Space Vestibulo-Neuroscience in the New Century

K.E.

Money

Defence and Civil Institute of Environmental Medicine, Downsview, Ont., Canada

Key Words

Spaceflight
Vestibular system
Otoliths
Semicircular canals
Orientation
Proprioception
Weightlessness
Motion sickness
Adaptation
Vection

Abstract

In the new century there will probably be more long spaceflights and fewer short spaceflights. There will probably be several flights to Mars, flights that (if chemical rockets are used) will involve one year to get there, a second year on Mars, and a third year to return. The **three-year** Mars scenario will probably include rotation of the spacecraft to provide artificial gravity. If nuclear thermal rockets are used, a manned exploration of Mars could be accomplished in less than one year. Vestibular research will be directed towards ensuring that astronauts, upon landing on Mars, will be able to walk with confidence and without delay. Research will be required to investigate vestibular adaptation in spaceflight, motion sickness, and the vestibular effects of rotation in spaceflight.

Dr. K.E. Money, DCIEM, PO Box 2000, Downsview, Ont., M3M 3B9 (Canada)

The forecast for vestibulo-neuroscience in the twenty-first century is for intense investigational activity and strong winds of change, especially in the early part of the century. The recent American presidential announcement of the intention to land humans on Mars within 50 years of the 1969 first landing on the moon, if the intention is realized, will necessitate advances in vestibular knowledge to achieve a safe and effective mission.

In all likelihood, the most important advances, the most important objectives, even the most important problems, have not yet been thought of. They will come into sight after we have climbed farther, and it is they that will determine the course of much of future research.

However, we can now clearly see a few steps of understanding that need to be taken, and they do suggest the directions that some vestibular research will take in the new century. These steps include studies of the unusual vestibular phenomena that occur in spaceflight and also the vestibular phenomena that occur after spaceflight (as a result of adaptation to the spaceflight conditions).

In spaceflight, phenomena of orientation (and vection), eye movements, vestibulo-spinal reflexes, proprioception, and motion sickness will no doubt require investigation. Orientation will be studied in order to understand the mechanisms of the inversion illusions sometimes reported by the cosmonauts, and to understand the mechanisms responsible for the general tendency to perceive down as where the feet are. Vection will continue to provide a measure of the change, with time in spaceflight, in the relative importance of the eyes and the vestibular apparatus in providing orientation information.

Eye movements in spaceflight, in response to vestibular inputs and optokinetic inputs, will continue to be studied for the quantitative information they can provide; they will tell us much about how the vestibulo-ocular reflex changes, and how the velocity storage mechanism changes, with time in weightlessness. They will also tell us how the influence of the different semicircular canals (horizontal vs. vertical) changes in spaceflight. Even resting torsional eye position and torsional eye movements

© 1993 S. Karger AG, Basel
0301-1569/93/0553-0173 \$2.75/0

will be studied in spaceflight to reveal how otolith function changes in weightlessness.

The otolithic influence on the H-reflex changes in weightlessness, and the H-reflex will continue to be studied in spaceflight for what it can tell us about how the vestibular system changes in spaceflight. The peculiarities of proprioception in spaceflight will also continue as objects of investigation, since they too are likely to reveal changes in neurological strategies that occur in spaceflight. Motion sickness will also persist as a problem requiring investigation.

It has been shown that labyrinthectomy causes defective responses to certain emetic poisons, and therefore it is reasonable to think that the vestibular system is normally part of a poison-response mechanism. (If the vestibular system is not part of a poison-response mechanism, then how can surgery on the ear drastically attenuate the emetic response to a poison injected into a muscle?) Apparently this poison-response mechanism can be activated by unnatural, conflicting or false information in the vestibular system to produce what is called motion sickness. (If the vestibular system is not part of a poison-response mechanism, then how can vestibular stimulation cause vomiting?) According to Treisman's theory, the conflicting information in the vestibular system simulates the early neurological dysfunction caused by poisoning. If motion sickness is in fact the activation of the vestibular part of a poison-response mechanism, then space sickness is in no sense a 'sickness' for which a cure can be found; it will persist stubbornly as the normal response of healthy people in an abnormal situation. In the new century, research should be done to acquire the ability to identify people who are deficient in this response and who are therefore resistant to space sickness. Research should be done to learn how to prehabituate (or pre-train, with autogenic techniques) those people who are normal in this respect, and how to speed up the habituation that occurs in flight. No doubt the search for better pharmacological approaches will also have to continue.

Although space sickness persisted for 14 days in one Soviet cosmonaut, it typically lasts for only the first 3 days of a flight and it should be a phenomenon of lesser importance for flights of longer duration. However, it will retain some degree of importance, since the first 3 days of longer flights will still occur, and the capability to do extravehicular activity during the first 3 days of spaceflights (not done now because of the threat of motion sickness in the EVA suit) could be important to the success of some missions.

After spaceflight, the process of vestibular readaptation to the normal 1 G environment will be studied using

most of the same techniques that were used in flight. There are additional hazards that will also need consideration in the new century, however, and they are the hazards of long-duration flights and the hazards of techniques that might be used to deal with some of the non-vestibular problems of long-duration flight. For example, some of the cosmonauts after long-duration flights have suffered motion sickness again upon stepping onto Earth; could this happen after a long-duration flight upon stepping onto Mars? What other vestibular phenomena might occur

upon stepping onto Mars or upon return to Earth? Postural or visual abnormalities upon stepping onto Mars could be extremely hazardous, as could motion sickness. If intermittent centrifugation is used during a year-long flight to Mars, to prevent loss of minerals from bone, what effect will it have on otolith function and on the ability to see and walk when stepping onto Mars? What effect would rotation of the whole spacecraft have on motion sickness early in the flight and on motion sickness after the flight? Even in the current shuttle flights there are vestibular changes picked up in orbit that would be hazardous if an emergency egress were required immediately after landing. How would these be altered by intermittent centrifugation or continuous rotation of the whole spacecraft during a long-duration flight?

Beyond Mars, it is possible that high levels of acceleration will be required for months in order to reach the more distant planets in a reasonable time. What would be the vestibular effects of adapting to these prolonged accelerations, and what would be the effects of stopping the acceleration? What would be the vestibular effects of walking under gravity after experiencing such prolonged accelerations? If deceleration in an atmosphere is used to save fuel, what would be the vestibular effects of very high G for a relatively long time? Might some otoconia come loose and get lodged in a cupula, and then might life under the gravity of a distant moon or planet be difficult? In the new century we shall need answers to some of these questions.

As knowledge of the basic physiology of the vestibular system on Earth grows, it will become easier to solve the vestibular problems of space flight. Therefore, some of the research in 'space vestibulo-neuroscience' in the new century will take place on Earth and will be directed toward understanding normal vestibular physiology. Also, some of the vestibular research in space will be directed toward understanding normal vestibular physiology. Weightlessness is a powerful tool that will make major contribution to studies of vestibular phenomena (including deficits and diseases) that occur on Earth.