# Individual Differences in Adaptation for Long Duration Space Exploration Missions*

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## Abstract

An evidence review was conducted to examine individual differences in adaptability for long duration missions. Deep space missions will expose astronauts to more intense stressors than previously encountered. Isolation will be greater and more prolonged, living and work areas more confined, and communications and resupply channels to earth longer and less reliable. These are compounded by prolonged exposure and greater distance from home and help. Astronauts on long duration missions also need to function more autonomously, with less guidance and support from earth. It is thus important to select and train future astronauts who can adapt and function effectively under extreme and variable conditions. It is well known that individuals differ in their ability to adapt, both physically and psychologically, to differing environments and changing conditions. This evidence review first provides a brief survey of the broad scientific literature on adaptability, focusing on the individual level. We next conduct a systematic review of the literature on cognitive and behavioral adaptability in ICE (Isolated, Confined, Extreme) environments. Finally, nine Subject Matter Experts (SMEs) with operational experience in spaceflight or analog ICE environments were interviewed in order to gain additional insights on factors associated with individual adaptability. Results identify personal attributes associated with adaptability, as well as contextual and organizational factors that can influence individual adaptability. Based on these findings, we provide recommendations for selection, training, and support of astronauts for long duration space missions. Recommendations for needed research are also provided.

## Introduction

A recognized risk area under NASA's Behavioral Health and Performance (BHP) element of the Human Research Program (HRP) concerns astronaut adaptation to the isolated, confined and extreme (ICE) conditions of long duration space missions. It is recognized that individuals vary in how well and fast they adapt to spaceflight and other ICE environments. It is important to understand the nature and causes of these differences in order to inform selection, training and risk mitigation strategies for long duration missions.

Deep space missions will entail unusual conditions to which astronauts must adapt including isolation from family and friends, confinement in cramped, small spaces, and having to live and work in extreme environmental conditions where there is a constant danger of serious injury or death should critical equipment fail or supplies run out. For long duration space exploration (LDSE) missions, greater distances from earth and coincident delays in communication will greatly increase the sense of isolation. Crews will have to function more autonomously, without timely advice or assistance from Mission Control. Space ships on LDSE missions will afford smaller living areas for astronauts, as more payload is needed for fuel and supplies. And exposure to environmental extremes will be greater, and for longer time periods. It is thus critically important that astronauts on LDSE missions be able to adapt quickly and effectively to the range of ICE conditions they are likely to encounter. This evidence report examines the current state of knowledge on the nature and most likely causes of individual differences in cognitive and behavioral adaptation to spaceflight and other ICE environments, potential methods for qualifying and predicting such differences, and possible mitigation strategies.

## Methods

Part 1: For background and context, we first reviewed the broad literature on psychosocial / behavioral adaptability. This allowed us to determine the key conceptual issues, and what is currently known regarding factors associated with individual differences in adaptability. The general review also led to a conceptual model that integrates available studies and can guide future research endeavors.

Part 2: We next conducted a systematic review of the literature on adaptability in ICE environments. Here we followed the standards for systematic reviews provided by the PRISMA group (Moher, Liberati, Tetzlaff, Altman, The PRISMA Group, 2009). We looked at databases PubMed, PsychINFO, EMBASE, and Web of Science, as well as NASA Technical Reports Server (NTRS) and Johnson Technikcal Reports Server (JTRS). Search included terms related to adaptability AND terms related to space or analog ICE environments AND terms related to health and performance.

**INCLUSION CRITERIA**: Published studies done in space or an analog ICE environment OR reporting retrospectively on ICE experiences; AND addressing some aspect of individual psychosocial / cognitive / behavioral adaptation; AND includes some measure of individual health, performance or well-being.

**EXCLUSION CRITERIA**: studies not in English; studies of team, crew, or organizational adaptation; animal studies.

Part 3: Finally, we conducted semi-structured operational interviews with N=9 subject matter experts including astronauts and former astronauts, flight support personnel, and arctic explorers. A thematic analysis of interview notes identified the most frequently mentioned factors related to individual adaptability.

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## Results

1. The broad literature on adaptability contains four divergent streams of research, each reflecting somewhat different underlying assumptions regarding adaptability. These are: (1) adaptability as *task performance*; (2) adaptability as changes in *cognitive processing*; (3) adaptability as *coping*; and (4) adaptability as *reacting to organizational change*. Following work by Ployhart & Bliese (2006) that integrates much of this research, we conceptualize **adaptability as a compound trait or meta-competency** that is a reasonably stable over time, and exerts general influence over how people react to environmental change and challenges. Adaptability in turn is influenced by a number of fundamental individual factors including personality and past experience.

2. The systematic literature review on individual adaptability in ICE environments identified *73 studies* that met all inclusion and exclusion criteria. Studies vary widely in terms of methods, populations studied, and fidelity to the space environment. Factors identified as having some influence on adaptability were: ***intelligence and cognitive ability; emotional stability; control; openness; optimism; mastery/achievement orientation; hardiness; past experience; sleep and shift work; physical - biological factors;*** and ***coping***. Results were somewhat mixed for conscientiousness, extraversion, and social support, with some studies showing positive effects on adaptation, and others showing negative ones. As regards sex-gender, some studies showed that women were better at adapting to ICE environments, while others suggest that women have more difficulties adapting compared to men.

3. Operational interviews largely confirmed the findings from the systematic review, while providing additional information regarding factors that may contribute to individual adaptability for long duration missions. Operational experts agreed on the importance of ***intelligence (especially practical intelligence); emotional stability; openness; achievement orientation; optimism; control; hardiness; past experience; sleep; physical - biological factors;*** and ***positive coping strategies.*** They also reinforced the mixed results on extraversion-introversion, indicating it is important to have a balance between introverted tendencies (e.g., maintaining privacy and emotional control), and extraverted qualities (e.g., sociability and working in a team). Subject matter experts also believed it was beneficial to be balanced with respect to achievement tendencies on the one hand, and willingness to accommodate and accept other approaches. These are both facets of the "Big Five" personality factor conscientiousness. Our results thus indicate that in ICE environments, some features of conscientiousness and extraversion have a positive influence on adaptability, while others appear to be negative. The table below summarizes results from the systematic review and operational interviews regarding factors found to influence individual adaptability.

| ***Factors influencing adaptability*** | ***Systematic literature review*** | ***Interviews with operational experts*** |
|---|---|---|
| Intelligence, cognitive ability | ✓Yes | ✓Yes; emphasis on practical intelligence, ability to tinker, fix things |
| Emotional stability | ✓Yes | ✓Yes; able to stay calm and focused despite stress |
| Openness | ✓Yes | ✓Yes; open to new ideas, different cultural perspectives; different roles; new procedures |
| Extraversion-introversion | Mixed results | Mixed; Important to be sociable and a team player, but also emotionally controlled and reserved |
| Conscientiousness | Mixed results | ✓Yes; reliable, task-oriented, striving, disciplined |
| Mastery/achievement orientation | Mixed results | ✓Yes; motivated, passionate; strong desire to learn and improve one's skills |
| Optimism | ✓Yes | ✓Yes, positive outlook, confidence in accomplishing tasks and overcoming obstacles |
| Control | ✓Yes | ✓Yes; belief one can solve problems and get things done; also, self-regulation, control over emotions |
| Hardiness | ✓Yes | ✓Yes; hardiness, resilience; interested and engaged; control, desire to learn, try new things and take risks |
| Past experience, background | ✓Yes | ✓Yes; broad life experience; past experiences with situations requiring adaptation |
| Sex - gender | Mixed results | Mixed; women on board can have positive or negative effects, depends on individual attitudes |
| Social support | Mixed results | ✓Yes; from family, crewmates, ground control |
| Sleep | ✓Yes | Not addressed directly; discipline and self - maintenance seen as important |
| Physical - biological factors | ✓Yes | ✓Yes; ability to meet physical demands of ICE seen as essential; need to maintain fitness and health |
| Coping strategies | ✓Yes | ✓Yes; Various positive coping strategies mentioned, self-development activities, mental imagery, family contact, special foods and meals, control emotions |

## Conclusions

This evidence report identifies key factors associated with individual adaptability in ICE environments. While the present results do not permit a rank-ordering of the relative importance of these variables, we are fairly confident that the most relevant factors are contained within this set. Future studies are needed to discern relative contributions and pathways of influence. Results can be applied by NASA to improve astronaut selection, training and sustainment programs for long duration missions. Additional research is also needed to improve measurement strategies, verify causal relations, and understand the complex interactions and underlying processes involved in positive human adaptation to the physical and psychosocial challenges of life in deep space.

*REFERENCES and full report available upon request to: bartonep@ndu.edu*