PREFACE

Why write this book? Of all the intricate components of the human body, the central nervous system is the most responsive to the environment, detecting and responding to changes immediately. Its complexity, however, also means that it is still one of nature's best-kept secrets. Considering that the exploration of space is often thought of as the final frontier in the discovery of our origin and the preparation for our future, ***Neuroscience in Space*** is a book addressing the last, and greatest, scientific frontier.

All living things on Earth have evolved in the presence of gravity and all of their biological systems have anatomical and physiological mechanisms designed to interpret and measure the force of gravity. However, in the near weightlessness of space, the sensory systems that provide basic information regarding linear acceleration no longer function as they did on Earth. As a result, most if not all, physiological systems dependent on the body's central nervous system are in flux until a new microgravity state is realized. This includes adaptation of basic life sustaining functions such as blood pressure control and cardiac function, as well as other critical functions for everyday activities including balance, coordinated movement in three-dimensional space, and the regulation of sleep. Bones that supported body weight on the ground no longer have that load to bear. They begin to lose mass and strength, as do weight-bearing and postural muscles in the legs. Reduced physical activity and a shift of fluids into the upper body combine to reduce cardiovascular capacity. While in space, cardiovascular, bone and muscle deconditioning does not present a serious problem. However, whether returning to Earth or landing on some other planet, the body's adaptation to microgravity increases the risk of bone fractures, reduces work capacity, and can result in severe balance disorders and even blackouts when standing.

Other significant changes take place in the central nervous systems of astronauts during and following exposure to microgravity. Space travelers are transported in vehicles that move in three-dimensional space and generate inertial forces that create environmental factors to which they are not accustomed, either by evolution or experience. The responses of the vestibular organs in the inner ear, as well the kinesthetic, pressure and touch receptors, may be altered by hyper- or hypogravity. These altered responses to inertial stimulation outside their normal physiological range, or, even within this range, signal appropriately for the force environment, but inappropriately for the other sensory systems. These changes can modify situational awareness, induce spatial disorientation, result in illusions of self-motion, trigger dizziness and vertigo, and bring about motion sickness. However, the plasticity of the central nervous system allows individuals to adapt to these altered sensory stimulus conditions, and after a few days in space the symptoms disappear. The price paid for this in-flight adaptation (what has become known as "space normal") is a deconditioning of antigravity responses necessary for effective living following a return to Earth or landing on Mars. The duration of these altered responses is function of the time spent in space. In order to minimize the impact of adaptation to microgravity on crew health and performance following long-duration space flight, effective countermeasures must be developed.

Since the first human space flight in 1961, extensive experimental and operational research has been performed to investigate these adaptive processes by looking at electrophysiological changes in neural activity, behavioral changes including movements of the eye or body segments compensating for head or visual surround, as well as changes in perception and spatial orientation. The results obtained during and after space flight have contributed to a better understanding of the functioning and adaptation of multi-sensory interaction within the central nervous system. It could be said that the microgravity environment of space flight provides the ideal laboratory to study the underlying function and interactions among physiological systems. This environment can only be improved by an ability to switch gravity on and off during flight. New concepts and questions about the functioning and adaptation of the balance system have been raised directly from results of studies conducted in space. For example, new knowledge of neuronal plasticity, the way nerve cells "re-wire" to compensate for disease or injury, has been gained from animal studies during space flight, and will allow insights into treatment of nervous system disorders.

If one were interested in studying space travel, one would have little difficulty finding descriptions of the early developments in the Soviet space activities, as well as of those who helped establish NASA and their efforts. Should one be more serious about studying the development of space programs, one can find libraries of information addressing the bureaucracy of space flight full of tomes written by mission managers and project engineers. A student of space studies can find a plethora of technical books describing the principals of propulsion and rocket development, orbital mechanics and astrodynamics, as well as books detailing the design of spacecraft and the ground stations required to control them and collect their data. Entire museums dedicated to the progression of flight technology, from the first brief aircraft flights to the development and assembly of the International Space Station, have been established world-wide. However, it is truly challenging for anyone to find a comprehensive history of the life sciences experiments that have been performed in space and the role that neuroscience has played in our quest for space flight.

Our intent and purpose of compiling this historical overview of neuroscience and its role in space flight serves two purposes. The first is to equip researchers with a single reference document compiling a representation of those neuroscience experiments that have been flown in space. The second is to highlight the accomplishments of many scientists who have contributed to the history of space neuroscience. It is our hope that insights generated by reading this book will greatly contribute to the future agenda of space neuroscience.

In a sense, this book originated in a small office in Paris, France when the authors were first introduced. From that initial meeting a shared interest for sensorimotor and vestibular function in space flight would come to define a collaboration that has lasted over 25 years.

We are indebted to all of those astronauts and cosmonauts who became the subjects for much of the work detailed in this book. In particular, we would like to acknowledge Patrick Baudry, Sonny Carter, Owen Garriott, Claudie Haigneré, Joe Kerwin, Bob Parker, Rhea Seddon, and William Thornton who have provided both guidance and inspiration.

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