Assessing and Promoting Functional Resilience in Flight Crews During Exploration Missions

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NASA plans to send humans to Mars in about 20 years. The NASA Human Research Program supports research to mitigate the major risks to human health and performance on extended missions. However, there will undoubtedly be unforeseen events on any mission of this nature – thus mitigation of known risks alone is not sufficient to ensure optimal crew health and performance. Research should be directed not only to mitigating known risks, but also to providing crews with the tools to assess and enhance resilience, as a group and individually.

We can draw on ideas from complexity theory and network theory to assess crew and individual resilience. The entire crew or the individual crewmember can be viewed as a complex system that is composed of subsystems (individual crewmembers or physiological subsystems), and the interactions between subsystems are of crucial importance for overall health and performance. An understanding of the structure of the interactions can provide important information even in the absence of complete information on the component subsystems. This is critical in human spaceflight, since insufficient flight opportunities exist to elucidate the details of each subsystem.

Enabled by recent advances in noninvasive measurement of physiological and behavioral parameters, subsystem monitoring can be implemented within a mission and also during preflight training to establish baseline values and ranges. Coupled with appropriate mathematical modeling, this can provide real-time assessment of health and function, and detect early indications of imminent breakdown. Since the interconnected web of physiological systems (and crewmembers) can be interpreted as a network in mathematical terms, we can draw on recent work that relates the structure of such networks to their resilience (ability to self-organize in the face of perturbation).

There are many parameters and interactions to choose from. Normal variability is an established characteristic of a healthy physiological response. Healthy coupling has been investigated less extensively, but there are cases in which too tight or too loose coupling can be problematic. This might be in inter-individual behaviors, such as sleep cycles, coordination of work and meal times, and coupled motions during communication. Less apparent are couplings of physiological systems, nevertheless examples abound of coupled systems which might be monitored: cardio-respiratory rhythms; circadian rhythms, body temperature, and sleep; stress markers and cognition, sleep, and performance; profiles of biochemical markers related to immune function and nutritional status; sensorimotor aspects such as motion sickness, ataxia, reaction time, and manual control.

Tools for resilience are then the means to measure and analyze these parameters, incorporate them into appropriate models of normal variability and interconnectedness, and recognize when parameters or their couplings are outside of normal limits. What to do when a problem is identified depends on its nature. Changes can be made to crew procedures, work pacing, interpersonal interactions, sleep cycles, meal timing and content, as guided by the model. Use and continued development of these methods could not only provide tools for resilience, but also meaningful autonomous work for the crew on an extended flight.