Challenges in Speech Communication Research

Future areas of interest for speech scientists of the Acoustical Society of America

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A Well-Laid Foundation

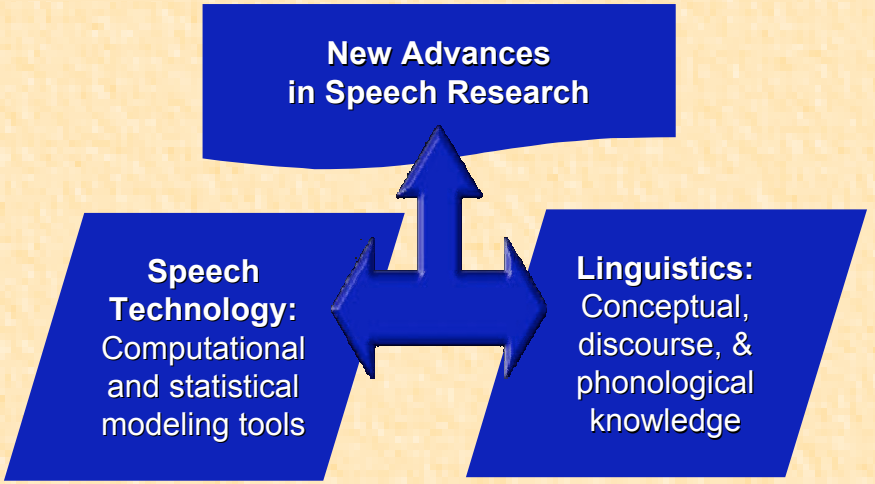
- Acoustical Society research has yielded a detailed understanding of the temporal and spectral properties of the speech signal.
- Strong foundation for pursuing a comparably rich understanding of how this acoustic signal is produced and processed.
  - peripheral: motor, biomechanical, & auditory
  - central: cognitive processing, production, & learning

Future Challenges

Three Promising Areas

1. **Naturalistic spoken language**
2. **Dynamic properties of speech**
3. **A biologically-situated approach**

New Tools Make Advances Possible



First Promising Area

1. **Naturalistic spoken language**
2. **Dynamic properties of speech**
3. **A biologically-situated approach**

Naturalistic Speech

In speech technology	In speech science
• audiovisual	• **Real-world speech variability** in controlled settings
• affectual	– dyadic interactions
• multi-lingual	– spontaneous (non-read) speech
	– multi-modal speech
	– manipulating information structure
	– language exposure in acquisition

Prosody

- "Say _____ again" experiments provided tightly controlled contexts
  - ideal for articulatory & acoustic characteristics of individual speech sounds.
- Now: overt manipulation of **prosodic structure**

Informational groups relevant to cognitive processing (phrasal organization):

When teenagers drive quickly *they get tickets.*

When teenagers drive quickly they get tickets.

Informational prominence within these constituents (focus):

There's no *smoking* on the plane…(but you can drink.)

There's no smoking on the *plane*…(but you can if you take the train.)

Timely Approaches to Prosody

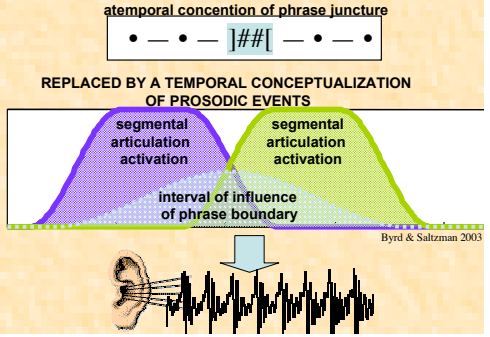
- **How is information structure encoded in articulatory behavior shaping the acoustic signal?**
  - Begin to understand the production and processing of prosodic events, including intonation, as **inherently temporal**.

Phrasal Junctural & Prominence Events:

✓ Interacting with articulatory events

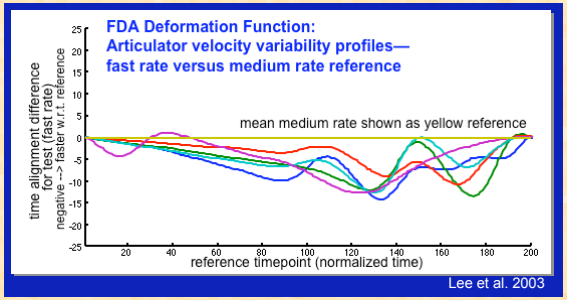
✓ Critically coordinated with those events

✓ Acoustic consequences utilized in real-time cognitive processing



Analyzing Variability

- Statistical tools for quantifying and evaluating **variability**:
- Two examples:
  - connectionist learning models
  - Functional Data Analysis (FDA) (see e.g. Ramsay & Silverman)



Lee et al. 2003

Learning Time-Course & Plasticity

- **Effects of distributional & acoustic variation in the natural language to which learners are exposed**
  - –E.g., rhythmic patterning, input from multiple talkers, patterns obtaining across the lexicon, **distributional frequency & transitional probabilities of phonetic exemplars**

(work by Aslin, Curtin, Maye, Gerken, Holt, Kluender, Kuhl, Lotto, Newport, Saffran, Storkel, Tees, Werker, & others)

Second Promising Area

1. Naturalistic spoken language
2. Dynamic properties of speech
3. A biologically-situated approach

Dynamic Speech

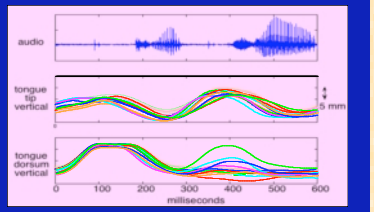
- Production studies will move away from:
  - snap-shot characterizations of vocal tract postures
  - characterizing (static) acoustic cues to phonetic contrasts
- Processing studies will move away from:
  - forced-choice perceptual responses in behavioral studies

An explosion of research in the area of real-time speech production, perception, and processing.

Real-Time Articulation

- Real-time data on articulator patterning and its resulting time-varying aerodynamic and acoustic consequences.

Articulatory point-tracking



Pouplier et al. Subm.

very new advances in
Real-time MRI of the vocal tract

24 frames/sec (no audio)
(Narayanan, Nayak, Lee, Sethy, & Byrd, *JASA* April 2004)

Real-Time Processing

measuring event-related potentials to changes in speech sounds in a 7-month-old infant (by permission, from Kuhl 2004)

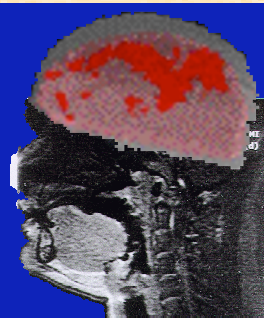
- Real-time cognitive creation and processing of spoken language
  - Time course of speech processing from the auditory to the cognitive
    - For example, MEG, ERP and eye-tracking instruments.
  - Data reduction challenges for high-dimensional data

An Exciting Possibility…

- **Unify studies** of real-time processing using *f*MRI imaging of brain activity during the production of spoken language with studies using real-time high-speed imaging of articulation

Rapidly going back and forth between the **high-speed anatomical imaging and functional brain imaging** during the creation and performance of spoken language

Krishna Nayak (USC): In the future we may be able to pseudo-interleave acquisitions on a 10-50 millisecond basis, with some hardware and *f*MRI SNR improvements.



Third Promising Area

1. Naturalistic spoken language
2. Dynamic properties of speech
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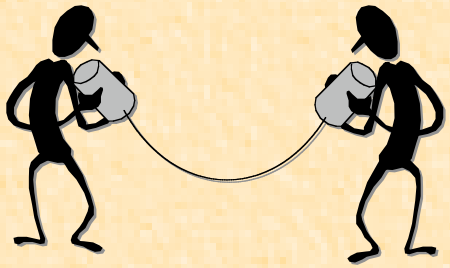
Biologically-Situated Speech



Language as a process not just shaping but shaped by the coupled interaction among participants in a physical world.

Physiology

Speech acoustics as a key connection allowing improvements in understanding physiologic constraints on spoken language…

Production
Have detailed articulatory-acoustic models. Need **biologically realistic models of the biomechanics of the vocal tract, aerodynamics, & voice production.**

Perception
Have detailed auditory models. Need a better understanding of the **neurophysiology of speech perception.**

Processing
Need knowledge of **cognitive functional organization of the processing of spoken language.**

Complex Systems

- Incorporate knowledge of **complex systems** into mainstream speech research
  - An example: the relevance of the behavior of coupled oscillators to understanding
    - articulatory coordination
    - speaker-listener interactions

NSF's new program solicitation for proposals in the area of Human and Social Dynamics:

> "the dynamics through which individuals and collective entities form, grow, learn, change, and act…; and explorations of the cognitive, computational, linguistic, developmental …[and] biological….processes as dynamic, evolving systems."

Summary

- Future Speech Communication research will take advantage of the detailed knowledge of speech acoustics being provided by ASA scientists to develop a comparably rich understanding of how this acoustic signal is produced and processed.
- Exciting progress can be anticipated in:
  - **naturalistic spoken language**
  - **dynamic properties of speech**
  - **a biologically-situated approach**