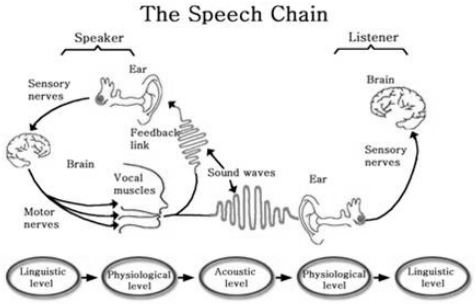
Why do imitation and analogy fail?

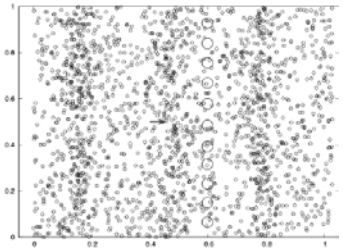
- Imitation
  - Children do imitate some things
  - Children say things they've never heard before
  - Children don't imitate when you want them to
- Analogy
  - I painted a red barn → I painted a blue barn
  - I painted a red barn → I painted a barn red
  - I painted a red barn → I saw a red barn
  - I painted a barn red → ** I saw a barn red
- Imitation and analogy could be used a little bit
  - Claim is not that imitation and analogy do nothing
  - -- rather, they clearly can't do everything
  - -- they don't appear to be the whole story

Development of Speech Perception

What has to develop?

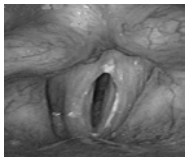


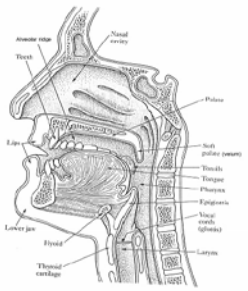
Sound Waves



The Vocal Tract

- Fundamental Frequency
  - Rate of vocal cord vibration
  - Gives voice its characteristic pitch





Development of Vocal Tract

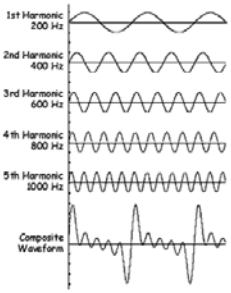
- Major articulators (tongue, vocal cords) fully formed by end of second trimester (week 22 or so)
- Vocal tract does not reach adult shape and length until later
  - Grows from about 6-8 cm in an infant to 15-18 cm in an adult

7 months

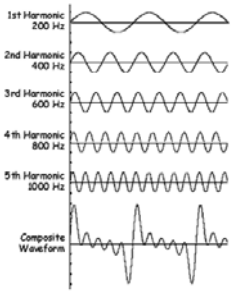
adult

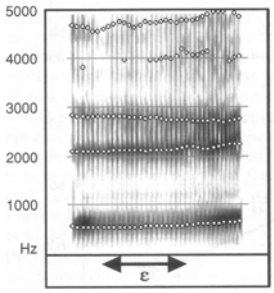
Acoustics of Speech

- Fundamental frequency
  - Carries prosodic information
  - Depends on vibration rate of vocal cords
    - Depends on size of vocal cords
  - Varies by age, sex, etc.



Formants





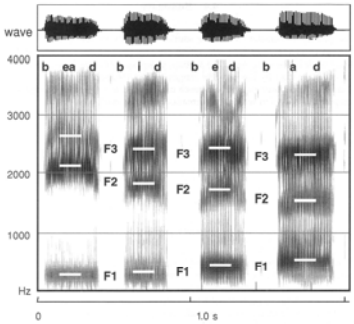
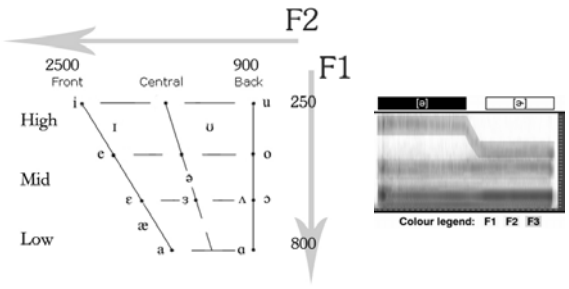


Figure 4.4 Upper part: the sound waves produced when the author said the words *head, bid, bed, bad*. Lower part: a spectrogram of these sound waves in which the complex sound waves are split into their component frequencies (overtone pitches), the amplitude (loudness) of each frequency being shown by the darkness. The three principal groups of overtones (the first three formants) are marked by white lines, labeled F1, F2, and F3.

English Vowels



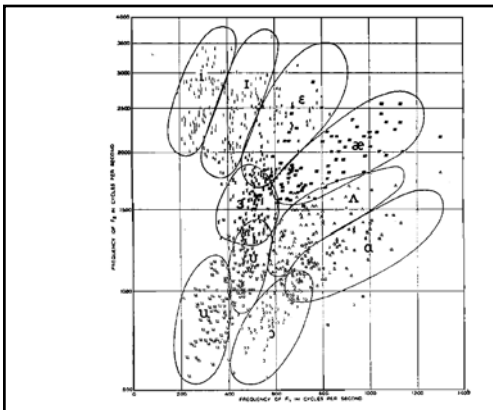
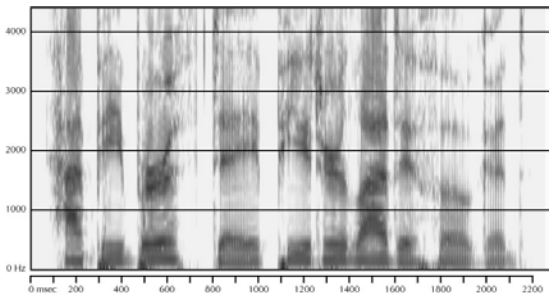


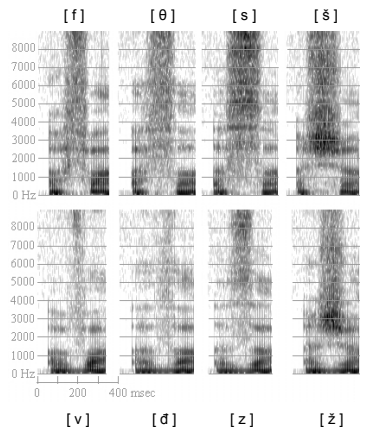
FIG. 8. Frequency of second formant *versus* frequency of first formant for ten vowels by 76 speakers.

Consonants

Manner of Articulation	Place of Articulation: Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Palatal	Velar	Glottal
Nasal	m		n				N	
Stop	p b		t d				k g	
Affricate				tS dZ				
Fricative		f v	T D	s z	S Z			h
Approximant			l r			j	w	

Spectrogram





- Alveolar vs. post-alveolar fricatives
  - e.g., [s] vs [š]
  - Distinguished by frequency (alveolar higher)
- Labio-dental vs inter-dental fricatives
  - e.g., [f] vs [θ]
  - Distinguished by formant transitions of vowels

The Ear

- Outer ear acts as a resonance chamber
  - Amplifies sounds at its resonant frequency (~3000 Hz)

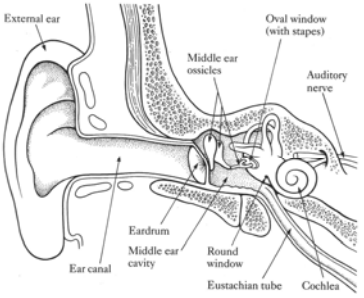


FIGURE 5.1 Cutaway view of the external, middle and inner ear.

The Middle Ear

- Structures in the middle ear function to transmit sound energy to inner ear
- Amplifies energy about 80x
  - Results in about 50% of energy crossing air/fluid boundary

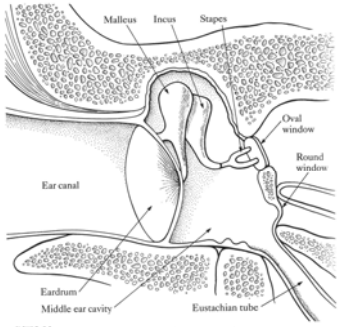


FIGURE 5.2 Cross-sectional view of the middle ear and ossicles.

The Inner Ear

- Structures in the inner ear transmit information about sound to brain

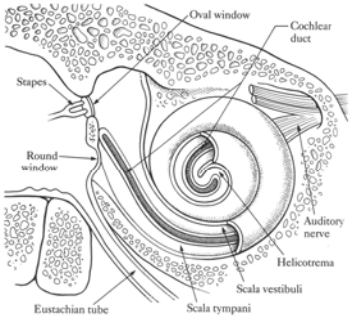


FIGURE 5.4 The cochlear portion of the inner ear.

The Cochlea

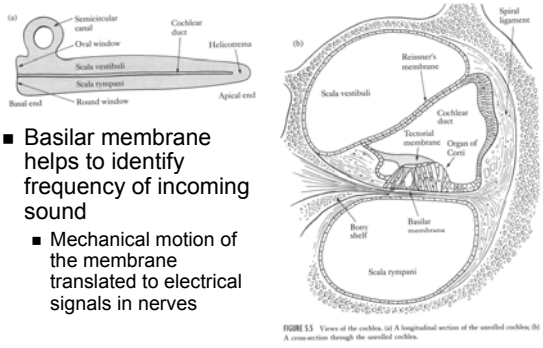


FIGURE 5.5 Views of the cochlea. (a) A longitudinal section of the unrolled cochlea; (b) A cross-section through the unrolled cochlea.

- Basilar membrane helps to identify frequency of incoming sound
  - Mechanical motion of the membrane translated to electrical signals in nerves

Development of the auditory system

The First Trimester

- Week 6:
  - Passageways for inner ear start to form
- Week 8:
  - Ears recognizable
- Week 10:
  - Outer ears close to final form
- Week 12:
  - Ears move up to side of head

The Second Trimester

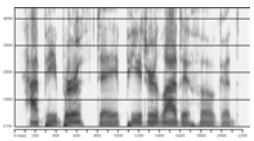
- Week 15:
  - Ears almost reached final position
  - Earbones in middle ear begin to harden
- Week 18:
  - Baby begins to hear
  - May startle in response to loud sounds
  - As hearing improves, can distinguish conversations
- Week 24:
  - Fully developed inner ear

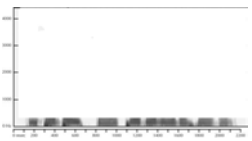
The Third Trimester

- Throughout the third trimester until birth (week 40) babies are able to hear the sounds they are surrounded by
- Amniotic fluid
  - Blurs phonetic detail
  - Leaves rhythm (fundamental frequency) intact

What does a fetus hear?

- Womb acts as a low-pass filter (~ 400 Hz)
  - Pregnant volunteers had microphones inserted onto the (outside) wall of the uterus





What does a fetus or newborn know about language?

Methods for Measurement

- How do you measure what a fetus knows?
  - Measure movement (kicking) or heart rate with ultrasound (essentially)
  - Play a sound to the fetus (speakers next to abdomen)
  - Wait until it gets bored (habituation)
  - Play a different sound
  - If the fetus moves or its heart rate changes, it detected the change

Methods for Measurement

- For post-natal studies:
  - High-amplitude sucking technique
  - Good for very young infants (who excel at sucking)
  - Measure pressure produced by sucking
  - Play a sound to the baby
  - Wait until it gets bored (habituation)
  - Play a different sound
  - If the increases its sucking rate, it detected the change

What does a fetus know?

- Doesn't know the meanings of words
- Won't recognize the phonemes of their language
- A fetus can distinguish
  - Language vs non-language
  - Differences in musical style
  - Mother vs non-mother
    - Prefer mother's in utero voice to ex-utero voice
    - Prefer mother's ex-utero voice to non-mother's voice
- Starting to learn the rhythm of their native language

What does a newborn know?

- Newborns prefer their native language
  - Don't discriminate between different other languages
  - French babies prefer French to Russian or English
- Why? What differs about these (and other) languages?

The Rhythmic Class Hypothesis

- Evidence shows that young infants can distinguish languages with different types of rhythm (English vs Japanese), but not languages with the same type of rhythm (English vs Dutch)
- Rhythm is one of the first things an infant learns about his/her language
  - Between birth and 2 months – learn rhythm
  - From five months – learn aspects of native language

Rhythym in Language

- Stress timed languages (e.g., English)
  - Words typically have a strong-weak stress pattern
  - MAtheMAtics PENcil
- Syllable timed languages (e.g., French)
  - All syllables in a word stressed equally
  - mathematique
- Mora timed languages (e.g., Japanese)
  - All moras given equal time; light vs heavy syllables
  - Honda = ho-n-da

Motherese

- Is infant-directed speech
  - Stress patterns are exaggerated
  - Prosodic contours (intonation) are exaggerated
    - Aren't YOU a nice BAby?
- Some cultures have no specific infant-directed speech – children in these cultures learn the language just fine
- Is it necessary? Maybe useful? Irrelevant?

(people talk to their pets this way too…)

What problems does the baby solve as she learns to perceive a native language?

- How do our brains identify phonetic segments?
  - Speech is really really fast (25-30 segments/second)
  - Speech is continuous
- The Lack of Invariance problem
  - Phonetic segments are not acoustically consistent
    - Context (co-articulation)
    - Individual differences (men vs women vs children)
    - Individual variation (people aren't consistent)
    - People don't even try to be consistent (situational rate of speech)
- Noise!
  - Articulation is messy (signal is imperfect from the start)
  - Trains, vacuum cleaners, etc.