

<b>Fiscal Year:</b>	FY 2017	<b>Task Last Updated:</b>	FY 05/09/2017
<b>PI Name:</b>	DeChurch, Leslie Ph.D.		
<b>Project Title:</b>	SCALE: Shared Cognitive Architectures for Long-term Exploration--GA Tech		
<b>Division Name:</b>	Human Research		
<b>Program/Discipline:</b>			
<b>Program/Discipline--Element/Subdiscipline:</b>	HUMAN RESEARCH--Behavior and performance		
<b>Joint Agency Name:</b>	<b>TechPort:</b>	No	
<b>Human Research Program Elements:</b>	(1) <b>HFBP</b> :Human Factors & Behavioral Performance (IRP Rev H)		
<b>Human Research Program Risks:</b>	(1) <b>Team</b> :Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team (IRP Rev F)		
<b>Space Biology Element:</b>	None		
<b>Space Biology Cross-Element Discipline:</b>	None		
<b>Space Biology Special Category:</b>	None		
<b>PI Email:</b>	<a href="mailto:dechurch@northwestern.edu">dechurch@northwestern.edu</a>	<b>Fax:</b>	FY
<b>PI Organization Type:</b>	UNIVERSITY	<b>Phone:</b>	954-646-5083
<b>Organization Name:</b>	Northwestern University		
<b>PI Address 1:</b>	Northwestern University		
<b>PI Address 2:</b>	School of Communication		
<b>PI Web Page:</b>			
<b>City:</b>	Evanston	<b>State:</b>	IL
<b>Zip Code:</b>	60208	<b>Congressional District:</b>	9
<b>Comments:</b>	NOTE: Previously at Georgia Institute of Technology until July 2016.		
<b>Project Type:</b>	GROUND	<b>Solicitation / Funding Source:</b>	2014-15 HERO NNJ14ZSA001N-Crew Health (FLAGSHIP & NSBRI)
<b>Start Date:</b>	07/01/2015	<b>End Date:</b>	10/05/2016
<b>No. of Post Docs:</b>	1	<b>No. of PhD Degrees:</b>	1
<b>No. of PhD Candidates:</b>	5	<b>No. of Master' Degrees:</b>	0
<b>No. of Master's Candidates:</b>	0	<b>No. of Bachelor's Degrees:</b>	0
<b>No. of Bachelor's Candidates:</b>	0	<b>Monitoring Center:</b>	NASA JSC
<b>Contact Monitor:</b>	Williams, Thomas	<b>Contact Phone:</b>	281-483-8773
<b>Contact Email:</b>	<a href="mailto:thomas.j.will1@nasa.gov">thomas.j.will1@nasa.gov</a>		
<b>Flight Program:</b>			
<b>Flight Assignment:</b>	NOTE: End date changed to 10/5/2016 (original due date was 6/30/2018) due to PI move to Northwestern University and new award granted (Ed., 2/12/18) NOTE: Element change to Human Factors & Behavioral Performance; previously Behavioral Health & Performance (Ed., 1/17/17)		
<b>Key Personnel Changes/Previous PI:</b>	July 2016: none		
<b>COI Name (Institution):</b>	Contractor, Noshir Ph.D. ( Northwestern University ) Johnson, Jeffrey Ph.D. ( University of Florida, Gainesville )		
<b>Grant/Contract No.:</b>	NNX15AM26G		
<b>Performance Goal No.:</b>			
<b>Performance Goal Text:</b>			

**Task Description:**

Among the remarkable team challenges NASA faces in long distance space exploration (LDSE) missions is the need to maintain team shared mental models (SMMs). Maintaining team SMMs requires the ability to detect shifts in cognition that will likely occur during the mission that could lead to ineffective crew functioning and performance. Maintaining team SMMs also requires validated countermeasures for bringing team members' cognitive understanding back into alignment. Leaving low Earth orbit is extreme teamwork -- team SMMs need to be maintained within teams operating close up (the crew), and between teams operating at an unprecedented distance (i.e., the crew & ground; 33 million miles in the case of a Mars Mission). A multidisciplinary research team will leverage expertise in Psychology, Industrial Engineering, & Anthropology to understand the emergence and outcomes of critical shifts in team cognition over LDSE missions. What are the triggering events of SMM divergence, how can we detect them, and which countermeasures most effectively bring them back into alignment? This project leverages a novel conceptual framework of shared cognitive architecture (SCA) to understand the patterns of SMMs that dynamically link members of teams, and teams to other teams, as they go beyond low Earth orbit. We use semantic analysis to identify cognitive shifts, and relational event network analysis to understand the antecedents and consequences of these shifts. We use these alongside an agent-based model fit on LDSE analogue data, so that we can explore an exhaustive set of potential triggering conditions that must be unpacked to conduct efficient ground analogue research. We then conduct this research in HERA (Human Exploration Research Analog), Moonwalk, and Antarctica. The project culminates in the evaluation of a dashboard fed with the results of computational modeling, human validation, and lexical markers to detect and suggest countermeasures to maintain SMMs through time and space.

NOTE: Project continues as "SCALE: Shared Cognitive Architectures for Long-term Exploration--80NSSC18K0221," due to Principal Investigator move to Northwestern University in Fall 2016.

**Rationale for HRP Directed Research:****Research Impact/Earth Benefits:**

Many of the environmental conditions faced by crews during LDSE missions are not unique to space travel. With our research program, we hope to reveal how conditions seen in organizations across the world impact shared cognitive architecture, and what we can do to mitigate these risks. Our meta-analysis has begun to investigate the impact of shared cognitive architecture on team outcomes across a variety of environmental conditions seen in LDSE missions that can also be applied to work in all organizations.

**Task Progress:**

Among the significant team challenges NASA will face during long distance space exploration is the need to maintain shared cognition within the space crew and among the system of teams that support the crew from Earth (i.e., the space exploration multiteam system). Shared cognition is defined as team members' shared understanding of knowledge regarding the team's environment, tasks, expertise, roles, and responsibilities. Shared cognition needs to be maintained within teams who operate at a short distance (i.e., the crew), and also between teams who operate at a great distance (i.e., the crew and ground). Research suggests the extent to which cognition is shared within the team and the broader multiteam system has implications for team process, performance, affect, and viability over time. Over the course of this three-year programmatic research program, we have three major foci of activity: (1) to develop and test ways to measure shared cognition in teams and multiteam systems, (2) to explore the antecedents, consequences, and moderating conditions associated with shared cognition, and (3) to model shared cognition in teams and within multiteam systems so as to inform interventions. In Year 2, we've made significant strides in each of these areas with six major projects that speak to one or more of the above foci.

In Study 1, we use meta-analysis to explore the conditions under which shared cognition is most important to crew performance. We explore three types of moderating variables, including team type (e.g., team diversity, autonomy, and lifespan), team context (e.g., virtuality, temporal and geographic dispersion, and organizational embeddedness), and team conditions (e.g., physical and psychological stressors). Results help us determine (1) the extent to which prior teams research is relevant to long distance space exploration, (2) factors which need to be modeled effectively in order to predict, diagnose, and prevent breakdowns in shared cognition, and (3) which antecedent and moderating conditions are most relevant to cognitive sharedness in long distance space exploration.

In Study 2, we developed an approach to using text analytics as an unobtrusive means of measuring shared cognition using the archived mission transcripts from the Skylab missions. We identified the text-based signatures of cognitive breakdown that ultimately led to conflict in Skylab 4. We also explored the dynamic conversational patterns in each mission that were indicative of cognitive sharedness or its breakdown. This study informs our broader goal of developing efficient and unobtrusive measures of shared cognition in multiteam systems.

In Study 3, we developed an agent based model (ABM) using empirical data collected from the HERA analog. We developed the ABM in two phases. First, we canvassed the relevant literature on shared cognition to identify its antecedent conditions. Second, we collected laboratory and analog data to estimate and then test the parameters of the agent based model. In particular, we explored personality factors, social relations, situational factors, and task stream characteristics that associate with cognitive sharedness. The ABM will be used in Year 3 to run "virtual experiments" wherein we can pose "what if" questions that will directly inform the development of interventions aimed at promoting shared cognition, ultimately informing our major goal associated with modeling shared cognition in teams and multiteam systems.

Studies 4-6 speak directly to our major goal of identifying antecedents conditions of cognitive sharedness. In Study 4, we collected data in the HERA analog using daily planning surveys and the Project RED task battery to explore the role of social connectedness, communication delay, and sleep deprivation on shared cognition. In Study 5, we conducted archival research on thirty documented Antarctic exploration missions to explore how social roles, leadership isomorphism, and group dynamics affected cognitive sharedness and ultimately team functioning and viability on these missions. Finally, in Study 6, we worked with Diego Urbina from Space Applications, Inc. to collect data in the Moonwalk analogs in Rio Tinto, Spain and Marseilles, France. In these analogs, we explored how information sharedness affects shared cognition.

Our research will provide fundamental, generalizable findings in the area of shared cognition in teams and multiteam systems. Researchers have bemoaned the inefficiencies associated with measuring shared cognition as historically such measurements have been intrusive and time-consuming. In this program of research, we are exploring the use of text analytics, social role network analyses, and surveys as efficient and less intrusive means of assessing cognitive sharedness within the team and broader multiteam system. Second, as teamwork becomes more prevalent across

	<p>workplaces and occupations and its nature more variable, a broader array of antecedent, moderating, and mediating conditions associated with shared cognition come into play. We are conducting meta-analytic, archival, experimental, and analog studies designed to identify and understand the antecedents and consequences of shared cognition in teams and multiteam systems. Finally, breakdowns in shared cognition must be identified and addressed quickly before team functioning is irrevocably affected. We use data collected in these meta-analytic, archival, experimental, and analog studies to develop an agent based model which will be used in Year 3 to conduct virtual experiments and ultimately create a dashboard for diagnosing and developing interventions for breakdowns in shared cognition.</p> <p>This research will be useful for investigating shared cognition in any modern-day organization facing complex collaborative challenges, such as NASA space exploration, large scientific consortia (e.g., CERN), cybersecurity teams, healthcare systems, and the military. Furthermore, findings could then be leveraged to develop system-wide interventions that increase overall work efficiency and resilience in safety-critical systems. In this review period, we have collected data across multiple platforms (please see subsequent sections of this report for details) to begin to understand the antecedent, consequent, and moderating conditions associated with shared cognition. In addition to providing Earth Benefits in the area of shared cognition in teams and multiteam systems, we are also testing our hypotheses in analogs that recreate the unique contexts in which astronauts operate (i.e., extreme, isolated/confined environments). We will compare results across research paradigms to see how effects of isolation/confinement may moderate shared cognition's role in team functioning, thus providing unique findings that will inform NASA's operations aboard the International Space Station (ISS) and on Long-Duration Space Exploration (LDSE) missions.</p> <p>NOTE: Project continues as "SCALE: Shared Cognitive Architectures for Long-term Exploration--80NSSC18K0221," due to Principal Investigator move to Northwestern University in Fall 2016. See that project for subsequent reporting.</p>
<b>Bibliography Type:</b>	Description: (Last Updated: 04/01/2022)
<b>Abstracts for Journals and Proceedings</b>	<p>Twyman M, DeChurch L, Contractor NS. "Using a network approach for modeling shared cognition of astronaut teams." Poster to be presented at NetSci 2017 International School and Conference on Network Science, Indianapolis, IN, June 19-23, 2017. NetSci 2017 International School and Conference on Network Science, Indianapolis, IN, June 19-23, 2017. , Jun-2017</p>
<b>Abstracts for Journals and Proceedings</b>	<p>Jeon G, DeChurch LA, Contractor NS. "Structural measures of specializations in teams." Presented at the XXXVI International Sunbelt Social Networks Conference, Newport Beach, CA, April 5-10, 2016. XXXVI International Sunbelt Social Networks Conference, Newport Beach, CA, April 5-10, 2016. Presentations and abstracts, p. 100-101. , Apr-2016</p>
<b>Abstracts for Journals and Proceedings</b>	<p>DeChurch LA, Schultz M, Johnson J, Contractor NS, Mesmer-Magnus J, Plummer G, Twyman M. "Structured text analysis for evaluating shared cognition." Presented at 2017 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 23-26, 2017. 2017 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 23-26, 2017. , Jan-2017</p>
<b>Abstracts for Journals and Proceedings</b>	<p>DeChurch LA, Niler A, Plummer G, Tanaka K, Contractor NS. "Impact of social connectedness, communication delay, and sleep deprivation on cognitive network similarity in analog teams." Presented at 2017 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 23-26, 2017. 2017 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 23-26, 2017. , Jan-2017</p>
<b>Abstracts for Journals and Proceedings</b>	<p>DeChurch LA, Larson L, Gómez-Zarà D, Jones BR, Contractor N, Johnson J. "Leadership emergence in space multiteam systems." Team, Training, and Performance Metrics. Presented at 2017 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 23-26, 2017. 2017 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 23-26, 2017. , Jan-2017</p>
<b>Abstracts for Journals and Proceedings</b>	<p>DeChurch LA, Contractor NS, Niler A, Mesmer-Magnus JR, Plummer G, Gomez-Zara D. "Shared cognition in multiteam systems: A NASA space analog study." Poster presented at the 23rd Organizational Science Winter Conference, Park City, UT, February 2-5, 2017. 23rd Organizational Science Winter Conference, Park City, UT, February 2-5, 2017. , Feb-2017</p>
<b>Abstracts for Journals and Proceedings</b>	<p>DeChurch LA, Mesmer-Magnus JR, Niler A, Plummer G, Larson L, Contractor NS. "The relative instrumentality of team cognition: A meta-analysis." Poster to be presented at the EAWOP17 European Association of Work and Organizational Psychology Congress, Dublin, Ireland, May 17-20, 2017. EAWOP17 European Association of Work and Organizational Psychology Congress, Dublin, Ireland, May 17-20, 2017. , May-2017</p>
<b>Articles in Peer-reviewed Journals</b>	<p>Wolak RJ, Johnson JC. "Social dynamics in an isolated, confined, and extreme workplace." Int J Biometeorol. 2021 Mar;65(3):437-51. <a href="https://doi.org/10.1007/s00120-021-01000-0">https://</a>; PMID: 33230641 , Mar-2021</p>
<b>Papers from Meeting Proceedings</b>	<p>Johnson JC, Zurek M, Contractor NS, DeChurch LA. "Team dynamics in spaceflight analogs: Shared mental models, informal social roles, and team viability and conflict in the Human Exploration Research Analog (HERA)." Paper presented at the XXXVII Sunbelt Social Networks Conference of the International Network for Social Network Analysis (INSNA), Beijing, China, May 30th – June 4th, 2017. XXXVII Sunbelt Social Networks Conference of the International Network for Social Network Analysis (INSNA), Beijing, China, May 30th – June 4th, 2017. , May-2017</p>
<b>Papers from Meeting Proceedings</b>	<p>DeChurch LA, Larson L, Jones BR, Gómez-Zarà D, Contractor N. "Social identification and leadership emergence within and between teams." Paper presented at the 2nd Interdisciplinary Perspectives on Leadership Symposium, Mykonos, Greece, May 4-6, 2017. 2nd Interdisciplinary Perspectives on Leadership Symposium, Mykonos, Greece, May 4-6, 2017. , May-2017</p>
<b>Papers from Meeting Proceedings</b>	<p>Tanaka K, Witz C, Niler AA, DeChurch LA, Contractor NS. "Misperceptions of social structure: Omission and commission errors in communication networks." Paper presented at the 2017 Organizational Communication Mini Conference, Athens, OH, October 13-15, 2017. 2017 Organizational Communication Mini Conference, Athens, OH, October 13-15, 2017. , Oct-2017</p>

<b>Papers from Meeting Proceedings</b>	Niler A, Gibson ZM, DeChurch LA. "The social forces behind leadership network formation in multiteam systems." Paper presented at the Academy of Management Annual Meeting, Atlanta, GA, August 1-3, 2017. Academy of Management Annual Meeting, Atlanta, GA, August 1-3, 2017. , Aug-2017
<b>Papers from Meeting Proceedings</b>	Larson LE, Jones BR, Gibson Z, DeChurch LA. "Language, leadership, and identity construction in multiteam systems." Paper presented at the Academy of Management Annual Meeting, Atlanta, GA, August 1-3, 2017. Academy of Management Annual Meeting, Atlanta, GA, August 1-3, 2017. , Aug-2017
<b>Papers from Meeting Proceedings</b>	Gomez-Zara D, Larson LE, Jones BR, DeChurch LA, Contractor NS. "Leadership and followership emergence in NASA space crews." Paper presented at the 2017 WSTNet Web Science Summer School, St. Petersburg, Russia, July 1-8, 2017. 2017 WSTNet Web Science Summer School, St. Petersburg, Russia, July 1-8, 2017. , Jul-2017
<b>Papers from Meeting Proceedings</b>	DeChurch LA, Schultz M, Contractor NS. "SCALE: Shared cognitive architecture for long-term exploration." Paper presented at the Buzz Aldrin Space Institute Mars Mission Social Sciences Workshop, Cape Canaveral, FL, May 30, 2017. Buzz Aldrin Space Institute Mars Mission Social Sciences Workshop, Cape Canaveral, FL, May 30, 2017. , May-2017
<b>Papers from Meeting Proceedings</b>	Gibson ZM, Carter DC, DeChurch LA. "Little words and big goals: Semantic indicators of leadership in multiteam systems." Paper presented at the 67th Annual Conference of the International Communication Association, San Diego, CA, May 25-29, 2017. 67th Annual Conference of the International Communication Association, San Diego, CA, May 25-29, 2017. , May-2017
<b>Papers from Meeting Proceedings</b>	Twyman M, Dechurch L, Contractor N. "Using a network approach for modeling shared cognition of astronaut teams." Paper presented at the NetSci 2017: International School and Conference on Network Science, Indianapolis, IN, June 21-23, 2017. NetSci 2017: International School and Conference on Network Science, Indianapolis, IN, June 21-23, 2017. , Jun-2017