Fiscal Year:	FY 2019	**Task Last Updated:**	FY 10/09/2019
PI Name:	Basner, Mathias M.D., Ph.D.		
Project Title:	Neurostructural, Cognitive, and Physiologic Changes During a 1-year Antarctic Winter-Over Mission		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Behavior and performance		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	19104-4209	**Congressional District:**	2
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2013 HERO NNJ13ZSA002N-Crew Health (FLAGSHIP & NSBRI)
Start Date:	08/01/2014	**End Date:**	03/31/2019
No. of Post Docs:	1	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
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Flight Program:			
Flight Assignment:	NOTE: End date changed to 3/31/2019 per NSSC information (Ed., 1/10/19) NOTE: End date changed to 12/31/2018 per NSSC information (Ed., 8/7/18) NOTE: Element change to Human Factors & Behavioral Performance; previously Behavioral Health & Performance (Ed., 1/17/17) NOTE: Extended to 7/31/2018 per K. Ohnesorge/JSC and NSSC information (Ed., 12/7/16)		
Key Personnel Changes/Previous PI:	June 2019: Michael Smith (Post-Doc) was added as a co-investigator. May 2017: Nathalie Pattyn (Vrije Universiteit Brussel, Belgium) was added as a co-investigator. She was the research MD on Halley station and will correlate Cognition data with SINSKILL data (also acquired in Halley). May 2016 report: Damien Leger and Gabi Ambrecht were added as Co-Investigators as we are sharing actigraphy data with them. May 2015 report: David Roalf, PhD was added as a Co-Investigator to take over most of the tasks of Ted Sattherthwaite, MD. Alexander Stahn, PhD and Hanns-Christian Gunga, MD PhD were added as Co-Investigators for Cognition in Neumayer-III and Halley-VI. Simone Macri and Mirjam Münch were added as Co-Investigators as we are sharing actigraphy data with them.		

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Grant/Contract No.:	NNX14AM81G
Performance Goal No.:	
Performance Goal Text:	
Task Description:	This proposal primarily addresses the Behavioral Medicine (BMed) 3 Gap on the nature and duration of cognitive performance changes in-flight and post mission, by assessing neurostructural, cognitive, behavioral, physiologic, and psychosocial changes in maximally N=24-28 crewmembers during a 10-12 month Antarctic winter-over in Concordia station, and in the same number of controls matched to crewmembers based on age, gender, and educational attainment. State-of -the-art quantitative structural and functional magnetic resonance imaging (fMRI), in both resting-state and activated; diffusion tensor imaging; and arterial spin labeled fMRI will be performed in crewmembers and controls 4 months before, immediately after, and 6 months after the mission. During the mission, crewmembers will wear a wrist-watch like device that measures movement activity and proximity to other devices 24/7 to investigate sleep-wake behavior and crew cohesion. Once monthly, subjects will perform the Cognition test battery to quantify changes in cognitive performance. Cognition was specifically designed for high-aptitude astronauts and astronaut surrogates. It consists of 10 brief, validated neuropsychological tests that cover a wide range of cognitive domains. A 24-hour, two-electrode electrocardiogram (ECG) will be performed monthly to investigate systematic changes in heart rate, heart rate variability, objectively assessed workload, and sleep fragmentation with time-in-mission. Behavioral alertness will be assessed with a 3 min. Psychomotor Vigilance Test (PVT) on a weekly basis along with brief surveys to assess subjective ratings of mood, workload, stress, sleep quality, tiredness, sickness, and conflicts among crewmembers. The results will be compared with findings from Mars520 and International Space Station (ISS), as many of the variables to be gathered overlap with those successfully obtained by our team in these and other space analog environments. The Cognition test battery was also implemented in the Antarctic stations Neumayer-III and Halley-VI. After this project we will have a much better understanding whether, to what extent, and for how long neurostructural and neurofunctional changes are induced in subjects over-wintering in the isolated and confined space analog environment of Concordia station.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	With the proposed work we will relevantly contribute to the goal of the Human Research Program (HRP) to provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration. More specifically, our findings, based on state-of-the-art neuroimaging technologies and on innovative, non-invasive, low burden, yet methodologically sound measurement technologies for cognitive, physiological, and crew cohesion outcomes, will relevantly contribute to the development of technologies to provide mission planners and system developers with strategies for monitoring and mitigating crew health and performance risks. These methodologies will also be useful for assessing subjects living in isolated, confined, and extreme environments on Earth.
	Due to their complex logistical operations, harsh threatening environmental conditions such as extreme cold, altered photoperiod, low humidity, isolation, and confinement, as well as analogous population of researchers with multicultural backgrounds, but similar educational background compared to astronauts, Antarctic research stations are considered a high-fidelity analog for long-duration space missions. This study investigated neurostructural and functional changes in 25 crewmembers over-wintering in the Antarctic Concordia station and in 26 age- and sex-matched controls at the German Aerospace Center (DLR). Structural and functional neuroimaging was obtained prior to, immediately after, and 6-month after the winter-over. Crewmembers and controls performed the Cognition test battery on a monthly basis in mission. They also wore a small device measuring heart rate for a 24-h period on a monthly basis. Finally, the crew continuously wore wrist actigraphs to measure wake activity and sleep-wake rhythmicity. These watches also recorded proximity to watches worn by the other crewmembers and to devices strategically placed throughout the station as surrogate measures of crew cohesion and habitat use. Two Antarctic research stations (Neumayer and Halley) were added after the start of the study. The crews in these stations (N=17 at Neumayer and N=25 at Halley) only performed the Cognition test battery on a monthly basis. At Neumayer station, neuroimaging was also available before and ca. 3 months after the mission. This study had the following specific aims: • Aim 1: Investigate neurostructural and neurofunctional changes • Aim 2: Investigate changes in cognitive performance • Aim 3: Investigate changes in sleep duration, sleep-wake rhythms, and light exposure • Aim 4: Investigate physiologic changes in heart rate and heart rate variability

Task Progress:

• Aim 5: Investigate changes in subjective assessments of mood, fatigue, health, energy, stress, workload, sleep quality, and conflicts

• Aim 6: Investigate changes in crew cohesion and habitat use.

For T1-weighted MRI, our results indicate small, but robust volume reductions immediately post-mission in the Antarctic winter-over group. Volume generally normalized by the 6-month follow-up, except for a small reduction in Parietal volume. In contrast to volume, gray matter density (GMD) increased in the Antarctic winter-over group, and normalized at the 6-months follow-up. These findings indicate that isolated, stressful environments are associated with transient brain volume reductions and by small increases in gray matter density. Increase in GMD may reflect experience-dependent structural plasticity and is also found in children who have experienced traumatic stressful events.

Most hippocampal subfield measurements indicated little to no change in the Antarctic winter-over group. There was a nominal decline in the parahippocampal cortex (PHC) immediately upon return that completely normalized. Changes in the PHC are relevant as this region of the brain is critical for memory encoding and retrieval that could affect performance. Moreover, extant research has shown that this hippocampal region is sensitive to stress and other environmental stressor (e.g., radiation). As such, alterations in these brain structures should continue to be closely monitored, particularly in longer duration missions.

For diffusion weighted imaging (DWI), functional anisotropy (FA) in white matter decreased in the winter-over group and returned to baseline at 6-month follow-up. There were no significant changes in brain mean diffusivity (MD). Alterations in brain white matter signify microstructural changes in neural communication that are critical for sustaining neurocognitive performance, in particular working memory and executive function, and may relate to the manifestation of clinical symptoms. As such, it is important to monitor changes in brain white matter, especially for longer missions. For functional MRI, Voxelwise regional homogeneity (ReHo) was nominally increased in Fronto-dorsal and Temporal lobes immediately upon return from winter-over that normalized at the 6-months follow-up. Amplitude of Low-Frequency Fluctuations (ALFF) was lower across the brain immediately upon return from winter-over and also normalized at the 6-months follow-up. Alterations in brain connectivity can be associated with significant change in performance and can indicate the presence of neurological or psychological dysfunction. While resting BOLD measures normalized after the mission was complete, it is unknown whether transient changes in functional connectivity have lasting consequences or whether repeated changes in functional connectivity are, in general, detrimental to the integrity of the neural system.

Correlations between brain volume changes in the MRI and cognitive performance changes across the mission showed the strongest associations in subcortical brain regions. Individuals with larger reduction in brain volume in the nucleus accumbens (bilateral) and the right hippocampus after the winter-over mission showed larger performance deficits (less efficient) on Cognition over time. These data indicate significant individual differences in the relationship between alterations in brain structure and performance. Moreover, these data suggest that even small changes in brain subcortical volume can significantly impact cognitive performance in some individuals. Additional biologic and performance measures should be sought to identify individuals that may be vulnerable to small changes in brain volume given the effect that these changes have on cognitive performance. Paradoxically, volume change in the cerebral cortex showed the opposite pattern. More volume reduction during the winter-over was associated with improved performance on Cognition over time. As noted above, this could be related to changes in the composition of brain gray matter that allow for structural plasticity while in an isolated, stressful environment. More comprehensive analyses are needed to better understand this pattern.

Analyses in the Neumayer crew showed that dentate gyrus, CA1, and CA3 volumes were significantly decreased after the expedition. The strongest effects were observed for the dentate gyrus. All other subfields also showed a reduction, but these changes did not reach statistical significance. There were no statistically significant correlations between linear trends in cognitive accuracy, speed, and efficiency (across cognitive domains) with time in mission and change in dentate gyrus volume.

Cognitive performance data suggest significant increases in cognitive speed and decreases in cognitive accuracy, with a net increase in cognitive efficiency, across study sites with increasing time in mission even after adjusting for practice effects. This suggests a change in response strategy (sacrificing accuracy for speed) rather than an isolated insult to cognitive accuracy. However, these changes were small (=0.055 SD per mission quintile; linear trend) and likely irrelevant. Except for a few cognitive domains, differences in accuracy and speed between sites were minor and statistically non-significant. The findings suggest no relevant negative effect on cognitive performance when spending prolonged periods of time (10-14 months) in Antarctic ICE environments on cognitive performance. The subtle change in response bias was observed both in Antarctic crews and DLR controls.

With ca. 6.5 hours total sleep time (TST) sleep duration in the Concordia crew fell a little short compared to the recommended 7 h of sleep per 24 h. However, these recommendations are largely based on self-reported sleep time, which over-estimates objectively assessed sleep duration and more likely reflects time-in-bed (TIB) rather than TST. TIB exceeded 7 hours both in the Concordia crew and in DLR controls. Sleep efficiency was borderline low in both the Concordia crew and DLR controls. Subjectively assessed sleep quality and sleepiness were in the average range and did not differ between sites. According to spectral analyses and visual inspection of double-plotted data the Concordia crew remained entrained to the 24-h day. Periodic breathing during sleep was a common phenomenon in the Concordia crew, but detailed analyses are still pending. Wake activity levels in the Concordia crew were mostly in the light to moderate range, and they did not differ significantly from DLR controls. These results do not suggest major sleep-wake problems in the Concordia crew on the group level, although more detailed analyses may reveal inter-individual differences among the crew.

We found some differences in sympathovagal balance between the first and the second half of the mission in the Concordia crew, with higher vagal activity in the afternoon and evening in the second mission half compared to the first. There was no difference in average heart rate between the Concordia crew and DLR controls. However, sympathovagal balance was shifted towards sympathetic activity in the Concordia crew relative to DLR controls, which could have been caused by the chronic hypobaric hypoxia at Concordia station.

Crews and controls subjectively reported low levels of stress, loneliness, depression, and conflict; high levels of happiness and health; and intermediate levels of workload, physical exhaustion, boredom, and monotony. Of note, the Halley crew scored highest on levels of boredom, monotony, loneliness, and depression. There were significant linear trends across mission quintiles for all of the studied outcomes, indicating a deterioration with increasing time in

	mission. Unobtrusive proximity measurements were found to provide useful information on who is spending time with whom as a proxy of crew cohesion, and how crew cohesion changed over time in mission. This technology could be extremely useful for NASA and would allow flight surgeons and Psych-Ops to continuously monitor crew interactions and intervene early if, e.g., a crewmember shows signs of withdrawal from the rest of the crew. The fact that the proximity technology was embedded in actigraphs that provide information on movement activity and sleep-wake rhythms at the same time was an advantage of the system used. Habitat use varied individually, by time of day, and by mission phase. The proximity technology allows unobtrusive investigation of habitat use, and may inform the design of future spacecraft. It also indirectly (through the use of common areas and private quarters) provided information on crew cohesion.
Bibliography Type:	Description: (Last Updated: 06/19/2025)
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