Betting on bits
contextual influences on the perception of ‘phonetic categories’

Sarah Hawkins
University of Cambridge
sh110@cam.ac.uk
Issues

• Context and phoneme/word identification

• Structuring a model of speech understanding
  – top-down vs. bottom-up information
  – abstraction vs exemplar representation
Oh yeah? So why doesn’t /wa/ sound the same in Lagos and Hollywood and Birmingham?

Oh yeah? So why doesn’t /wa/ sound the same in Tahiti and Hawaii and Huntingdon?

We can understand speech because there’s an invariant acoustic correlate for every one of Morris’ features.
Fine phonetic detail (FPD): random or systematic?

much is systematic & perceptually salient

but does **NOT** help to identify citation form words or phonemes
Fine phonetic detail indicates:

- position in syllable; syllable structure
- word boundaries
- grammatical status
- places where you can join in a conversation
- discourse function of ‘the same’ words
- other things crucial to a normal conversation
- gross and subtle indexical information
Systematizing fine phonetic detail

• a different way of conceptualizing
  – phonetic and phonological structure (Firthian)
  – the processes of understanding speech

• *Journal of Phonetics* 31(3/4)
  especially John Local; Sarah Hawkins

• Hawkins & Smith (2001)
  *Italian Journal of Linguistics – Riv. de Ling.* 13, 99-188
  http://kiri.ling.cam.ac.uk/sarah/pubs.html
Systematizing fine phonetic detail

– the processes of understanding speech

• *Journal of Phonetics* 31(3/4)
especially John Local; Sarah Hawkins

• Hawkins & Smith (2001)
  *Italian Journal of Linguistics – Riv. de Ling.* 13, 99-188
  [http://kiri.ling.cam.ac.uk/sarah/pubs.html](http://kiri.ling.cam.ac.uk/sarah/pubs.html)
What is a category?

A class or division in a system of classification

(OED)
Structure of a category

Quality of exemplars

Boundaries

good  best

ok

poor
Thrush in summer

Thrush in snow

Sparrow in summer
"Please say what this word is:
  bit  bet  bat  but

F1 of CARRIER
  bet  200-380 Hz
  bit  380-660 Hz

Ladefoged and Broadbent (1957) JASA 29, 98-104
“Range effects” on CP boundary

- identification expt e.g.
- VOT continuum
da...........ta
- when stimuli are removed from one end, the 50% id boundary shifts towards the other
What causes a boundary shift?

- stimulus range (distribution)
- perceived rate of speech
- lexicality/Ganong (word~nonword)
- sentence meaning (if the task is appropriate)

What causes a boundary shift?

Perception adjusts to the distribution of stimuli and is more forgiving about unclear sounds if the message makes sense.

---

Much evidence that ‘better’ instances of phonemes exert stronger perceptual effects of many types:

Samuel (P&P 1982 adaptation)
Kuhl (1992 perceptual magnet effect [PME])

And that context affects category goodness
Hawkins & Barrett (ASA 04: PME)
Allen & Miller (P&P 2001: rate and lexicality)
CP: category goodness

Mediated Priming in lexical decision task

A /t/ with a short VOT primes unrelated words via rhymes that have /d/ instead of /t/

$t^*$ime primes penny via dime

Misiurski et al. (2005) Brain & Lang. 93, 64-78
Linguistic categories: summary

• Perception adjusts to the distribution of stimuli and is more forgiving about unclear sounds if the message makes sense or the task encourages it.

• ‘Units’ are functionally inseparable from ‘context’.

• Implication: mental representations of linguistic-phonetic categories are relational and plastic.
How might this plasticity occur?

An example
Plasticity of single neurons in the Primary Auditory Cortex (PAC)
Spectro-temporal receptive fields (STRFs) in PAC

• Recording from single neurons in PAC
• Sensitive to particular frequency ranges and temporal relationships
• Training:
  – broadband noise: lick
  – tone (constant frequency sine wave): don’t lick
• Test: different tone frequency

Fritz, Elhilali, Shamma, et al. 2003, 2005
Plasticity of STRFs in PAC

- Shift in excitatory response to tone of similar frequency
- Additional field to yet more different tone
- Only when a response is required: ‘meaning’
- Poorer task performance and weaker plasticity are correlated

**Excitatory field**  BF neuron best freq
**Inhibitory field**  target freq
Summary: STRF changes in PAC

• Swift (2.5-8 minutes); last several hours

• Reflect
  – sensory content
  – changing behavioral meaning of acoustic stimuli

• Consistent with facts of speech perception

• Similar adaptation/learning probably occurs earlier (lower down) in the auditory pathway
Brain activation for category boundaries

- Many studies: Superior Temporal Gyrus (STG) is active when phonetic decisions are made (+ many other areas)
- STG activation does not differ when the decisions are hard (other areas do e.g. frontal regions)

Brain activation for category boundaries: Ganong effect

• STG is sensitive to change in category boundary due to lexical status: gift-kift; giss-kiss

• Conclusion: lexical knowledge influences basic phonetic categorization processes

Myers & Blumstein (CNS 2005)
yet also.... simple ba-da continuum

• brain activation differs for category centers & boundaries (adaptation fMRI)

  centers: Primary auditory cortex, left parietal
  boundaries: left SMG, L middle frontal, R prefrontal, Right cerebellum, anterior cingulate

Raizada & Poldrack (CNS 2004; in prep)
What does this mean?

• Category boundaries and centers are analyzed in many different parts of the brain: don’t and can’t act independently

• **Relationships** in current signal are constantly interpreted from all available evidence:
  – knowledge
  – current sensation (quite detailed)
  – attention
Fine phonetic detail provides all sorts of information, not just phonological. Here, it is grammatical.
Summary

• Brain is ‘opportunistic’: it uses all available information to understand a message

• Fine phonetic detail can be fundamental

• What listeners do with FPD depends on what they are doing at the moment
Modeling phonetic representation

• Phonetic categories can map directly to phonological categories BUT
  – relational, dynamic, self-organizing, (multi-modal), context-sensitive, task-sensitive

• Sound patterns map to meaning via processes that involve complex (embodied?) structures:
  – MULTIPLE UNITS of speech perception

• Top-down and bottom-up information, episodic vs abstract representation, may not be distinguishable in speech communication