided into two categories, engineering and training. Training-wise, one asked for more practice time in the tank while another other was more concerned with safety protocol development in pre-flight training.

Table 10: EVA Stressors

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Performed EVA?	Yes	No	Yes	Yes	Yes
Time spent in EVA	Approximately 6 hours totally	-	3 hours	Approximately 12 hours	Few hours
Witness conflicts during EVA	No	No	No	No	No
Describe EVA conflicts	-	-	-	-	EVA is so dangerous and limited in time that there is no chance to develop conflict
Ways to reduce EVA stress	Increase the number of hours for practice in buoyancy tank	-	Further development for space suit design	EVA protocols development on the basis safety considerations Pre-flight training	Further increase mobility and reliability of life support for EVA

Questions Regarding Command Stressors

Questions 21 through 24 asked specifically about any conflicts noticed while in command of a mission. None of the five astronauts and cosmonauts were in command of a mission, therefore no results were provided for this section.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

General Summary

The human body and the human mind are very sensitive to the increased stresses brought about by modern environments far removed from the original environment in which we evolved. Living in high-density cities and dealing with ever changing personal microenvironments (fluctuating temperatures due to air conditioning, humidity, air and water pollution, differences in noise), increased crowding and aggression, reduced relaxations and ways to escape conflict, as well as overdependence on a reduced quantity of species used as food sources, has led to increased physiological and psychological stress. In the confined spacecraft environment, these stressors are further increased due to not only the further confined environment status, but also due to the high risk of danger if the confined environment is breached or difficulties develop.

While we have decent understanding about the physiological consequences during microgravity exposure, there is still a general lack of understanding of the psychological dynamics and consequences during long-term space missions. In part, this is due to not considering our evolutionary past and the basic understanding of why certain stressors are, in fact, stressors. Further, the difficulties relating to the simple act of asking astronauts about their short/medium duration experiences continues to make this a difficult subject to research.

There are many reasons that make this project and similar projects very difficult. First there are the difficulties with accessing the space agency officials in charge. Often, requests will go unanswered. When requests are answered officially, there are usually mountains of paperwork and restrictions placed in the way of the researcher. Further, even going through unofficial channels, there is unwillingness for astronauts and cosmonauts to answer any survey. This could be due to any number of reasons from lack or time to a fear of being grounded if their results get back to their space agencies.

Five subjects representing three space agencies were surveyed about their experiences. Somewhat unsurprisingly, the results and experiences varied regarding most stressors although there was a tendency for those who were in space the longest to report greater concern regarding the possibility of mission failure regarding the various stressors.

In comparison to the physiological changes that occur during microgravity exposure, psychological issues are not only much more difficult to predict but also tend to take a longer time, a few months or more, to develop. Psychological reactions tend to vary depending on the individual and there is little way to predict who is going to suffer from psychological difficulties or even which particular stressor will affect someone the worst.

While all long duration experiments have been performed close to Earth, either in LEO or in relatively isolated areas on Earth and thus allowing a return to civilization quickly, during a long duration mission to Mars where there is little way to return unstable astronauts, the study of psychological stressors will continue to increase in importance. Further development of the area of psychological stressors during long duration spaceflight and available countermeasures for stress mitigation will be needed.

Conclusions

Five astronauts and cosmonauts responded to a survey and their answers were broken down into short duration space missions and medium to long duration space missions. Effects and concerns regarding stressors varied depending on the length of time the subject was in space. As the space missions become of longer and longer duration and eventually go out beyond the Earth's orbit, human psychology will become a top priority due to the difficulties in psychological stabilization and the difficulty in returning a crewmember back to Earth quickly.

Validity of Methods Applied for Analysis

Due to the inherent difficulty in accessing astronauts and cosmonauts through official channels such as the space agencies, the unofficial channels seem to be the more efficient way of accessing the subjects. Whether or not official or unofficial channels are used, there runs the risk of bias for self-selection. Further there are additional pressures on astronauts and cosmonauts to not submit to psychological testing either inside or outside of a space agency setting. In some ways, since these contacts were unofficial and unsanctioned by the space agencies, the subjects might have been more at ease voicing their concerns since any results from this study would be anonymous and unlikely to result in grounding due to psychological concerns. All other statistical techniques applied are considered as valid for this type of research.

Conclusions Regarding Stressor Dynamics

In general, those subjects who engaged in longer duration space missions were more likely to report an increase in experienced stressors and their intensity as well as ranked them as likely to cause mission failure while in LEO. The subjects who flew shorter duration missions did not perceive as many stressors during their spaceflight, nor did they believe the stressors were as likely to cause mission failure in LEO. However, short duration subjects did acknowledge an increased concern for long duration missions such as that of a mission to Mars. Those longer duration subjects who had already believed the stressors they experienced were more intense and likely to cause mission failure in LEO, they did not believe the stressors for a longer duration interplanetary mission would be any worse than a long duration LEO mission.

Conclusions Regarding Pre-flight Training

Although the subjects tended to report that their pre-flight training was sufficient in many areas, the nature of longer duration flights would indicate a need for a change in pre-flight training. This change could be accomplished by increasing the psychological and stress-reducing training that is required as well as by increasing the overall length of pre-flight training for the most important aspects of the mission. Pre-flight training could be extended beyond standard set of practices in order to reduce future stress.

Initial Recommendations Regarding Stressor Reduction

Since the astronauts and cosmonauts are subjected to intense and combined stress (physical parameters, physiological adaptations to microgravity, human factors and computer/human interfaces, interpersonal social issues, etc), it would be important to follow their lead regarding their suggestions of how to reduce their future spaceflight stressors during pre-flight training and on orbit or during interplanetary missions. Some suggested ways to reduce stressors have focused on more rigorous crew selection although no subject was specific on the details regarding crew selection and none mentioned if the crew selection in question was the space crew or the ground crew, although two subjects suggested increased support from ground crew would reduce some of the stressors they experienced.

Another common topic of concern is related to pre-flight training. Three subjects suggested an increase in training of psychological and interpersonal communication skills such as relaxation techniques (an example of which could be meditation) and social deprivation, while others suggested an increase in training in general such as more practice in a buoyancy tank for EVA to further their technical training. The training in social deprivation would allow a subject to experience the isolation in a controlled way in order to see if the subject would be able to survive a longer duration mission. Relaxation may reduce interpersonal conflicts by reduce the overall stress, which each person carries. Better-developed safety protocols and more practice problem solving as a team were also considered as possible ways to improve pre-flight training. Better communication skills could also reduce miscommunication and increase crew cohesiveness. Providing greater positive contact with Earth such as with loved ones, or the possibly of married crewmembers would also help reduce some of the loneliness.

Engineering wise, life support and other vital pieces of equipment need to be made more reliable in order to reduce the fear of danger stressor. When one is far from Earth, the breaking down of a piece of equipment becomes an even greater priority since it is much more difficult to replace. EVA suits need to continuously better designed and made easier to managed. Since the subjects reported difficulties with sleep disturbances, perhaps the noise of the cabin could be reduced and other engineering solutions could be made to deal with this stressor.

Future Directions

There are a number of improvements that could be made in order to maximize and improve research into psychological stressors among astronauts and cosmonauts. As it is a difficult area and one where there are extensive barriers to subjects, it is important to maximize any research that can be done from the limited sample pool as well as to hopefully increase the sample size.

Future questionnaires might be better served by asking for a more specific answer to the time spent in space question as well as to more specific answers for other free response questions including discussing the difference between verbal and nonverbal communication skills. Other improvements could be additional questions which ask about each individual stressor and how it affected the subject. For example, sleep disturbances were reported, however, they did not say if the disturbances were due to the ground crew communications, their workload, noise, or if they were due to other reasons. This questionnaire might be better served in face-to-face format so additional questions can be asked depending on subject response.

One great difficulty was due to the difficulty in accessing the subjects through both official and unofficial channels. Work needs to be done to develop and maintain a network of subjects willing to answer questions either officially or unofficially.

Methods of Data Integration Development

One of the suggestions made was for an increase in pre-flight training. Unfortunately, pre-flight training can be rather costly in terms of time and money as it is not a real mission with expected outcomes. Thus there is a need to use quantitative methods in space psychology in order to get a more accurate description of how much pre-flight training is optimal. Due to the multi-dimensional nature of this research and huge number of variables involved, some mathematical models could be and are applied for the space life sciences (Miller 1992).

The typical matrix representing NASA's approach in organizing combined stressors in the environment appears as [Input Variables]*[Process Variables] = [Output Variables].[1] The matrix variables according to the abbreviated list based on Geuna et al (1995) are: 1) changes in motivation, 2) feelings of confinement, 3) isolation from friends and family, 4) transcendental experiences, 5) fear of danger, 6) workload, 7) sleep disturbances, 8) time sense disturbances, 9) interpersonal conflict, and 10) development of psychiatric disorders. This matrix is a linear line-matrix and the only restriction for matrix elements is the sum always must equal 1, indicating unequal stress distribution. As stress reduction tools are available, they represent the process variables. This matrix is [MxN] dimensional, where:

M = number of stressors (10 general stressors);

N = number of available instrumental support for stress coping

These process variables (N) could lead to stress reduction or they might not. They describe the effect of stress reduction techniques to the original set of stresses. The

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[1] More details on matrix analysis can be found in Mathews and Walker (1964).

results are indicated by the output variables and consist of numbers which in sum could be:

1, which indicate no changes in stress level;

<1, which indicates the stress level is reduced; or

>1, which indicates the stress has increased compared to original levels

An expert must assess the numerical assignments for the matrix elements. That is a particular goal for this work, to get an accurate description of the stress and to find the most efficient stress reduction techniques.

APPENDICES

APPENDIX A

SPACEFLIGHT STRESSORS SURVEY

The following is the English language Word document version of the survey which includes the website version's instructions. The Russian Word document version kept the same meaning as the original English versions. The purpose of this survey was to assess astronauts/cosmonauts reactions to environmental & social-psychological stressors, which stressors are considered to be the worst, and ask for suggestions on how to reduce future stressors.

Introductory Text

Hello, my name is Melinda Marsh and I am a Space Studies graduate student at the University of North Dakota. I am studying the social and psychological stressors in order to learn how to reduce them for a possible long duration mission to Mars.

You have been sent the link to this URL or a Word version of this survey because your name was provided by one of the space agencies as someone who has experience in short- to medium- duration spaceflight.

Please complete this survey and either submit it through this website or if you were given an electronic "Word" copy, you are encouraged to return it anonymously. You can do this by 1) using an anonymous email address such as hotmail or gmail, 2) using either melinda.marsh@und.edu or vrygalov@space.edu as the return email address (this can be done in Microsoft Outlook as well as other program), 3) or any other creative ways you can think of to remain anonymous are encouraged.

By completing and returning this survey, you are giving your implied consent. Compensation will not be provided for completion of the survey.

You may remove yourself and your data from the project at any time by use of a self-chosen identification code on the final page of the survey. If you have any questions, please email me at melinda.marsh@und.edu or my advisor Dr. Vadim Rygalov vrygalov@space.edu at any time.

This project has been approved by the University of North Dakota's Institutional Review Board. The project number is IRB-200612-181.

Survey Questions:

1) There have been a number of items put forth as possible stressors in the manned space program. Please tell me how often you have been stressed by these possible stressors.

a) Changes in motivation: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

b) Feelings of confinement: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

c) Isolation from friends and family: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

d) Transcendental experiences (ie "Superman Syndrome"): Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

e) Fear of danger: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

f) Workload (too much, too little, etc): Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

g) Sleep disturbances: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

h) Time sense disturbances: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

i) Personal conflicts (either intracrew and/or intercrew): Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

j) Development of unforeseen psychiatric diseases: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

2) Please tell me your experiences with the following types of personal conflicts.

a) Personal conflicts with Mission control: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

b) Intracrew conflicts relating to professional differences: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

c) Personality conflicts: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

d) Personal conflicts regarding difficulties with "rookies": Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

e) Personal conflicts regarding difficulties with veterans: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

f) Personal conflicts regarding difficulties regarding rank/status (commander, mission specialist, etc) among the crew: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

g) Personal conflicts regarding difficulties with aggression: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

h) Personal conflicts regarding cultural difficulties: Extensively Experienced, Experienced, Somewhat Experienced, Not at all Experienced

3) Which of the stressors affected you the most? (only pick one)

a) changes in motivation

b) feelings of confinement

c) being unable to communicate with friends and family

d) transcendental experiences (such as excessive euphoria, "Superman Syndrome," etc)

e) fear of danger

f) workload (too much, too little, or alternating between extremes)

g) sleep disturbances

h) time sense disturbances

i) personal conflicts (either intracrew and/or ground control related)

j) development of unforeseen psychiatric diseases

If i is selected to #3, please answer #4, if not skip to #5

4) If you selected personal conflicts, which type of personal conflict affected you the most?

a) Personal conflicts with Mission control/ground crew

b) Intracrew conflicts relating to professional differences

c) Personality conflicts

d) Personal conflicts regarding difficulties with "rookies"

e) Personal conflicts regarding difficulties with veterans

f) Personal conflicts regarding difficulties regarding rank/status (commander, mission specialist, etc) among the crew

g) Personal conflicts regarding difficulties with aggression

h) Personal conflicts regarding cultural difficulties

5) Please rate on a scale of 1-10 (1 being not at all a problem, 10 causing mission failure), your perceived risk of the following stressors on the success of a mission taking place in LEO.

a) changes in motivation:

b) feelings of confinement:

c) being unable to communicate with friends and family:

d) transcendental experiences (such as excessive euphoria, "Superman Syndrome," etc):

e) fear of danger:

f) workload (too much, too little, or alternating between extremes):

g) sleep disturbances:

h) time sense disturbances:

i) personal conflicts (either intracrew and/or ground control related):

j) development of unforeseen psychiatric diseases:

6) Please rate on a scale of 1-10 (1 being not at all a problem, 10 causing mission failure), your perceived risk of the following personal conflict stressors on the success of a mission taking place in LEO.

a) Personal conflicts with Mission control/ground crew

b) Intracrew conflicts relating to professional differences

c) Personality conflicts

d) Personal conflicts regarding difficulties with "rookies"

e) Personal conflicts regarding difficulties with veterans

f) Personal conflicts regarding difficulties regarding rank/status (commander, mission specialist, etc) among the crew

g) Personal conflicts regarding difficulties with aggression

h) Personal conflicts regarding cultural difficulties

7) Do you expect stressors for a Mars mission would be the same as those of a LEO mission? Yes/No

If no is selected, please continue to #8. If yes is selected, please skip to #9.

8) Thinking back to the previous question, which stressors (motivation, isolation, confinement, transcendental experiences fear of danger, workload, sleep disturbances, time sense disturbances, personal conflicts, psychiatric diseases) do you suspect would be experienced differently for a crew on a Mars mission versus a LEO mission? On the same scale of 1 to 10, how do you suspect the values would change? (Verbose entry)

9) Of the stressors listed (motivation, isolation, confinement, transcendental experiences fear of danger, workload, sleep disturbances, personal conflicts, psychiatric diseases can you suggest ways to reduce these stressors during either a LEO mission or a Mars mission? (Verbose entry)

10) If you have experienced personal conflicts, what was/were the cause(s) of these conflicts? (Verbose entry)

11) What steps were taken to reduce stress or end the conflict? Was this successful in ending the conflict? Why or why not? (Verbose entry)

12) Part of the purpose of preflight training is to increase group cohesion and reduce social conflict. How would you rate the effectiveness of your preflight training in reducing social conflict on a scale of 1 to 10, with 10 being the most effective?

13) What was the most effective part of your preflight training in reducing conflicts? (Verbose entry)

14) What was the least effective part of your preflight training in reducing conflicts? (Verbose entry)

15) How could preflight training be improved in order to further reduce social conflict? (Verbose entry)

16) Have you ever performed an EVA? Yes/No

If yes is selected, please go on to #17. If no, please skip to #21.

17) How much time have you spent performing EVAs? (Verbose entry)

18) Have you experienced or witnessed personal conflicts (either intracrew and/or ground control related) during an EVA? Yes/No/Not Sure

19) If you have witnessed or experienced personal conflicts during an EVA, please describe the situations and how they ended? (Verbose entry)

20) How can NASA/RSA/etc reduce the stress involved in an EVA? (Verbose entry)

21) Have you ever commanded a mission? Yes/No

If yes please continue to the next question. If no, please skip to 25

22) How many missions have you commanded? How much time in space have you spent as a commander, (if known)? (Verbose entry)

23) During the time you were a commander, on your mission were there any personal conflicts, either among the crew or between the crew and Mission Control? Yes/No

If yes, continue to #24. If no, please skip to #25

24) If conflicts were present, what were the causes of these conflicts? How did you as commander help reduce the stress? (Verbose entry)

Demographic Questions

25) Sex?: Male/Female

26) Marital status: Married/ Partnered, Divorced, Separated, Widowed, Never married

27) Number of Children

28) Would you say you are: Very close to your family, close to your family, somewhat close to your family, not at all close to your family

29) Would you say you are: Very religious, religious, somewhat religious, not at all religious

30) Which space agency do you work for? (verbose)

31) You can best be described as: Pilot, Mission Specialist, Payload Specialist, Engineer, Other (specify)

32) How much time have you spent in space? (Verbose)

33) Have you been a part of a space station mission of any duration?: Yes/no

If yes, please continue to #34, if no, please skip to #36

34) On which space stations have you flown?: ISS, Mir, Salyut, Skylab

35) How much time did you live aboard this station? (Verbose entry)

36) Thank you for providing this information. As promised you may remove your data from my project at any time. Please provide an unique code (up to 10 letters and digits) this will be used as your identifier in the event you wish your data removed. (Required)

Closing Text: Thank you again for answering my survey.

Landing page on survey completion (for web version): http://www.space.edu

APPENDIX B

GRAPHICAL SURVEY RESULTS

Experienced Spaceflight Stressors

Figure 1: Frequency of General Stressors

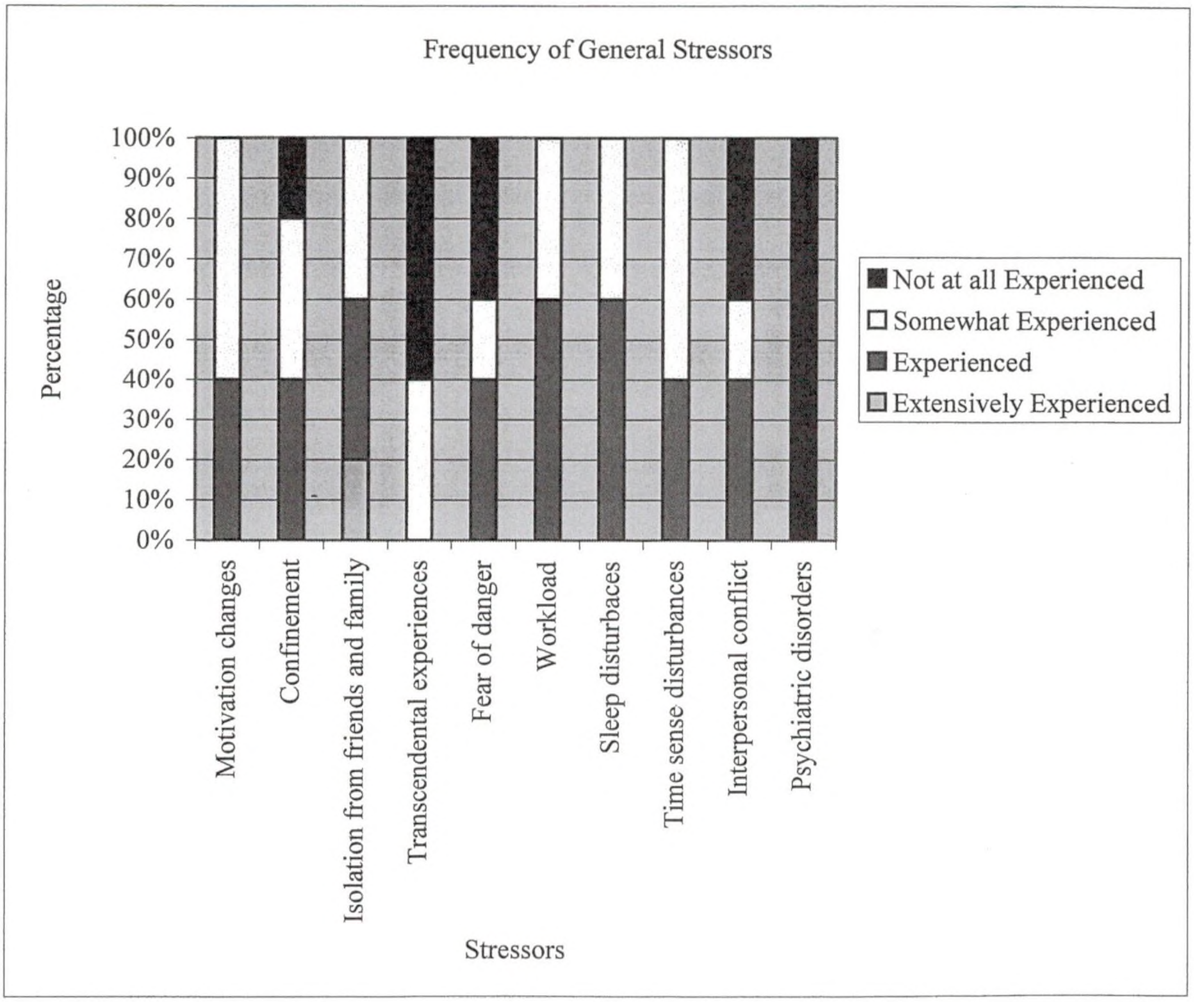


Figure 2: Frequency of Interpersonal Stressors

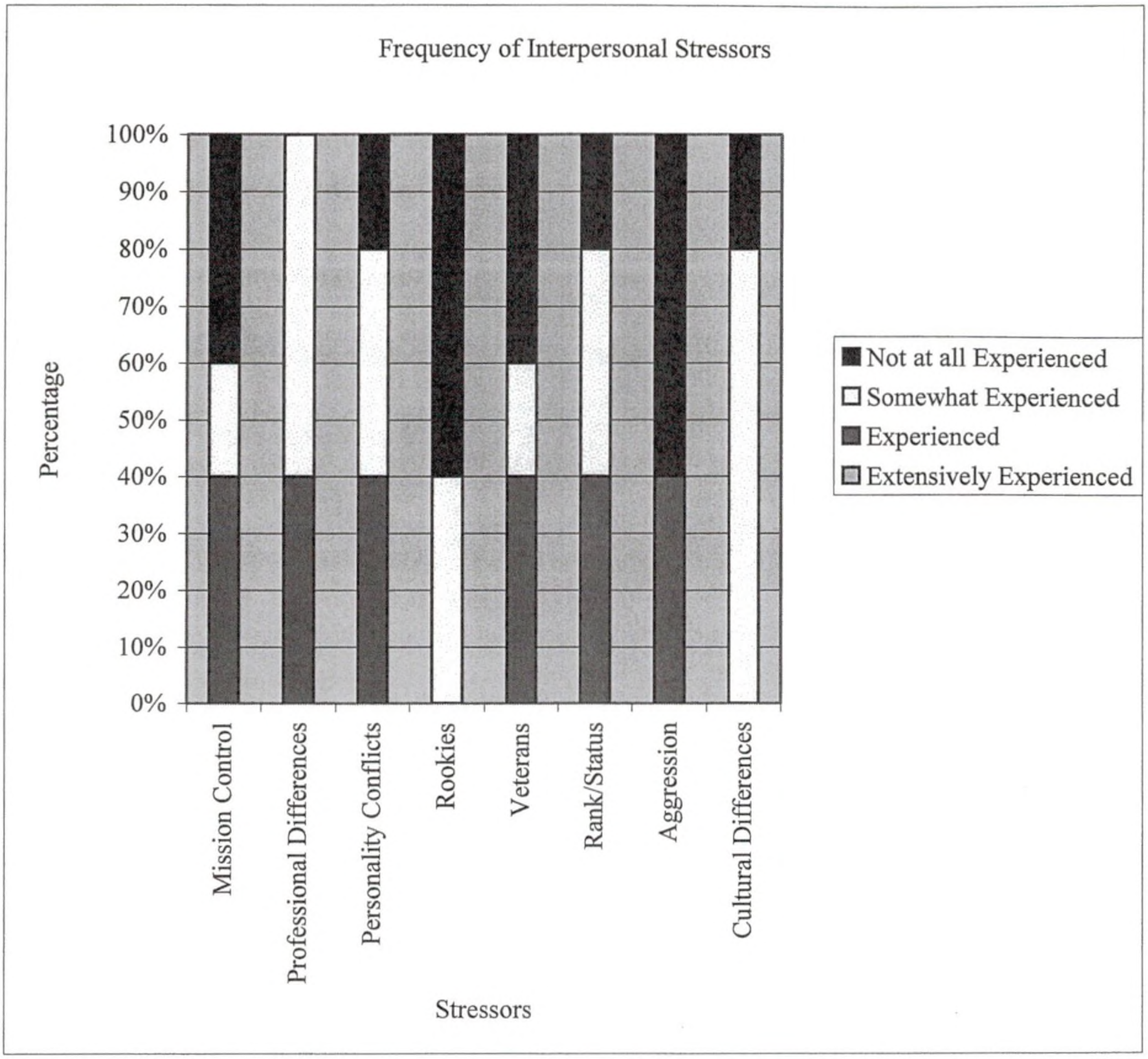


Figure 3: Average Response for General Stressors, Based on Duration

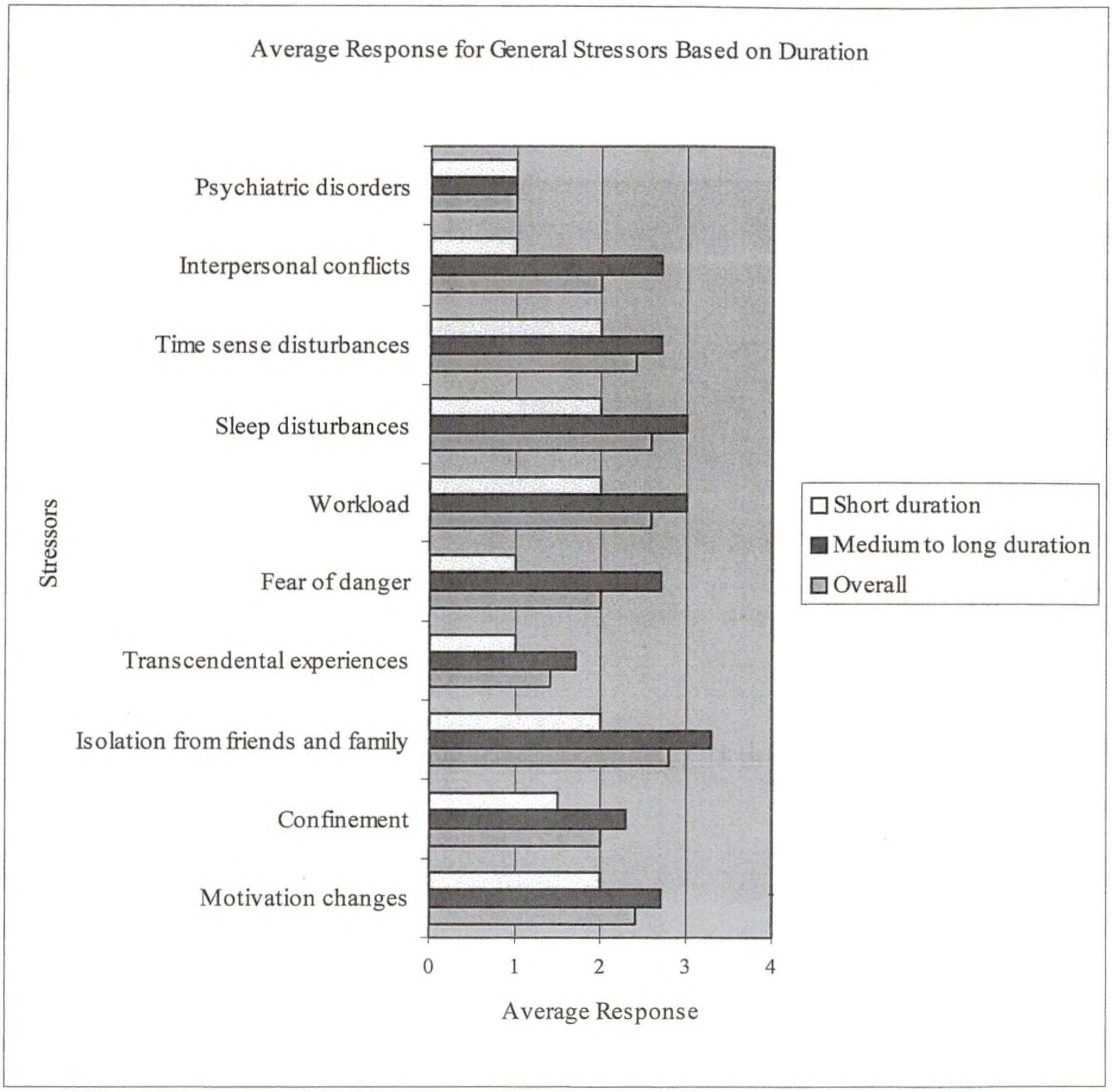
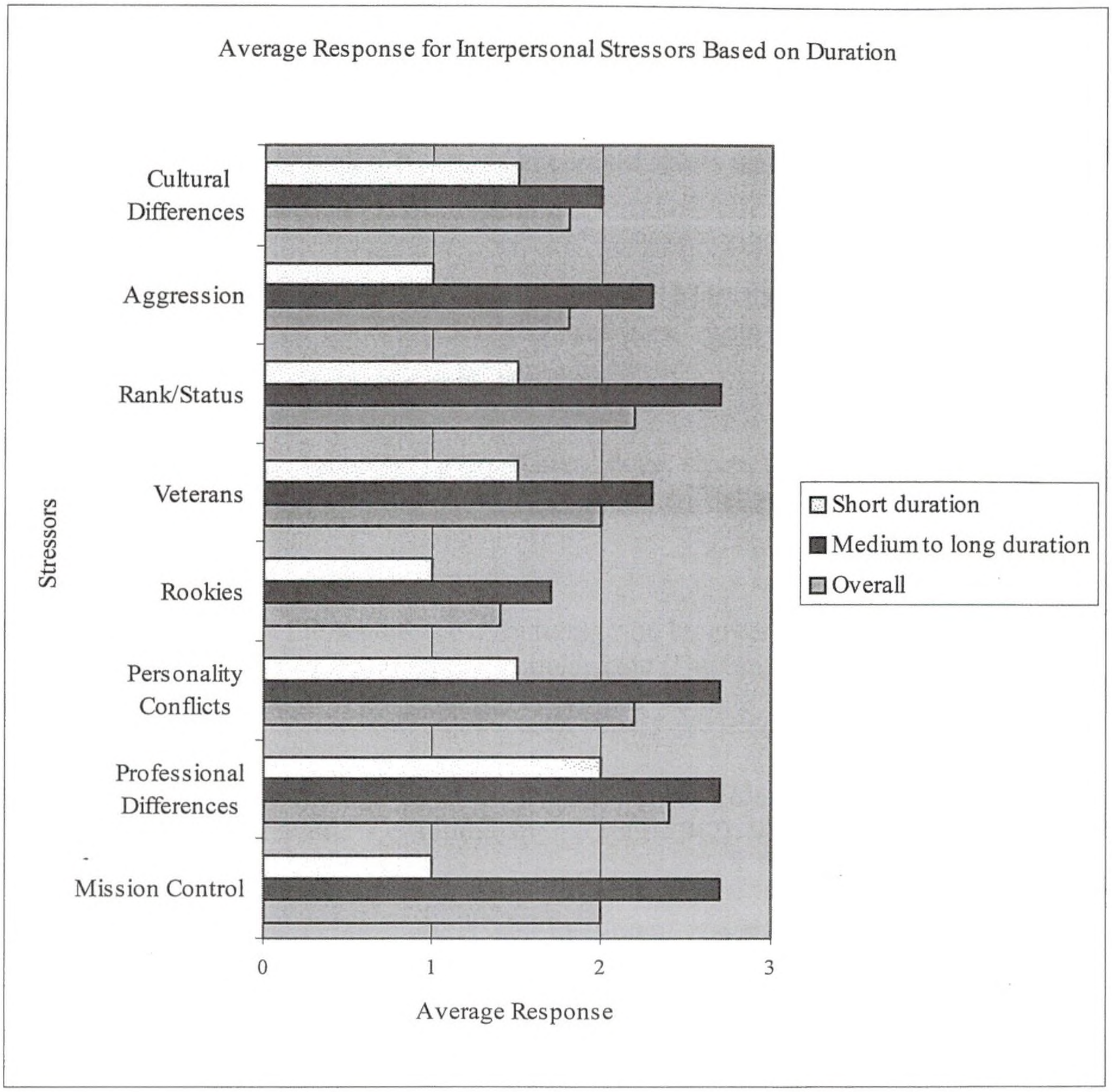


Figure 4: Average Response for Interpersonal Stressors, Based on Duration



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