Project B – Temporal Nature of Cognitive and Visuospatial Brain Domain Changes During Long-Duration Low-Earth Orbit Missions

HYPOCAMPUS IN I1YMP: SPATIAL COGNITION AND HIPPOCAMPAL PLASTICITY DURING LONG-DURATION LOW-EARTH ORBIT MISSIONS

A. C. Stahn[1], M. Basner[2], B.E. Riecke[3], T. Hartley[4], T. Wolbers[5], K. Brauns[1], A. Friedl-Werner[1,6], P. Denise[6], S. Besnard[6], H.C. Gunga[1], D.F. Dinges[2], M. Stangl[7], S. Kühn[8,9]

[1]Charité – Universitätsmedizin Berlin, Institute of Physiology, Berlin, Germany (alexander.stahn@charite.de); [2]Dept. of Psychiatry, University of Pennsylvania, Philadelphia, PA; [3]School of Interactive Arts & Technology (SIAT), Simon Fraser University, Surrey, Canada; [4]Dept. of Psychology, University of York, York, UK; [5]German Center for Neurodegenerative Diseases (DZNE), Magdeburg, Germany; [6]Université de Caen Normandie, 14000 Caen, France; [7]Semel Institute for Neuroscience and Human Behavior, University of California, Los Angeles (UCLA), CA; [8]Dept. of Psychiatry and Psychotherapy, University Medical Center Hamburg-Eppendorf, Hamburg, Germany; [9]Max-Planck-Institute for Human Development, Berlin, Germany

"From an evolutionary perspective, navigation—the ability to estimate one's own position and track and plan one's own path in physical space—is key to survival." [1]. As part of the ESA/DLR sponsored experiment *"HypoCampus – Impact of Long-Duration Spaceflight on Hippocampal Volume and Visuo-Spatial Memory"* we investigate the effects of 6-month space missions on spatial cognition and its neural basis, notably the hippocampal-entorhinal brain region and associated structures that control key processes for spatial learning, memory formation, and navigation.

Given the impact of visuospatial brain domain changes on neurobehavioral functioning, operations and safety during LDM (i.e., docking, landing, navigating on the planetary surface), spatial cognition and its neural basis warrant confirmation in a larger cohort of astronauts and during extended mission durations. The experiment was therefore selected as part of the integrated "One-Year Mission Project (i1YMP)", also referred to as "Complement of Integrated Protocols for Human Exploration Research (CIPHER)" to specifically target NASA's particular interest in studying the "Cognitive-perceptual-visuospatial brain domain changes due to isolation and confinement". The experiment is part of an international project consisting of two experiments (Project A and B) with synergistic aims that are being carried out in a joint effort by NASA and DLR/ESA.

Using a comprehensive cutting-edge neuroimaging protocol, including high-resolution hippocampal imaging, functional MRI tasks that specifically target the hippocampus; navigation tasks in a Martian environment to determine grid-cell like firing patterns of the entorhinal cortex; and a unique set of spatial navigation tasks in virtual environments, we will assess visuospatial brain domain changes and spatial cognition in the 30 crewmembers of the i1YMP during 2-, 6-, and 12-month ISS missions. We will perform brain imaging before and after the missions; assess spatial cognition before, during and after spaceflight; and determine key neurotrophic and growth factors at identical time points. These data will be compared within each astronaut and across astronauts to assess changes from pre- to post-flight as well as different phases during the mission. We will specify the relationships between the changes in hippocampal plasticity and visuospatial performance. We will also assess whether the biochemical data can predict changes in neuroplasticity and neurobehavioral coping during spaceflight. Following NASA's recommendation to complement CIPHER by long-duration isolation missions, we leverage our previous and ongoing research efforts by comparing the CIPHER data to our measures from historic and ongoing studies, investigating the effects of hippocampal and neurocognitive changes associated with long-duration overwintering in Antarctica. We will be able to compare study outcomes to isolation studies performed at the HERA facility (campaigns C3, C4 and C5) as well as bed rest studies, since the neuroimaging and cognitive measures largely overlap among studies. These data, comprising N>150 subjects studied in different ICC, ICE, and bed rest studies (30, 45, 60 days and 12 months) will also help to differentiate the impact of different stressors and significantly contribute to extrapolating the neurocognitive effects of LDM. Thus, the project will (1) demonstrate the impacts of isolation and environmental stressors on visuospatial brain domain changes and spatial navigation; (2) establish a normative baseline of these data for Deep Space Gateway and Deep Space Transport missions; (3) prove the presence or absence of unacceptable deleterious neurocognitive effects beyond the experience base of 6-month expedition; and (4) make predictions of adverse neurocognitive trends for LDM expeditions of up to 2-3 years.

Literature: [1] Focus on spatial cognition. Nat Neurosci 20, 1431 (2017).

Support: ESA, NASA, and DLR through grant 50WB2115.