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PI Name:	Lieberman, Philip Ph.D.		
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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
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Radiation in space or on the moon can result in brain damage that degrades an astronaut's ability to perform cognitive tasks, particularly ones involving changing the course of one's actions. Shifts in personality can also occur. Task demands, sleep deprivation and psychosocial stressors can also degrade cognitive performance. Our goal is a speech monitoring system suitable for space-flight that will detect degraded cognitive ability and stress by means of automatic, ongoing acoustic analysis of an astronaut's speech. The system would provide astronauts and ground-control with timely warnings before profound disability occurs, and provide ongoing assessment of ability to perform. No additional sensors attached to individuals or tasks would be involved; it would be impossible to evade the voice monitoring system. Moreover, our voice analysis techniques preserve confidentiality because the relevant acoustic measures reflect impaired speech motor control rather than message content.

Our procedures are based on recent insight on how brains work. Complex behaviors such as walking, talking,

Task Description:

comprehending the meaning of a sentence, or deciding what you should do when circumstance change, involve linked activity in different parts of the brain. The subcortical basal ganglia are structures of the brain that support "circuits" (akin to electrical pathways) connecting different regions of the brain. Independent studies show that circuits involving the basal ganglia regulate motor control, cognition, emotional responses and some aspects of a person's personality. Damage to the basal ganglia, which are sensitive to both radiation and oxygen deprivation (hypoxia), thus can degrade these aspects of behavior. We have confirmed that acoustic measures quantifying slow speech motor control can be used to monitor cognitive impairment induced by hypoxic and cosmic-ray induced insult to the brain, as well as degraded cognitive performance resulting from task difficulty, other stressors and sleep deprivation. Other acoustic metrics can identify sleep deprivation and stress derived from perceived poor performance. We are moving towards an operational system and have developed a prototype computer algorithm that automatically measures speech rates in low noise environments.

Our project has two complementary components. 1- Our Everest Space-Analog studies provide the foundation for an operational system that uses acoustic measures of a person's speech to detect cognitive deficits resulting from exposure to radiation in space or on the moon, as well as hypoxia in spacewalks. 2- Our cooperative laboratory study with the NSBRI project directed by Dr. David Dinges at the Medical School of the University of Pennsylvania has yielded a procedure that uses these acoustic measures and additional ones to detect impaired cognitive performance resulting from the stress of task difficulty, as well as psychosocial stressors and sleep deprivation. We have developed prototype computer algorithms that automatically derive relevant acoustic measures from running speech

Everest Space–Analog.

Independent NSBRI research confirms that the basal ganglia are sensitive to radiation; they also are susceptible to oxygen deprivation (hypoxic insult) in climbers breathing thin air at extreme altitudes. Thus we can use climbers ascending Everest as models for the some of the effects of radiation on crews in space. The research is ethical because subjects willfully expose themselves to the dangers of climbing Everest. Climbing Everest entails ascending to a series of high camps. At each camp with progressively lower oxygen, our climber–subjects perform sentence comprehension tests, the Wisconsin Card Sorting Test (WCST), and mental arithmetic tests that simulate operational tasks encountered in spaceflight. WCST performance translates to the ability to change plans when circumstances change. At higher altitudes, error rates on the WCST and arithmetic tests tend to increase and it takes longer to comprehend the meanings of sentences. We have used the BLISS interactive speech analysis computer algorithms developed at Brown University to derive acoustic speech measures that reflect slower motor control. These acoustic metrics track cognitive dysfunction. Our procedures detect lower sentence comprehension or degraded WCST performance 91% of the time. A system that used measures of speech rate to monitor these cognitive deficits would have had a 3% miss rate and 6% "false alarm" rate (decisions that do not reflect with impairment).

Task difficulty, stress and sleep deprivation.

In the Dinges laboratory setting subjects had to perform easy and difficult mental arithmetic tasks. Subjects also performed these tasks after sleep deprivation and with a psychosocial stressor (being informed that their performance was deficient). Measures of slower speech tracked higher error rates and fewer solutions as they performed the more difficult task. Acoustic measures that reflect laryngeal activity identified those subjects who were sleep deprived or subjected to the psychosocial stressor.

Earthbound applications

Our objective acoustic analyses provide direction for focused intervention for children having verbal apraxia (speech motor sequencing difficulties). Our procedures have been used to evaluate new procedures for the treatment of Parkinson's disease, which involves basal ganglia degeneration. The effects of task difficulty, sleep deprivation and other stressors could be voice monitored in applications ranging from enhancing computer-implemented instruction to safely driving a truck.

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 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. Hypoxia resulting from such depressurization degrades cognitive function and crew members not only are unable to perform their tasks but fail to notice their own impairment, leading to disaster. Speech-based systems could monitor both motor and cognitive dysfunction resulting from stress and sleep deprivation in occupations ranging from air traffic controllers to truck drivers. Measures of vowel and pause durations could be used to pace computer-aided instruction, adjusting the presentation of information to an individual's cognitive ability.

Our project's techniques have already been used to assess the efficacy of new surgical procedures for the treatment of Parkinson's disease. 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 that can delay or even arrest further decline. Our techniques may have application to the diagnosis, assessment, and treatment of other human pathologies stemming from impaired 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. Our computer-implemented speech analysis techniques identify specific deficits that are not evident by listening to the children; therapy can then be directed towards the remediation of these problems. We also can identify the specific cognitive deficits accompanying many instances of verbal apraxia, again directing treatment.

Our research can be useful in identifying genetic and environmental factors underlying the condition. We will be extending this line of enquiry to autism, working with specialists in pediatric neurology.

Another potential application is in assessing the truthfulness of verbal statements. Dissimulation generally involves greater cognitive effort, activating more brain structures that would be the case for truthful statements. This yields slower speech which we can readily detect.

Task Progress:	We have directed our attention towards deriving speech measures that can be implemented in a space-capable system monitoring cognitive deficits deriving from cosmic-ray induced brain dysfunction, cognitive load, sleep deprivation and other stressors. Structures of the brain that support cognition also take part in regulating motor control. Stressors impeding cognition also slow down motor activity. We have confirmed that acoustic measures quantifying slow speech, can be used to monitor cognitive impairment induced by hypoxic and cosmic-ray induced insult to the brain, as well as degraded cognitive performance resulting from task difficulty, other stress and sleep deprivation. We have moved towards an operational system and have developed a prototype computer algorithm that automatically measures speech rates in low noise environments. Hypoxic cognitive dysfunction As our climber-subjects ascended Mount Everest cognitive performance was impaired to varying degrees in different individuals. Set shifting error rates on the Wisconsin Card Sorting Test (WCST) tended to increase. WCST performance translates to the ability to adjust to change plans as circumstances change. It generally took longer to comprehend the meanings of sentences. The rate at which the subjects talked slowed down. In our 2007 study, the climber-subjects also performed mental arithmetic tests which simulate many of the cognitive tasks encountered in space-flight. Combined data for subjects studied between 2003 and 2006 showed that our procedures detects lower sentence comprehension or degraded WCST performance 91% of the time. A system that used measures of speech rate to monitor these cognitive deficits would have had a 3% miss rate and 6% "false alarm" rate (decisions that do not reflect with impairment). Data analysis from May 2007, which started in June, is in progress. Task difficulty, stress and sleep deprivation. In a laboratory setting subjects had to perform easy and difficult mental arithmetic tasks that simulate some of the tasks performed by astronauts. Similar speechmetrics tracked degraded performance on the difficult task. Slower speech and acoustic measures that reflect laryngeal activity identify those subjects who were sleep deprived or subjected to psychosocial stress. Algorithms for a space-capable system We developed a prototype computer algorithm that automatically derives acoustic measures that reflect slow speech rates from discourse in relatively noise-free environments. Our goal is a speech monitoring system suitable for space-flight that will provide astronauts and ground-control with timely warnings before profound disability occurs, and provide ongoing assessment of ability to perform. Earthbound applications Studies of children having verbal apraxia (speech motor sequencing difficulties) show an additional earthbound application. They have cognitive and speech deficits occur that appear to derive from damage to basal ganglia.
Bibliography Type:	Description: (Last Updated: 02/27/2014)
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