How to make astronauts more resilient on long-term missions

NASA plans to send people to Mars in about 20 years. A great deal of research is now being performed to identify and mitigate the major known risks to human health and performance during these types of flights. Astronauts are highly trained and highly motivated, and spaceflight missions are designed and carried out with the utmost attention to detail. Nevertheless, the unexpected will happen on something as challenging as a mission to Mars. Crews on these missions will face risks to health and performance that have not yet been identified, and will need to maintain resilience, flexibility, and adaptability in order to deal with these unknowns. This is especially apparent when one considers that, in the vicinity of Mars, one-way communication time to Earth can be on the order of 20 minutes; crews will need to have a high degree of autonomy to recognize problems at an early stage and deal with them effectively.

One form of autonomy comes in the form of resilience, or the ability to adapt to changing circumstances and recover from perturbations (injury, anomaly, emergency). This can be at the level of the single individual (physiological and psychological resilience) or it can involve the entire crew and their interactions with each other (psychosocial relations and teamwork). In order to provide such resilience, we propose to draw on concepts from network theory and complex systems.

A defining feature of a complex system is one that is composed of a number of independent but closely interacting subsystems, so that system properties arise that would not be expected from an understanding of each component subsystem. Mathematical tools are available to assess resilience in such systems. The definition of a complex system might apply to the individual astronaut in space, with the various subsystems consisting of the main physiological components (cardiovascular, musculoskeletal, sensorimotor, etc.). It might also apply to the group of individuals that make up the crew (including their interactions with ground control). Thus it is possible that complexity theory can provide the tools to assess, monitor, and improve resilience in astronaut crews. These tools might also provide early indicators of a breakdown in resilience, so that appropriate interventions can be suggested.

This approach is feasible because the technology is rapidly developing for continuous, minimally invasive, measurement of key parameters from human physiology and behavior. The resulting data can be sent to the mathematical algorithms that assess resilience. Quoting from the original article: “Within this framework, tools for resilience are then the means to measure and analyze these physiological and behavioral parameters, incorporate them into models of normal variability and interconnectedness, and recognize when parameters or their couplings are outside of normal limits.”

The International Space Station (ISS) is an ideal setting in which to carry out these types of studies. Many of the confounding factors that would make such an investigation infeasible in a terrestrial study are removed: the astronaut population is relatively homogeneous in terms of health status, fitness, and age; the environment is well understood and continuously monitored; the astronaut subjects are well characterized, and highly motivated.

Since this approach also establishes a unique personal “physiological signature” for each individual (to be able to assess deviations), it is also a form of personalized medicine (or personalized countermeasure design), which can augment on the physiological and functional level those approaches to precision medicine that are now being pursued in the various “omics” fields (genomics, proteomics, etc.).

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Publication

A call for research to assess and promote functional resilience in astronaut crews.
Shelhamer M
J Appl Physiol (1985). 2016 Feb 15