Assessment of physical exercise benefits on brain health for long-duration spaceflight

Study Reference Number: 15-6301
Type of activity: Standard study (25/35 k€)

Project Summary

Objective

This project will investigate potential effects of physical exercise on brain health to derive potential exercise patterns for future human spaceflight.

Target university partner competences

Hibernation, sleep, EEG-collection and analysis, neuronal activity testing equipment, animal testing facilities

ACT provided competences

Biomimetics, Statistics, Programming, EEG analysis

Keywords

Brain, health, exercise, EEG, neuronal activity, hibernation

Study Objective

This study aims to investigate the fundamental neurophysiological basis of the relation between exercise and reported benefits to the brain.

The first objective is to establish if there are measurable effects of physical exercise on the brain by investigating differences in the brain activities associated with e.g. stress, learning, memory, decisiveness, social behaviour, depression (e.g. via EEG patterns of brain activity between periods of rest and exercise in human subjects and/or laboratory animals). In case such links were found, the second objective is to characterise and eventually classify the type of physical exercises with respect to their beneficial impact on the brain to derive preliminary recommendations.

Background and Study Motivation

Physical exercise is known to have numerous health benefits and has been shown to be effective in preventing or treating cardiovascular disorders, diabetes and cancer. Moreover, it is the main countermeasure to bone and muscle loss during space flight. Recently, the health benefits of physical exercise to the human brain have received increasing attention [1–3].

There is evidence for beneficial effects of physical exercise in neurodegenerative disorders, such as Alzheimer disease and it has been used successfully as a non-pharmacological therapy in mood disorders, such as depression. The underlying mechanisms are still unknown, but a recent study in

rodents suggested that it may involve changes in kynurenine metabolism [4]. Even in healthy individuals, exercise can affect cognitive functions substantially. For example, it has been shown that non-strenuous activities, like walking, can boost creativity by about 60% [5]. Exercise has also powerful psychological effects, which may be associated with changes in brain morphology. Specifically, an increased grey matter volume in the frontal, temporal, and parietal cortices has been reported in physically fit people. These parts of the brain are important for decision-making, creativity, problem-solving, executive functions, emotional regulation, memory, confidence, learning languages and processing sensory (e.g. auditory) information [6]. Important insights have been provided from studies in animal models. For example, it has been shown in mice that running leads to increased neurogenesis in the hippocampus – the brain area crucially implicated in memory and emotions [7]. Moreover, it has been shown in mice that during locomotion the signal-to-noise ratio in the visual stimulus detection increases.

Exercise is already considered important for the physical and mental health of astronauts that have to cope with substantial levels of stress during space missions. Leach-Huntoon et al. report on the importance of stress in human spaceflight and the significant elevations in the stress hormones during launch and after landing [8]. Vernikos et al. have recently hypothesized on the potential positive impact of the practice of Yoga breathing, stretching, relaxation techniques, and meditation to relief astronauts from physiological stress associated with the adaptation to spaceflight, as well as complement the effectiveness of physical counter measures, specifically focusing on stress relief before and during the flight, post-flight support and rehabilitation, and counteracting in-flight symptoms [9]. However, many fundamental questions remain to be addressed. The practical questions include the type of exercise which is most beneficial for the brain, and specific regimens, which on the one hand should not interfere with the daily routine of the astronauts, but on the other hand provide maximal effects. However, before practical questions can be answered, it is important to provide better understanding of the neurophysiological mechanisms underlying the positive effects of exercise on the brain.

Based on these indications, in this study we hypothesise that there are further benefits of physical exercise to human spaceflight and specifically mental conditions of astronauts. We furthermore hypothesise that some of these benefits might be accessible via the analysis of EEG patterns, which offer the potential of understanding fundamental relations between them. Based on recently published work by Peretti et al., we further hypothesise that there might also be parallels to brain activity patters observed in hibernating animals especially during their sleep phases. [10]

A better understanding of the relation of physical exercise and mental status would benefit the current human exploration plans beyond low Earth orbits.

Proposed Methodology

The following study logic is proposed, though the universities and research groups are invited to propose different approaches to achieve the main goals of the study.

- Collecting brain activity data from active and passive humans or animals – both during and after exercise
- Investigate neurophysiologic mechanisms underlying the observed effects of exercise on the brain
- Determine brain regions that are involved in both active and passive behaviour
- Investigate the effects of various forms/amount/intensity of exercise on specific cognitive functions and emotional regulation

- Compare effects of voluntary vs forced exercise on measures of mood, depression, anxiety and learning
- Investigate the temporal scale of benefits provided by exercise, such as immediate effects, delayed, chronic, etc.
- Combine exercise, such as walking on a treadmill with sensory and cognitive tasks.

ACT Contribution

This study is addressed to research groups having expertise in measuring EEG signals in animals or humans in relation to physical exercise.

The project will be conducted in close scientific collaboration with ESA researchers. In particular ESA researchers will provide support on the practical aspects of this study and will contribute to quantitative analysis of brain signals. ESA researchers will also provide technical and experimental knowledge of space-based exercise currently employed to ensure realistic newly proposed exercises. Finally, ESA researchers will reanalyse previously generated EEG-data already collected in experiments like Mars500 to back-up the conclusions generated.

Bibliography

[1] L. Bherer, K. I. Erickson, T. Liu-Ambrose, Journal of aging research 2013, 2013.
[2] J. E. Ahlskog, Y. E. Geda, N. R. Graff-Radford, R. C. Petersen, in Mayo Clinic Proceedings, 2011, pp. 876–884.
[3] M. W. Austin, M. Ploughman, L. Glynn, D. Corbett, Neuroscience research 2014, 87, 8.
[4] L. Z. Agudelo, T. Femenia, F. Orhan, M. Porsmyr-Palmertz, M. Goiny, V. Martinez-Redondo, J. C. Correia, M. Izadi, M. Bhat, I. Schuppe-Koistinen, others, Cell 2014, 159, 33.
[5] M. Oppezzo, D. L. Schwartz, American Psychological Association 2014, 40, 1142.
[6] W. D. Killgore, E. A. Olson, M. Weber, Nature, Scientific reports 2013, 3.
[7] H. Van Praag, T. Shubert, C. Zhao, F. H. Gage, The Journal of Neuroscience 2005, 25, 8680.
[8] C. Huntoon, N. Cintron, P. Whitson, Space Physiology and Medicine 1994, 334.
[9] J. Vernikos, A. Deepak, D. K. Sarkar, C. A. Rickards, V. A. Convertino, Gravitational and Space Research 2012, 26.
[10] Peretti, D., Bastide, A., Radford, H., Verity, N., Molloy, C., Martin, M.G., Moreno, J.A., Steinert, J.R., Smith, T., Dinsdale, D., et al. (2015). RBM3 mediates structural plasticity and protective effects of cooling in neurodegeneration. Nature.