Vocal Biomarkers for Monitoring Neurological Disorders

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Structure: Ten Divisions (e.g., Homeland Protection, Communication Systems, Cyber Security) with about eight groups within each division

Bioengineering Systems and Technology Group: Preserve and enhance human health and performance through monitoring, analysis, and interventions

- New group ~3 years: Highly interdisciplinary
- Staff: ~50 scientists, engineers, students, support
- Funding sources: DoD, NIH, Internal
- Broad technical areas: Biomedical research, synthetic biology, bioinformatics, biometrics

Speech, hearing, and neuro-cognitive analysis
Speech, Hearing and Neuro-cognitive Analysis
Motivation, Objective, Approach

Motivation
• Many conditions that affect cognitive performance
• Includes neurological and stress conditions

Objective
• Simple, sensitive method to detect and monitor a condition
• Distinguish across conditions

Approach: Vocal biomarkers
• Reflect underlying neurophysiological changes that alter speech motor control
• Reflect coordination changes across speech production components, as well with other modalities
MIT Lincoln Research Focus

Research in vocal biomarkers

Articulatory coordination
Phonetic timing

Evolving research areas

ALS
Cognitive Load
Parkinson's
Vocal Fatigue

From laboratory to mobile device

| MIT LL/MIT BCS | Traumatic brain injury: Piloting Apps for NCAA | Effectiveness of drug treatment: Interest in Apps for depression monitoring |

Depression
Data (2013 AVEC Depression Challenge):
- Audio from 50 train/50 test subjects
Objective:
- Predict BECK depression assessment score from audio

Mild Traumatic Brain Injury
Data: Full Season Athlete Collection (Purdue)
Subjects
8 female 14–18
24 male 14–18
Objective: Detect cognitive impairment (using IMPACT)

Dementia
Data: audio from 200 elderly
Objective:
- Detect cognitive impairment
Making an Impact
Research Areas

- Data Collections
- Modeling
- Advanced Feature Extraction
- Clinical Acceptance
Making an Impact
Research Areas

- Data Collections
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Explain old and guide new vocal biomarkers
Making an Impact
Research Areas

Scientific Foundation

Data Collections
Modeling

Advanced Feature Extraction

Clinical Acceptance

Explain old and guide new vocal biomarkers
Large-scale behavioral collections
• Audio databases with on-body platforms
  – Option to extract vocal features and remove audio
• Collections with related modalities (e.g., robust wireless EEG)

Imaging collections
• Brain, vocal tract, and vocal fold imaging
  – Improved real-time MRI; ultra high-speed 3D video
• Ultimate is simultaneous measurements during speaking

Improved protocols
• Speaking tasks that illicit specific parts of the brain and speech motor processes
• Speaking tasks that bring out specific neural and motor components effected by different neurological conditions
Need for model-based approaches to enhance scientific foundation for use of vocal biomarkers

Computational neural modeling
• Basic neural circuitry of speech production
• Modulation by non-speech networks (e.g., limbic)
• Disturbances in the distressed brain
• Directions into Velocities of Articulators (DIVA) model is one basis

Computational physiological modeling
• Understanding of multitude of muscles and their coordination in speech production
• Disorders both in articulatory and laryngeal (vocal fold) movement
Mapping of changes in neural and physiological models to changes in the acoustic signal

Robust and high-resolution signal processing to reflect dynamic and subtle aspects of complex changes in neural and physiological systems, beyond standard features
Clinical Acceptance

- Objective measures as an aid, not replacement
- Early identification of neurologic disease onset
- Prediction of relapse or recovery
- Prediction should be specific as well as sensitive
  - Many sub-classes of speech disorders common to a variety of neurological disorders
- Monitoring should be personalized with biofeedback
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Publications


