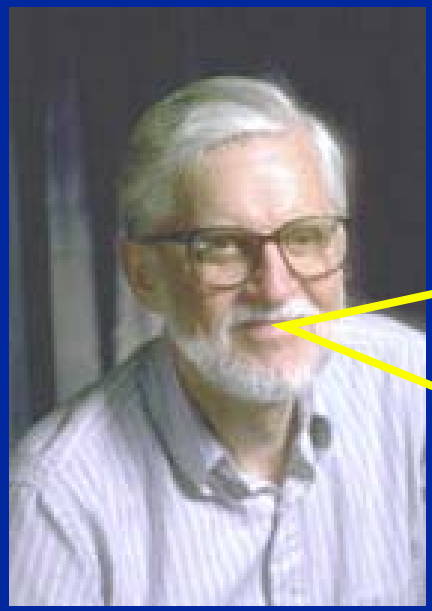
Betting on bits
contextual influences on the perception of 'phonetic categories'

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



We can understand speech because there's an invariant acoustic correlate for every one of Morris' features

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

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

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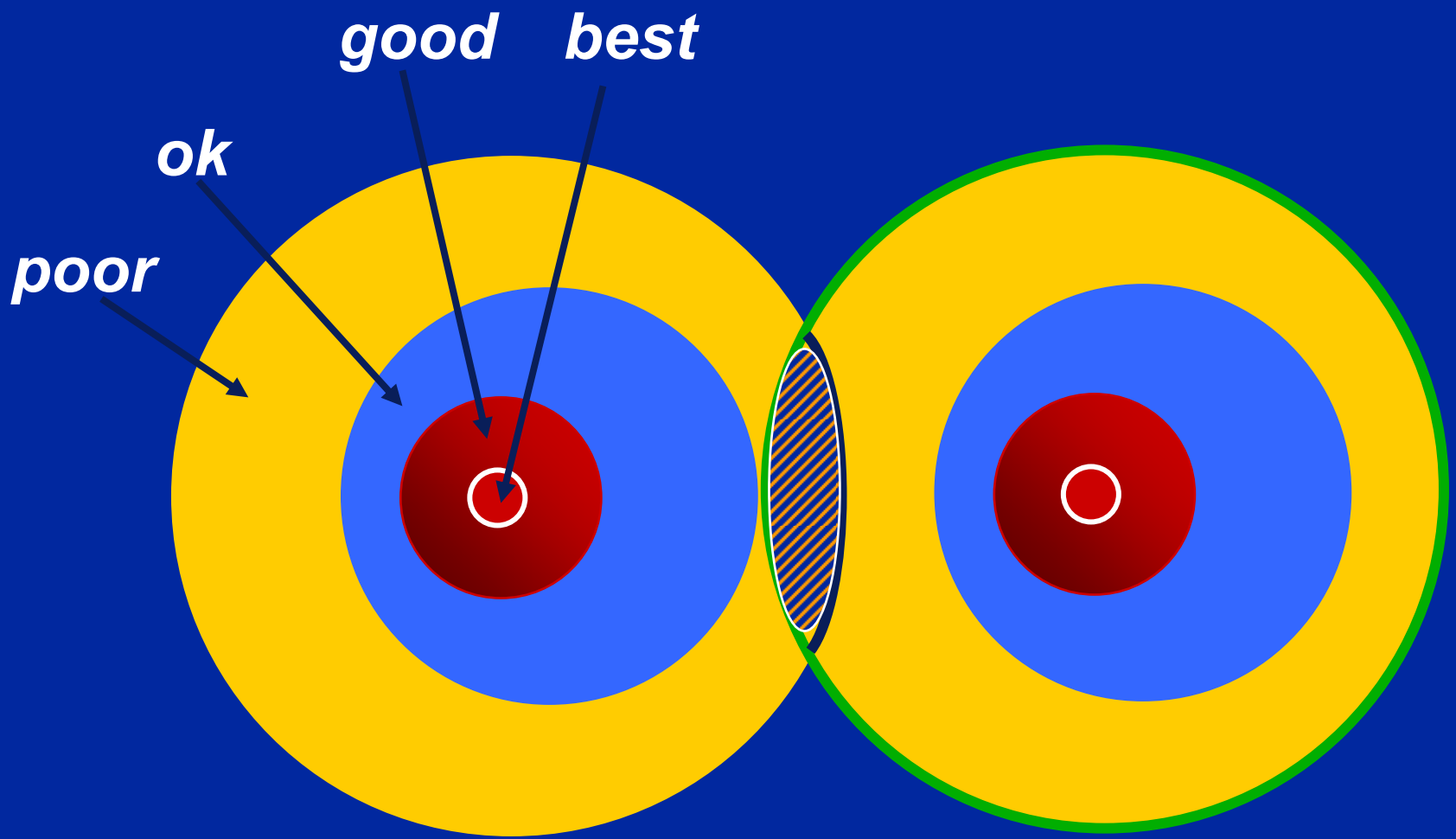
What is a category?

A class or division in a system of classification

(OED)

Structure of a category



Quality of exemplars

Boundaries

✓ Thrush in summer

✓ Thrush in snow

✗ Sparrow in summer

Ladefoged and Broadbent (1957)

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

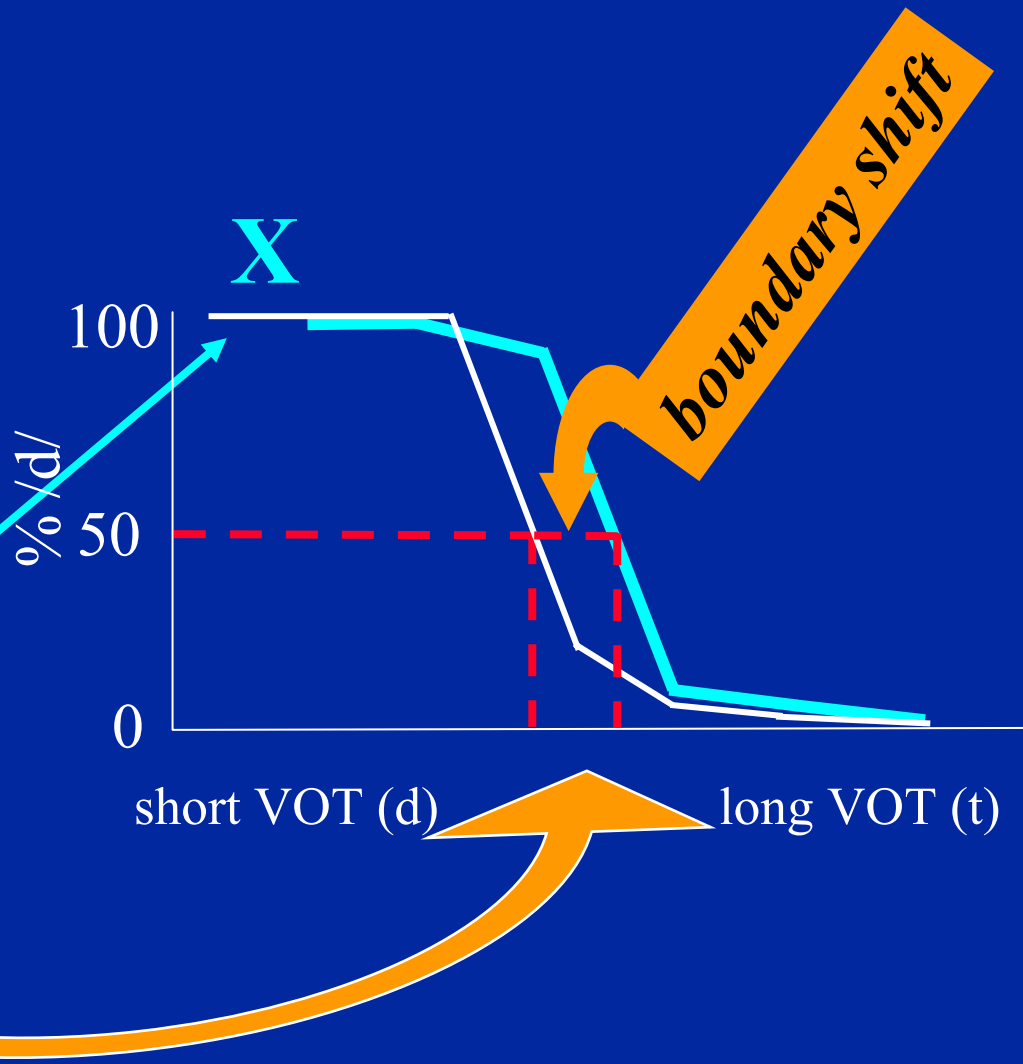
		F1 of CARRIER
bet		200-380 Hz
bit		380-660 Hz

Ladefoged and Broadbent (1957) *JASA* 29, 98-104

"Range effects" on CP boundary

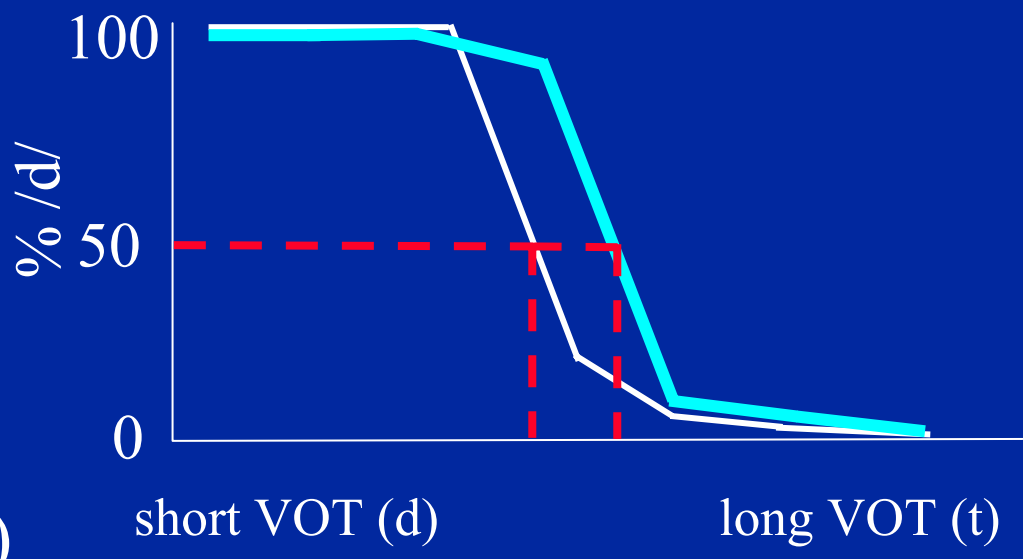
- identification expt e.g.
- VOT continuum

  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)



Summerfield (1981) *JEP:HPP* 7, 1074-1095

Ganong (1980) *J. Exp. Psych: HPP* 6, 110-125

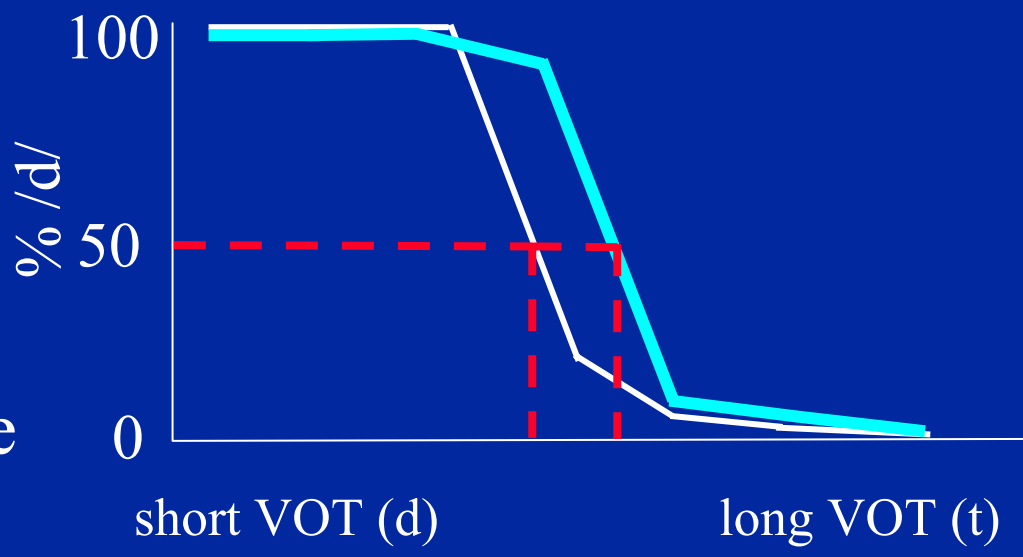
Borsky, Shapiro, Tuller (2000) *J. Psycholinguistic Res. 29*, 155-168

What causes a boundary shift?

Perception adjusts to the distribution of stimuli

&

is more forgiving about unclear sounds if the message makes sense



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CP: category goodness

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])

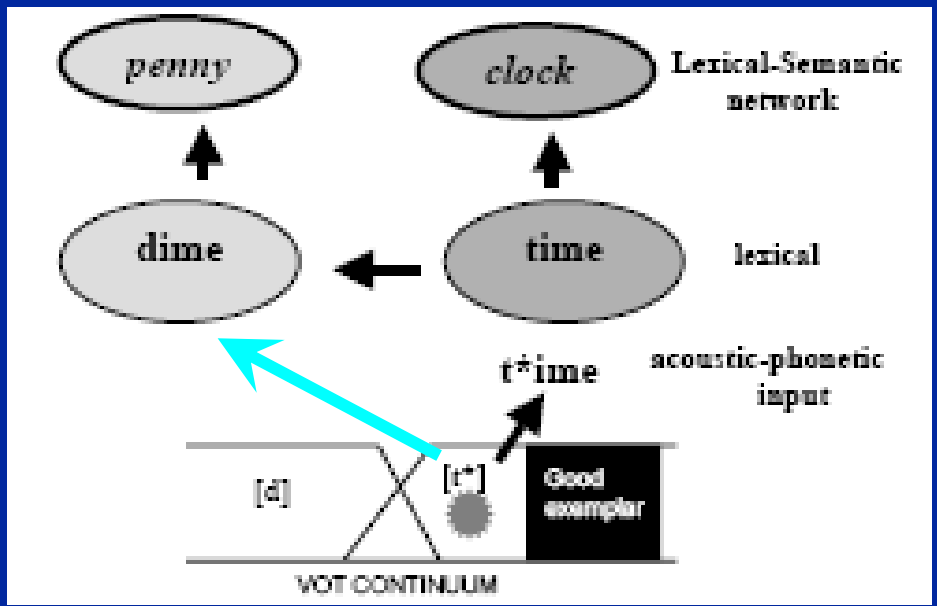
And that context affects category goodness

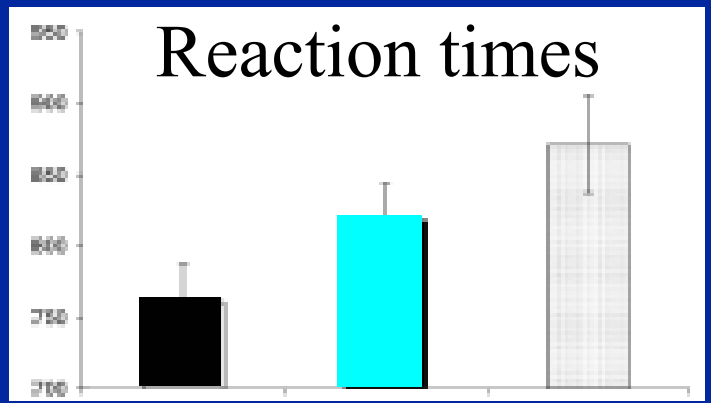
- Hawkins & Barrett (ASA 04: PME)
- Allen & Miller (P&P 2001: rate and lexicality)

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

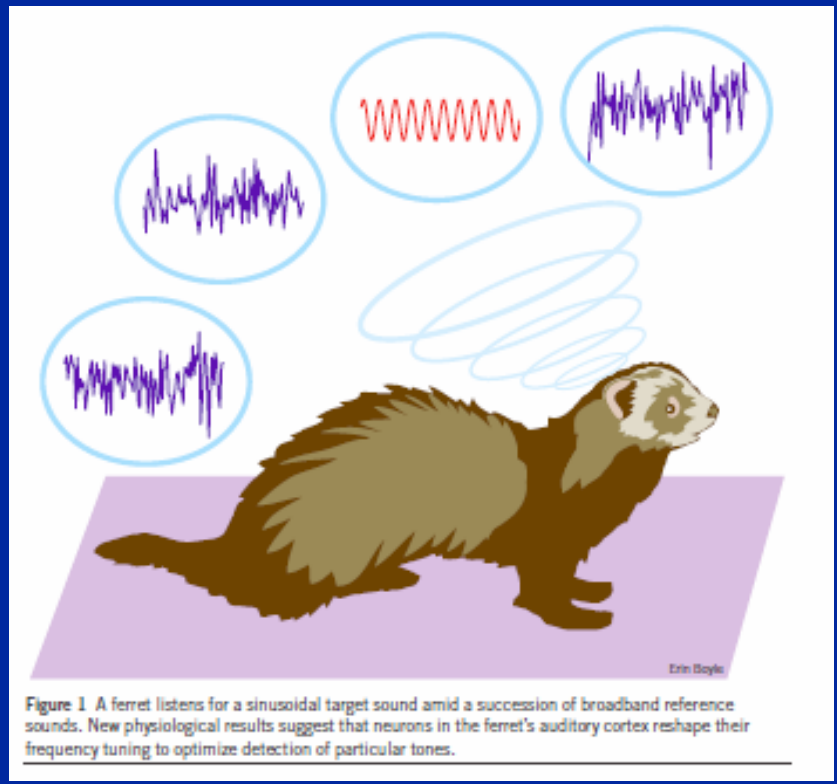
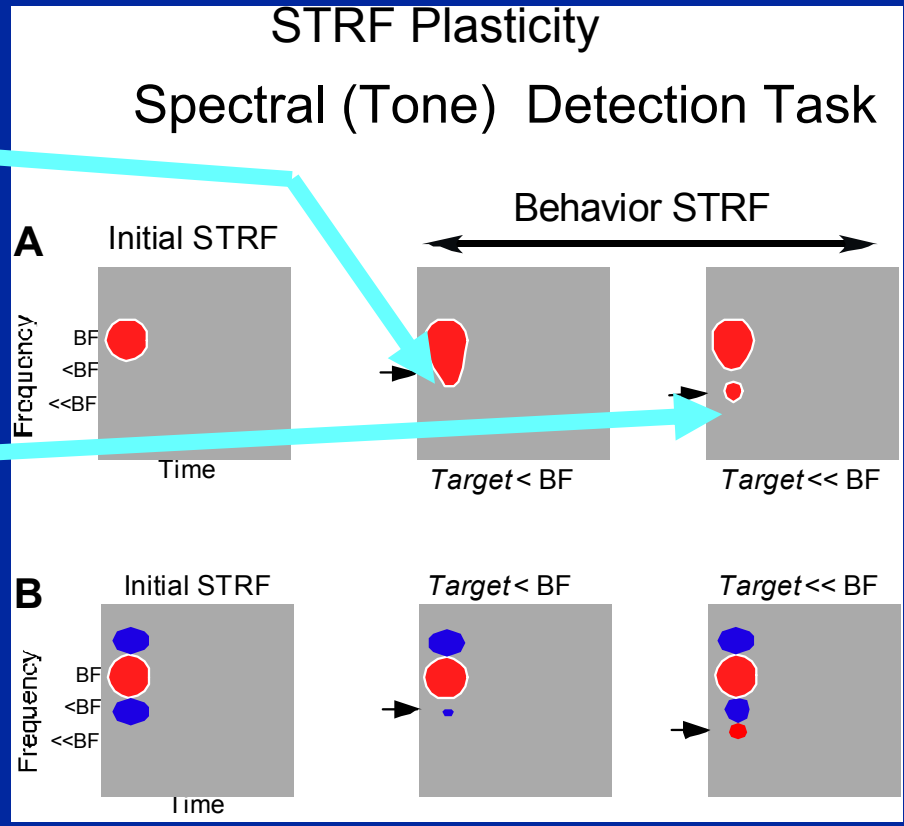


Figure 1 A ferret listens for a sinusoidal target sound amid a succession of broadband reference sounds. New physiological results suggest that neurons in the ferret's auditory cortex reshape their frequency tuning to optimize detection of particular tones.

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

inhibitory field

BF neuron best freq

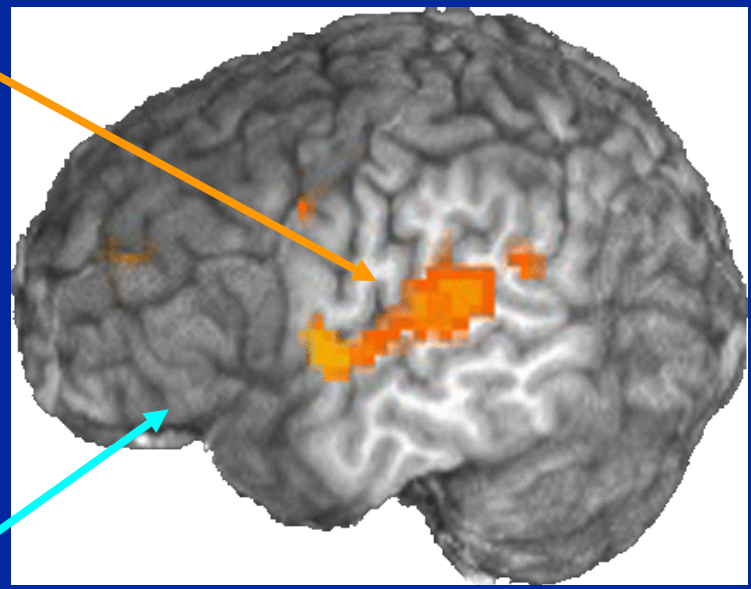
→ target freq

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

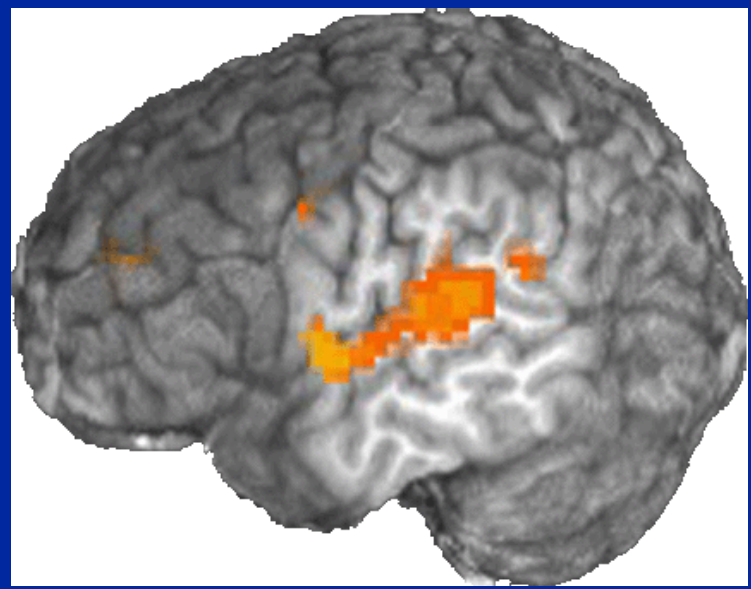
- Many studies: Superior Temporal Gyrus (STG) is active when phonetic decisions are made (+ many other areas)
- STG activation does not differ when the decisions are hard (other areas do e.g. frontal regions)



Binder *et al.* (2004) *Nat.Neurosci.* 7, 295-301
Blumstein *et al.* (2005) *J. Cog. Neuroscience* 17, 1353-1366

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

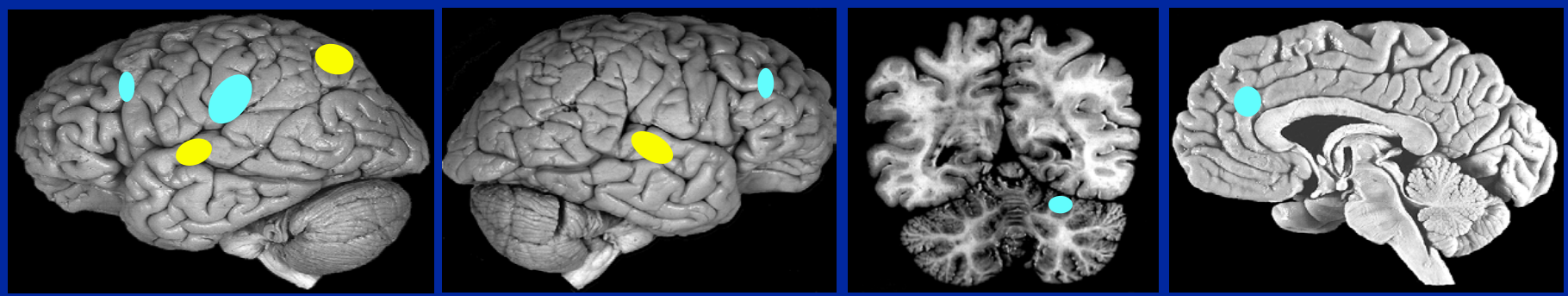
Myers & Blumstein (CNS 2005)

yet also.... simple ba-da continuum

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

centers: Primary auditory cortex, left parietal

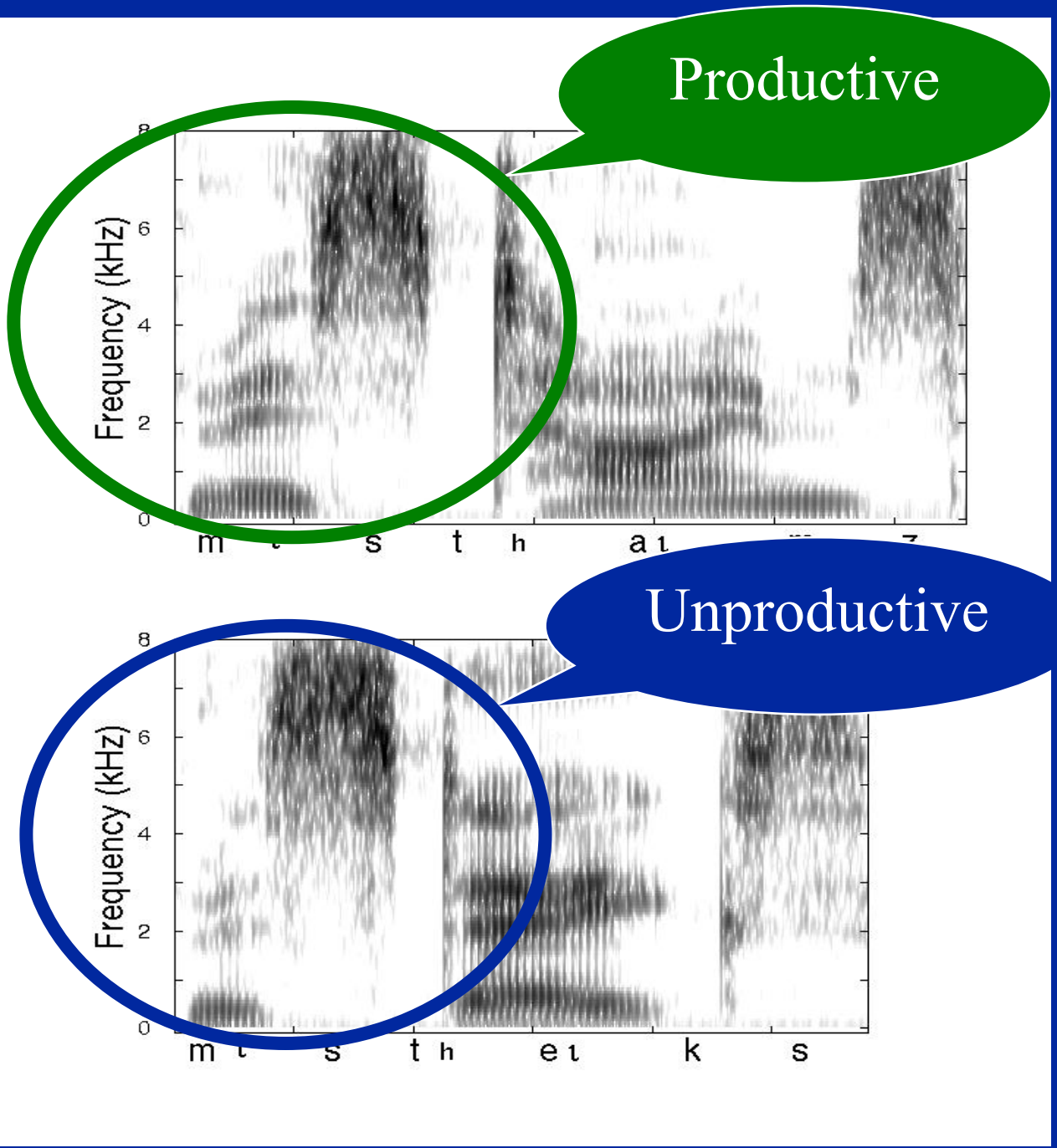
boundaries: left SMG, L middle frontal, R prefrontal, Right cerebellum, anterior cingulate



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