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PI Name:	Lieberman, Philip Ph.D.		
Project Title:	Speech monitoring of cognitive deficits and stress		
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Program/Discipline:	NSBRI Teams		
Program/Discipline--Element/Subdiscipline:	NSBRI Teams--Neurobehavioral and Psychosocial Factors Team		
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Human Research Program Risks:	(1) BMed :Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders		
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Space Biology Cross-Element Discipline:	None		
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PI Email:	philip_lieberman@brown.edu	Fax:	FY 401-863-2255
PI Organization Type:	UNIVERSITY	Phone:	401-863-1857
Organization Name:	Brown University		
PI Address 1:	Department of Cognitive and Linguistic Sciences		
PI Address 2:	190 Thayer Street Room 120		
PI Web Page:			
City:	Providence	State:	RI
Zip Code:	02912	Congressional District:	2
Comments:			
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No. of Bachelor's Candidates:	4	Monitoring Center:	NSBRI
Contact Monitor:	Contact Phone:		
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COI Name (Institution):	Dinges, David (University of Pennsylvania)		
Grant/Contract No.:	NCC 9-58-NBPF00406		
Performance Goal No.:			
Performance Goal Text:	<p>Our project's goal is to derive and validate acoustic measures of speech that permit automatic, unobtrusive on-line monitoring of effects of stress and neurological impairment on astronauts' ability to perform in extended deep-space missions. Our project integrates ongoing NSBRI research aimed at systems that monitor the ability to perform using facial markers of stress, acoustic measures of stress and impaired cognition, and tests that permit rapid psychometric assessment of cognitive status. The project establishes a synergy between a space-analog study of climbers ascending Mount Everest, who experience stress and neurologic impairment similar to that from exposure to cosmic rays, and laboratory studies of task-induced stress. Our proposed system will detect psychological changes before performance is severely impaired, giving crews time to invoke countermeasures. It will derive acoustic parameters from conversation via automated procedures and without intrusive devices. Because the acoustic measures are largely outside of conscious control, crewmembers will not be able to improve with practice or "fool" the system. It will protect privacy and mission</p>		

Task Description:

security because it does not depend on the content of speech, only its acoustics. In the past year, working with David Dinges's NSBRI-funded group at the University of Pennsylvania, we validated measurements of speech acoustics as stress indices. We measured fundamental frequency of phonation (F0), word duration and pause duration in spoken responses made by Dinges's subjects while performing a Stroop task in high-stress (incongruent) and low-stress (congruent) conditions. Mean, minimum and maximum F0; F0 range; pause duration and word length were significantly greater in the high-stress condition. Moreover, a process based on three measures – pause duration, word duration and maximum F0 – discriminated with total certainty between high- and low-stress conditions for the 42 subjects measured. We also continued research on speech and cognition in climbers on Everest. Deep-space missions will expose crews to cosmic rays, which may damage the basal ganglia and hippocampus. These subcortical brain structures are also vulnerable to oxygen deprivation. Humans cannot acclimatize to the low oxygen levels at altitudes above Everest Base Camp. Thus we use climbers on Everest as models for crews in space. Everest also resembles long-term spaceflight in that a small group in close contact must make critical decisions in life-threatening situations. The research is ethical because subjects willfully expose themselves to the dangers of climbing Everest. The basal ganglia are linked with cortical regions in circuits regulating motor control, cognition and personality. A major function of the basal ganglia is regulating sequences of motor acts and cognitive operations. Parkinson's disease (PD), which results from dysfunction of the basal ganglia, impairs not only motor control but cognitive abilities that require processing sequences, such as sentence comprehension and set-shifting. PD also impairs sequential speech motor acts such as production of voice-onset time (VOT). VOT is the time, for word-initial stop consonants, between the noise "burst" when an oral tract closure (e.g., the lips for [b] or [p]) is opened and the onset of the vowel. VOTs for voiced stops like [b] are usually at least 20 msec less than those for voiceless stops like [p]; in PD patients this difference may be reduced. This VOT convergence correlates with sentence comprehension deficits in PD. Hypoxia on Everest yields speech and cognitive deficits similar to if less extreme than those in PD. We obtain speech measurements by using radios to record climbers reading words at different altitudes. We also give the Wisconsin Card Sorting Task, which requires subjects to sort stimuli using different criteria and to shift criteria based on feedback. Climbers carry picture booklets so that we can administer sentence-picture matching tests of language comprehension. Climbers also take the MiniCog test battery, developed in Stephen Kosslyn's NSBRI-funded research at Harvard, on Palm Pilot PDAs that they carry. We have in recent years added an implicit memory test reflecting hippocampal function. Past Everest results show that VOT convergence and increased vowel duration at high altitudes track impairment on cognitive tasks dependent on basal ganglia function, including sentence comprehension, set-shifting and working memory. Preliminary analyses indicate that hypoxia also impairs hippocampal function. In April-May 2005 we obtained speech recordings and cognitive test results for 20 more climber-subjects. Preliminary analyses appear consistent with our past results. Results on implicit memory were also obtained for 2 additional climbers. Our findings set the stage for an operational system for detecting potentially dangerous shifts in psychological state via speech acoustic measures. Our techniques may be used to monitor PD and have potential for detecting early Alzheimer's disease. We are applying the techniques to assess verbal apraxia, a disorder affecting language and cognition in children, with the aim of isolating genetic anomalies underlying this condition. Our techniques have potential applications in general aviation, where hypoxia has led to disasters, and for monitoring stress in occupations like air traffic control. In the coming year we will complete analysis of this year's Everest data and plan for a spring 2006 Everest research trip. We will better characterize our stress metrics by correlating them with physiological and behavioral indices obtained by the Dinges group. We plan to validate other acoustic stress measures, namely jitter (the period-by-period variability in wavelength) and spectral properties. We also intend to validate our metrics of task-induced stress, derived in lab recordings, by testing them on speech recordings obtained in stressful conditions on Everest.

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

The techniques we are developing for unobtrusively monitoring cognitive status and stress via automated measurement of speech parameters may have applications in general aviation. Systems based on these techniques could be used to monitor air crews for gradual effects of partial or slow failure of aircraft pressurization systems. The hypoxia resulting from such depressurization – which degrades cognitive function so that crew members not only are unable to perform their tasks but fail to notice their own impairment – has led to flight disasters in the past. A speech-based system may also be useful in monitoring motor and cognitive dysfunction resulting from stress and sleep deprivation in, for example, air traffic controllers. Our project's techniques have already been used to assess the efficacy of new surgical procedures for the treatment of Parkinson's disease. They can be used to monitor disease state in Parkinson's. They may also provide instruments that can detect memory loss in the early stages of Alzheimer's disease. Such early detection would permit clinicians to take maximal advantage of therapies, now under development, that can delay or even arrest further decline. In addition to Parkinson's disease, our techniques may have application to the diagnosis, assessment, and treatment of other human pathologies stemming from impaired dopaminergic basal ganglia function in neural circuits regulating speech production, cognition and personality. These include not only neurodegenerative diseases but also the results of acute insult. For example, hypoxia during birth can lead to verbal apraxia in children – a syndrome where speech motor and orofacial motor control is degraded and which can result in cognitive and linguistic deficits. In an independent pilot study we have already applied our techniques to the diagnosis and possible remediation of verbal apraxia; we aim to use results of this research in isolating potential genetic anomalies underlying the condition.

Task Progress:

One of our project's main goals is to derive and validate robust, reliable indices of cognitive degradation due to impairment of subcortical brain structures – the basal ganglia and hippocampus – that are vulnerable to damage from cosmic radiation during long-term spaceflight. Because these same structures are susceptible to hypoxic damage, we study climbers ascending Mount Everest as an analog to crews in deep space. Research on Parkinson's disease (PD) indicates that voice-onset time (VOT), a speech parameter whose production involves sequencing the opening of a supralaryngeal closure and the onset of laryngeal phonation, depends on intact basal ganglia function – consistent with the structure's role as a "sequencing engine" in motor and cognitive domains. VOT "convergence" in PD correlates with deficits in comprehending sentences with moderately complex syntax. In past NSBRI-funded research on Everest we found VOT "convergence" and lengthened vowels in climbers at high altitudes. Moreover, we found reliable relationships between these changes (which are not seen in all climbers) and impaired performance on cognitive tests reflecting basal ganglia function, including sentence comprehension, cognitive set-shifting and working memory. (Such relationships were not seen for tasks that do not depend on the basal ganglia.) Our latest Everest expedition, in April-May 2005, involved several improvements on past years' procedures. We stressed the need for familiarization with the Mini-Cog test battery (developed in Kosslyn's NSBRI-funded research). This battery tests a variety of cognitive capacities, including both ones that are sensitive to basal ganglia function and ones that are not. Familiarization allows

	subjects to reach performance plateaus before attempting to summit Everest; otherwise comparisons between lower and higher altitudes may reflect both performance decrements due to hypoxia and improvements due to practice. We also used fewer Mini-Cog tests to reduce time demands while still adequately assessing cognition. Our research team substantially expanded our data base, obtaining speech recordings and cognitive test results for 20 climbers. Preliminary analyses appear consistent with our past results. We also obtained results on an implicit memory test reflecting hippocampal function for two additional climbers, adding to data obtained in 2004. Our other main goal is to derive and validate speech acoustic indices of stress based on speech acoustic properties. This past year we obtained results showing that mean, minimum and maximum fundamental frequency of phonation (F0); F0 range; pause duration and word length were significantly greater in spoken responses during a high-stress, incongruent Stroop task than a low-stress, congruent Stroop task. Moreover, a process based on three measures – pause duration, word duration and maximum F0 – discriminated w
Bibliography Type:	Description: (Last Updated: 02/27/2014)
Books/Book Chapters	Lieberman P. "Towards an evolutionary biology of language." Harvard University Press, in press as of January 2004., Jan-2004
Presentation	Hochstadt, J., and Lieberman, P. "Eye Movements During Sentence-Picture Matching Track Linguistic Processing: Novel Findings in Normal Participants and Parkinson's Disease Patients" N/A Apr-2005
Presentation	Lieberman, P. "The FOXP2 gene and human motor, cognitive and linguistic ability" N/A Apr-2005
Presentation	Lieberman, P. "The NSBRI Everest Space-Analog Study" N/A Jun-2005
Presentation	Lieberman, P., J. Hochstadt, A. Morey, M. Larson, S. Mather, and J. Mertus "Speech Monitoring of Cognitive Deficits and Stress: A Space-Analog Study" N/A Jan-2005