The Institute of Aerospace Medicine at the German Aerospace Center (DLR) comprises departments in Cologne and in Hamburg with an internationally unique research expertise and infrastructure. At DLR, our Institute serves as interface between sophisticated technology and life sciences research including biology, medicine, and psychology. We conduct our research in close collaboration with leading national and international research institutions and industry. The long-standing experience of the Institute in selecting and caring for pilots, air traffic controllers, and astronauts in particular directly after return to Earth provides a solid foundation guiding our research efforts. Mechanism-oriented human research, which is a particular strength of our Institute, is fostered by the state-of-the-art research infrastructure at the :envihab facility. Systematic ground-based studies in radiation, astro- and gravitational biology in dedicated simulation facilities are complemented by successful investigations in space. Our overarching goal is to conduct research that improves the human healthspan in space, in aeronautics, and on Earth.

The present report exemplifies our research activities in 2019. One of the major tasks this year was planning and executing two AGBRESA (Artificial Gravity Bed Rest Study) bed rest study campaigns, which we carried out together with NASA and ESA. In each campaign, twelve volunteers spent a total of three months with us, of those two months in strict head-down bed rest. In collaboration with more than 100 international scientists, many sophisticated experiments and examinations were conducted ranging from microbiota profiling to state-of-the-art brain imaging and cognitive testing. The endeavor illustrates our interdisciplinary and translational research approach. However, we were also involved in many other research activities in space, in aeronautics, and on Earth as shown in this report. We are very grateful for all the support from collaborators and funding agencies and look forward to tackle future challenges.
# Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>03</td>
</tr>
<tr>
<td><strong>Cardiovascular Aerospace Medicine</strong></td>
<td>07</td>
</tr>
<tr>
<td>Möstl, S. et al.: PW-Doppler from the suprasternal notch underestimates aortic blood flow velocity compared to MRI</td>
<td>08</td>
</tr>
<tr>
<td>Plath, G. et al.: Battery-driven microneurography amplifier for sympathetic nerve recordings</td>
<td>10</td>
</tr>
<tr>
<td>Gerlach, D. et al.: Hypoxic challenge activates human sympathetic brainstem and hypothalamic sites</td>
<td>12</td>
</tr>
<tr>
<td>Hoffmann, F. et al.: Early vascular ageing biomarkers following long-term space flights: An oscillometric approach</td>
<td>14</td>
</tr>
<tr>
<td><strong>Muscle and Bone Metabolism</strong></td>
<td>17</td>
</tr>
<tr>
<td>Mittag, U.; Rittweger, J.: In-silico simulation of vertical jumping in lunar gravity</td>
<td>18</td>
</tr>
<tr>
<td>Michély, S. et al.: Contraction-related muscle fascicle dynamics in masters athletes between 35 and 95 years of age</td>
<td>20</td>
</tr>
<tr>
<td>Thot, G. et al.: AGBRESA study: Intramuscular connective tissue in soleus muscle before and after 60 days of bed rest</td>
<td>22</td>
</tr>
<tr>
<td><strong>Sleep and Human Factors</strong></td>
<td>25</td>
</tr>
<tr>
<td>Elmenhorst, E.-M. et al.: Combined effects of sleep restriction and sleep deprivation on cognitive performance and glucose tolerance</td>
<td>26</td>
</tr>
<tr>
<td>Mühl, C. et al.: Trading accuracy for speed in selective attention tasks during sleep deprivation</td>
<td>28</td>
</tr>
<tr>
<td>De Gioannis, R. et al.: Effects of increased ambient carbon dioxide and hypobaric hypoxia on blood oxygenation</td>
<td>30</td>
</tr>
<tr>
<td>Bartels, S. et al.: Effects of nocturnal aircraft noise on objective and subjective sleep quality in primary school children</td>
<td>32</td>
</tr>
<tr>
<td>Weidenfeld, S. et al.: Noise annoyance due to nighttime traffic: Role of the noise source and the acoustical metric</td>
<td>34</td>
</tr>
<tr>
<td>Rooney, D. et al.: Speech intelligibility and pressure changes: implications for next-generation train travel</td>
<td>36</td>
</tr>
<tr>
<td><strong>Clinical Aerospace Medicine</strong></td>
<td>39</td>
</tr>
<tr>
<td>Stern, C. et al.: Research in bed rest: The challenge of eye examination in the supine position</td>
<td>40</td>
</tr>
<tr>
<td>Stern, C. et al.: Does refraction change during 60 days of -6° headdown tilt bed rest as it does in astronauts?</td>
<td>42</td>
</tr>
<tr>
<td><strong>Study Team</strong></td>
<td>45</td>
</tr>
<tr>
<td>Ewald, A. et al.: Alterations in resting metabolic rate in the course of a sixty days bed rest study</td>
<td>46</td>
</tr>
<tr>
<td>Nitsche, A. et al.: Recruitment of test subjects for (long-term) bed rest studies – management and challenges</td>
<td>48</td>
</tr>
<tr>
<td><strong>Aviation and Space Psychology</strong></td>
<td>51</td>
</tr>
<tr>
<td>Elßfeldt, H.; Vogelpohl, V.: Drone acceptance and noise concerns</td>
<td>52</td>
</tr>
<tr>
<td>Gayraud, K. et al.: Eye tracking in the context of air traffic controller selection</td>
<td>54</td>
</tr>
</tbody>
</table>
Möstl, S. et al.: PW-Doppler from the suprasternal notch underestimates aortic blood flow velocity compared to MRI 08

Plath, G. et al.: Battery-driven microneurography amplifier for sympathetic nerve recordings 10

Gerlach, D. et al.: Hypoxic challenge activates human sympathetic brainstem and hypothalamic sites 12

Hoffmann, F. et al.: Early vascular ageing biomarkers following long-term space flights: An oscillometric approach 14
PW-Doppler from the suprasternal notch underestimates aortic blood flow velocity compared to MRI

S. Möstl¹, I. Naendrup¹,², F. Hoffmann¹,³, K. Kempter¹, A. von Waechter¹, J. Jordan¹, J. Tank¹

¹Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany, ²University Duisburg-Essen, Faculty of Engineering, Duisburg, Germany, ³University Hospital Cologne, Department of Cardiology, Cologne, Germany

Fig. 1: Triangulation for calculating the distance (green dashed line, hypotenuse) between the suprasternal notch (1) and the acquisition point of 2DMRI (green line) in order to compare it with the insonation depth of the sCD. Orange solid line represents the distance between the suprasternal notch and the corresponding MRI plane containing the ascending aorta and therefore equals the amount of slices in between. Accordingly, the orange dashed line represents the distance between this transferred point of the suprasternal notch (2) and the 2DMRI acquisition plane.

Background
Continuous pulsed-wave Doppler readings of flow velocity in the ascending aorta from the suprasternal position (sCD) are widely used in estimating stroke volume, particularly during physiological challenge maneuvers such as head-up tilt testing. Stroke volume is derived from velocity time integrals and vessel area. We compared the sCD against an established gold standard.

Methods
In 12 healthy women and men, we obtained 2D cross sectional, velocity encoded phase contrast MRI of the ascending aorta (2DMRI) and sCD to measure mean blood flow velocity (Vmean) at the ascending aorta. We compared sCD insonation depth to the distance between Doppler probe and sinotubular junction measured by MRI (Fig. 1). Within an aortic 4D-Flow dataset, allowing
flow measurements in every anatomical point along the ascending aorta, $V_{\text{mean}}$ was determined at the sCD measurement point for comparison (Fig. 2).

**Results**

sCD significantly underestimated $V_{\text{mean}}$ compared with 2DMRI at the sinotubular junction ($V_{\text{mean 2DMRI}} - V_{\text{mean sCD}} = 24.42 \text{ cm/s} \pm 12.55 \text{ cm/s}$, $p = <0.001$). Moreover, sCD sampled flow velocities $21.8 \text{ mm} \pm 7\text{ mm}$ ($p = <0.001$) or 26% off the sinotubular junction. Yet, depth and velocity differences between sCD and 2DMRI were not correlated with each other (Pearson $r = -0.147$; $p = 0.648$). When we applied 4DMRI to assess flow velocity at the sCD measurement site, the $V_{\text{mean}}$ difference between methodologies was reduced to $9.1 \text{ cm/s} \pm 12.38 \text{ cm/s}$ ($p = 0.035$).

**Conclusion**

sCD profoundly underestimates $V_{\text{mean}}$ in the ascending aorta compared to 4DMRI. The methodology has important limitations in accessing the ideal position for aortic flow measurements and precise information regarding the position of data acquisition for vessel area quantification cannot be ascertained. Overall, sCD is of limited utility in measuring absolute stroke volume.

Corresponding author: stefan.moestl@dlr.de
The autonomic nervous system (ANS) plays a crucial role in cardiovascular regulation. Depending on the dysfunctional subsystem, ANS malfunction is associated with a variety of conditions, e.g. autonomic failure or baroreflex failure. There are several methods to assess ANS integrity in human volunteers or patients with their pros and cons.

Microneurography is an advanced technique to directly record electrical potentials in nerves to determine the activity of the sympathetic part of the ANS. The technique has been developed 50 years ago. A very fine tungsten microelectrode is advanced through the skin into a nerve, e.g. the peroneal nerve in the hollow of the knee. The peroneal nerve consists of several thou-
Fig. 4: Original recording of muscle sympathetic nerve activity (MSNA) in a diabetic patient with C fibers still intact. Asterisks: An arrhythmic event with a slightly lower-than-normal diastolic pressure triggers a prominent sympathetic burst. This burst causes blood pressure to increase during the next heart beats which in turn silences the MSNA (S).

Cardiovascular Aerospace Medicine

Thousands of single nerve fibers with different functions. Fibers that regulate blood pressure by adjusting the diameter of blood vessels are extremely thin. The diameter of these so-called C fibers is about 1 µm which is ~50 times smaller than a normal human hair.

The amplitude of nerve fiber action potentials depends on the thickness and myelination of these fibers. Therefore, the thin and unmyelinated C fibers that we are interested in produce only very small action potentials with amplitudes of ~10 µV which are hard to measure. For comparison ECG R waves are more than 100 times as high. Recording C fiber activity requires amplifiers with high input impedance and low inherent noise.

We tried to design and build a microneurography amplifier that combines the favorable features of three existing devices. (Fig. 1-3). We decided to test and optimize the amplifier components step-by-step. So far, tests of the preamplifier proved its compatibility to the preamplifier of the Iowa University Bioengineering Department that we used extensively in the past (Fig. 4). The amplifier’s main unit offers additional features, e.g. simultaneous analog output of nerve signals with different band width. We are confident that these features will optimize sympathetic recordings and subsequent digital signal processing.

Corresponding author: karsten.heusser@dlr.de
Hypoxic challenge activates human sympathetic brainstem and hypothalamic sites

D. Gerlach¹, J. Manuel², A. Hoff¹, H. Kronsbein¹, F. Hoffmann¹, K. Heusser¹, H. Ehmke³, J. Jordan¹,², F. Beissner², J. Tank¹

¹ Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany; ² Institute for Neuroradiology, Hannover Medical School, Hannover, Germany; ³ Institute of Cellular and Integrative Physiology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

Background
Peripheral carotid chemoreceptors, which raise sympathetic activation at the brainstem level, may be altered through atmospheric condition and are further affected by weightlessness-induced neural plasticity. However, human peripheral chemoreflex regulation in the brainstem is poorly understood due to the lack of suitable methodologies. Therefore, we combined measurements of beat-by-beat blood pressure and SpO₂ and high-resolution functional magnetic resonance imaging (fMRI) to elucidate human brainstem circuits engaged through hypoxic peripheral chemoreceptor activation.

Method and Material
We submitted 12 healthy men (29.7 ±6.6 years; 24.0 ±1.86 kg/m²) to five hypoxic episodes by breathing 10% oxygen for 180 seconds followed by 90 seconds normoxia during multiband fMRI brain acquisitions. We monitored continuous finger arterial blood pressure using customized hardware, ECG, and SpO₂. Brainstem and hypothalamic fMRI images were analyzed to identify nuclei involved in peripheral chemoreflex processing. Systolic blood pressure (SBP) and SpO₂ time courses were correlated with the blood-oxygen-level-dependent signals with a general linear model.

Fig. 1: General linear model analysis reveals hypothalamic activation: paraventricular nucleus (PVN), anterior hypothalamic area (AH), dorsomedial hypothalamic nucleus (DMH), lateral hypothalamic area (LH), and supraoptic nucleus (SO).

Results

With hypoxia, SpO\textsubscript{2} decreased by 12.32 ±3.68\% (p < 0.01), heart rate increased by 13.86 ±3.47 (p < 0.01), and SBP decreased with hypoxia by 5.45 ±5.5 mmHg (p < 0.01). In the brainstem, the nucleus tractus solitarii (t-values: SpO\textsubscript{2}: 5.9; SBP: 4.79), the caudal ventrolateral medulla (SBP: 5.59), intermediate reticular nucleus (SBP: 5.98), nucleus ambiguus (SBP: 5.59), dorsal motor nucleus of the vagal nerve (SBP: 4.79), and inferior olive (SpO\textsubscript{2}: 4.7; SBP: 6.16) were identified with high sensitivity and corrected for multiple comparisons (p < 0.01). Furthermore, we observed an activation of the following hypothalamic nuclei: paraventricular nucleus (SpO\textsubscript{2}: 7.67), anterior and lateral hypothalamic area (SpO\textsubscript{2}: 7.67, SBP: 4.79), supraoptic nucleus and tuberomammillary nucleus (SpO\textsubscript{2}: 7.07).

Conclusion

High-resolution brainstem fMRI during repeated hypoxia traces brainstem circuits engaged by peripheral chemoreceptors. This methodology allows the analysis of neural adaptation to atmospheric conditioning and short- and long term weightlessness. Furthermore, the understanding of the peripheral chemoreceptor contributions to human cardiovascular disease may enlighten not only antihypertensive therapy.

Corresponding author: darius.gerlach@dlr.de

---

Fig. 2: Masked independent component analysis (mICA) of the lower brainstem activation reveals one component with the left rostral ventrolateral medulla (rVLM), the nucleus tractus solitarii (NTS) and the interior olive (IO) that have the same signal fluctuation, thus are connected to each other. This approach decomposes the BOLD signal into spatially independent components where each independent component consists of voxels that show similar signal fluctuations. Correlation of the component time course with the SpO\textsubscript{2} time course have a highly significant match (p< 0.0001: Z = 16.07). Left: transversal lower brainstem slices and the corresponding atlas slice. Middle: BOLD overlay with the brainstem atlas. Right: sagittal view of the brainstem with marked corresponding transversal slices. A: anterior, P: posterior, L: left, R: right.
Early vascular ageing biomarkers following long-term space flights: An oscillometric approach

F. Hoffmann\(^1,2\), S. Möstl\(^1\), E. Luchitskaya\(^3\), I. Funtova\(^3\), J. Jordan\(^1\), R. Baevsky\(^3\), J. Tank\(^1\)

\(^1\)Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany, \(^2\)Clinic III for Internal Medicine, Heart Center University of Cologne, Cologne, Germany, \(^3\)Federal State Budgetary Research Institution, State Scientific Center of the Russian Federation, Institute of Biomedical Problems, Russian Academy of Sciences, Moscow, Russian Federation

Purpose
The environmental conditions in space, particularly exposure to cosmic radiation, coupled with micro-gravity induced decreased mobility, altered glucose metabolism, and hemodynamic changes may promote cardiovascular disease \([1, 2]\). Therefore, we assessed early vascular ageing markers and hemodynamics using a novel oscillometric blood pressure device.

Methodology
In eight cosmonauts (46.5±5.3 yrs, 77.6±8.2 kg, 176±6.2 cm, 7 men/1woman), we determined heart rate, peripheral blood pressure, central blood pressure, and pulse wave velocity in the supine position using an oscillometric brachial device coupled with transfer function analysis (Fig. 1). We obtained measurements at baseline (65-90 days before flight) and four days (R+4) and eight days (R+8) after return from a six months mission on-board the International Space Station.

Results
Compared to baseline, heart rate increased significantly on R+4 (58.6±6.4 vs. 70.3±5.2 bpm) but did not differ between baseline and R+8. Central systolic blood pressure increased from 112.5±13.5 on baseline to 125.6±18.5 on R+4 and went back to 121.6±9.5 mmHg on R+8, albeit showing no statistical significance compared to baseline \((p=0.243/0.295)\). Peripheral diastolic and systolic as well as central diastolic blood pressure measurements followed this trend. Pulse wave velocity increased non-significantly from baseline (6.7±0.8

Fig. 1: On the left side: The Mobil-O-Graph PWA® (I.E.M., Stolberg, Germany) used for oscillometric measurements and calculation of hemodynamic parameters. On the right side: The Mobil-O-Graph measures the peripheral pulse wave and calculates the central pulse wave with pressure values under guidance of an assumed model of the central flow in the ascending aorta.
m/s) to R+4 (7.2±0.8 m/s, p=0.499) and stayed elevated on R+8 (7.1±0.5 m/s, p=0.614). See Fig. 2 for results and trends.

Conclusion
The important finding of our study is that six months in a near-earth orbit do not lead to clinically significant changes in early vascular ageing biomarkers, such as pulse wave velocity which is deemed to be of clinical importance in cardiovascular health assessment [3]. However, these findings cannot be extrapolated to the conditions encountered in deep space, especially in terms of longer flight durations and greater exposure to radiation. Non-invasive testing of vascular biomarkers may have utility in detecting vascular risks during space travel at an early stage.

Fig. 2: Individual data on heart rate (A), pulse wave velocity (B), central systolic blood pressure (C), peripheral systolic blood pressure (D), central diastolic blood pressure (E), and peripheral diastolic blood pressure (F), all sorted by time point. PRE: 90 to 65 days before flight; R+4/ R+8: post flight measurements four/eight days after return.

References
Muscle and Bone Metabolism

Mittag, U.; Rittweger, J.: In-silico simulation of vertical jumping in lunar gravity 18

Michély, S. et al.: Contraction-related muscle fascicle dynamics in masters athletes between 35 and 95 years of age 20

Thot, G. et al.: AGBRESA study: Intramuscular connective tissue in soleus muscle before and after 60 days of bed rest 22
New space flight programs of NASA and ESA foresee a return to the Moon during the next decade. Unlike the Apollo missions in the 1970s, the plan is to go beyond short visits with tiny lunar landers that allowed for not more than small trips in full EVA dress in the near environment. Rather, there shall be a lunar base for residing in a shirt sleeve environment. For the Apollo astronauts moving on Moon was a big challenge, due to the unusual gravity conditions in combination with the heavy and stiff space suits. In the future lunar base, the space suit will be off and the lunarians can freely move. Ballistic equation dictates that the jump height and air-borne time on Moon, for a given take-off velocity, will be six times higher than on Earth (neglecting any air drag). But what about the push-up phase? Will take-off speed be affected by gravity? In a first approach we might assume that kinematics and dynamics of the body segments will be similar on Moon and Earth, leading to the expression:

\[ h_{\text{max}} = \frac{g_E}{g_M} h_{\text{maxE}} + h_{\text{rvp}} \left( \frac{g_E - g_M}{g_M} \right) \]  \hspace{1cm} (1)

where \( g_E \) and \( g_M \) are the gravitational accelerations on Earth and Moon, \( h_{\text{max}} \) being the range of the push-up in terms of the total center of mass (COM). While the first term reflects the \( g_E / g_M \) dependency of the basic ballistics, the second term results from reduced potential energy, as only a sixth of it is required on Moon for rising the COM by \( h_{\text{rvp}} \) during push-up. As a consequence, dynamics will be faster on the Moon. However, muscle contractile force is inversely related to contraction velocity. How can we estimate these factors? Computer modelling is an opportune means to investigate dynamics under conditions that are not easily achievable in reality. We introduced a simple four-segment model adapting a model [1] and compared it with similar models [2-3]. For integration of equations of motion we used a leap frog algorithm, a standard second order method for numerical simulation. The model was implemented in Python 3.7/Sympy and validated by checking conservation of total energy and by keeping a stable squatted position over half a second.

Fig. 1: Illustration of the model. A) Scheme of the multi body model with four rigid segments in this study based on a model approach described in [1]. P1 is fixed on ground; the global coordinate system is as depicted with origin in P1; 3rd dimension is needed for rotational vectors as z perpendicular to the plane. B) 3D plot of the moment-to-joint angle and moment-to-joint extension-velocity (omega) relationship was taken from [2], and is here exemplified for the knee. Integration step was 0.25ms.
We used the simulation parameters of [2] in its L3/T3/H3 posture combination. Motor coordination across the different joints was modelled by applying the bang-bang approach [3]. This method varies the timely onset of full activation for the three different joint moments. Any simulation run was stopped when ground reaction force vanished (take-off). We proceeded in two steps with increasing grid resolution (50 and 6.25 ms) to find an optimal triple of best onset times (BOT) for the maximum vertical velocity at take-off. Results are shown in table 1.

Table 1 Results; best onset times (BOT) show opposite orders for knee and hip extensor activation on Earth and on the Moon: jump height and duration of air-borne phase were calculated from maximal $v_{ymax}$ using ballistic equation; efficiency is total vertical work divided by joint extension work; horizontal work was low for the optimized solutions.

<table>
<thead>
<tr>
<th></th>
<th>BOT ankle [ms]</th>
<th>BOT knee [ms]</th>
<th>BOT hip [ms]</th>
<th>$v_{ymax}$ [m/s]</th>
<th>Jump height [cm]</th>
<th>Duration air-borne phase [s]</th>
<th>Total Vertical work [J]</th>
<th>Joint extension work [J]</th>
<th>Efficiency [%]</th>
<th>Push-up Range COM $h_{rp}$ [cm]</th>
<th>Net push-up time [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth</td>
<td>18.8</td>
<td>56.3</td>
<td>50</td>
<td>2.33</td>
<td>28</td>
<td>0.48</td>
<td>520.7</td>
<td>697.9</td>
<td>79</td>
<td>35</td>
<td>200</td>
</tr>
<tr>
<td>Moon</td>
<td>0</td>
<td>25</td>
<td>12.5</td>
<td>2.93</td>
<td>265</td>
<td>3.62</td>
<td>409.6</td>
<td>517.5</td>
<td>79</td>
<td>33</td>
<td>155</td>
</tr>
<tr>
<td>predicted for moon eq. (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 B shows that in both cases the acceleration phase starts with a delay. Obviously time is needed to optimize the orientation pattern of the segments. The durations of the net push-phases (between blue bars) are approximately 200 ms on Earth and 155 ms on Moon. The stick figures in Fig. 2 A for Moon show larger distances in the final push-phase indicating higher speed. Results for jump height on Moon (265 cm) were quite in the middle of expectations based on purely ballistic effects (168 cm, i.e. the sixfold as on Earth) and expectations from equation (2) (342 cm). The main reason for over-estimation by equation (1) seems to be of the higher angular joint speeds (and reduced torques) reducing the joint extension work generated during push-up by 25%. Interestingly, BOTs for knee and hip extensors are in opposite order on Moon and on Earth (Table 1), indicating that the motor control strategy needs to be adapted on the moon.

In conclusion, the push phase before vertical jumps may be associated with smaller musculo-skeletal forces on the Moon, and jump height and air-borne time will be increased significantly more than six-fold. Future research shall establish whether prolonged flight time constitute an occupational hazard. Second, we will extend our focus onto hopping as a potential countermeasure exercise strategy.

Corresponding author: uwe.mittag@dlr.de

References
2. Selbie & Caldwell, Biomech. 9, 1996
3. van Soest, A et al., J. Biomech.26, 1993
It is well known that the human body is subject to a number of changes during the ageing process. Thus, skeletal muscle mass, power and strength all decline [1]. Little is known about muscular connective tissue, and it seems straightforward to assume that alterations in muscular connective tissue will affect muscle fascicle dynamics at old age. Theoretically, this could affect the muscle fascicles’ working range, the effectiveness of internal force transmission and thereby contribute to the age-related decline in muscle power output.

We decided to study the interrelationship between muscle fascicle dynamics, force generation and ageing in masters athletes. These are people who train for and compete in athletics beyond their fourth decade of life. As they depict very little sedentarism even at old age, they are an ideal population for the study of ageing. It was hypothesized that the working range of muscle fascicles, assessed as the contraction-related change in fascicle pennation angle between 5% and 95% of the maximum contractile force, is affected by ageing.

We conducted this study from 4th to 16th of September 2018 during the World Master Athletics Championships (WMAC) in Málaga, Spain. In total, 200 competing athletes aged 35 to 95 years were recruited into this study.

Our participants performed gradually increasing plantar flexion contractions in a dynamometer, with a clinical ultrasound probe attached over the fascicles of the right medial gastrocnemius muscle in the sagittal plane in B-mode.

The way in which the muscle fascicles are organized forms the macro architecture of a muscle. This architecture is made visible on the ultrasound image by longitudinal measurements [2].

Preliminary Results

Whilst statistical analyses are still under way, first results obtained so far show that there is a tendency that in endurance athletes (runners & walkers) the range of motion of the fascicle increases with age, in contrast to the fascicle range, which decreases in power athletes (sprinter & throwers) in old age. In addition, the stroke range was smaller in women than in men.

Apart to the initial hypothesis, which had surmised the straight alignment of the fascicles in the muscle, we also found fascinating other fascicle forms (Fig. 1). This had not been formerly reported in literature.

Thus, in many cases fascicles were straight at rest, but strongly curved during contraction. Currently, we are working on the systematic quantification

![Fig. 1: Overview of ultrasound images of four medialis gastrocnemius muscles in four athletes (No.1-4) during isometric plantar flexions contractions each at 0%, 55% and 100% MVC (maximum voluntary contraction).](image-url)
of curvi-linear fascicle shapes, to then explore possible relationships with age, gender, training history or athletic specialization.

Findings of an additional muscle
A separate fascicle or a head which runs with or in the heads of the gastrocnemius muscle is known as the caput tertium or gastrocnemius tertius muscle, has been first described in the 17th century [5]. Connected to the lateral part of the gastrocnemius, an accessor muscle is more frequently found than in the medial gastrocnemius [3]. It is therefore a rare phenomenon with different prevalence present in the respective populations [5]. We found an additional muscle at the medial gastrocnemius in 4% (8 out of 200) of the scanned athletes. The additional head was always characterized by an opposite feathering to the gastrocnemius medialis. In our cases, the appearance varied from a common aponeurosis with a divided intermediate tendon to a separate muscle differentiated from the gastrocnemius medialis (Fig. 2).

Clinically, this finding also has significance an additional head at the gastrocnemius medialis, as opposed to the lateral gastrocnemius, is said to be the cause of the popliteal vascular entrapment syndrome [4]. Particularly among athletes, more cases of entrapment syndromes in the popliteal fossa have been described in recent years. An early diagnosis and treatment is of great importance to avoid vascular complications and to support the early rehabilitation of athletes [6].

References
[5] Liu et al., Skeletal Radiol. 34, 2005

Fig. 2: Ultrasound images of the accessor muscle in the MAFS-18 athletes. An overview of the different appearance of the gastrocnemius tertius (GT), part of the gastrocnemius medialis (GM) and the soleus muscle (Sol).
AGBRESA study: Intramuscular connective tissue in soleus muscle before and after 60 days of bed rest

G. Thot¹, C. Berwanger¹, E. Mulder¹, J. Lee¹, B. Ganse², H. Degens², I. Duran³, E. Schönau³, C. S. Clemen⁴,⁵,⁶, B. Brachvogel³, J. Rittweger¹⁷

¹Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany, ²Manchester Metropolitan University, Manchester, United Kingdom, ³Center of Prevention and Rehabilitation, Cologne University Hospital and Medical Faculty, Germany, ⁴Institute of Biochemistry I, Medical Faculty, University of Cologne, Cologne, Germany, ⁵Institute of Neuropathology, University Hospital Erlangen, Germany, ⁶Institute of Vegetative Physiology, Medical Faculty, University of Cologne, Cologne, Germany, ⁷Department of Pediatrics and Adolescent Medicine, University of Cologne, Cologne, Germany

Scant knowledge on intramuscular force transmission exists. It has been proposed that endomysium plays an important role therein. Endomysium is the smallest component of the intramuscular connective tissue network and engulfs each individual muscle fiber. Perimysium engulfs muscle bundles, while epimysium engulfs the entire muscle. Previous studies [1] on mice demonstrated an increase in intramuscular connective tissue during long-term immobilization while muscle fibers atrophied. No studies have to date confirmed this effect in humans. We therefore hypothesized that endomysium content increases in the human soleus muscle in response to long-term immobilization using the 60-day AGBRESA bed rest study.

The AGBRESA study was conducted in collaboration between NASA, ESA and the German Aerospace Center. The object of the AGBRESA study was to determine the effectiveness of artificial gravity as provided by a human short-arm centrifuge as a countermeasure to the negative effects of microgravity on the human body. Two different protocols of continuous and intermittent centrifugation with 1g at the center of mass were thereby compared to a control group. The AGBRESA study included a ground-based version of Sarcolab-3 being performed on the ISS. Biopsies were thereby taken from the soleus muscle of 11 healthy subjects (8 males and 3 females) at baseline (BDC) and during the 6th and 55th day of head down tilt bed rest (HDT6 and HDT55) under sterile conditions.

Fig. 1: Immunofluorescence staining of a soleus muscle biopsy showing basement membrane (laminin in green) and nuclei (blue).
We chose to examine the soleus muscle because it shows significant changes when deprived of its physiological function as a load-bearing muscle. Biopsies were snap-frozen in liquid nitrogen after extraction and sectioned on a cryostat at -20 °C to slices of 8 µm. Slices were stained by indirect immunofluorescence using an antibody against laminin subunit gamma-1 which stained the basement membrane of the muscle fibers. The area between the basement membranes was used to determine the intramuscular connective tissue area. Sections were viewed and photographed with a Zeiss Observer Z1 microscope and the integrated ZENdesk 2.6 software. The area of the connective tissue network as well as the length of the connective tissue network were computed to approximate the endomysium to fiber area ratio and the endomysium thickness.

Preliminary results are based on the first AGBRESA campaign and show an increased endomysium to fiber area ratio on day 6 (p < 0.05), which ratio became even more evident on day 55 (p < 0.001). Endomysium thickness showed the same change.

To exclude the possibility that these results were merely based on artefacts of muscle fiber atrophy, the endomysium to fiber number was additionally calculated. This factor increased on day 55 (p < 0.05), but showed no significant increase on day 6 (p = 0.12). These results demonstrate that the increase of intramuscular connective tissue in the soleus muscle of humans during long-term immobilization cannot solely be explained through muscle fiber atrophy.

These results will need to be confirmed by further analysis after the second AGBRESA campaign has been completed.

Corresponding author: georgina.thot@dlr.de

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elmenhorst, E.-M. et al.: Combined effects of sleep restriction and sleep deprivation on cognitive performance and glucose tolerance</td>
<td>26</td>
</tr>
<tr>
<td>Mühl, C. et al.: Trading accuracy for speed in selective attention tasks during sleep deprivation</td>
<td>28</td>
</tr>
<tr>
<td>De Gioannis, R. et al.: Effects of increased ambient carbon dioxide and hypobaric hypoxia on blood oxygenation</td>
<td>30</td>
</tr>
<tr>
<td>Bartels, S. et al.: Effects of nocturnal aircraft noise on objective and subjective sleep quality in primary school children</td>
<td>32</td>
</tr>
<tr>
<td>Weidenfeld, S. et al.: Noise annoyance due to nighttime traffic: Role of the noise source and the acoustical metric</td>
<td>34</td>
</tr>
<tr>
<td>Rooney, D. et al.: Speech intelligibility and pressure changes: implications for next-generation train travel</td>
<td>36</td>
</tr>
</tbody>
</table>
Combined effects of sleep restriction and sleep deprivation on cognitive performance and glucose tolerance

E.-M. Elmenhorst¹, D. Elmenhorst², E. Hennecke², D. Lange¹, J. Fronczek-Poncelet², A. Bauer², D. Aeschbach¹

¹ Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany; ² Institute of Neuroscience and Medicine (INM-2), Forschungszentrum Jülich, Jülich, Germany

Short sleep is very prevalent in our society; 30-40% of the population sleep less than the recommended minimum of 7 hours on a regular basis. Short sleep has epidemiologically been associated with cardio-metabolic diseases and cognitive decline [1-4]. We examined whether one 8-hour night after chronic sleep restriction is sufficient to restore cognitive deficits and glucose metabolism to rested baseline levels.

Thirty-six healthy volunteers underwent a 12-day sleep lab study. In a sequential design, they completed one adaptation night and two baseline nights with 8 h time in bed (TIB) each, 5 nights with 5 h TIB (sleep restriction group: N=21, 9 female, mean age 26 ± 4 years SD, mean BMI 23.1 ± 1.9 kg/cm² SD) or 5 nights with 8 h TIB (control group: N=15, 5 female, mean age 28 ± 6 years SD, mean BMI 23.6 ± 2.9 kg/cm² SD), followed by one night with 8 h TIB, one 38-h period of acute sleep deprivation, and a final night with 10 h TIB. Reaction speed (1/s) was analyzed two hours after awakening in a psychomotor vigilance task (10-min PVT). Oral glucose tolerance was tested in the morning immediately after lights on (>10 h fasting). Fasting serum glucose and insulin levels, as well as those 30, 60, 90, and 120 min after glucose intake were analyzed in blood samples. Areas under the curve (AUC) for glucose, insulin, and the dependent variables at the second baseline day (B), after 5 nights with 5 h or 8 h TIB (E5), after the recovery night (R), and after 26 h of sustained wakefulness (SD) were analyzed with mixed ANOVAs with SAS software.

The sleep restriction group had a reduced speed (Fig. 2) at E5 (p=0.001), R (p=0.014), and SD (p<0.001) in comparison to B, while the control group showed impairments at SD only (p<0.001). Speed was slower in the sleep restriction group than in the control group at E5 (p=0.027) and SD (p=0.013), but not at R (p=0.367). In comparison to baseline AUC of glucose, insulin, and the ho-
meostasis model assessment of the sleep restriction group were increased at E5 (all p=0.0003), stayed elevated at R (all p<0.02), but returned to baseline levels at SD (all p>0.6). The control group did not show significant deviations from baseline in glucose tolerance and insulin sensitivity in any of the conditions.

One 8-hour night of scheduled recovery sleep following sleep restriction did not restore PVT performance, glucose tolerance, and insulin sensitivity to rested levels. Cumulative impairment effects of prior sleep restriction and acute sleep deprivation were found for performance but not for glucose metabolism.

---

Corresponding author: eva-maria.elmenhorst@dlr.de


---

**Fig. 2:** Reaction speed in a 10-min Psychomotor Vigilance Task (PVT) at baseline (B), at E5 after 5 nights with restricted bed times to 5 hours per night, after one 8-h recovery night (R), and after 26 h of sleep deprivation (SD) for the sleep restriction group in red and for the control group in blue. * indicate significant differences: in black between groups, in red within the sleep restriction group in comparison to B, and in blue within the control group in comparison to B.
Trading accuracy for speed in selective attention tasks during sleep deprivation

C. Mühl, S. Benderoth, D. Aeschbach

Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Selective attention is a critical cognitive function in job tasks that require careful monitoring and may be impaired by sleep deprivation (SD). Monitoring tasks can be operationalized in the laboratory by visual search tasks, in which the subject has to identify target items among distractor items. Visual search under SD leads to a decrease of overall response speed and accuracy. However, an increase of response speed per item with an increasing number of items was also found under SD – resulting from stronger decreases of response speed in simple (few distractor items) and their absence in complex search conditions (many distractor items). This might indicate an unfavorable speed-accuracy trade-off: decision speed per item increases, while accuracy decreases in turn. Eye gaze tracking may provide additional indications for the duration of individual decisions during the search process.

Methods
We recorded gaze behavior during a spatial configuration search task (SST) to explore if SD leads to faster and sloppier decisions per item. Visual search performance (response time and sensitivity d’) and the associated gaze behavior were tested in two groups of subjects. While sleep deprived participants (N=24, age=25 ± 5 SD; 12 women) were kept awake during a 24 hour period, participants of a control group (N=24, age=26 ± 4 SD; 10 women) were allowed to sleep (TIB=8 hours). To focus on changes in visuo-cognitive performance, we only analyzed fixations longer than 100 ms – excluding very brief “precognitive” fixations associated with oculomotoric activity in the absence of visual perception. We calculated changes of total fixation duration, median fixation duration, number of fixations and total gaze path length for search trials according to the number of distractors (10 to 40) and target present/absent.

Results
We found an increase of response time under SD compared to the control group (p < 0.001), with a shallower slope of response time over the number of distractors (p = 0.0157) and a decrease in sensitivity d’ (p < 0.001). We observed marked oculomotoric effects of sleep deprivation: total fixation duration increased (p < 0.001), the number of fixations increased (p < 0.01) and median fixation duration increased (p = 0.016). Most interestingly, total fixation duration (p = 0.01) and number of fixation (p = 0.017) showed significant interactions between SD and distractor number, with the SD-related increases only significant for simple search conditions (Fig. 1). We did not find any SD-related change in path length.

Conclusion
Sleep deprivation has profound effects on the scanning behavior during visual search. Subjects execute more and longer fixations, leading to the observed increase of total fixation duration and reaction time. The interactions of sleep deprivation with distractor number corroborate earlier findings for response time: additional resources, like additional fixations, to cope with cognitive effects of sleep deprivation are allocated to simple, not to complex search screens. The absence of changes of search path length suggest that coping with the effect of SD is limited to processing time increases, not affecting the overall search space coverage.
The observed changes are in line with an unfavorable change of a speed-accuracy trade-off [1, 2] to explain decreases of search rates for sleep deprived subjects. They might therefore indicate decreases in the quality of the decision processes with increasing distractor number, resulting from a de-facto decrease of decision time per search item.

In occupational settings where visual information has to be processed during night shifts, our results are of twofold relevance. First, cluttered information presentation, resembling complex search conditions, needs to be avoided. Second, oculomotoric measures might allow the automatic recognition of fatigue. Future studies need to clarify, which measures reliably reflect cognitive degradation independent of task characteristics.

Fig. 1. Estimated effects and confidence intervals of changes from baseline for oculomotoric parameters for SD and control group (* p<0.05, ** p<0.01).

Effects of increased ambient carbon dioxide and hypobaric hypoxia on blood oxygenation

R. De Gioannis¹, D. Rooney¹, M. Wittkowski¹, T. Post¹,², J. Rittweger¹, D. Aeschbach¹

¹ Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany; ² The Center for Human Drug Research (CHDR), Leiden, The Netherlands

The combined effects of high environmental carbon dioxide (CO₂) and hypoxia on humans are of great interest for physiological research and aerospace industry. In particular, a lower cabin fresh air supply could reduce aircrafts fuel consumption. This would come at the cost of a higher cabin CO₂ concentration. In this study, we aim to examine the effects of CO₂ and hypobaric hypoxia (2438 meters) on blood oxygenation and alveolar ventilation. The primary hypothesis of our study is that higher ambient CO₂ partial pressure determines a significant improvement of blood oxygenation under hypoxic conditions in healthy subjects.

The study had a randomized, double-blind, crossover design. The study population was composed of 17 healthy nonsmoking subjects (Age<40 years; 8 females, 9 males). Every subject was exposed to hypobaric hypoxia (corresponding to an altitude of 2438 meters) with two CO₂ partial pressure levels on two experimental days: on one day CO₂ partial pressure was 1 hPa and on the other 10 hPa. The hypobaric hypoxia and the atmospheric CO₂ air enrichment were obtained using a hypobaric chamber. On every experimental day, two subjects spent six hours in the hypobaric chamber. Cognitive performance, level of subjective comfort and physiological parameters (breath to breath spirometry, blood oxygen saturation, heart rate, blood pressure, muscle and brain oxygen saturation) were measured every hour. Blood, muscle and
Brain oxygen saturation measurement and spirometry were performed simultaneously for 12 minutes per hour. Before the exposure to hypoxia a baseline measurement was conducted in normobaric conditions. Additionally a capillary blood-gas analysis was conducted at baseline, after 15 minutes of hypoxic exposure and after six hours of hypoxic exposure. Venous blood was collected at baseline and after 6 hours of hypoxic exposure. During the hypoxic exposure urine was collected.

Two-way analysis of variance was conducted to compare the main effects of ambient CO₂ partial pressure, measurement time point and the interaction between the two on capillary oxygen partial pressure (pO₂). Ambient CO₂ partial pressure included two levels (1 hPa, 10 hPa) and measurement time point included three levels (baseline, +15 minutes under hypoxia, +6 hours under hypoxia). The effect of ambient CO₂ partial pressure and measurement session was statistically significant at the 0.05 significance level. Post-hoc paired T-test was conducted to compare mean pO₂ after 15 minutes and 6 hours under hypoxia in the two conditions. After 15 minutes with 10 hPa of CO₂ subjects showed a significantly higher pO₂ (M=60.30 mmHg, SD=11.6) compared to the 1 hPa of CO₂ condition (M=70.03 mmHg, SD=16.42, p=0.046). After six hours under hypoxia this difference was still observed (61.47 vs 66.65 mmHg, p=0.013) (Fig. 1). P values were corrected for repeated measure with the Holm-Bonferroni method.

Blood oxygen saturation was lower than 90% for a significantly longer time in the low CO₂ condition compared to the high CO₂ condition [35.1 vs 6.1 % of the time during hypoxic exposure (p=0.0027), T-test].

Our results show that higher CO₂ partial pressure in hypobaric hypoxia improves blood oxygenation in healthy subjects during a 6 hours period. These data are important for the future design of new aircrafts air recirculation systems. Nevertheless more studies are needed in order to understand if higher environmental CO₂ in hypoxic conditions is safe for aircraft passengers with medical conditions.

Corresponding author: riccardo.degioannis@dlr.de
Effects of nocturnal aircraft noise on objective and subjective sleep quality in primary school children

S. Bartels, J. Quehl, D. Aeschbach
Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Fig. 1: Acoustic and polysomnographic measurement devices.

Children are thought to be more at risk to adverse effects of transportation noise on sleep, since, amongst other factors, undisturbed sleep is vital for their physiological and cognitive development [1]. However, little is known about childhood sleep exposed to nocturnal aircraft noise. An investigation seemed particularly necessary due to the differences of sleep architecture between children and adults.

We investigated the acute effects of nighttime aircraft noise on objective and subjective sleep quality in a field study conducted around Cologne/Bonn Airport. Sleep of 51 children aged 8 to 10 years was measured polysomnographically (via EEG, EMG, EOG, ECG, and pulse oximetry) during four consecutive nights at home. During each night, aircraft noise exposure was recorded inside the children’s bedrooms and noise metrics were calculated.

Children rated their sleep quality (“1 = very good” to “5 = very poor”) and fatigue (“1 = very alert” to “5 = very tired”) on five-point scales in the morning.

For the prediction of objective sleep quality from aircraft noise exposure, we applied mixed models with random intercept and the number of aircraft noise events as dichotomous factor (median split at 37.5 events). The following variables were analyzed: a) proportion of slow wave sleep (S3 and S4) per total sleep time (in %), b) proportion of waking during sleep period time (in %), c) sleep efficiency (proportion of total sleep time during time in bed, in %), d) proportion of REM sleep per total sleep time (in %), e) number of noise-associated awakenings, f) self-rated sleep quality (“1 = very good” to “5 = very bad”).

Aircraft noise exposure affected the macrostructure of sleep. A higher exposure was associated...
with a significantly lower proportion of slow wave sleep ($p = .034$, Fig. 2) and an increased proportion of waking (5.0 % in higher vs. 3.8 % in lower exposure group, $p = .023$).

Sleep efficiency was not significantly reduced in nights with higher noise exposure ($p = .112$), neither was the proportion of REM sleep ($p = .834$). The number of noise-associated awakenings was increased in higher exposure nights ($p < .001$, Fig. 3). In a mixed logistic regression analysis, the probability of an awakening reaction was influenced by the maximum sound pressure level of the aircraft noise event (positive effect) as well as by further acoustic factors, including the duration of the noise event (negative), the background sound pressure level (positive), and the maximum rise rate of an event’s sound pressure level (positive). Situational factors including the current sleep stage and the elapsed time asleep had an influence, too.

Subjective sleep quality did not differ between the two exposure groups ($p = .694$). The same applied to self-rated fatigue in the morning ($p = .269$).

From the results, it was concluded that nighttime aircraft noise exposure can objectively impair childhood sleep with regard to sleep depth and a fragmentation of sleep due to noise-associated awakenings. However, these deteriorations are not reflected by self-rated fatigue in the morning and subjective sleep quality. These findings stress the importance of objective polysomnographic measures for identifying noise-induced changes in children’s sleep even though they are time-consuming and cost-intensive. The magnitude of slow wave sleep reduction due to higher exposure was similar to the findings in a study comparing sleep parameters in healthy children vs. children with obstructive sleep apnea syndrome [2]. The potential health impact of the small but recurrent loss of slow wave sleep due to aircraft noise is currently unknown, and should be the focus of future research.
Noise annoyance due to nighttime traffic: Role of the noise source and the acoustical metric

S. Weidenfeld, E.-M. Elmenhorst, S. Sanok, U. Müller, D. Aeschbach

Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Since many traffic noise studies were based on laboratory surveys or exhibited shortcomings in noise measurement, there is a lack of valid comparable exposure-response relationships between traffic noise and annoyance. To fill this gap, we explored the effect of different traffic noise sources on annoyance assessed by precise measurements of noise parameters (e.g. A-weighted energy equivalent sound pressure level [LAeq] and number of events) in the field. In the present field study on road traffic noise forty healthy participants were investigated at their homes in areas with moderate nighttime road traffic in the vicinity of Cologne and Bonn. On four consecutive mornings the participants completed a questionnaire that asked about their annoyance due to road traffic noise in the previous night (1 = “not at all” to 5 = “extremely annoyed”) as well as about non-acoustical factors potentially influencing annoyance (e.g. perceived degree of having adapted to road traffic noise). Measurements of acoustic parameters were undertaken inside the participants’ bedroom. The DLR Institute of Aerospace Medicine had previously conducted two field studies to investigate the effect of nocturnal railway ([1]; N = 33) and aircraft noise ([2]; N = 64) on annoyance by using an identical approach. We combined the data of these two studies with those from the present survey on road traffic to derive exposure-response curves for noise-in-
duced annoyance by road, railway and air traffic. We applied a logistic regression using Generalized Estimating Equations (GEE) models to predict the probability to be annoyed (categories ≥ 2) by road traffic, railway, and aircraft noise. In the first pooled model the LAeq and the perceived adaptation to traffic noise were included by a stepwise forward selection process (Fig. 1). The second model contained the number of traffic noise events, interaction terms between the number of events and the traffic modes and again the adaptation to the traffic noise source (Fig. 2).

The first model revealed a significant rise in annoyance with increasing LAeq (p = .001, OR = 1.043). While road traffic noise (p = .001, OR = 3.026) was significantly more annoying than aircraft noise, no difference was found between railway and air traffic noise (p = .079, OR = 1.812). Greater adaptation to traffic noise exposure had a reducing effect (p < .001, OR = .528) on annoyance. In the second model, annoyance increased with increasing number of traffic noise events (p < .001, OR = 1.019). A high degree of adaptation to traffic noise reduced annoyance again (p < .001, OR = .524).

The probability to be annoyed was significantly higher for railway noise than for aircraft noise (p = .032, OR = 3.471), whereas road traffic did not differ from aircraft noise in its impact on annoyance (p = .067, OR = 2.932). As long as the number of traffic noise events was below 105 railway noise caused the highest annoyance reactions. However, with an increasing number of noise events air traffic became more annoying than road (p = .004, OR = .986) and railway (p = .149, OR = .989) traffic.

The current study delivers comparative prediction models for noise-induced nocturnal short-term annoyance by road, railway and air traffic in the vicinity of Cologne and Bonn and emphasizes the importance of the perceived degree of an individual’s adaptation to traffic noise. The analysis revealed the LAeq and the number of events to be significant acoustical predictors of annoyance. Interestingly, we found that the extent of annoyance varied not only depending on the respective noise source, but also depending on the acoustical metric. The significant variations in annoyance reactions between the traffic modes might be explained by the different acoustical properties and by the different temporal patterns of noise distribution throughout the night.

Modern societies are characterised by a growing demand for mobility of individuals and high speed trains are becoming a backbone of the transportation infrastructure. To facilitate safe operation in increasingly complex railway networks advanced driver assistance systems are under development. The auditory channel can be used to provide information without disrupting visual attention, but it must be interruption-free. Disequilibrium of tympanic air pressure promotes conductive hearing loss and it is not known whether the transient pressure changes experienced in high speed trains when passing through tunnels may interfere with speech intelligibility.

The primary question of this experiment was whether transient pressure changes of 25 hPa in 2 s, the most severe pressure events expected in high-speed trains, affect speech intelligibility in individuals with normal hearing ability and secondly whether the direction of the pressure change makes a difference.

Data for a reliable power calculation was non-existent and we conducted a pilot study with 20 participants (10 female, mean age 27 years ± 6 SD) to estimate variability. The upper 80% confidence limit guided sample size of the main campaign. Studying 72 participants (35 female, 25 years ± 5 SD) enabled us to identify a 10% difference in speech intelligibility while limiting the chance of alpha and beta error to 5% and 10% respectively.
Speech intelligibility was measured using a monosyllable word test [1]. Subsequent to each audibly presented test word participants were asked to identify the word from five written alternatives, each differing in one of three phonemes. Using a cross-over design, each participant was studied in a single one hour session. Participants were presented with two test blocks of 50 words each. In one block each test word was played immediately after a pressure change, while the other block was performed at steady ambient pressure of 950 hPa. To account for potential order effects we permuted the pressure condition. A speech simulating background noise of 67 dB(A) was constantly played throughout the experiment, masking the operating sounds of the chamber. The signal to noise ratio of the presented test words was adjusted to yield 50% speech intelligibility without pressure changes.

To maintain an overall family-wise error rate of 5% we devised hierarchical testing using complete alpha spending from the primary to the secondary hypothesis. Participants understood on average 0.7 (±4.5 SD) more words when listening in steady ambient pressure, compared to experiencing a pressure change before announcement of the test word. This would equate to an effect size of 0.1, however, a two-sided Wilcoxon signed rank test (Z=1.29; p=0.20) did not detect this to be distinguishable from chance. When comparing increasing and decreasing pressure the average understanding differed by 0.2 (±3.9 SD) words, which was not formally tested due to lacking significance of the primary hypothesis.

Drivers of high speed train are not only operating their vehicles in ever more complex railway infrastructures, but they are also subject to a multitude of factors, such as monotonous operating cycles and shift work, known to increase the likelihood of fatigue and human error, consequences of which may be catastrophic. Advanced assistance systems are a necessity to ensure safe rail operation in this ever more demanding environment. Such systems can safely make use of speech to communicate relevant information to train drivers. The fast pressure changes occurring during the passage of tunnels, a peculiarity of the train environment, do not interfere with speech intelligibility and do not appear to be a risk factor for disruption of verbal communication.

Corresponding author: daniel.rooney@dlr.de

Clinical Aerospace Medicine

Stern, C. et al.: Research in bed rest: The challenge of eye examination in the supine position 40

Stern, C. et al.: Does refraction change during 60 days of -6° headdown tilt bed rest as it does in astronauts? 42
Research in bed rest: The challenge of eye examination in the supine position

Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Long-duration space travel challenges ocular health as evidenced by the “Spaceflight associated Neuro-ocular Syndrome” (SANS). The syndrome comprises optic disc edema, choroidal folds, cotton wool spots, globe flattening with hyperopic shift, and enlargement of the optic nerve sheath distension. In the VaPER study, 30 days -6° head down tilt with raised ambient CO₂ reproduced SANS-like findings in 5 of 11 subjects. During the first campaign of the following 60 day -6° head down tilt AGBRESA study with a normal atmosphere, 5 of 12 test subjects developed optic disc edema.

In the past, International Standard Measures during bed rest studies included ocular ultrasound, tonometry, and fundus examination, which was replaced by Optical Coherence Tomography (OCT) to monitor potential changes in test subjects and make their participation as safe as possible. From a research point of view it is important to use as many objective methods as possible e.g. replace ocular ultrasound by optical biometry. Space agencies followed suit and updated eye examination standards. However, more detailed examinations may be required.

Examinations
To identify acute eye diseases and to monitor potential changes in ocular health, we perform tests both before and after the bed rest phase. Testing includes best corrected visual acuity in distance and near, visual field testing, slit lamp examination, tonometry, color vision, ultrasound, objective refraction and fundoscopy with fundus imaging in cycloplegia, Heidelberg Retina Tomography (HRT), and OCT. Objective refraction in cycloplegia can detect hyperopic shift, visual field exams can detect retinal and optic nerve changes, and color vi-

Fig. 1: Automated visual field testing is performed for the very first time in the supine position.
sion exams can detect changes in optic disc diseases. HRT gauges the optic nerve head and OCT quantifies optic nerve and retinal thickness with high sensitivity. The OCT radial pattern identifies changes better than the formerly used circle scan over the optic disc. During the bed rest phase, we perform near visual acuity to identify early hyperopic shifts with a decrease in near visual acuity and tonometry because intraocular pressure rises, especially during the first phase of bed rest. It is hypothesized that the pressure difference between intracranial and intraocular pressure may be causal for the development of optic disc edema. To measure intraocular pressure we use the iCare Pro Tonometer which can also be used in the supine position. OCT examinations are normally performed in the seating position. For the bed rest studies the OCT was mounted on a surgery arm to use it in the seated and supine position. In case of a relevant increase in retinal thickness, we individually also perform direct ophthalmoscopy to exclude optic disc edema. In the AGBRESA study, we introduced visual field testing in the supine position. For that purpose our assembling workshop mounted the visual field instrument on a pillar and flexible arm so that the instrument can be maneuvered in front of the eye. This is the very first time that visual field testings have been performed by an automated instrument in the supine position. Also during AGBRESA we introduced objective refraction as well as subjective refraction measurements in the supine position for the first time to detect hyperopic shift. The objective refraction was performed by Nidek hand held autorefractor, which is also licensed in the supine position.

Conclusion
Recognition of SANS-like findings during head down tilt bed rest provides an impetus for more detailed ophthalmology examinations. In addition to maintaining ocular health of participants in bed rest studies, more testing may be required during the bed rest phase, but also months to years after to ensure test subject safety and progress in SANS mechanisms and targets for countermeasures. The change and development of instruments for examinations and medical monitoring in the supine position will also improve the situation for bedridden patients.

Corresponding author: claudia.stern@dlr.de

[1] Laune et al., Ophthalmology 126, 2019
Does refraction change during 60 days of -6° head-down tilt bed rest as it does in astronauts?

C. Stern, M. Pittius, S. Ritter, D. Mittelstädt, K. Klink, S. Stupp
Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Introduction
Spaceflight associated Neuro-ocular Syndrome (SANS) describes several ocular changes that can appear in astronauts, especially after long-duration missions. One of these changes, besides optic disc edema, is globe flattening in association with a hyperopic shift. This shift can result in a reduction in near vision, often the first and only symptom that astronauts realize. The length of the eye globe is measured by ocular ultrasound pre-, in- and postflight, but ultrasound measuring is not an exact method and influenced by examiner, angle of the probe and the evaluator. To better and precisely measure the length of the globe, examinations by Zeiss IOL Master 500 (optical biometry) are performed pre- and immediately postflight. Optical biometry uses partial coherence interferometry to non-invasively measure the various anatomical characteristics of the eye.

During a 30-day bed rest study with increased CO₂ (0.5%) and a strict -6° head down tilt position (VaPER), we simulated the effects of microgravity on the human body and observed optic disc edema for the first time in bed rest. The question arose as to whether we could also observe globe flattening with hyperopic shift and which possibilities exist to potentially recognize these changes in long-duration missions (e.g., to Mars with limited transport options).

Methods
12 test subjects took part in the first campaign of the 60 days -6° head down tilt AGBRESA bed rest study, which included centrifuge runs as a countermeasure. The length of the eye was measured by a Zeiss IOL Master 500. In addition, objective refraction in cycloplegia (dilated pupil with suppression of accommodation) was measured pre
and post bed rest by a Nidek autorefractor ARK -1s. A different and easy way to determine changes in refraction is to perform subjective refraction measurements. Thus, hyperopic glasses were held in front of the eyes, spectacles or determined optimal correction of test subjects to detect hyperopic shift. To objectify the subjective information, objective automatic measurements of the refraction were also performed for the first time in bed rest studies.

Results
Out of the 12 test subjects, 5 developed optic disc edema. Mean axial length (measured by Zeiss IOL master 500) increased from pre to post bed rest (23.87 to 23.92 mm), which was confirmed by a negative increase in objective refraction from -0.44 to -0.57 diopters (spherical equivalent). Mean subjective refraction decreased from 0.15 to 0.11 diopters from head down tilt (HDT) day 15 to 58. However, mean subjective refraction in cases with optic disc edema became more positive from -0.05 to +0.15 diopters from HDT day 15 to 58.

Discussion
Axial length increased during the study, which was confirmed by an increase in the negative (more myopic) objective refraction. These findings suggest that measurement of objective refraction in cycloplegia before and after the bed rest is useful for excluding hyperopic shift from globe flattening. In addition to that it is an easy and non-invasive measurement which should be included as a standard measure in all bed rest subjects. However, the increase in eye globe length is contrary to the globe changes observed in astronauts. Furthermore, there is a subjective hyperopic shift in the subjective refraction of test subjects with optic disc edema, which probably comes from retinal thickening that is not measured by the IOL Master biometry system, which refers to the retinal pigment epithelium. The retinal pigment epithelium lays further behind for incoming light rays as the several anterior layers. The optical coherence tomography shows an increase in retinal nerve fiber layers in optic disc edema, which can therefore bring the retinal surface forward. As always in spaceflight and its simulation we need to work with small “n”s which makes the conclusion statistically difficult. Altogether, it seems that refraction may be an easy and efficient method to screen for optic disc edema during deep space exploration.

Corresponding author: claudia.stern@dlr.de

[2] Laurie et al., Ophthalmology 126, 2019
Study Team

Ewald, A. et al.: Alterations in resting metabolic rate in the course of a sixty days bed rest study 46

Nitsche, A. et al.: Recruitment of test subjects for (long-term) bed rest studies – management and challenges 48
Alterations in resting metabolic rate in the course of a sixty days bed rest study

A. Ewald, O. Hand, P. Frings-Meuthen
Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Resting metabolic rate (RMR) is defined as the energy a body requires to maintain all vital organs [1]. The connection between physical activity and RMR is well known. Animal studies have generally shown that single exercise events and longer-term training produce increases in RMR. This effect is observed in longer-term interventions despite parallel decreases in body mass and fat mass. Long-term effects of training include increases in RMR due to increases in lean muscle mass [2]. Less is known about the opposite, meaning inactivity with decreases in lean muscle mass. Only a few studies show that (partial) inactivity can lead to a reduced RMR [3]. But there are no findings of changes in RMR due to inactivity and no information about the time course of RMR changes during inactivity in healthy beings. In the Institute of Aerospace Medicine we are performing head down tilt bed rest studies as a model to simulate inactivity caused by zero gravity which astronauts experience in space. In young, healthy adults subjected to bed rest, the loss of lower body lean mass appears to be in the order of 100-200 g·wk⁻¹ [4, 5]. In the frame of the NASA-ESA-DLR AGBRESA study our objective was to investigate changes in RMR of test subjects during the time course of a 60 days bed rest study.

The RMR was measured by indirect calorimetry with a hood, using the Quark RMR by COSMED. This measurement is based on the consumption of O₂ and production of CO₂ while in a resting state [6, 7]. Twelve test subjects from the first study
campaign (8 male and 4 female) were measured under standardized conditions: in the morning, after 12 hours fasting, quiet surrounding and standardized room temperature on the first study day (BDC-14), the 32\textsuperscript{nd} and 55\textsuperscript{th} day of bed rest (HDT32; HDT55) and 12 days after the end of bed rest (R+12). In the frame of an individually tailored, standardized diet, body weight was kept constant (± 3\%) during the bed rest period. Since individual energy intake is usually calculated by several predictive equations instead of performing the elaborated measurement, we calculated the individual resting metabolic rate with the most commonly used Harris-Benedict equation in parallel.

The measured RMR on the first study day was 1703±72.5 kcal/day in the mean and agreed 100\% with the estimated RMR by Harris-Benedict with a calculated value of 1700±53.1 kcal/day. After 32 days of bed rest RMR was reduced by 8.8\% to 1553±57.0 kcal/day. Resting metabolic rate stays stable for the subsequent time in bed with a measured value of 1527±45.6 kcal/day. After twelve days of normal activity (R+12) measured RMR increased again to 1673±64.0 kcal/day (Fig. 1).

In summary, resting metabolic rate was reduced due to bed rest despite maintaining body weight. Consequently this results in deviations from the most commonly used Harris-Benedict equation taking into account only body weight, body height, sex and age.

Reason for this will be most likely found in a decrease in lean body mass due to muscle loss while staying inactively in bed. However, resting metabolic rate was not further reduced after 55 days of bed rest. Interestingly, only twelve days of "normal" activity seem to be sufficient to increase resting metabolic rate to almost baseline level. More results of the second campaign of the AGBRESA study are expected in December 2019 in order to verify the results from the first campaign. In addition, we will obtain body composition data for the further interpretation of the resting metabolic rate results.

Corresponding author: ann.ewald@dlr.de

Recruitment of test subjects for (long-term) bed rest studies – management and challenges

Recruiting and selecting appropriate test subjects is crucial for the success of any study. The longer and more complex the study, the more emphasis has to be put not only on general health, but also on aspects like stamina, compliance and emotional stability. Subject recruitment is a complex task involving experienced medical, psychological, and management staff.

According to GCP, active recruitment must not start before having a positive vote of the Ethics Board. All aspects of the study have to be described in detail, using layperson’s terms and providing all necessary information without discouraging potential applicants.

Promoting the study
When promoting the study, information is spread: basic information is sent to potential participants listed in the test subject database, studies are advertised on the institute’s homepage as well as on major social media channels. For the AGBRESA study, the website “dlr-probandensuche.de” was created, which led to innumerable expressions of interest from all over the world.

Information sessions
All applicants receive a questionnaire to evaluate general eligibility. Apart from basic data like age, profession, height, or weight, this questionnaire covers medical history, current medication as well as nutritional and lifestyle habits. If this “self-assessment” meets the criteria, the applicants are invited to an information session. Here, all aspects of the study - scientific, medical and organizational - are presented by experienced staff.

Informed consent of the applicants is obtained dur-
ing individual medical consultation. Here, the physician once more runs through the risks of study. Subsequently, all applicants have to fill in psychological questionnaires which are evaluated by DLR specialists regarding psychological eligibility.

**Medical examination, part I**
Comprehensive examinations ensure that future test subjects are in good health and meet the scientific requirements to avoid health hazards and drop-outs. The medical part also includes blood and urine tests, eye exams, resting and stress ECG, genetic counseling for thrombophilia testing, and a stand test.

**Psychological interviews**
Successful medical examination is followed by the psychological interview. Prior, a questionnaire has to be filled out, delivering information on personality traits like health concerns, conscientiousness or extraversion. The interview is led by two psychologists, complemented by the project lead, head medical doctor and recruitment lead in order to find out whether the candidates are mentally stable, compliant, and well aware of the strain and efforts they will encounter.

**Medical examination, part II**
The last step consists of one more blood draw (hepatitis, HIV, tuberculosis) and a bone density measurement by dual-energy X-ray absorptiometry (DEXA).

**Final selections**
When all steps described have been passed successfully, the applicants are ranked according to their medical and psychological eligibility. The top twelve applicants are enrolled, the remaining applicants – hardly ever more than two to three – become back-up candidates.

**Conclusion**
Study duration, complexity of the study protocol and the amount of (invasive) experiments have an immediate effect on the number of applicants. Extensive exclusion criteria as well as withdrawals for personal or professional reasons even after the final selection increase the attrition rate. Often, late applicants cannot be considered since there is no time to stop smoking or medication to meet the inclusion criteria. The challenge is to have sufficient applicants in every recruitment step to finally end up with enough appropriate test subjects plus back-ups. This requires the identification of exclusion criteria at the earliest possible point, simultaneously considering financial and labour resources.

---

**Table 1: Recruitment funnel for AGBRESA campaign 1 and 2**

<table>
<thead>
<tr>
<th>Recruitment step</th>
<th>Participants</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returned questionnaires</td>
<td>1653</td>
<td>100,0</td>
</tr>
<tr>
<td>Invited for information session</td>
<td>1079</td>
<td>65,3</td>
</tr>
<tr>
<td>Participating in information session</td>
<td>201</td>
<td>12,2</td>
</tr>
<tr>
<td>Participating in medical examination 1</td>
<td>100</td>
<td>6,0</td>
</tr>
<tr>
<td>Participating in psychological interview</td>
<td>61</td>
<td>3,7</td>
</tr>
<tr>
<td>Participating in medical examination 2</td>
<td>46</td>
<td>2,8</td>
</tr>
<tr>
<td>Selected test subjects &amp; backups</td>
<td>25</td>
<td>1,5</td>
</tr>
</tbody>
</table>

*Corresponding author: andrea.nitsche@dlr.de*
Aviation and Space Psychology

Eißfeldt, H.; Vogelpohl, V.: Drone acceptance and noise concerns ........................................... 52

Gayraud, K. et al.: Eye tracking in the context of air traffic controller selection ............................. 54

Goerke, P. et al.: Psychological screening of bed rest subjects: A validation study ......................... 56

Hörmann, H.-J. et al.: Enhanced thermal comfort in next generation long-distance trains .............. 58

Maier, J.; Goerke, P.: Relationships between a Situational Judgement Test for teamwork and Assessment Center performance .......................................................... 60

Pecena, Y. et al.: Individual differences in response to sleep deprivation in a space analog environment ......................................................... 62

Schulze Kissing, D.; Bruder, C.: Metrics of team collaboration: Relating collective attention, communication, and performance ....................................................... 64
Drone acceptance and noise concerns

H. Eißfeldt, V. Vogelpohl

Institute of Aerospace Medicine, German Aerospace Center (DLR), Hamburg, Germany, In cooperation with the Institute for Flight Guidance, Braunschweig, Germany, and infas GmbH, Bonn, Germany

To examine the public perception of civil unmanned aerial vehicles in Germany, a nationwide telephone study was conducted in spring 2018. Results revealed an attitude slightly more in favour of drones. When asked about their general attitude towards civil drones, 49% of the participants (N=832) responded rather positive, 43% rather negative, and about 8% undecided.

According to the results acceptance of civil drones varies with several sociodemographic factors such as gender, age, income and place of residence (for further information see [1], [2]).

When asked to what extent they are concerned about certain aspects of civil drone usage, most of the respondents confirmed their concern about misusing drones for criminal purposes (Fig. 3), followed by privacy concerns. Concerns connected with mishaps ranged between 72% and 75% followed closely by concerns about animal welfare. Somewhat surprising was the rather low level of concern about drone noise (53%), as this had been discussed as being a potential barrier of drone proliferation in literature before [3].

About half of the participants (47%) reported having experiences with drones in their personal lives (37%), on the job (4%), or in both contexts (6%). Throughout all areas of concerns these are higher for participants reporting no experience with civil drones. Chi-square tests at the 10% level reveal significant differences for concerns about damages and injuries $\chi^2 (1) = 3.09$, $p = .08$, OR = .76, animal welfare $\chi^2 (1) = 4.29$, $p = .04$, OR = .73, and transport safety $\chi^2 (1) = 3.39$, $p = .07$, OR = .75.

The influence of the various concerns about civil drones on the public acceptance was further analysed using Chi-square Automatic Interaction Detection (CHAID). This method partitions a contingency table produced from cross-tabulation by using a semi hierarchical, sequential procedure [4] and can be used with non-parametric survey data.
In the resulting model the attitude towards civil drones was the parent group variable to be split up by the different categories of the various areas of concerns. At first level concerns about noise entered the analysis, followed by concerns about transport safety among those concerned about noise, and concerns about the violation of privacy among those not concerned about noise.

Of all areas of concern listed in Fig. 3, being/not being rather concerned about noise explained the attitude towards civil drones among all respondents best $\chi^2 (2) = 38.6, \ p = .000, \ OR = .41$ and entered the analysis first. Fig. 4 shows the strong interaction effect. Concerns about transport safety among those concerned about noise, and concerns about the violation of privacy among those not concerned about noise followed on the second level of the CHAID model.

The relatively low level of concern about drone noise (53%) in the total sample could be an issue of lacking acoustic experience. Among those reporting experiences with drones (N=387), a more detailed look into the kind of experience with drones revealed a significantly higher percentage of noise concern for those reporting having heard a drone: $\chi^2 (1) = 3.29, \ p = .07, \ OR = 1.45$.

In summary, noise is reported least among all different concerns about drones, however has the strongest impact on acceptance. Further research will focus on perception and mitigation of drone noise to foster public acceptance of civil drones in Germany.

Corresponding author: hinnerk.eissfeldt@dlr.de

[3] ITF (OECD), 2018
Air traffic controllers work in a highly safety-critical environment. Therefore, selection of air traffic controller applicants follows a thorough multiple-stage process. Applicants’ performance on cognitive ability and work sample tests is usually assessed by performance measures, i.e., response accuracy and speed. To gain deeper insight into the cognitive processes underlying performance on visual tasks, different approaches such as eye tracking are required. Specifically, the analysis of eye movements would allow visualizing (Fig. 1) and quantifying visual search activities, including the strategy of solving a task.

So far, little research on the relationship between gaze behaviour and inter-individual differences in cognitive performance exists [e.g. 1, 2]. This dissertation project fills this gap by investigating the role of eye movements in personnel selection, specifically, the selection of air traffic controllers [3]. Two work packages (WPs) addressing the relation between gaze behaviour and performance in a cognitive selection test were defined and implemented.

**WP 1: Development of a new work sample test**

In the first WP, a new computer-based work sample test, the Eye Movement CONflict Detection Test (CON, Fig. 1), was developed. The CON includes tasks pertinent to working in an aviation context, and is specifically adapted to meet the special requirements for eye movement analysis. The CON simulates conflict detection between aircraft, a key task of air traffic controllers, but does so in a simpli-
fied way such that applicants without any aviation experience are able to perform the task. Development of the CON involved a substantial evaluation phase, including one reliability study with 252 applicants for air traffic control training or pilot training, and one expert study with two experienced air traffic controllers of the DFS Deutsche Flugsicherung GmbH. Overall, the data show that the CON is an objective, reliable and valid test for application in eye tracking studies.

WP 2: Relationship between gaze behaviour and cognitive performance differences

To examine the relationship between eye movement data and test performance, eye movements of air traffic control training applicants and students were tracked while they were performing the CON (N = 113). The study was conducted using a remote registration method at DLR facilities, using four computer workstations that had been equipped with eye trackers (Fig. 2).

Performance measures (response accuracy and speed) were calculated for each participant. Eye movement parameters such as fixation count, fixation duration, and gaze transition entropy were determined to quantify the individual’s distribution of attention, and their strategy to detect conflicts on the task. Regression analyses showed that several eye movement parameters were significantly associated with performance variables, and predicted 54 % of the overall task performance in the CON. Moreover, data from individuals who had participated both on the CON and on several cognitive tests during ATC selection indicated that eye movement parameters can significantly contribute to the prediction of the CON performance in addition to behavioural performance variables of the cognitive ability tests (e.g., memory, attention).

Discussion

This project shows that eye tracking provides an objective measure of individual performance differences during selection, making the process of visual search transparent, quantifiable and comparable between participants. Outcomes demonstrated that the gaze behavior is associated with test performance and contributes relevant additional information about attentional and strategic processes of an applicant. In the future, technical improvements of the eye tracking technology could further benefit the accuracy of the analysis of strategic gaze behavior, and additional psychological research, including validation studies that assess predictive power, is required to establish decision criteria based on eye movement analysis.

Corresponding author: katja.gayraud@dlr.de

Long-term bed rest studies are a well-established method to simulate the effects of microgravity. Study participants are confined to bed in a 6° head down tilt position and have to deal with a lack of privacy, a degree of dependence on others and limited social contact.

Most of the studies focus on detrimental physiological aspects and potential countermeasures. Recently, psychological and psychosocial factors were recognised as important factors for long-duration spaceflights as well as for long-term bed rest studies [1]. Personality factors like Emotional Stability, Extraversion and Aggressiveness have been shown to influence subjects’ behavior, mood and performance in bed rest [1] and antarctic confinement studies [2] as well as in space missions [3]. Furthermore aspects like achievement motivation, stress tolerance and the ability to get along with others might influence the suitability of the candidates [4]. Therefore, in addition to the medical screening of participants, a thorough psychological screening in the selection process is essential for the success of a long-term bed rest study. The German Aerospace Center (DLR) carries out long- and midterm bed rest studies for ESA and NASA on a regular basis. The psychological selection process includes two personality inventories (Freiburger Persönlichkeitsinventar (FPI) [5]; Temperament Structure Scales (TSS) [6]), a biographical data sheet and a final interview led by a psychologist. The selection board consists of psychologists, project lead and physicians, who...
eventually agree on a final interview score which is based on a prognosis concerning factors like perseverance, compliance, and adaptability. The aim of this study is to validate the selection process on different performance criteria. It is based on three bed rest studies: Medium-term bed rest whey protein (MEP), Reactive Jumps in a Sledge Jump System as a Countermeasure during Longterm bed rest (RSL), VIIP (Visual Impairment and Intracranial Pressure) and Psychological :envihab Research Study (VaPER) conducted by the DLR at the AMSAN and at the :envihab, respectively. N = 44 subjects (39 m, 5 f) were included in either 2 x 21 days (MEP), 30 days (VaPER) or 60 days (RSL) of bed rest. Subjects’ study performance was rated by the support team (MEP: N = 29, RSL: N = 18, VaPER: N = 20) on seven rating scales concerning different aspects: General Study Fit, Low Abortion Tendency, Compliance, Care Expense, Adaptability to Care Staff, Adaptability to Subject Group and Mood Swing. Correlations between personality dimensions (TSS) and performance criteria have been calculated while controlling the effect of Openness.

Correlation analyses showed significant negative correlations between the two personality dimensions Emotional Instability and Aggressiveness and the different performance criteria. Extraversion shows high correlations with Adaptability to Care Staff and Subject group. Moreover, the final interview score correlates significantly positive with all performance criteria. Thus, a thorough subject selection process including especially the assessment of Emotional Instability and Aggressiveness in combination with a structured psychological interview reduces the likelihood of dropouts and enhances the quality of subject performance.

Table 1: Correlations: Personality Dimensions, Interview Rating and Performance Criteria.

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Instability</th>
<th>Extraversion</th>
<th>Aggressiveness</th>
<th>Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>General fit</td>
<td>-.38**</td>
<td>.17</td>
<td>-.36*</td>
<td>.40**</td>
</tr>
<tr>
<td>Low abortion tendency</td>
<td>-.40**</td>
<td>.15</td>
<td>-.28'</td>
<td>.41**</td>
</tr>
<tr>
<td>Compliance</td>
<td>-.41**</td>
<td>-.05</td>
<td>-.38*</td>
<td>.41**</td>
</tr>
<tr>
<td>Care expense</td>
<td>-.19</td>
<td>.08</td>
<td>-.39'</td>
<td>.37’</td>
</tr>
<tr>
<td>Adapt. care</td>
<td>-.31’</td>
<td>.31’</td>
<td>-.33'</td>
<td>.40’</td>
</tr>
<tr>
<td>Adapt. subj. group</td>
<td>-.23</td>
<td>.36’</td>
<td>-.31’</td>
<td>.33’</td>
</tr>
<tr>
<td>Mood swings</td>
<td>-.32’</td>
<td>.03</td>
<td>-.47'</td>
<td>.46’</td>
</tr>
</tbody>
</table>

"p<.01, ’p<.05, ’p<.10

Corresponding author: panja.goerke@dlr.de

Enhanced thermal comfort in next generation long-distance trains


Institute of Aerospace Medicine, German Aerospace Center (DLR), Hamburg, Germany; In cooperation with the DLR Institute of Aerodynamics and Flow Technology, Göttingen

Objectives
As part of the DLR program Next Generation Train (NGT), this project is aligned with the efforts of the European Commission to achieve a 60% reduction of CO₂ emissions by shifting a significant proportion of middle distance passenger journeys from road to other modes of transportation. Due to its low environmental impact the railway system is the prime candidate to enable domestic and continental mass passenger mobility. Our efforts aim to substantially increase the attractiveness of railway journeys for travelers by analyzing and enhancing comfort conditions. While the previous work has examined comfort conditions such as lighting, noise and vibrations, in our current research we develop and evaluate in cooperation with the DLR Institute of Aerodynamics and Flow Technology at Göttingen novel heating, ventilation and air conditioning technologies (HVAC), which could provide the highest quality of thermal comfort during rail travel.

Approach
Based on the ASHRAE Standard 55, thermal comfort is defined as “that condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation” [1]. The distributions of indoor air temperature, air flow, air quality, and air humidity are the main environmental parameters that determine individual thermal comfort. We investigate individual thermal comfort under controlled conditions with different HVAC-systems in a generic train compartment in Göttingen (Fig. 1). We focus especially on low-momentum ventilation techniques such as Cabin Displacement ventilation (CDV), Ceiling-integrated
(CLMV) or Hatrack-integrated low-momentum ventilation (HLMV) in comparison to state-of-the-art Microjet ventilation (MJV). Objective as well as subjective comfort parameters are recorded throughout each exposition phase. Meanwhile, over 280 subjects participated in our empirical studies.

**Results**

In regard to energy efficiency CDV is clearly superior to any other of the examined ventilation systems. As shown on the left side of Fig. 2, the heat removal efficiency coefficient (HRE) of CDV is 20% better than the present technology [2]. However, a CDV disadvantage is its higher vertical temperature gradient, which can cause some discomfort (Fig. 2, right side, [3]).

In order to compensate for the steep vertical temperature gradient of CDV, infrared (IR) panels were mounted in the lower section of the cabin for each individual seat. Additionally, subjects received a simple remote control, which allowed them to adjust their auxiliary IR-panels according to personal preferences. While still being more energy efficient than MJV, this configuration received the highest evaluations for thermal comfort by the subjects (CDV+IR) [3].

**Implications**

Our results have shown that no single HVAC-system can simultaneously maximize both criteria: energy efficiency and thermal comfort. Therefore we suggest a hybrid combination of two HVAC-systems to gain optimal conditions. This will be targeted in coming subject trials. Evaluations of thermal comfort by humans are always subject to some inter-individual differences. Depending on personal preferences, different clothes, or different activity levels people tend to prefer either warmer or colder temperatures with higher or lower air velocity. It will not be possible to satisfy everybody’s needs by averaging thermal conditions in a train compartment. Therefore, we propose to provide the option of individually adjustable thermal conditions to train travelers at least in more exclusive personal comfort areas. Currently, we intend to further optimize the HVAC’s energy balance through demand-dependent ventilation.

**Corresponding author:** hans.hoermann@dlr.de

---

Assessment centers (AC) are widely used for personnel selection although they are rather time-consuming and resource-intensive. Less costly alternatives are Situational Judgment Tests (SJTs) that confront applicants with written or video-based descriptions of job-relevant situations. As response format applicants can choose from different possible behavioral reactions. In their conventional form, they are established for the prediction of job performance and cognitive ability [1]. More recent approaches show that SJTs which have been developed to measure concrete constructs had an improved validity and minimized effects of social desirability [2, 3].

In this study, a SJT for selecting individuals for teamwork (SJT-TW [4]) was analyzed with regard to its usefulness for behavioral observations in the context of assessment centers. It consisted of 30 items covering several aspects of teamwork behaviors (example see Fig. 1).

The collection of data took place in the premises of the DLR Hamburg. The sample consisted of N = 181 applicants (w = 21, m = 160; mean age = 21.2, SD = 2.8) for the job of a pilot who took part in a two-stage selection process. In the first stage, applicants worked on several computer-based performance and knowledge tests and a personality test. Positive candidates were admitted to the
In sum, convergent and discriminant relationships were identified for the SJT-TW. Significant correlations were found between the SJT-TW and behavioral observations from the AC, which shows that the SJT-TW can be used to assess teamwork relevant aspects of applicants’ behavior. As opposed to this, there were only low to zero relationships with the tests from stage 1 confirming the construct validity of the SJT-TW. Contrary to general expectations there was also no significant relationship with the final prognosis after the interview. This might be explained by the restricted variance in the dataset, which is a result of the previous selection stages where negative candidates were ousted.

Corresponding author: julia.maier@dlr.de

Individual differences in response to sleep deprivation in a space analog environment

Y. Pecena, V. Vogelpohl, A. End

Institute of Aerospace Medicine, German Aerospace Center (DLR), Hamburg, Germany

Adverse conditions in space severely affect astronauts’ sleep [1]. Importantly, even minor sleep deprivation has the potential to massively influence individual performance [2]. Thus, considering the high risk operational working environment of space missions, it is essential to study potential influences on the effects of sleep deprivation. As part of a larger NASA project, our study aimed at investigating whether individual characteristics such as personality traits predict vulnerability to sleep deprivation with respect to individuals’ performance and perceived fatigue.

The study was conducted in the NASA Human Exploration Research Analog (HERA), a ground-based habitat that serves as an analog for isolation and confinement in space (Fig. 1). Data were collected from four crews, each consisting of four healthy non-smokers (age: 30-55 years), who volunteered to partake in HERA Campaign 4 for a total duration of 45 days. Before participating, individual traits such as personality (TSS [3]), trait anxiety (STAI [4]) as well as perceived emotional irritation [5] were assessed. During confinement, the crew members were instructed to maintain a sleep rhythm of eight hours per night during weekends and five hours per night during weekdays (i.e., inducing sleep deprivation). Moreover, repeatedly during the mission, participants’ performance was measured by means of the psychomotor vigilance task (PVT [6]) and, additionally, several rating scales were administered (e.g. perceived fatigue). For data analysis, each individual’s impairment in response to sleep deprivation was calculated with respect to PVT performance (i.e. reaction times) as well as perceived fatigue. In order to examine whether crewmembers with certain characteristics were especially vulnerable to

Fig. 1: HERA habitat (https://www.nasa.gov/analogs/hera/experience-hera), consisting of an airlock (left part), the core and loft (middle part) and a hygiene module (right part).
suffer from relative lacks of sleep, for each trait, the current sample was divided into two groups by means of a median split.

In contrast to prior research [7], the personality trait extraversion did not predict differential impairment in PVT performance or perceived fatigue as a result of sleep deprivation in the present study. However, we found smaller effects of sleep deprivation on performance for crewmembers with higher as compared to lower scores in rigidity (Mann-Whitney-U = 10.0, p = .021; Fig. 2). This observation was further supported by the fact that rigidity was negatively correlated with PVT performance impairment (Kendall’s τ = -.56, p = .003; cf. [8]). A similar association was observed for dominance (U = 22.0, p = .33; τ = -.38, p = .045). In contrast, the opposite relationship was found for aggressiveness (U = 57.0, p = .007; τ = .68, p < .001), emotional irritation (U = 55.0, p = .015; τ = .38, p = .045), and anxiety (U = 59.0, p = .002; τ = .38, p = .045). Hence, larger effects of sleep deprivation on performance were revealed for crewmembers with higher as compared to lower scores on these three traits.

As opposed to the individual characteristics described above, achievement motivation did not influence the impairment in PVT performance. However, the increase in perceived fatigue in response to sleep deprivation was found to be weaker for crewmembers with lower as compared to higher scores on this personality dimension (U = 53.0, p = .023; τ = .23, p = .22).

Present results corroborate previous work in demonstrating a relationship between personality traits and vulnerability to sleep deprivation. However, additional research is desirable in order to gain a better insight into the precise relationship between specific personality traits and vulnerability to sleep deprivation.

In sum, the present study used an ecologically valid space analog and showed that crewmembers with certain individual characteristics may be particularly resilient to sleep deprivation. For practitioners these results might benefit future astronaut selection campaigns.

---

**Fig. 2: Mean difference in PVT reaction times (in ms) in response to sleep deprivation (i.e., 5 vs. 8 hours of sleep), separately for four different traits. Error bars denote SEM.**

---

**Scores in different traits**
- Lower score
- Higher score

---

**Corresponding author:** yvonne.pecena@dlr.de

Metrics of team collaboration: Relating collective attention, communication, and performance

D. Schulze Kissing, C. Bruder
Institute of Aerospace Medicine, German Aerospace Center (DLR), Hamburg, Germany

Introduction
Methods of nonlinear dynamic systems (NDS) analysis might provide an innovative approach to visual sampling behavior of operators in complex systems, and this not only within individuals (e.g., [1]), but also within teams. In contrast to traditional approaches, which use normative models to find the functions driving visual sampling behavior of individuals ([2]-[5]), in NDS-terms visual sampling can be conceptualized as being driven by nonlinear oscillators (cf. [6]). In less predictable situations, these oscillators are more stochastic in nature and so produce higher entropy in visual sampling behavior. The analytical method that fits well with the resulting kind of non-stationary (and noisy) data is recurrence quantification analysis (RQA, [7]). Furthermore, with cross-recurrence-quantification analysis (CRQA) synchrony on team level can be assessed. In an experimental campaign it is explored if synchronization can be observed in visual sampling behavior and, if so, if synchronization metrics provide sensitive indicators for team processes. The results of one experiment are reported below.

Method
In the synthetic task environment (STE) ConCenT (Control Center Task Environment; cf. [8]) teams of three observe an array of instruments for events signaling dysfunctions (Fig. 1). Because of a very short reaction-time window (set to 4s) and a low signal salience team members can hardly succeed in this task without visual search bounded by expectations. Overall patterns of system behaviour provide information to guide alertness about upcoming events. However, a team can only identify these patterns through communication.
Design
A scenario comprises 68 monitoring-task items of 30s duration to be performed consecutively. Expectation is manipulated by introducing two item types: a) 34 items displaying a sequence of successive alert signals resulting in final alert signals (of which 6 actually predict a dysfunction event) and b) 34 occasionally displaying a safety signal. The team can detect the safety and alert signals only in collaboration. Shared alertness should decrease in task trials with safety signals occurring, compared to trials with a constant increase in alertness. This should be reflected in lower attention synchronization values within teams.

Participants
14 teams with complete gaze-data sets are considered for analysis. The mean age of participants is 22.02 (SD= 3.57).

Data Preparation
For an attention synchronization metric the Matlab toolbox “crptoolbox” [9] was used to calculate three cross recurrence rates (CRR) based on the individual gaze-time series. The mean of the resulting three CRR formed the synchronization coefficient.

Results
As shown in Fig. 2, the effect of item type on the synchronization of gaze behavior within teams is significant (cf. Tab. 1). Synchronization of gaze behavior decreased in the task-trials of the second half of the scenario compared to the first half (cf. Tab. 1). A significant interaction of Phase x Type (cf. Tab. 1) indicates that this effect is attributable to synchronization during alert trials, only.

Discussion
Methods of nonlinear dynamic systems (NDS) analysis provide an innovative approach to visual sampling behavior of teams in complex systems. As assumed, shared alertness measured by CRQA is lower in trials with safety signals. With longer time on task fatigue might have selectively affected synchronization of gaze behavior for alert trials, only, because of the more attention demanding processes behind.

Outlook
In further analyses it will be tested if a decrease in a teams’ attention synchronization predicts upcoming performance decrements.

Tab. 1: Mixed Model ANOVA results on the synchronization coefficient.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>All monitoring trials</th>
<th>Alert Signal Trials Only</th>
<th>Safety Signal Trials Only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase (1/2)</td>
<td>1 7.76***</td>
<td>1   8.90**</td>
<td>1 .24</td>
</tr>
<tr>
<td>Item Type</td>
<td>1 92.66***</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(alert/safety)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase x Type</td>
<td>1 5.11*</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2: Mean difference in PVT reaction times (in ms) in response to sleep deprivation (i.e., 5 vs. 8 hours of sleep), separately for four different traits. Error bars denote SEM.

Corresponding author: dirk.schulze-kissing@dlr.de

[1] Schulze Kissing et al., Proc. EAAP, 2018
Radiation Biology

Berger, T. et al.: The RAMIS radiation detector on the DLR Eu:CROPIS mission ................................. 68

Meier, M. et al.: New European radiation protection standards in aviation ........................................... 70

Konda, B. et al.: Response of mammalian eye lenses to space radiation qualities in vitro and in organ culture .......... 72

Rettberg, P. et al.: The microbiome inside the International Space Station (ISS) ......................................... 74

Möller, R. et al.: Changes in the skin microbiome during head-down tilt bedrest ..................................... 76
The RAMIS radiation detector on the DLR Eu:CROPIS mission

Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

The RAduation Measurements In Space (RAMIS) instrument (Fig. 1) was developed, constructed, tested and built in the Biophysics group of the Radiation Biology department of the Institute of Aerospace Medicine. RAMIS is operated in the frame of the DLR Eu:CROPIS satellite mission to provide measurements of the radiation environment. For this mission two identical RAMIS systems were built. The first one (PL3M2) is mounted at the top surface of the satellite under very low shielding conditions (Fig. 2). The second one (PL1M1) is positioned as a sensor within the primary Eu:CROPIS payload [1] and measures radiation quantities providing dosimetry for the biological samples.

RAMIS uses an arrangement of two silicon detectors in telescope geometry, and enables to investigate the following scientific objectives. The first objective is the exact determination of the fluxes of protons and electrons in the Earth’s radiation belts. These data serve as input for the validation and benchmarking of current radiation field models and additionally for further model development. As a second objective the experiment determines the variation of the galactic cosmic radiation (GCR) contribution to the radiation field by measuring the relevant parameters in dependence of the orbit of the satellite and in dependence on the solar cycle. In addition RAMIS also provides relevant quantities for radiation dosimetry as absorbed dose, energy deposition spectra and relevant dose equivalent.

The Eu:CROPIS satellite was launched on 3 December 2018 into a polar orbit. The RAMIS instruments have been activated on 5 December 2018.
for first measurements and commissioning. Since 11 December 2018 onwards the RAMIS detector PL3M2 on the outside of the satellite is collecting science data. Fig. 3 shows the average count rate of the detector between December 2018 and October 2019.

With RAMIS we are in a perfect orbit, since we cover at one hand the nominal areas where the International Space Station (ISS) is flying (up to ± 50° latitude), but in addition we are crossing the north and the south pole going up to latitudes of ± 83° (Fig. 3 top). These crossings enable us to measure the radiation environment as encountered in free space, due to the fact, that geomagnetic shielding at the poles is negligible. With this, RAMIS offers a perfect tool for comparison with instruments for example in lunar orbit (CRA TER) or on the surface of the Moon (LND). In addition we can measure the highly complex and temporally extremely fast changing behavior of electrons in the outer radiation belts (as seen in the band like structure given in the top Fig. 3). Further on, the crossing of the South Atlantic Anomaly (seen in zoomed version in Fig. 3 bottom) can be studied. RAMIS PL3M2 has worked flawlessly for over 11 months, and is still collecting valuable data for the changes in the radiation environment over time and over the solar cycle. Further, in depth data evaluation is in progress and publications are in writing.

Fig. 2: RAMIS PL3M2 mounted on the top outer surface of the Eu:CROPIS satellite.

Fig. 3: RAMIS PL3M2 count rates over the Eu:CROPIS orbit. Top: Full Earth picture; Bottom: Zoom into the South Atlantic Anomaly. (Dataset: 05 December 2018 – 29 October 2019).

Corresponding author: thomas.berger@dlr.de

New European radiation protection standards in aviation

M. Meier, D. Matthiä, K. Schennetten, M. Wirtz, C. Baumstark-Khan, C.E. Hellweg

Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Radiation protection for aircrew has been legally regulated in the European Union (EU) for more than 20 years. The first EU directive including aircrew as occupationally exposed radiation workers had been 96/29/EURATOM that was repealed and replaced by the directive 2013/59/EURATOM in 2013, which had to be implemented in the national legal systems of the member states, i.e. the laws, regulations and administrative provisions necessary to comply with this directive, by 6 February 2018 [1]. The new European basic safety standards for protection against the dangers arising from exposure to ionizing radiation are based on the most recent recommendations of the International Commission on Radiological Protection (ICRP) that were adopted on 21 March 2007, after eight years of discussion, involving scientists, regulators, and users all around the world and published as ICRP Publication 103 [2].

The Radiation Protection in Aviation Group of the Radiation Biology Department has offered scientific services for airlines since radiation protection regulations became legally binding in Germany in 2001. For example, the workgroup has developed the computer program Professional Aviation DOse CAIculator (PANDOCA) based on an atmospheric radiation model of the radiation field due to cosmic radiation for the official dose assessment of aircrew registered in Germany [3]. Furthermore, measuring techniques have been established as standards for quality assurance [4-6].

Beside the hitherto existing radiation protection measures, new legal requirements have to be implemented by the airline industry by the end of 2020. This requires that existing products and services have to be adapted and new products and services have to be developed based on the knowledge and previous research results of the workgroup. For example, the most recent ICRP recommendations concerning radiation and tissue weighting factors for the calculation of the effective dose had to be implemented into the PANDOCA-program used for the operational dose assessment for more than half of the German flight personnel. An analysis of the consequences on the accrued flight doses has shown a corresponding decrease in dose rates of up to about 30 % during solar minimum conditions, which are going to prevail for the coming years (Fig. 1) [7].

A new legal requirement obliges airline companies to appoint radiation protection officers with a requisite qualification in radiation protection in aviation that has to be achieved by the successful attendance at a corresponding 2-day training course. The content of teaching ranges from the basics in nuclear physics and radiation biology to imparting knowledge on legal and operational matters. A space weather lesson is included as well. The Radiation Biology Department has already become one of few chartered course providers in Germany [8].

Furthermore, the German Radiation Protection Act stipulates a new dose limit for the ambient dose in the uterus of female flight attendants of childbearing age of 2 mSv per month that might even be infringed in rare cases on a single flight by
Fig. 1: Ratio of the effective dose rates after the recommendations by ICRP103 and ICRP60 at different altitudes during solar minimum conditions in dependence on the effective geomagnetic cut-off rigidity $R_C$, a parameter used for the quantification of the shielding effect of the Earth’s magnetic field (from [7]).

a strong solar particle radiation event. Therefore, it will be an ongoing challenge for the workgroup to develop further services, e.g. for early space weather radiation alerts in order to support airlines in their efforts not to infringe any dose limits and keep exposures due to cosmic radiation for crew and passengers during their flights as low as reasonably achievable.

Corresponding author: matthias.meier@dlr.de

Response of mammalian eye lenses to space radiation qualities \textit{in vitro} and in organ culture

B. Konda, C. Baumstark-Khan, C.E. Hellweg

\textit{Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany}

Astronauts on long-term space missions have a higher risk for the expression of radiation late effects such as cancer or sub-capsular cortical eye lens opacities. This is due to higher dose and different patterns of cellular energy deposition from high-linear-energy-transfer (LET) components of galactic cosmic radiation in space than that of low-LET radiation on Earth. The eye lens is a radiation sensitive organ as it contains a germinative zone in the lens epithelium with actively proliferating cells that finally differentiate into transparent lens fibers and an elimination mechanism for damaged cells is lacking. Radiation-induced cataract is reported to occur with a threshold absorbed dose of 0.5 Gy (0 - 1 Gy) of sparsely ionizing radiation. On the International Space Station (ISS), the effective dose rate quantified by human phantom experiments amounted to 550-570 $\mu$Sv/d inside the station and 690-720 $\mu$Sv/d during extravehicular activities [1,2], resulting in a doses accrued by astronauts during a six-months mission of around 100 mSv, with variations depending on the flight altitude and solar activity. During a mission to Mars, astronauts will accumulate considerable doses of galactic cosmic radiation of about 1 Sv [3,4], thereby reaching the upper limit of the cataract-induction threshold dose.

Radiation-induced lens opacification is assumed to initiate from post irradiation proliferative activity of genetically damaged lens epithelial cells with alterations in cell cycle control, apoptosis, differentiation, and cellular disorganization, or other pathways controlling lens fiber cells’ differentiation. As the porcine eye lens is similar to the human lens in size and anatomy, DNA damage response after X-ray exposure was investigated in ex-vivo porcine lenses in organ culture (Fig. 1), in \textit{in-vitro} cultivated lens epithelial slabs and in porcine lens epithelial

\textit{Fig. 1: Lens organ culture. The photographs of a lens were taken after 7 and 14 days incubation at 37°C and 5% CO$_2$ in humidified atmosphere.}
cells. Cell survival of proliferative cells was calculated from colony forming ability (CFA) assay. The phosphorylated form of H2AX (γH2AX) was used as a molecular marker to visualize DNA double strand breaks (DSB) and their repair. Propidium iodide based DNA staining for cellular DNA content marked radiation-induced cell cycle disturbances. In porcine lens epithelial cells, the cell survival curve of X-irradiated and immediately plated cells and cells plated after a recovery period of 24 h followed the equation $S=1.40xD+\ln 1.47$ and $S=1.59xD+\ln 1.79$, respectively. DNA DSB are induced in a dose-dependent manner (≈18 DSB/cell/Gy) and repaired during successive recovery (≈5 DSB/cell/Gy residual damage after 24 h) (Fig. 2). For doses >2 Gy, a cell cycle arrest in G2 phase occurred 24 h after X-irradiation and persisted up to 72 h post-irradiation. DNA DSB induction and repair were documented for lens epithelial slabs and whole lenses after X-irradiation. In whole lenses, the amount of residual damage (after 24 h and 48 h) was highest in the equatorial zone while in the central epithelial zone DSB repair seemed to proceed with time in a manner comparable to in-vitro cultivated porcine lens epithelial cells. In conclusion, lens organ culture allows cellular metabolism and DNA synthesis in whole lenses. Repair of DNA DSB takes place in the central epithelial layer and is reduced in the equatorial region of cultivated lenses.

Corresponding author: christine.hellweg@dlr.de


Fig. 2: Immunofluorescence staining of γH2AX in porcine lens epithelial cells. Cells were fixed with 3.5 % formaldehyde 1 h and 24 h after X-ray exposure. Fluorescent antibody staining for γH2AX is given by pink foci whereas the blue stain of the cell nuclei is due to DAPI stain. Scale bars represent 20 µm.
The microbiome inside the International Space Station (ISS)

Human space exploration beyond Low Earth Orbit to the Moon and to Mars is a declared goal of the space-faring agencies. Maintenance of crew’s health during a several hundred days journey in a confined artificial environment in space is one of the key aspects, which has to be addressed. Several risks with respect to microorganisms and human spaceflight have been identified. These include the compromised human immune system during spaceflight and a potentially increased infection risk, as it has been shown that microgravity affects the virulence of certain pathogenic microorganisms, the potential increase of antimicrobial resistances as recently shown for highly-maintained, confined built environments and the deleterious effect of so-called technophilic microorganisms causing damage to structural materials as well as malfunctioning of various space systems and equipment.

In the space experiment EXTREMOPHILES the microbial communities from several areas aboard the International Space Station were analysed at three time points [1]. The microbial diversity, distribution, functional capacity and resistance profile was investigated using a combination of cultivation-independent analyses (amplicon and shot-gun sequencing) and cultivation-dependent analyses (physiological and genetic characterization of microbial isolates, antibiotic resistance tests, co-incubation experiments).

The microbial community composition was assessed by amplicon sequence analysis and shot-gun metagenomics of wipe samples from the ISS and from a spacecraft assembly cleanroom for compari-

---

Fig. 1: Microbiome composition in clean rooms (utmost left three columns) and the ISS.
son (Fig. 1). The ISS microbiome is dominated by human-associated microorganisms such as Streptococcus, Corynebacterium, Lactobacillus, Acinetobacter, Staphylococcus, and varies over time and locations inside the ISS (Fig. 2). Archaeal signatures were also detected frequently. In contrast, in the cleanroom samples the majority of microorganisms belong to alpha-proteobacterial genera. The ISS microbial communities are highly similar to those present in ground-based confined indoor environments and are subject to fluctuations, although a core microbiome persists over time and locations.

By different cultivation approaches including pretreatment with ionising or non-ionising radiation, growth at high or low pH, growth at high or low temperature, exposure to a heat-shock etc. 76 unique bacterial isolates were obtained in addition to several fungi. No archaea could be grown from any sampling site. Antimicrobial susceptibility testing was performed for 17 clinically relevant antibiotics and the microbial resistance potential was found to be similar to that of ground controls.

The genomic and physiological features selected by ISS conditions do not appear to be directly relevant to human health, although adaptations towards biofilm formation and surface interactions were observed. The results do not raise direct reason for concern with respect to crew health, but indicate a potential threat towards material integrity in moist areas.

Corresponding author: petra.rettberg@dlr.de

Changes in the skin microbiome during head-down tilt bedrest

E. Muratov, T. Erler, S. Koch, K. Siems, A. Schröder, E. Mulder, C.E. Hellweg, R. Möller

Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Although health status of astronauts such as immunological and physiological problems has been investigated, less attention has been paid to the microbiome and its significant role in the astronauts’ health [1]. In extended missions, a wide range of physiological adaptations or even diseases may affect astronauts. In order to simulate the effects of spaceflight on the human health and performance extensive terrestrial studies are and were conducted to gain better understanding in the human physiology. In the NASA-ESA-DLR long-term bedrest study AGBRESA (*Artificial
Gravity Bed Rest Study”) a first campaign was conducted to study the physiological changes in the skin with correlation towards microbial shifts. AGBRESA provided a platform for investigation of microbiota shifts and altered skin properties through a 60 days-long period of simulated microgravity.

Our skin is home to millions of bacteria, fungi and viruses that compose the skin microbiota [2]. Similar to those in our gut, skin microorganisms play essential roles in the protection against invading pathogens, the education of our immune system and others [3]. As the largest organ of the human body, skin is colonized by beneficial microorganisms and serves as a physical barrier to prevent the invasion of pathogens. In circumstances where the barrier is broken or when the balance between commensals and pathogens is disturbed, skin disease or even systemic disease can result.

Structurally, the skin is composed of two distinct layers: the epidermis and dermis. The outermost layer (the epidermis) is composed of layers of differentiated keratinocytes. The top layer, or stratum corneum, is composed of terminally differentiated, enucleated keratinocytes that are chemically crosslinked to fortify the barrier of the skin [3]. In addition to this conserved layered structure, different body parts provide diverse microenvironments that vary in pH, temperature, moisture, sebum content and topography [2].

The AGBRESA study was divided in three stages: baseline data collection (BDC) of 15 days, a 60 days-long period of a head-down-tilt (HDT) to simulate unloading and fluid shifts occurring under microgravity conditions and a recovery (R) section of 14 days. In the course of the study at regular intervals swab samples were taken from all subjects (Fig. 1). Measurements of the physiological skin parameters (e.g., pH, level of hydration and sebum content) were taken accordingly using dermatological probes. Both cultivation-based and cultivation-independent methods were used to determine microbial composition, diversity and dynamics of the skin swabs (of the subjects’ ears, forehead and spinal column). During simulated microgravity, it is expected that members of particular genera are redistributed caused by physiological skin adaptation. An enrichment of lipophilic organisms such as Propionibacteria or Corynebacteria sp. was found during the HDT. The pH of the forehead showed a significant decrease whereas the amount of sebum and the level of skin hydration increased. The analysis of bacterial communities on forehead indicated that skin microbiota consists of highly individual compositions.

By identifying microbial compositions and especially its changes during a long-term bedrest, appropriate countermeasures can be developed [4, 5]. Regarding these changes, preventive measures can be taken in the form of creams or probiotics [4]. In future bedrest studies, aspects such as individual body care (e.g., creams or make-up products) combined with disparate frequency of showers should be considered to gain further details on the population dynamics of the skin microbiome.

Corresponding author: ralf.moeller@dlr.de

Gravitational Biology

Frett, T. et al.: AGBRESA: Daily centrifugation as countermeasure during long-term 6° head down tilt bed rest  80

Lichterfeld, Y. et al.: Live imaging of astrocytic behavior during exposure to hypergravity  82

Otto, T. et al.: Application of the C.R.O.P®-filter technology for manure processing in terrestrial agriculture  84

Hauslage, J. et al.: Life sciences experiments on sounding rockets (Mapheus 8/ATEK)  86

Voß, S. et al.: Development of novel hydrogel substrates for neuronal 3-D cultures  88
AGBRESA: Daily centrifugation as countermeasure during long-term 6° head down tilt bed rest


Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Future long-term crewed exploration missions (e.g. to Moon or Mars) will extend human exposure to microgravity. Current exercise countermeasures on the ISS still result in decrements of astronauts’ fitness. Artificial Gravity (AG) generated by centrifugation is a promising multi-system countermeasure for physiological deconditioning during long duration space flights. To validate AG as an effective countermeasure research questions concerning tolerability of frequent centrifugation, physiological effects and evaluation of continuous or intermittent AG profiles have to be answered [1]. Primary objective of the AGBRESA study is to compare the effects of daily continuous (30 min, group cAG) and interval (6 times 5 min, group iAG) passive exposure to Artificial Gravity with +1Gz at the center of mass and +2Gz at the feet. 24 subjects were recruited and formed three groups, one as control without AG intervention. Before the head down tilt phase all subjects were familiarized with the intervention protocol including training of leg muscle pump maneuvers to reduce the risk of syncope or orthostatic instabilities during centrifugation. Beyond this, no further exercises (e.g., leg movements etc.) were allowed. Video surveillance was used to observe subjects’ compliance during centrifuge intervention. During daily centrifugation subjects were allowed to have audio entertainment (e.g., music) if not restricted by peri-AG experiments. To ensure subjects safety continuous monitoring of vital parameters (heart rate, blood pressure, oxygen saturation) by a physician was performed. We investigated the tolerability of daily centrifugation, particularly concerning motion sickness, rate of perceived exertion and physiological parameters (heart rate, blood pressure) to compare both intervention groups. Subjects were asked to report motion sickness and subjective exertion on a daily basis. Medical monitoring data are analyzed for e.g. changes in resting or peak heart rate and
blood pressure during centrifugation across 60
days of bed rest.
Results from the first (of 2) campaign showed
good tolerability of both centrifuge profiles. The
first 8 subjects (5 males) completed 480 centri-
fuge runs in total. Only six centrifuge runs had to
be aborted prematurely for medical reasons, 4
during continuous and 2 during intermittent cen-
trifugation due to development of presyncopal
symptoms. During bed rest 2 cases of vertigo
occurred in the control group. In both interven-
tion groups no cases in group iAG and 2 cases in
group cAG of vertigo occurred. Vertigo is associ-
ated with symptoms like nausea, tumbling or
postural instability.
After daily centrifugation mean values (in arbi-
trary units) for motion sickness scoring were in
general low (group iAG = 1.59 ± 1.9, group cAG
= 2.89 ± 1.4, control group = 2.28 ± 2.2), but
showed significant differences (iAG vs. cAG: p <
0.001, iAG vs. control group: p = 0.009, cAG vs.
control group: p 0.001). Average scoring for sub-
jective exertion were moderate (group iAG =
8.70, group cAG = 9.02), and the difference was
not significant.
In conclusion, daily centrifugation seems to be
feasible during long-term bed rest. Future bed rest
studies with Artificial Gravity as countermeasure
should include exercises like leg press or jumping
to increase the effects on maintaining bones or
muscles. Recent studies revealed that moderate
exercises during centrifugation results in no signif-
icant motion sickness scoring [2, 3] and should
therefore be evaluated for long-term application.

Corresponding author: timo.frett@dlr.de

Business Media, 2007
[2] T. Piotrowski et al., Front. Physiol. 9, 2018
[3] T. Frett et al., Motion sickness symptoms during jumping
exercise on a short-arm centrifuge, J. Vest. Res. (under review)
Live imaging of astrocytic behavior during exposure to hypergravity

Y. Lichterfeld, L. Kalinski, Y. Nabawi, T. Frett, R. Hemmersbach, C. Liemersdorf
Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Neural regeneration following injuries to the central nervous system (CNS) in mammals is inhibited by several factors [1]. One important mechanism preventing axon regrowth and thus the healing of a CNS injury is the formation of the glial scar. Key players in glial scar formation are reactive astrocytes that migrate into the region of the injury and produce an inhibitory extracellular environment, rich in chondroitin sulfate proteoglycans (CSPGs) and other signaling molecules [2]. These, in turn, have an inhibiting effect on axon growth and even actively induce axon dystrophy, which have severe consequences for patients, e.g., loss of neuronal signaling and in some cases permanent paralysis [3]. We cultured primary murine cortical astrocytes in hypergravity to modulate key aspects of their role in glial scar formation. Employing the DLR Hyperscope centrifuge microscope platform (Department of Gravitational Biology: https://www.dlr.de/me/desktopdefault.aspx/tabid-1769/, Fig. 1), we were able...
to investigate astrocytic behavioral dynamics directly under the influence of hypergravity. One aspect of investigation was the cell adhesion and spreading of astrocytes after seeding them into a cell culture dish. Cells were imaged under 2g hypergravity over the course of 5 hours and the cell area was continuously measured. When compared to the 1g control, it became apparent that the cell spreading speed was reduced by approx. 50% by culturing in hypergravity (Fig. 2). Since cell spreading is based on similar active intracellular mechanisms as cell motility [4], we applied the Hyperscope platform to live-image astrocytic migration via so-called scratch-assays.

After 24 hours the total migration speed of astrocytes in hypergravity was reduced by approx. 40% compared to 1g controls (Fig. 3). Visualizing the migration speed over time revealed a so far unknown dynamic of astrocyte migration in hypergravity. In the first 2-3 hours, migration speed of the cells in hypergravity was only slightly reduced compared to 1g. However, after this “latency period” the full extent of migration inhibition induced by hypergravity was apparent.

The next steps are live-imaging of intracellular cytoskeletal dynamics under the influence of hypergravity to elucidate the mechanisms which are induced under increased gravitational stimulation and thus increased mechanical loading.

Corresponding author: christian.liemersdorf@dlr.de

Application of the C.R.O.P.®-filter technology for manure processing in terrestrial agriculture

T. Otto, J. Overath, J. Hauslage, G. Bornemann

Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

The DLR C.R.O.P.® (Combined Regenerative Organic food Production) focuses on nutrient recycling from biological wastes aiming at the production of fresh food in closed environments like planetary stations. In recent years, an aqueous fixed bed biofiltration system applicable to convert human urine into plant-available fertilizer was developed and tested [1-3]. Closing material loops is also a necessary prerequisite to develop sustainable agricultural practice on Earth with minimized consumption of finite resources and low leakage of pollutants. Therefore, the C.R.O.P.®-biofilter was adapted for the processing of cattle slurry with the objective of developing a marketable system for agricultural purposes.

Pilot Slurry System
The C.R.O.P.®-biofilter is a technically simple system consisting of a filter tube filled with pumice, a tank and a pump which circulates the liquid from the tank through the filter material in the tube [2]. The configuration of the urine filter system was changed according to the higher dry substance content of slurry compared to human urine. Grain size of the filter material was increased (pumice, 25-100 mm); stronger pumps (1500 l/h) and larger filter tubes (200 mm diameter, 10 l filter volume) were chosen. Tanks have a volume of 60 l. Three filters were started by adding garden soil, filtrate from urine processing filters and synthetic urine [1]. After onset of nitrification slurry (screw-press separated liquid) was added. In the following
two months, filters were operated continuously with a daily exchange of 1 l filtrate versus 1 l fresh slurry.

Nitrification of Slurry

The filter design is based on the assumption that a natural microbial population as it is established by inoculation with garden soil enables flexibility of filter function [1]. This assumption was supported by the short period of adaptation following the change from urine to slurry (Fig. 1 A-C). The successive peaks of ammonium and nitrite concentrations followed by an increase in nitrate concentration are in accordance with the characteristic start-up dynamics of nitrifying systems [2]. Within the first 60 days ammonium concentration decreased to less than 0.3 g/l and nitrite concentration to less than 0.1 g/l. The amount of nitrogen bound in form of nitrate, which is the desired product, reached 88 to 95 %. This proportion is dependent on the amount of slurry added per day and will be optimized in the course of further filter operation.

Conclusion and Outlook

The smooth transition from urine to slurry showed that the filters can be flexibly applied and changes of influent composition do not cause relevant disturbances in operation. Nevertheless, unexpected problems arose, for example in the form of strong foam formation, which were not observed with urine and require further structural adjustments. The next step is the optimization of slurry nitrification followed by filter design improvements to elevate easy maintenance and additional functions like nutrient separation and drying processes for enhanced transportability.

---

[2] Bornemann et al., Life Sci. Space Res. 18, 2018

---

**Fig. 1:** The onset of nitrification after the start of cattle slurry addition. A: Development of ammonium concentration over time. B: Development of nitrite concentration over time. C: Development of nitrate concentration over time. The different symbols correspond to the three different units analysed.
Life sciences experiments on sounding rockets (Mapheus 8/ATEK)

J. Hauslage, C. Liemersdorf, Y. Lichterfeld, T. Berger, K. Marsalek, N. Maas, R. Hemmersbach

1 Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany, 2 Microgravity User Support Center (Space Operations and Astronaut Training), Cologne, Germany

MAPHEUS (MAterialPHysikalische Experimente Unter Schwerkraft) is a DLR rocket program for material physics and gravitational biology experiments under microgravity conditions. Development and construction of the scientific payload is performed by the involved institutes. The rockets are launched under the responsibility of DLR MORABA from ESRANGE Space Center in Kiruna, Sweden. On 13th of June 2019 the DLR rocket MAPHEUS 8 was successfully launched providing a microgravity period of 360s and carrying four life science and two related technological experiments, which are briefly described here (for details, see [1, 2]).

The CellFix module was constructed to study the influence of altered gravity on the physiology of single cells and consists of two culture bags containing cell cultures in a temperature-controlled pressure vessel. Fixation of the cells is performed by pumping the fixative from a connected bag into the cell suspension. The mechatronic basis of the experiment unit is based on compartments of the shelf (COTS) parts. Murine primary cortical astrocytes, which represent the prevalent type of glial cells in the brain of mammals, were successfully fixed inflight, as revealed by the cell morphology, demonstrating that CellFix provides a multi-usable experiment unit to perform life science experiments in space.

The experiment MemEx (in cooperation with the University of Hohenheim) addressed biophysical alterations of (cell) membranes in microgravity. Fluidity and incorporation of substances (e.g., lidocaine) were studied in artificially produced lipid vesicle membranes, measured with photomultiplier techniques in combination with Open Source microcontrollers (ARDUINO). Microgravity-induced changes in fluorescence anisotropy demonstrate an increased fluidity of the lipid-bilayer membrane and a decreased capacity to integrate hydrophobic molecules (lidocaine). These results indicate that pharmacokinetics might be altered under microgravity conditions.
The experiment HIA – Yeast in Space was carried out (in cooperation with the Weincampus Neustadt and the Landauer Bierprojekt) to analyze the metabolic activity and gravity-induced potential changes in the genome of a selected yeast strain. During long-term crewed space travel, the production of vitamin B₁₂ by animals is strongly limited and plants do not provide this vitamin. However, yeast cultures are excellent suppliers of vitamin B₁₂, which is essential to e.g. avoid damages of the neuronal system. First analyses indicate no differences between the ground control and the flight samples, which supports yeast as a candidate for the supply of vitamin B₁₂ for astronauts.

The experiment ROPUM addressed the technological demonstration of a microscope using the rotation of Paramecium, a unicellular organism, during forward movement as test system. The microscope consists of a machined cuvette/optical cell combined with a commercially available objective/tube lens and a Fused Deposition Modeling printed frame and camera adapter to achieve a small, lightweight, cost-efficient and durable science instrument. Continuous video recording has successfully been performed during the rocket flight and is under analysis. Upgrading of the microscopical capacities by autofocusing as well as fluorescence excitation will be the next steps.

The apex – advanced processors, encryption and security experiment comprised a new On-Board Computer (OBC), using COTS components, which has successfully been flight-tested during MAPHEUS-8. The main advantages of the apex OBC, in comparison with earlier OBCs, lies in the speed and simplicity of the design while maintaining operational security with a redundant master-master microcontroller system.

The experiment M42 – Radiation measurement detected the radiation dose during the mission. The total mission dose during the 6 minutes of μ-gravity equalled around half a day of background radiation on Earth.

---

Corresponding author: jens.hauslage@dlr.de

Cultured cells derived from organisms, particularly mammals including humans, have been widely used for decades to understand cellular functions and to test new potential medical applications. Such cell cultures usually are two-dimensional, with a variety of different isolated cell types growing on surfaces like glass or plastics. Although 2D cell cultures in vitro are well established and allow the observation of, e.g., cell differentiation, growth, physiological adaptations and gene expression changes when particular environmental stimuli or chemicals are applied, the results from 2D culture experiments might differ from those obtained from cells in vivo in their native tissue environment, which has to be critically considered.

Therefore, attempts have been undertaken in order to develop 3D cultures with the objective to obtain scaffolds for cell cultures mimicking the natural cellular arrangement as physiologically as possible. Such scaffolds are mostly polysaccharide- or protein-based hydrogels.

In the present study, a variety of different novel hydrogels consisting of polysaccharide- and silica-derivates were screened regarding their suitability to support growth, survival and network building of primary neuronal cells, i.e. astrocytes. Astrocytes are localized in the CNS and support neurons by, among other tasks, actively controlling neuronal activity and synaptic transmission via regulating, e.g., calcium homeostasis.

Artificial 3D scaffolds for the further analysis of the interaction between primary astrocytes and neurons were established, and the suitability of 3D cultivation for biomedical applications, such as inhibiting glial scar formation, was investigated. Several of the hydrogels tested are biocompatible, but lack sufficient cell adhesion sites on their basic constituents. A functionalization of gel types with known RGD-peptides improved cell growth due to an increase in cell adhesion sites. In alginate, e.g., cells remain spherical without visible filopodia. In contrast, RGD-alginate cultured cells show long and narrow filopodia. In addition, often neglected features of hydrogels were assessed, such as the pore size and stiffness of the respective gel that has tremendous impact on cellular development. Certain gel types revealed capacities in terms of pore sizes and gel stiffness that was related to neural tissues and thus potentially optimal for neuronal cell development. All successfully 3D cultured astrocytes showed different morphological features as compared to cells grown in 2D.

2D cultures will keep their position in future cell biology research, but 3D cultures will come closer than ever to in vivo conditions and possibly may even partially replace experiments with animals. Certainly, they will open completely new approaches to cell biology in general. One may envisage that hydrogels will be injected into injured spinal cord tissue to replace healthy tissue and stop intruding astrocytes, which will reduce glial scar formation and possibly promote healing paralysis without complex surgical procedures. With astrocytes and neurons in 3D co-cultures, different new cellular characteristics could be measured, such as 3D network formation, synaptic compartmentalization or differentiation.
Further studies will focus on peptide-hydrogels or even so-called self-assembly peptides (SAPs). These are very long chains of defined amino acids, which fold themselves into secondary structures by the action of environmental micro-climates in an incubator. Such peptides can gel around cells of interest, providing defined recognition sites that can be chosen for the respective cell type of interest and help forming a translucent gel for many applications analyses.

Corresponding author: christian.liemersdorf@dlr.de
Annex

Studies and Projects ........................................... 92

Publications ...................................................... 94

Events, Presentations, Talks .................................. 102

Institute Lectures ................................................ 102

Workshops, Events, Seminars at the Institute ............. 103

Teaching Activities .............................................. 105

Graduations ....................................................... 107

Awards ............................................................. 108

Imprint ............................................................. 112
# Studies and Projects

## Studies of the Institute of Aerospace Medicine with use of the facilities in :envihab 2019

<table>
<thead>
<tr>
<th>Study</th>
<th>PI/responsible person DLR</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGBRESA</strong> (Artificial Gravity Bed Rest Study ESA): Two long term bed rest study campaigns with NASA and ESA at :envihab. Twelve volunteers spent a total of three months with us, two months in strict 6 degree head-down bed rest. In collaboration with more than 100 international scientists, many sophisticated experiments and examinations were conducted ranging from microbiota profiling to state-of-the-art brain imaging and cognitive testing. Blog: <a href="https://www.dlr.de/blogs/desktopdefault.aspx/tabid-5893/9577_read-1125/">https://www.dlr.de/blogs/desktopdefault.aspx/tabid-5893/9577_read-1125/</a></td>
<td>Edwin Mulder/Jessica Lee, Muscle and Bone Metabolism Freia Paulke, Study Team (study responsible physician)</td>
<td>Campaign 1: 3/2019-6/2019 Campaign 2: 8/2019-12/2019 Pre- and post-tests in 2018 and 2020</td>
</tr>
<tr>
<td><strong>Cardio Brain2</strong>: fMRI of hypothalamic and brainstem nuclei to assess baroreflex and chemoreflex function.</td>
<td>Jens Tank/Darius Gerlach, Cardiovascular Aerospace Medicine</td>
<td>Tests on 25 days 1/2019-12/2020</td>
</tr>
<tr>
<td><strong>LOCAR</strong>: LBNP study of autoregulation of cerebral blood flow.</td>
<td>Jens Tank/Stefan Moestl, Cardiovascular Aerospace Medicine</td>
<td>Tests on 10 days 1/2019-12/2020</td>
</tr>
<tr>
<td><strong>MyoCardioGen</strong>: Normobaric hypoxia and heart function: follow-up-tests of the hypoxia study conducted in the pressure chamber in 2018: Two climbers have lived in the pressure chamber at :envihab at an altitude of up to 7000 metres with a significantly reduced oxygen content. Blog: <a href="https://www.dlr.de/blogs/desktopdefault.aspx/tabid-5893/9577_read-1009/">https://www.dlr.de/blogs/desktopdefault.aspx/tabid-5893/9577_read-1009/</a></td>
<td>Jens Tank/Ulrich Limper, Cardiovascular Aerospace Medicine Jörn Rittweger, Muscle and Bone Metabolism</td>
<td>Tests on 4 days 1/2019-7/2019</td>
</tr>
<tr>
<td><strong>EMPA-MSNA</strong>: Effects of the antidiabetic agent Empagliflozin on muscle sympathetic nerve activity (MSNA). Investigator-initiated trial (IIT) in cooperation with Profil Neuss.</td>
<td>Jens Tank/Karsten Heußer, Cardiovascular Aerospace Medicine</td>
<td>Tests on 90 days in 2019</td>
</tr>
<tr>
<td><strong>ITC</strong> (Inter Team Collaboration): Investigation of the effect of total sleep deprivation on decision making in and between teams.</td>
<td>Christian Mühl, Sleep and Human Factors</td>
<td>9/2019-12/2019 84 volunteers in groups of 3 for 5 days</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>BDC ESA Astronauts</strong>: Scientific baseline experiments with ESA astronauts pre- and postflight</td>
<td>Edwin Mulder, Muscle and Bone Metabolism</td>
<td>Several tests in 2019</td>
</tr>
<tr>
<td><strong>MuXLiH</strong> (Muscle Phenotype in X-linked Phosphatemic Hypophosphatemia): X-chromosome linked Hypophosphatemia is a hereditary disorder, in which aberrant FGF-23 signaling leads to extremely low phosphate availability in the body. So far, the phenotype has mostly been described with regards to bone. However, phosphate is also essential for skeletal muscle energy metabolism, and XLH patients report muscle pain and fatigue. Hence, MuXLiH explores the potential deficits in muscle function in these patients.</td>
<td>Sarah Michély/Jörn Rittweger/Jochen Zange, Muscle and Bone Metabolism</td>
<td>7/2019-10/2019</td>
</tr>
<tr>
<td><strong>PET-Kaffee</strong>: Effect of coffee/placebo treatment during chronic sleep restriction.</td>
<td>Eva-Maria Elmenhorst/Denise Lange/Daniel Aeschbach, Sleep and Human Factors</td>
<td>4/2017-12/2020 Volunteers are present for 10 days</td>
</tr>
</tbody>
</table>
Journal articles (peer-reviewed)

DOI: 10.3390/cells8040352. ISSN 2073-4409.

DOI: 10.1111/smss.13404. ISSN 0905-7188.

DOI: 10.3390/cells8040352. ISSN 2073-4409.

DOI: 10.1111/maps.13232. ISSN 1086-9379.

DOI: 10.3769/radioisotopes.68.411. ISSN 0033-8303.

DOI: 10.3769/radioisotopes.68.433. ISSN 0033-8303.

DOI: 10.1063/1.5122301 ISSN 0034-6748.

DOI: 10.1089/ast.2018.1904. ISSN 1531-1074.

DOI: 10.1016/j.jacc.2019.10.027 ISSN 0735-1097.

DOI: 10.1089/ast.2018.1900. ISSN 1531-1074.

DOI: 10.3389/fphys.2019.00397. ISSN 1664-042X.


DOI: 10.1016/j.chb.2018.11.040. ISSN 0747-5632.

DOI: 10.3389/fphys.2019.00012. ISSN 1664-042X.

DOI: 10.1038/s41598-019-40343-w ISSN 2045-2322.

DOI: 10.1016/j.ijchy.2019.100013 ISSN 2590-0862.

DOI: 10.1016/j.appet.2019.04.017 ISSN 0195-6663.

DOI: 10.1089/ast.2018.1889. ISSN 1531-1074.

DOI: 10.3357/AMHP.5351.2019. ISSN 2375-6314.

DOI: 10.1097/HJH.0000000000002078 ISSN 0263-6352.

DOI: 10.1097/HCO.0000000000000630 ISSN 0268-4705.

DOI: 10.1097/HCO.0000000000000633 ISSN 0268-4705.

DOI: 10.1161/HYPERTENSIONAHA.119.13835 ISSN 0194-911X.

DOI: 10.1161/HYPERTENSIONAHA.119.12685 ISSN 0194-911X.


Journal articles (without peer-review)


Publications in scientific books


**Publications in an anthology**


**Theses**


Events, Presentations and Talks

Institute Lectures

15.01.2019  
**PD Dr. Olga Ramich**, Deutsches Institut für Ernährungsforschung, Abt. Molekulare Toxikologie, AG Molekulare Ernährungsmedizin, Nuthetal, Germany and **Univ. Prof. Dr. med. Andreas Pfeiffer**, Charité – Universitätsmedizin Berlin, Klinik für Endokrinologie, Stoffwechsel- und Ernährungsmedizin, Berlin, Germany: “**Circadian Regulation of Metabolism**”

21.01.2019  
**Dr. André Antunes**, Senior Lecturer, Biology Department, Edge Hill University, Ormskirk, Lancashire, UK: “**The Secret Life of Brines: Deep-Sea Brines and Their Inhabitants**”

29.01.2019  
**Dr. Kristina Beblo-Vranesevic**, Astrobiology Working Group, Radiation Biology Department, Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany: “**Mars Analogues for Space Exploration**”

05.02.2019  
**Prof. Dr. Markus Egert**, Hochschule Furtwangen, Campus VS-Schwenningen, Fakultät "Medical and Life Sciences" (MLS), Institut für "Precision Medicine" (IPM), Leiter AG Allgemeine Mikrobiologie & Hygiene, Schwenningen, Germany: “**The Built Environment Microbiome - Consequences for Human Health**”

12.02.2019  
**Prof. Dr. Jan Peters**, Biologische Psychologie, Universität zu Köln, Köln, Germany: “**Prospection and Exploration in Decision-Making**”

19.02.2019  
**Prof. Dr.-Ing. Vera Meyer**, Department Applied and Molecular Microbiology, Institute of Biotechnology, Technische Universität Berlin, Berlin, Germany: “**Systems and Synthetic Biology Approaches to Understand and Reprogram the Cell Factory Aspergillus niger**”

19.03.2019  
**Prof. Dr. Ulrich Kalinke**, Institut für Experimentelle Infektionsforschung, TWINCORE, Zentrum für Experimentelle und Klinische Infektionsforschung Hannover, Germany: “**Virus Control at the Brain Border**”

02.04.2019  
**Dr. Petra Rettberg**, Head of the Astrobiology Working Group, Radiation Biology Department, Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany: “**Astrobiology and Planetary Protection – How Can We Make Sure to Identify Reliably Extraterrestrial Traces of Life?**”

21.05.2019  
**Prof. Dr. Alexander J. Probst**, Aquatic Microbial Ecology, Biofilm Center, University of Duisburg-Essen, Essen, Germany: “**Pirating the Pirates: Microbial Interactions in the Deep Terrestrial Biosphere**”

28.05.2019  

04.06.2019  
**Adrienne Kish**, PhD, Associate Professor, Head of Bacteriology Service, Muséum National d’Histoire Naturelle, Communication Molecules and Adaptation of Microorganisms, Paris, Ile de France, France: “**Stranger than Fiction: Life in the Extremes**”

25.06.2019  
**Petra Mittler**, Astronautentraining im integrierten Team des EAC, Das Europäische Astronautenzentrum (EAC), Köln, Germany: “**LUNA, nebenan auf dem Mond**”

19.09.2019  
**Prof. Dr. Hans-Curt Flemming**, Universitätsprofessor em./i.R., Biofilm Center, Fakultät für Chemie, Universität Duisburg-Essen, Germany: “**Bacteria and Archaea on Earth and their Abundance in Biofilms**”

24.09.2019  
**Prof. Dr. med. Frank Bengel**, Direktor, Klinik für Nuklearmedizin, Medizinische Hochschule Hannover (MHH), Hannover, Germany: “**Kardiale Positronen-Emissions-Tomographie in der klinischen Forschung**”

08.10.2019  
**Dr. Klaus Slenzka**, OHB SYSTEM AG, Head: Life Sciences, Bremen, Germany: “**The ModuLES Program – 1st Modul: Photobioreactor**”
29.10.2019
Rainer Schüller-Fengler, Markterschließung, German Aerospace Center (DLR), Cologne, Germany: “Die Ideenplattform DLR. IDEASPACE”

05.11.2019
Dr. Ralf Möller, Head of the Space Microbiology Research Group, Radiation Biology Department, Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany: “Living Together - Understanding Microbial Biofilm Formation Under Spaceflight Conditions”

12.11.2019
Prof. Dr. Dina Grohmann, Lehrstuhl für Mikrobiologie & Archeenzentrum, Institut für Biochemie, Genetik und Mikrobiologie, Universität Regensburg, Regensburg, Germany: “Analysis of Microbial Community Composition Based on 16S rRNA Profiling Via Nanopore Sequencing”

19.11.2019
Prof. Dr. Konrad Förstner, ZB MED – Informationszentrum Lebenswissenschaften, Cologne, Germany: “Translating High-Throughput Sequencing Data Into Microbiological Insights”

26.11.2019
Flottillenarzt PD Dr. med. Ramin Naraghi, Klinik XII – Neurochirurgie, Bundeswehrzentralkrankenhaus Koblenz, Koblenz, Germany: “Neurovaskuläre Kompression”

03.12.2019
Prof. Sarah Baatout, Head of Radiobiology Unit, SCK•CEN | Belgian Nuclear Research Center, Belgium: “Human Space Exploration Challenges from a Radiation Protection Perspective”

Workshops, Events, Seminars at the Institute

December 2018/January 2019
Direct Return Alexander Gerst at :envihab

17.1.2019
Visit: Scientific Committee EASA

18.01.2019
Visit: TU Braunschweig/RWTH Aachen

22.1.2019
Visit: Molekulare Phytomedizin Universität Bonn

28.1.2019
Visit: RWTH Aachen

29.1.2019
Visit: RWTH Aachen

4.2.2019
Visit: Representatives Federal Ministry of Defense

13.-14.2.2019
Workshops: ESA Space Health Student Week

14.2.2019
Lecture: Women in Aerospace: Professor Dorothee Dzwonnek

19.2.2019
Visit: TU Berlin

6.-7.3.2019
Workshop: KNIMS Kompetenznetzwerk Immobilisationsbedingte Muskelstörungen

11.3.2019
Presentation: First Lego League

12.3.2019
Visit: Institut des Hautes Études pour l’Innovation et l’Entrepreneuriat

16.3.2019
Seminar: VBIO: Bewegungsmangel – Vom Molekül bis zum Astronauten

21.3.2019
Press conference: AGBRESA Bed Rest Study
22.3.2019
Visit: Head TH Cologne

25.3.2019
Visit: Chinese Delegation Qian Lab

28.3.2019
Girls Day

28.3.2019
Visit: Academie de l'Air et de l'Espace

14.5.2019
Press conference: MIDAS Study

16.5.2019
Visit: “ResearchTrack”, Medical students, Cologne University

5.6.2019
Visit: Representatives Planet Lab

13.6.2019
Visit: Delegation CMSA

15.6.2019
Workshop: DLR Fliegerarzttage

17.6.2019
Lecture: MyoCardioGen Study

27.6.2019
Visit: Students University Stuttgart/Cusanuswerk

3.7.2019
Visit: W. Allen Kilgore, Deputy Director for Aerosciences, NASA Langley Research Center

3.7.2019
Visit: RWTH Aachen

5.7.2019
Visit: World Congress Science Journalists

8.7.2019
Visit: University Delft

15.7.2019
Visit: University Göttingen

15.7.2019
Visit: Members of Saarland parliament

23.7.2019
Visit: German-Japanese RLV/Spaceplane Workshop

26.7.2019
Visit: Member of the German Bundestag Nezahat Baradari

7.8.2019
Visit: Delegation ROSKOSMOS

13.8.2019
Visit: Indian participants SummerSchool University Cologne

16.8.2019
Visit: Thomas Jarzombek, Commissioner for the Digital Industry and Start-ups and Federal Government Coordinator of German Aerospace Policy

20.8.2019
Visit: Universität Augenklinik Bonn

21.8.2019
Visit: Bernard Foing and EuroMoonMars

21.8.2019
Visit: Gesundheitsregion Köln/Bonn

28.-31.8.2019
Seminar: Verkehrsmedizinische Woche

2.9.2019
Visit: Victorian Delegation Australia

3.9.2019
Visit: Graduate Program DLR

5.9.2019
Visit: Junior-Ingenieur-Akademie Liebfrauenschule Bonn

6.9.2019
Visit: Legal Department RWTH Aachen

13.9.2019
Visit: Women in Nuclear

7.10.2019
Visit: Representatives City of Brampton, Canada

8.10.2019
Visit: Representatives International Air Forces

10.10.2019
Visit: Rotary Club Bonn
14.10.2019
Visit: Winner My Space Dream contest ESA

15.10.2019
Visit: Head of department of the Ministry of Economics of Niedersachsen

21.10.2019
Visit: Delegation University Melbourne

29.10.2019
Visit: Alanus Hochschule

5.11.2019
Visit: Deutsche Physikalische Gesellschaft

7.11.2019
Visit: African Delegation UN-SPIDER International Conference

8.11.2019
Visit: Representatives Philips

13.11.2019
Seminar: King’s College London: “Space Physician Training Course 2019”

14.11.2019
Visit: International Biomedical Engineer Working Group ESA

20.11.2019
Visit: Regierungender Bürgermeister Berlin, Michael Müller

22.11.2019
Visit: Industriebeirat FH Aachen

26.11.2019
Visit: RWTH Aachen

7.12.2019
Human Physiology Workshop

9.12.2019
Visit: Representatives Bezirksregierung Köln

17.12.2019
Visit: General Consuls

---

### Teaching Activities

<table>
<thead>
<tr>
<th>Name</th>
<th>University</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeschbach, Daniel</td>
<td>Harvard Medical School</td>
<td>Sleep Medicine</td>
</tr>
<tr>
<td>Anken, Ralf</td>
<td>Universität Hohenheim</td>
<td>Zoologie</td>
</tr>
<tr>
<td>Baumstark-Kahn, Christa</td>
<td>Lufthansa</td>
<td>Fachkundekurs für Strahlenschutzbeauftragte</td>
</tr>
<tr>
<td>Berger, Thomas/Hellweg, Christine</td>
<td>ISU Strasbourg</td>
<td>Master of Space Studie (MSS)</td>
</tr>
<tr>
<td>Berger, Thomas/Hellweg, Christine</td>
<td>Universität Bonn</td>
<td>Strahlenschutzkurs</td>
</tr>
<tr>
<td>Elmenhorst, Eva Maria</td>
<td>RWTH Aachen</td>
<td>Flug/Reisemedizin</td>
</tr>
<tr>
<td>Elmenhorst, Eva Maria</td>
<td>RWTH Aachen</td>
<td>Raumfahrtmedizin</td>
</tr>
<tr>
<td>Elmenhorst, Eva Maria</td>
<td>Universität Köln</td>
<td>Medizin (Wahlpflichtblock Weltraumphysiologie)</td>
</tr>
<tr>
<td>Frings-Meuthen, Petra</td>
<td>Universität Köln</td>
<td>Medizin (Wahlpflichtblock Weltraumphysiologie)</td>
</tr>
<tr>
<td>Goerke, Panja</td>
<td>Leuphana Universität, Lüneburg</td>
<td>Differentielle Psychologie</td>
</tr>
<tr>
<td>Goerke, Panja</td>
<td>Fachhochschule Wedel</td>
<td>Communication and Social Skills</td>
</tr>
<tr>
<td>Hauslage, Jens</td>
<td>ISU Strasbourg</td>
<td>Gravitational Biology</td>
</tr>
<tr>
<td>Hauslage, Jens</td>
<td>ISU Strasbourg</td>
<td>Biological Life Support Systems</td>
</tr>
<tr>
<td>Hauslage, Jens</td>
<td>Tiermedizinische Hochschule Hannover</td>
<td>Gravitational Biology</td>
</tr>
<tr>
<td>Hauslage, Jens</td>
<td>Universidade de São Paulo</td>
<td>Gravitational Biology/Biological Life Support Systems</td>
</tr>
<tr>
<td>Name</td>
<td>University/Institution</td>
<td>Course/Area</td>
</tr>
<tr>
<td>--------------------</td>
<td>------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Hellweg, Christine</td>
<td>FU Berlin</td>
<td>Pathologie</td>
</tr>
<tr>
<td>Hellweg, Christine</td>
<td>FU Berlin</td>
<td>Immunologie</td>
</tr>
<tr>
<td>Hellweg, Christine</td>
<td>Universität Bonn</td>
<td>Radiopharmaziekurs</td>
</tr>
<tr>
<td>Hellweg, Christine</td>
<td>Universität Köln</td>
<td>Medizin (Wahlpflichtblock Weltraumphysiologie)</td>
</tr>
<tr>
<td>Hemmersbach, Ruth</td>
<td>Universität Bonn</td>
<td>Biologie</td>
</tr>
<tr>
<td>Heusser, Karsten</td>
<td>Universität Köln</td>
<td>Weltraumphysiologie</td>
</tr>
<tr>
<td>Heusser, Karsten</td>
<td>RWTH Aachen</td>
<td>Physiologie</td>
</tr>
<tr>
<td>Herzog, Merle</td>
<td>Universität Hamburg</td>
<td>Psychologische Diagnostik</td>
</tr>
<tr>
<td>Hörmann, Hans-Jürgen</td>
<td>Technische Universität München</td>
<td>Luftfahrtpsychologie</td>
</tr>
<tr>
<td>Jordan, Jens</td>
<td>Universität Köln</td>
<td>Medizin (Wahlpflichtblock Weltraumphysiologie)</td>
</tr>
<tr>
<td>Kölzer, Anna</td>
<td>Fachhochschule Wedel</td>
<td>Communication and Social Skills</td>
</tr>
<tr>
<td>Liemersdorf, Christian</td>
<td>Universität Bonn</td>
<td>Biologie</td>
</tr>
<tr>
<td>Lindlar, Markus</td>
<td>Hochschule Bonn-Rhein-Sieg</td>
<td>Med. Businessystem</td>
</tr>
<tr>
<td>Lindlar, Markus</td>
<td>Hochschule Bonn-Rhein-Sieg</td>
<td>Biomed. Informatik</td>
</tr>
<tr>
<td>Marggraf-Micheel, Claudia</td>
<td>Fachhochschule Wedel</td>
<td>Communication Skills</td>
</tr>
<tr>
<td>Meier, Matthias</td>
<td>Joint Space Weather Summer Camp</td>
<td>Radiation Protection in Aviation</td>
</tr>
<tr>
<td>Meier, Matthias</td>
<td>Lufthansa</td>
<td>Fachkundekurs für Strahlenschutzbeauftragte</td>
</tr>
<tr>
<td>Mittelstädt, Justin</td>
<td>Universität Hamburg</td>
<td>Psychologische Diagnostik</td>
</tr>
<tr>
<td>Mulder, Edwin</td>
<td>Universität Köln</td>
<td>Medizin (Wahlpflichtblock Weltraumphysiologie)</td>
</tr>
<tr>
<td>Oubaid, Viktor</td>
<td>Medical School Hamburg</td>
<td>Differentielle Psychologie &amp; Persönlichkeitsforschung</td>
</tr>
<tr>
<td>Pustowalow, Willi</td>
<td>Hochschule Bonn-Rhein-Sieg</td>
<td>Informatik</td>
</tr>
<tr>
<td>Rittweger, Jörn</td>
<td>Universität Köln</td>
<td>Medizin (Wahlpflichtblock Weltraumphysiologie)</td>
</tr>
<tr>
<td>Rittweger, Jörn</td>
<td>Universität Köln</td>
<td>Medizin (Spezielle Pädiatrie)</td>
</tr>
<tr>
<td>Schudlik, Kai</td>
<td>Lufthansa</td>
<td>Fachkundekurs für Strahlenschutzbeauftragte</td>
</tr>
<tr>
<td>Schulze Kissing, Dirk</td>
<td>HS Fresenius</td>
<td>Allgemeine Psychologie</td>
</tr>
<tr>
<td>Stelling, Dirk</td>
<td>HS Fresenius</td>
<td>Differentielle Psychologie (SS)</td>
</tr>
<tr>
<td>Stelling, Dirk</td>
<td>HS Fresenius</td>
<td>Differentielle Psychologie (WS)</td>
</tr>
<tr>
<td>Stelling, Dirk</td>
<td>HS Fresenius</td>
<td>Experimentelles Parktikum</td>
</tr>
<tr>
<td>Stern, Claudia</td>
<td>Technische Universität Braunschweig</td>
<td>Luft- und Raumfahrtmedizin</td>
</tr>
<tr>
<td>Stern, Claudia</td>
<td>Universität der Bundeswehr</td>
<td>Raumfahrtmedizin</td>
</tr>
<tr>
<td>Stern, Claudia</td>
<td>ISU Strasbourg</td>
<td>Master of Space Studies (MSS)</td>
</tr>
<tr>
<td>Stern, Claudia</td>
<td>ISU Space Studies Program</td>
<td>Space Ophthalmology</td>
</tr>
<tr>
<td>Stern, Claudia</td>
<td>European School of Aviation Medicine</td>
<td>Basic Course Ophthalmology I</td>
</tr>
<tr>
<td>Stern, Claudia</td>
<td>European School of Aviation Medicine</td>
<td>Advanced Course Ophthalmology II</td>
</tr>
<tr>
<td>Stern, Claudia</td>
<td>Universität Köln</td>
<td>Medizin (Wahlpflichtblock Weltraumphysiologie)</td>
</tr>
<tr>
<td>Tank, Jens</td>
<td>Medizinische Hochschule Hannover</td>
<td>Propädeutik</td>
</tr>
<tr>
<td>Zange, Jochen</td>
<td>Universität Köln</td>
<td>Medizin (Wahlpflichtblock Weltraumphysiologie)</td>
</tr>
<tr>
<td>Zange, Jochen</td>
<td>Universität Köln</td>
<td>Medizin (Research Track)</td>
</tr>
<tr>
<td>Zinn, Frank</td>
<td>Universität Hamburg</td>
<td>Psychologische Diagnostik</td>
</tr>
</tbody>
</table>
## Graduations

### Supervised Doctoral Students

<table>
<thead>
<tr>
<th>University</th>
<th>Space</th>
<th>Aviation</th>
<th>Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medizinische HS Hannover</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manchester Metropolitan University</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruhr-Universität Bochum</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISU Strasbourg</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RWTH Aachen</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Universität Bonn</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universität Hamburg</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universität Duisburg-Essen</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universität Göttingen</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universität Köln</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SpOHO Köln</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universität Leiden</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Universität des Saarlandes</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delft University of Technology</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universität Salzburg</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Darmstadt</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>FH Aachen</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Universität Regensburg</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universität Erlangen</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Bachelor Degrees

<table>
<thead>
<tr>
<th>University</th>
<th>Space</th>
<th>Aviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hochschule Bonn-Rhein-Sieg</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Universität Bonn</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>European University of Applied Sciences Rhein/Erft</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>University of Applied Sciences Remagen</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>FH Aachen</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Universität Leipzig</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

### Diploma Theses/Master Degrees

<table>
<thead>
<tr>
<th>University</th>
<th>Space</th>
<th>Traffic</th>
<th>Aviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FH Aachen</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Universität Ulm</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>HS Niederrhein</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>HS Emden-Leer</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Universität Giessen</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>RWTH Aachen</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Universität Bonn</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Universität Köln</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>HAW Hamburg</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

### Doctorates

<table>
<thead>
<tr>
<th>University</th>
<th>Space</th>
<th>Aviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universität Erlangen</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Universität Hamburg</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Technische Universität Dresden</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Leuphana Universität Lüneburg</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Universität des Saarlandes</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Awards

Yannick Lichterfeld
Travel grant, 26th Assembly of the European Low Gravity Research Association, Granada, Spain, September 24-27, 2019

Yannick Lichterfeld
Travel Grant, 57. Jahrestagung der Deutschen Gesellschaft für Luft- und Raumfahrtmedizin, Schönhagen, 24-26 October, 2019

Kendrick Solano
Travel grant, 26th Assembly of the European Low Gravity Research Association, Granada, Spain, September 24-27, 2019

Kendrick Solano
Member of the Month (10/2019) of the Student European Low Gravity Research Association

Willi Pustowalow
Student Award 2019 der Konferenz für Angewandte Automatisierungstechnik in Lehre und Entwicklung in der Kategorie beste Bachelor-Arbeit

Katja Gayraud
Werner-Straub-Preis der TU Dresden

Eva-Maria Elmenhorst
Albrecht-Ludwig-Berblinger Preis der Deutschen Gesellschaft für Luft- und Raumfahrtmedizin

Matthias Meier
NASA Group Achievement Award

Stella Koch
1st prize – Student contest “Space Factor”, 19th EANA Astrobiology Conference, Orléans, France, September 3-6, 2019

Marta Cortesão
EANA 2019 Poster Award, 19th EANA Astrobiology Conference, Orléans, France, September 3-6, 2019

Darius Gerlach
Deutsche Hochdruckliga e.V. DHL®: Reisestipendium und Einladung zu den „Best of …“ Sessions

Katharina Siems
Honorable Mention, Art Competition, American Society for Gravitational and Space Research (ASGSR), November 20-23, Denver, USA, 2019

Katharina Siems
1st Prize for start up idea, German Biotechnology Conference, Würzburg, April 9-10, 2019

Luisa Becher
2nd Prize for start up idea, German Biotechnology Conference, Würzburg, April 9-10, 2019
DLR at a glance

The German Aerospace Center (DLR) is the national aeronautics and space research center of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport, security and digitalisation is integrated into national and international cooperative ventures. In addition to its own research, as Germany’s space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation’s largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Goettingen, Hamburg, Jena, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

Imprint

Publisher:
German Aerospace Center (DLR)
Institute of Aerospace Medicine

Address:
Linder Höhe, 51147 Cologne, Germany
Phone +49 2203 601-0
E-mail info-me@dlr.de

DLR.de

Images DLR (CC-BY 3.0), unless otherwise stated.