Vocal Biomarkers for Monitoring Neurological Disorders

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MIT Lincoln Laboratory

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Massachusetts Institute of Technology

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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

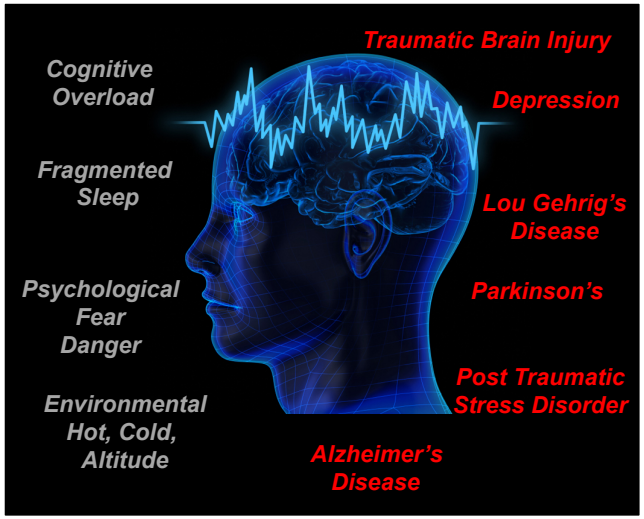
Speech, hearing, and neuro-cognitive analysis

Speech, Hearing and Neuro-cognitive Analysis

Motivation, Objective, Approach

Motivation

- Many conditions that effect cognitive performance
- Includes neurological and stress conditions

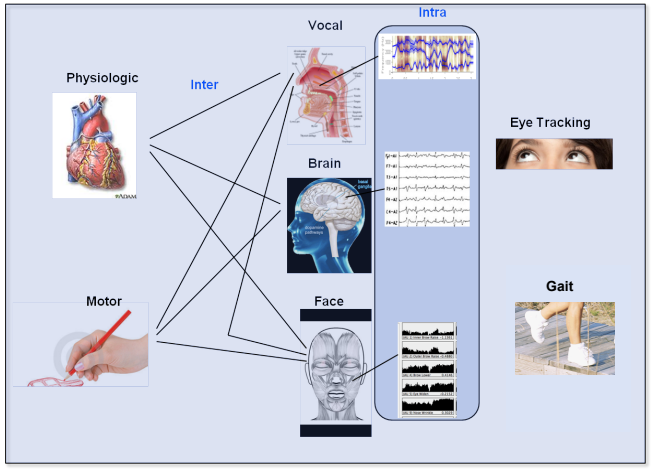


Objective

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

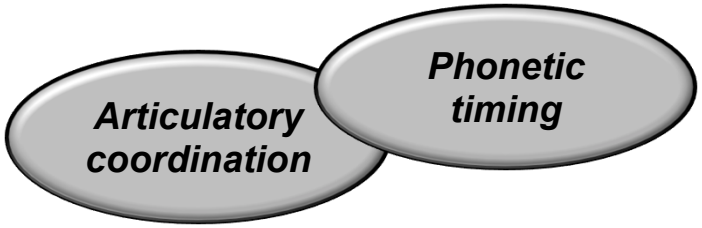
Approach: Vocal biomarkers

- Reflect underlying neurophysiological changes that alter speech motor control
- Reflect coordination changes across speech production components, as well with other modalities

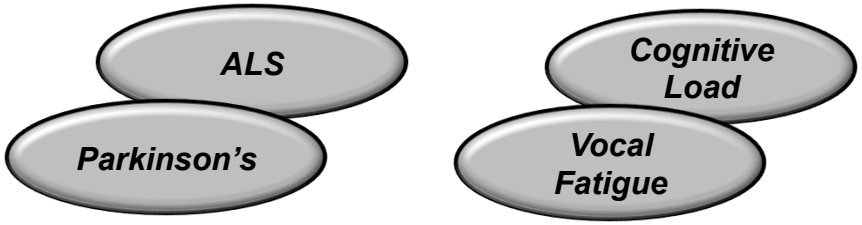


MIT Lincoln Research Focus

Research in vocal biomarkers



Evolving research areas



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

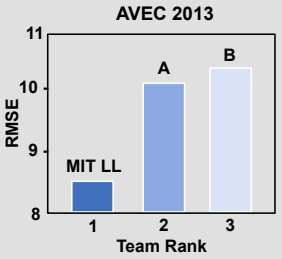
Depression

Data (2013 AVEC Depression Challenge):

- Audio from 50 train/50 test subjects

Objective:

- Predict BECK depression assessment score from audio

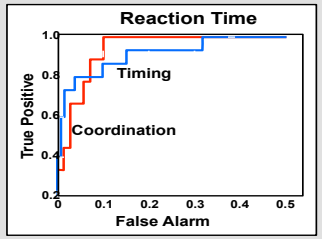


Mild Traumatic Brain Injury

Data: Full Season Athlete Collection (Purdue)

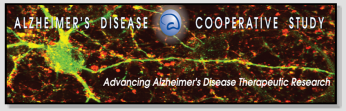
Subjects	Ages	Sport
8 female	14–18	
24 male	14–18	

Objective: Detect cognitive impairment (using IMPACT)



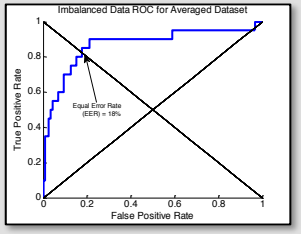
Dementia

Data: audio from 200 elderly

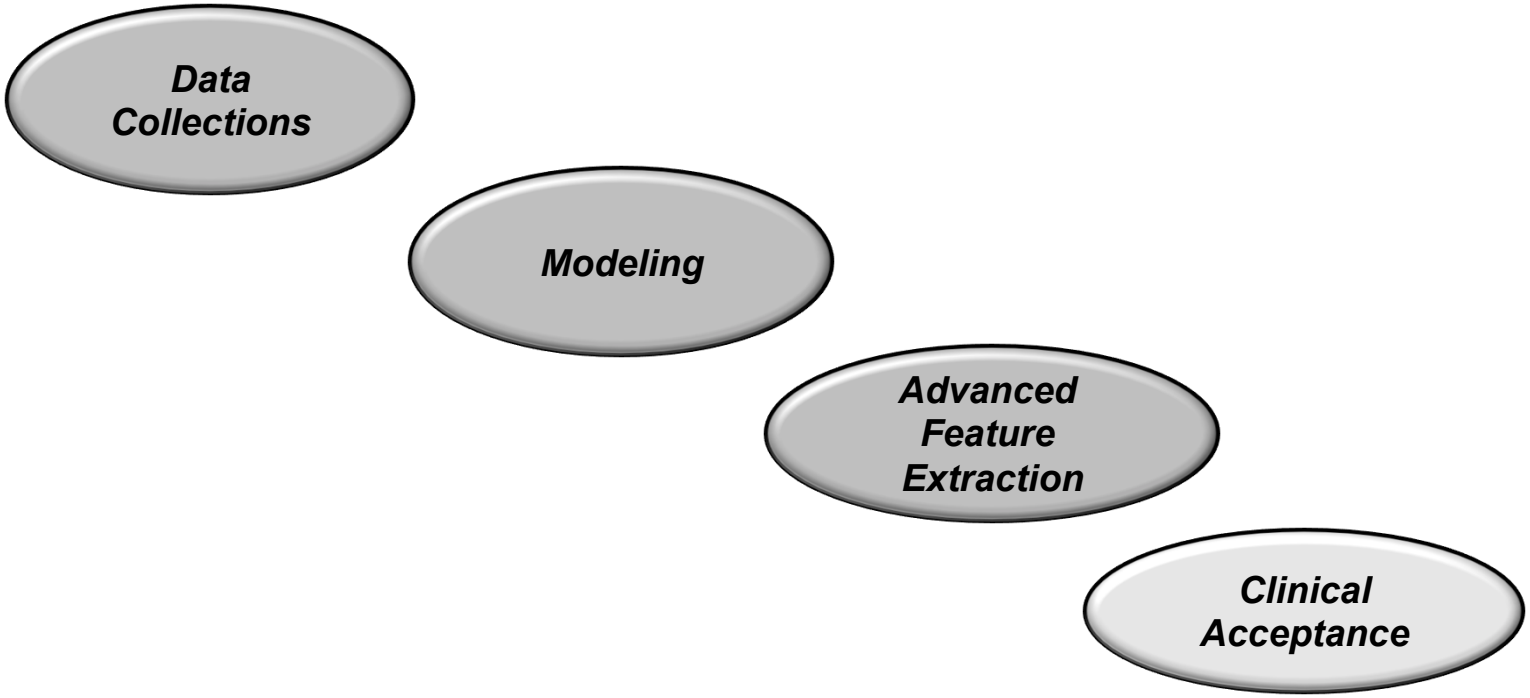


Objective:

- Detect cognitive impairment



Making an Impact
Research Areas



Making an Impact
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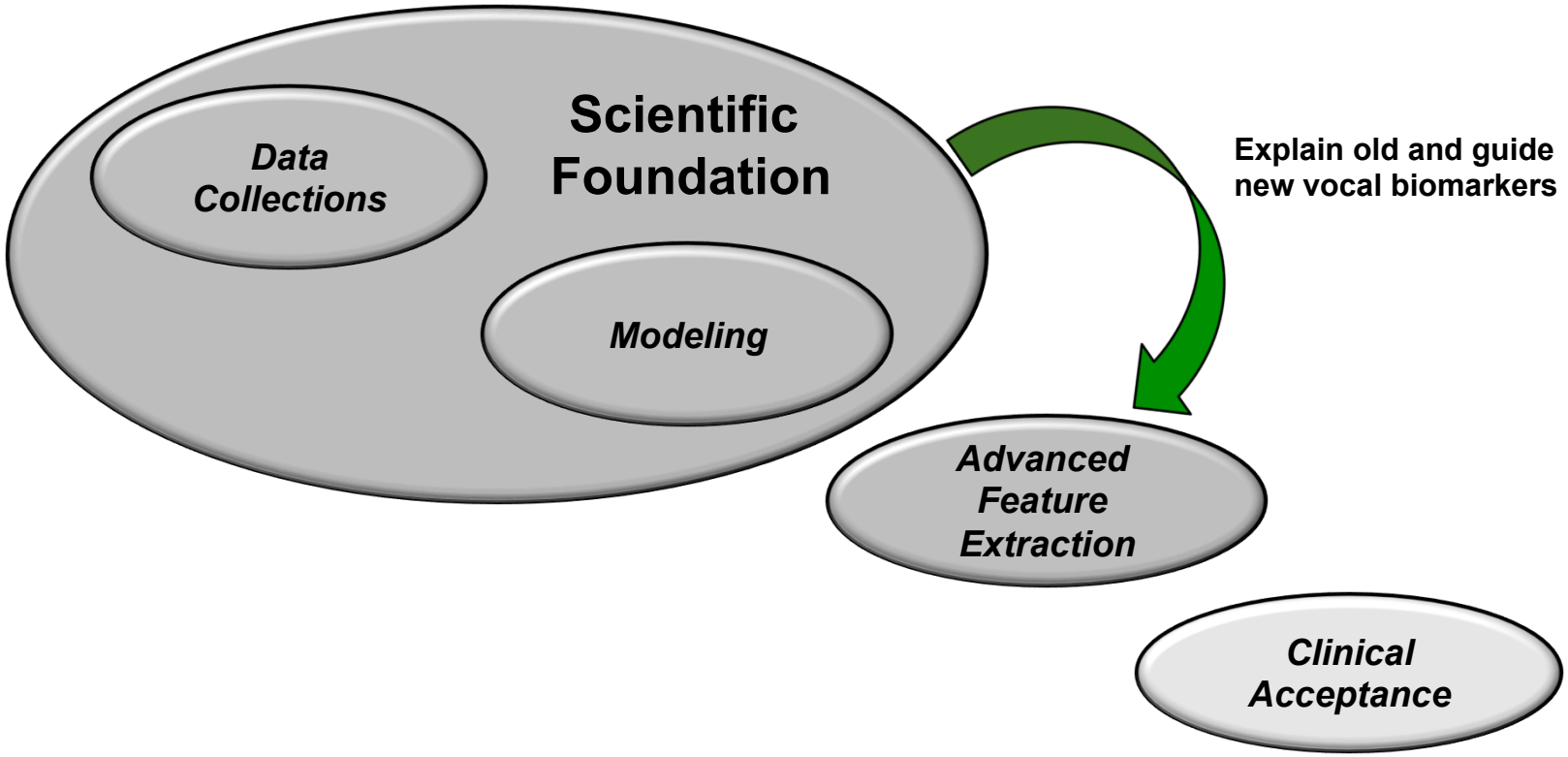

Making an Impact
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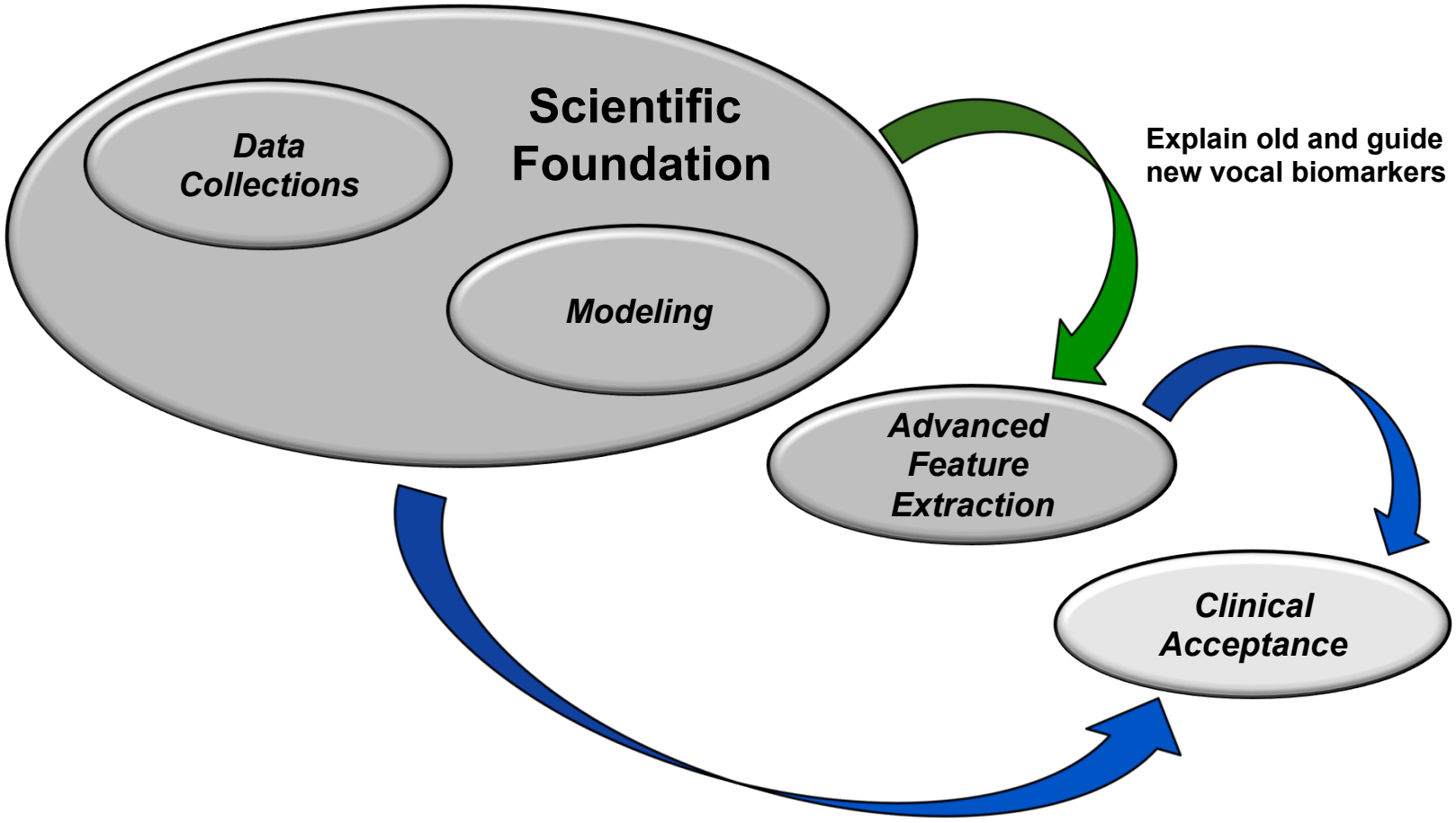
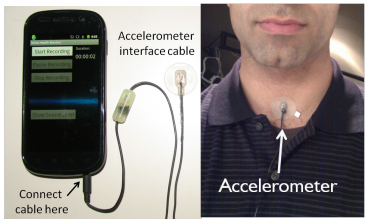
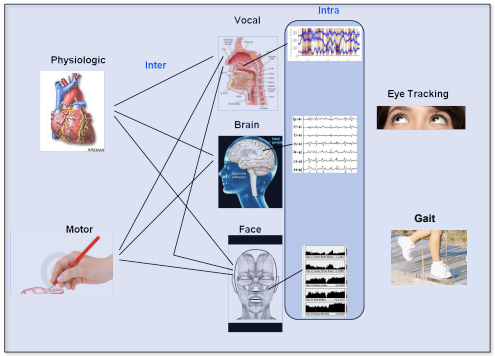


Research Areas
Databases



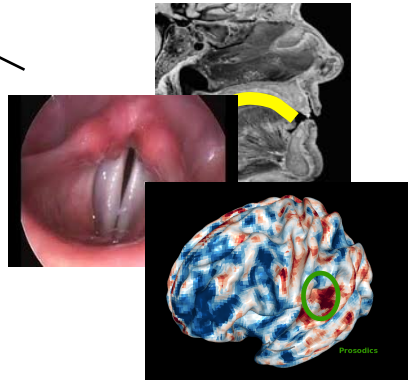
Large-scale behavioral collections

- 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

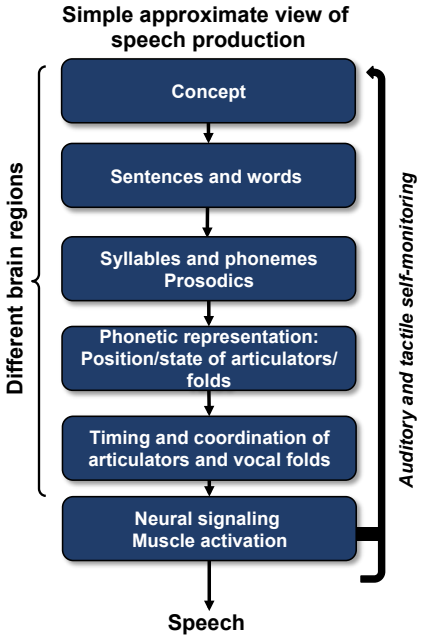


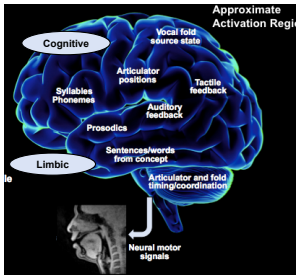
Improved protocols

- 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

Research Areas
Modeling

Need for model-based approaches to enhance scientific foundation for use of vocal biomarkers



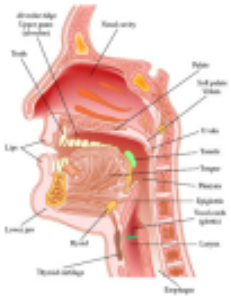


Computational neural modeling

- 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



Research Areas

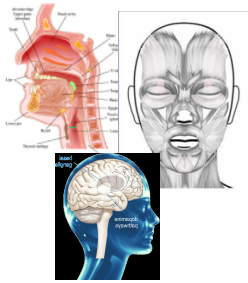
Advanced Feature Extraction

- 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

Acknowledgments



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Visar Berisha – Arizona State, Speech and Hearing Science

Publications

Trevino, A., Quatieri, T. F. and Malyska, N., "Phonologically-based biomarkers for major depressive disorder," EURASIP Journal on Advances in Signal Processing: Special Issue on Emotion and Mental State Recognition from Speech, 42:2011–2042, 2011.

Williamson, J.R., Quatieri, T.F., Helfer, B.S., Horwitz, R., Yu, B., and Mehta, D.D., "Vocal biomarkers of depression based on motor incoordination," in Proceedings of the 3rd ACM international workshop on Audio/visual emotion challenge, 2013, pp. 41–48.

Helfer, B.S., T. F. Quatieri, Williamson, J.R., Mehta, D.D., Horwitz, R ., and B. Yu, "Classification of depression state based on articulatory precision.," in Interspeech, 2013, pp. 2172–2176.

Quatieri, T. F. and Malyska, N., "Vocal-source biomarkers for depression: A link to psychomotor activity," Proceedings of Interspeech, 2012.

Horwitz, R., Quatieri, T.F., Helfer, B.S., Yu, B., Williamson, J.R., and Mundt, J., "On the Relative Importance of Vocal Source, System, and Prosody in Human Depression." IEEE Body Sensor Network Conference, Cambridge, MA, May 2013.

Helfer, B.S., Quatieri, T.F., Williamson, J.R., Keyes, L., Evans, B., Greene, W.N., Vian, T., Lacirignola, J., Shenk, T., Talavage, T., Palmer, J., and Heaton, K., "Articulatory dynamics and coordination in classifying cognitive change in preclinical mTBI," Interspeech 2014.

Yu, B., Quatieri, T.F., Williamson, J.R., and Mundt, J., "Prediction of cognitive performance in an animal fluency task based on rate and articulatory markers," Interspeech 2014.

L. Keyes, J. Su, T. Quatieri, B. Evans, J. Lacirignola, T. Vian, W. Greene, D. Strom, and A. Dai, "FY12 Line-Supported Bio-Medical Initiative Program: Multi-modal Early Detection Interactive Classifier (MEDIC) for Mild Traumatic Brain Injury (mTBI) Triage," MIT Lincoln Laboratory Project Report LSP-41, 2012.