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Operational Performance during Space Flight: Sensorimotor Influences

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ABSTRACT: The Central Nervous System/Behavioral Medicine/Sensorimotor (CBS) Integrated Research Plan describes methods to assess the combined, possibly synergistic, effects of concurrent exposures to spaceflight hazards that affect the central nervous system (CNS) and operationally relevant behaviour and performance. With this integrated strategy, NASA's Human Research Project (HRP) risks—the Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders (BMed) and the Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight—will be systematically identified and investigated (SM).

I. SENSORY MOTOR FUNCTIONS & SPACEFLIGHT

In many instances, distinctions between the constructions are fabricated. Even though the sensorimotor domain has benefited much from discipline specialisation, it is challenging to address the many constructs independently in a way that is accurate to the science and to the practical consequences. For instance, although balance, gaze control, movement, and vestibular function are all intimately connected, they are frequently treated as separate, distinct problems. Speaking of balance and movement would be incomplete without mentioning the vestibular system. Perception is another illustration. Perception has some role in almost every sensorimotor construct, including vestibular perception, which impacts balance. A vestibular effect, variations in microgravity affect how upright you perceive yourself to be. Once more, it is challenging to disentangle these distinct structures in terms of biomarkers and operational usefulness.

The many constructions interact, and they do so throughout a variety of time cycles. In contrast to other vestibular-mediated functions (such as the sensation of being truly at ease with the three-dimensional aspects of motion in a weightless environment), the most overt and acute forms of vestibular adaptation (related to space motion sickness) take place over the course of a few days. This is associated with the concept of interdependent constructions. The majority of sensorimotor actions and perceptions result from the concurrent activation of several different sensory systems. The use of both vestibular and visual information to govern gaze is a clear example (vestibulo-ocular reflex [VOR]). Another is the prominence of proprioceptive and kinesthetic impacts on posture and movement, in addition to vestibular and visual cues. Multiple stresses, including environmental, psychological, and physiological ones, are present at once during spaceflight. These have extensive and occasionally undetected effects on sensorimotor function, and they very likely also affect the capacity to change sensorimotor function in an adaptive way. Examples include how stress affects both motion sickness and motor learning. (Stress influences adaptation, which changes motor learning, which changes how quickly one recovers from motion sickness, which changes stress.) The linkages mentioned above, which create confounds, can make this challenging. Consider the enticing sign of nociception (pain perception), which can be measured in standardised methods and is supported by relevant animal models. However, it is obvious that the use of pain as a biomarker is challenging when one takes into account all the components that affect how pain is perceived. Similar time courses to those found in comparable situations on the ground are followed by certain adaptive sensorimotor changes that take place in space. For instance, the shifting contributions of vestibular, proprioceptive, and efference copy information during recovery from labyrinthectomy in an animal model have time courses that match recovery of motor control during locomotion following spaceflight (Cullen, 2019). (Mulavara et al., 2018). Similarly, tests conducted on the ground with animals reveal that the efference copy development over a period of weeks resembles the corresponding timeframe in astronauts' development of their three-dimensional spatial sense. These could

be components of the same underlying process, according to the comparable time courses. This might present potential for translating findings from animal models used on the ground and could help develop preadaptation paradigms for spaceflight. Nearly every individual construct demonstrates adaptable behaviours. The efficacy of these adaptive behaviours as biomarkers may be hampered since they will alter the response being measured as it adapts to spaceflight. Naturally, such adaptability is beneficial and ought to be encouraged, but it makes it more difficult to use the biomarker. This would be particularly true for missions with a long length when it's possible that the adaptation mechanisms are not well known. It would be ideal to have a particular biomarker for learning and adaptability. For instance, there is little to no evidence that the angular VOR varies much as a result of spaceflight or that any changes have an operational influence. It has, however, been extensively investigated and is simple to quantify.

II. NEURAL NETWORKS.

Neuronal circuit interpretation is not always simple. Animals, where the majority of the circuits have been defined, are not necessarily directly comparable to humans in terms of brain circuitry, and humans also experience adaptive changes that make it challenging to define conventional circuits. The interpretation of behavioural markers may be aided by understanding some circuit properties, such as neurotransmitters and common routes, as circuit function is implicitly assessed by behavioural measures. It is operationally important and directly links cognition and sensorimotor processes when there is a relationship between cognition and the vestibular system as well as impacts of the vestibular system on cognition. Many patients with vestibular issues exhibit this link. There isn't a precise framework for this, and coming up with a specific biomarker is challenging a few weeks.

III. CONCLUSION

Visual function is easily measured (i.e., acuity, visual fields, etc.), and these measures may help to parse out visual effects from motor effects when there is a functional deficit. Optical coherence tomography (in flight) can measure retinal change and produce a biomarker. It is obvious that these features are translatable because many of them can be evaluated in rodents, such as visual acuity in mice and even real-time visual tracking. Clearly, this serves as a helpful biomarker. It's crucial to be spatially oriented. The entorhinal cortex's grid cells, which support spatial orientation, were a major topic of discussion throughout the panel. These cells are crucial because they offer data that can be used to evaluate spatial orientation as it adjusts to changes in gravity, and because mice can access grid cells, this data is also applicable and transferable. As a result, neuronal networks in the medial entorhinal cortex and hippocampus can be found. There is a tonne of knowledge on vestibular function in space. Although higher-level derived functions (such as spatial orientation and tilt-translation perception) and central processing are frequently affected by space, basic vestibular function is not considerably impacted by it. However, it is crucial to take into account vestibular alterations in the context of the combined stresses of spaceflight. As was previously said, the VOR doesn't alter much in weightlessness, but it would still be helpful to evaluate the VOR in the context of other stressors (radiation, weariness, etc.); that is, what is the overall effect of all the stressors? These elements can be tested on animals and require further clarification (Dr. Cullen mentioned the narrow balance beam as a viable animal assessment). This biomarker is appropriate. One of the constructs with the greatest degree of interconnection and considerable overlap with other constructs was found to be proprioception. Little is known about how stress, such as radiation, affects the peripheral nervous system, which affects proprioception (this is a gap in knowledge). Because it is possible to evaluate proprioception in mice, a mouse model offers chances for translation (tape removal test, whisker test). This biomarker is appropriate. Hearing loss is frequently a side effect of spaceflight, possibly because of fluid movements. A hearing evaluation during flight could be useful for separating the effects of fluid shift and noise-induced loss. Hearing loss has not been a functional issue, thus the panel pointed out that these facts are not very significant from an operational standpoint. There is no priority for this marking. Motion sickness is a known issue that requires additional investigation since it can seriously impair performance when a person first enters a gravity field after a period of prolonged weightlessness. Susceptibility to motion sickness is still uncertain. This area of research may be explored in light of more current discoveries on brain learning and adaptation, or its relevance to certain operational tasks may be examined. We are unsure of the relationship between stress and motion sickness or how it affects astronauts' general health. In various circumstances, researchers have looked at how motion sickness, stress, and crew performance interact. Although this work has to be examined, considering how spaceflight is unique in its demands and several concurrent stresses, it would still be worthwhile to look into these impacts. There are several overlapping biomarkers

once more. Translatability is a problem since measuring motion sickness in rats is exceedingly challenging. Despite some translational aspect concerns, this is a helpful biomarker. As social beings, smell and taste are very significant to humans. They are also obviously significant in space. The wellbeing and operational effectiveness of astronauts are shared concepts. Olfaction and smell can serve as indicators of neurodegeneration. Loss of smell (anosmia) is a biomarker for neurodegeneration that can be easily examined in rats since it is an early indicator of Alzheimer's disease. This biomarker has a high rating. Important operational considerations include balance and posture. The overlap of several circuits for multisensory integration and motor control makes it difficult to separate their activities to specific brain circuits, which makes them troublesome as biomarkers. Because there are differences between the circuits and roles of two- and four-legged creatures, animal models can be rather tricky (humans). Locomotion is operationally useful and significant, just like posture and balance, yet there aren't many reliable animal models available. Instead of focusing on posture or movement, it could be helpful to think about static and dynamic balance management. Due to the numerous confounds, it is challenging to evaluate fine motor control. Changes in proprioception, hand-eye coordination, and other related aspects are examples of related issues that can affect fine motor performance. Although crucial for functionality, it may not be very pertinent for operational control duties, since there are no reliable animal models. This is a challenge as a discrete biomarker simply because of the numerous confounds. Since perception includes concepts like spatial orientation, depth perception, vestibular orientation, temporal perception, and others, it is actually a part of practically all other constructions. Although there are numerous overlaps, understanding this concept is crucial since it would address many other structures. Although proprioception can be affected and is a serious problem on its own, it is most crucial to treat it in the context of other stresses. It would be advantageous to take perception into account in this performance context since specific perception-related features have been noticed in spaceflight and can have an operational influence. Separating perceptual effects per se is still challenging. As a result, this was disregarded as a reliable identifier in and of itself. For the same reasons as stated above, the panel did not give gaze or pain a high ranking as biomarkers. The regulation of gaze can be included under vestibular function as it overlaps with vestibular function in many ways and has received almost as much research. Because there are differences between how pain is perceived and how it actually feels, it is not a suitable biomarker in and of itself. The sex of the person and other personal characteristics might affect nociception. Although there are blood biomarkers for inflammation that are linked to pain, pain itself is not a reliable distinct biomarker.

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