These slides are largely derived from course and talk materials by Colin Phillips. Visit his U of Maryland website for lots more excellent materials on these issues.

http://www.ling.umd.edu/colin/
The task of the listener

- To map acoustic input onto lexical representations.
- Requires mapping the acoustic information onto phonemic representations.
Voicing

Voicing = whether or not your vocal folds are vibrating when the sound is produced (try s vs. z)

With stop consonants voicing is determined by the time difference between when the closure is released and when the vocal chords start vibrating.
Timing - Voicing
Voice Onset Time (VOT)

60 msec
English VOT production

- Not uniform
- 2 categories

*Figure 5–3.* VOT productions of a single normal adult speaker of American English for words beginning with /d/ and /t/. (Figure adapted with permission from Blumstein, Cooper, Goodglass, Statlender, & Gottlieb, [1980]. Production Deficits in Aphasia: A Voice Onset-Time Analysis. *Brain and Language*, 9, 153–170. Copyright 1980 by Academic Press.)
Perceiving VOT

‘Categorical Perception’
**Discrimination**

- **A More Systematic Test**

  - Same/Different
    - 0ms 60ms
  - Same/Different
    - 0ms 10ms
  - Same/Different
    - 40ms 40ms

**Within-Category Discrimination is Hard**
Cross-Language Differences

English vs. Japanese R-L

Figure 12.2. Test of the categorical perception of /ra/ and /la/ by American and Japanese adults. American listeners show the characteristic peak in discrimination at the phonetic boundary; Japanese listeners do not. (From Miyawaki et al., 1975.)
Universal Listeners

- Infants may be able to discriminate all speech contrasts from the languages of the world!
When does Change Occur?

- Hindi and Salish contrasts tested on English kids

Janet Werker

U. of British Columbia
How can they do this?

- Innate speech-processing capacity?
- General properties of auditory system?
What About Non-Humans?

- Chinchillas show categorical perception of voicing contrasts!
What are the neural bases of phonemic representation?

- Tool: Mismatch negativity (MMN) (or Mismatch Field, MMF)
Mismatch Response

Latency: 150-250 msec.
Localization: Supratemporal auditory cortex
Many-to-one ratio between standards and deviants
Localization of Mismatch Response

(Phillips, Pellathy, Marantz et al., 2000)
Basic MMN elicitation
MMN Amplitude Variation

MMN as a Function of Frequency Change

Sams et al. 1985
Place of Articulation

- Acoustic variation: F2 & F3 transitions
Place of Articulation

[bæ]  [dæ]

- Acoustic variation: F2 & F3 transitions
Place of Articulation

- Acoustic variation: F2 & F3 transitions
Place of Articulation

- Acoustic variation: F2 & F3 transitions

Within category: [bæ]  Between category: [dæ]
Place of Articulation

- No effect of category boundary on MMN amplitude (Sharma et al. 1993)
- Similar findings in Sams et al. (1991), Maiste et al. (1995)
but...
Näätänen et al. (1997)
Auditory Cortex Accesses Phonological Categories: An MEG Mismatch Study


Journal of Cognitive Neuroscience, 2000
Voice Onset Time (VOT)

60 msec
Categorical Perception
## Design

**Fixed Design - Discrimination**

| 20ms | 40ms | 60ms |
Design

Fixed Design - Discrimination

20ms

0ms 8ms 16ms 24ms

40ms 48ms 56ms 64ms

60ms

Grouped Design - Categorization
Design

Fixed Design - Discrimination

- 0ms
- 8ms
- 16ms
- 24ms
- 20ms
- 40ms
- 60ms

Grouped Design - Categorization

- 40ms
- 48ms
- 56ms
- 64ms
- 40ms
Figure 1. Design of phonological mismatch experiment, illustrating acoustic and phonological representation of sequence of stimuli: (a–b) phonological contrast experiment; (c–d) acoustic contrast experiment.
- 37-channel MEG recordings
- Sensors positioned above left hemisphere auditory cortex
- 700:100 standard:deviant ratio
- Figure shows *difference* between response to dæ-as-standard and response to dæ-as-deviant
Preliminary Conclusion

- Auditory cortex generator of MMF accesses representations that treat members of the same category as *identical*

- No indication of what might be the form of these representations, or where they might be stored
Phonological Natural Classes exist because...

- Phonemes are composed of features - the smallest building blocks of language
- Phonemes that share a feature form a natural class

Effect of Feature-based organization observed in…

- Language development
- Language disorders
- Historical change
- Synchronic processes

Roman Jakobson, 1896-1982
Sound Groupings in the Brain

pæ, tæ, tæ, kæ, dæ, pæ, kæ, tæ, pæ, kæ, bæ, tæ...

(Phillips, Pellathy & Marantz 2000)
Sound Groupings in the Brain

pæ, tæ, tæ, kæ, dæ, pæ, kæ, tæ, pæ, kæ, bæ, tæ...

(Phillips, Pellathy & Marantz 2000)
Feature Mismatch: Stimuli

(Phillips, Pellathy & Marantz 2000)
Feature Mismatch Design

(Phillips, Pellathy & Marantz 2000)
Sound Groupings in the Brain

pæ tæ tæ kæ dæ pæ kæ tæ pæ kæ bæ tæ ...

(Phillips, Pellathy & Marantz 2000)
Sound Groupings in the Brain

pæ tæ tæ kæ dæ pæ kæ tæ pæ kæ bæ tæ ...

— — — — [+]voi

(Phillips, Pellathy & Marantz 2000)
Sound Groupings in the Brain

\[ \text{pæ tæ tæ kæ dæ pæ kæ tæ pæ kæ bæ tæ } \ldots \]

\[ \text{+[voi] } \text{[+]voi} \ldots \]

(Phillips, Pellathy & Marantz 2000)
Sound Groupings in the Brain

\[ \text{pæ tæ tæ kæ dæ pæ kæ tæ pæ kæ bæ tæ ...} \]

\[ \text{– – – – [+voi] – – – – – [+voi] – ...} \]

- Voiceless phonemes are in many-to-one ratio with [+voice] phonemes
- No other many-to-one ratio in this sequence

(Phillips, Pellathy & Marantz 2000)
Feature Mismatch

(Phillips, Pellathy & Marantz 2000)
Control Experiment - ‘Acoustic Condition’

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<tr>
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<th>D/T</th>
<th>G/K</th>
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- Identical acoustical variability
- No phonological many-to-one ratio

(Phillips, Pellathy & Marantz 2000)
Control Experiment - ‘Acoustic Condition’

- No Mismatch response.

(Phillips, Pellathy & Marantz 2000)
Hemispheric Contrast in MMF

• Studies of acoustic and phonetic contrasts consistently report **bilateral** mismatch responses


• Striking difference in our finding of a **left-hemisphere only** mismatch response elicited by phonological feature contrast

• Our studies probe a more abstract level of phonological representation