LANGUAGE

Professor John Gabrieli
LANGUAGE

• Comprehension
  Auditory
  Visual
• Production
  Speaking
  Writing

Endlessly generative - 100 trillion years to memorize all the sentences we can produce
LANGUAGE

• Phonology - sounds of language
• Syntax (grammar, structure)
• Semantics (meaning)
• Pragmatics

Discourse
Emotional Comprehension/Production
PHONOLOGY

- Phonemes are building blocks of speech sounds (*boy* vs. *toy*)
- Humans use 100 phonemes - 45 in English (26 letters; letters are not phonemes - “hot” and “cold”)
- Born to hear all phonemes - use or lose it in development after 6/8 months
- We can understand 250 words/min - normal rate is about 180 words/min = 14 phonemes/second in continuous stream
HEARING A WORD

- acoustic information to the ear
- phonemes
- word?
Difference Between a Word and What you Hear

"captain"

Silence
What do you mean?
The dog snapped at

Spectrogram from sentence “John said that the dog snapped at him.”

Note that the gaps between sounds generally occur within the words, rather than between words.

Source: Foss, D. J., and D. T. Hakes. *Psycholinguistics* (1978). © Pearson / Prentice Hall. All rights reserved. This content is excluded from our Creative Commons license. For more information, see http://ocw.mit.edu/fairuse.
For speech, 10’s of milliseconds can change the meaning of a word. These waveforms are identical except for an inserted 100ms silent gap, yet we hear two different words.
10’s of milliseconds can determine which syllable we hear

Many speech sounds (phonemes) differ only by brief spectral and/or temporal changes, specifically within 10’s of milliseconds

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WHAT DO YOU HEAR?
WHAT DO YOU HEAR?

“little” from Mary saw the three little pigs in the corridor

“little” in isolation

Mary saw the three little pigs in the corridor
Changes in the lead consonant are induced by the following vowel problem of invariance

Spectrographs for /b/ and /d/ syllable families:
• The /b/ sounds in *bet* and *bird* are perceived similarly, yet spectrographs are quite different.
• The /b/ and /d/ sounds in *bet* and *debt* have similar spectrographs, but are perceived as different phonemes.

Source: Jusczyk, P. W., L. B. Smith, and C. Murphy. "The Perceptual Classification of Speech." *Attention, Perception, & Psychophysics* 30, no. 1 (1981): 10-23. © Springer. All rights reserved. This content is excluded from our Creative Commons license. For more information, see [http://ocw.mit.edu/fairuse](http://ocw.mit.edu/fairuse).
CATEGORICAL PERCEPTION

Many different sounds must be categorized into phonemes & words
CATEGORICAL PERCEPTION

Categorical Perception

speech sounds vary \textit{continuously}

... but we perceive them in \textit{categories}

“BA” \hspace{1cm} \uparrow \hspace{1cm} \uparrow \hspace{1cm} ”PA” \hspace{1cm} \uparrow
VOICE ONSET TIME (VOT)

- VOT = length of time from when a consonant is released to when voicing begins (vibration of vocal cords)

- negative VOT = vocal cords vibrate before stop is released

FIGURE 2.19: The difference between [b] and [p], the delay between the release of the lips and voicing in the case of [p]. (From Psychology and language by Herbert H. Clark and Eve E. Clark. Copyright by Harcourt Brace Jovanovich. Reproduced by permission of the publisher.)

FIGURE 2.20: Percentage identification of [b] versus [p] as a function of voice-onset time. A sharp shift in these identification functions occurs at about 25 milliseconds. (From Lisker & Abramson, 1970.)
SYNTAX

• structure of sentence
• “The model embraced the designer and the photographer ……”

“The model embraced the designer and the photographer laughed.”
SEMANTICS

- meaning of word or sentence
- *morphemes* are smallest unit of meaning

“Colorless green ideas sleep furiously.”

“Fastly eat dinner, ballgame start soon.”
Semantics/Syntax Interaction

The old man the boats
Semantics/Syntax Interaction

Jay Leno talked about sex with Lindsey Lohan
EVOKED RESPONSE POTENTIALS (ERPS)

- measures changes in electrical activity in msec
- uses surface electrodes placed on the scalp (16-100)
- signal requires a few hundred thousand neurons to fire synchronously
- measures time-locked averages (modest localization)

Photo courtesy of squashpicker on Flickr.
N400 to Semantic Incongruence

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See lecture video.


N400 for semantic incongruence ("socks"); P650 for surprise (BIG FONT)
P600 to Syntactic Incongruence

Image removed due to copyright restrictions.
See lecture video.


SPS = Syntactic Positivity Shift
PRAGMATICS

• practical understanding
• “Do you know what time it is?” “Yes”
• humor, sarcasm (“Two negatives make a positive, but two positives don’t make a negative.” “Yeah, yeah”)
COMPREHENSION OF AMBIGUOUS WORDS

“bugs”
**Lexical Decision Task**

*Real word?*

- DOCTOR
- POCTOR
- SPY
- SYP

**CHURCH**

**DOCTOR**

**NURSE**

**DOCTOR**

*slower*

*faster*
“Rumor has it that for years the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other bugs in the corner of his room.”

After hearing “bugs” see for lexical decision either “ANT” or “SPY” or “SEW”
COMPREHENSION OF AMBIGUOUS WORDS

After hearing “bugs” see for lexical decision

<table>
<thead>
<tr>
<th>Word</th>
<th>Delay (msec)</th>
<th>Response</th>
<th>Delay (msec)</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>“ANT”</td>
<td>500</td>
<td>fast</td>
<td>2000</td>
<td>fast</td>
</tr>
<tr>
<td>“SPY”</td>
<td>500</td>
<td>fast</td>
<td>2000</td>
<td>slow</td>
</tr>
<tr>
<td>“SEW”</td>
<td>500</td>
<td>slow</td>
<td>2000</td>
<td>slow</td>
</tr>
</tbody>
</table>

Exhaustive lexical access - all meanings are activated, correct one is maintained, incorrect one is suppressed
PRAGMATICS

• practical understanding
• “Do you know what time it is?” “Yes”
• humor, sarcasm (“Two negatives make a positive, but two positives don’t make a negative.” “Yeah, yeah”)
• emotional intonation & right hemisphere
SUPERIOR IDENTIFICATION OF LIES BY PATIENTS WITH LEFT HEMISPHERE LESIONS

Table 1. Success in interpreting lying cues

<table>
<thead>
<tr>
<th>Group</th>
<th>Vocal pitch cues only</th>
<th>Facial expression cues only</th>
<th>Facial and vocal cues</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH</td>
<td>0.30</td>
<td>0.73</td>
<td>0.60</td>
</tr>
<tr>
<td>RH</td>
<td>0.20</td>
<td>0.50</td>
<td>0.45</td>
</tr>
<tr>
<td>C</td>
<td>0.20</td>
<td>0.57</td>
<td>0.47</td>
</tr>
<tr>
<td>UC</td>
<td>0.32</td>
<td>0.50</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Values represent proportion correctly identifying liars. LH, left-hemisphere-damaged aphasics, mean age 58.4 years, patients at the Massachusetts General Hospital who gave informed consent. Their diagnoses, based on neurological examinations and MRI, were left middle cerebral artery infarct (nine patients) and subarachnoid haemorrhage (one subject). Neuropsychological testing revealed at least low average intellectual and perceptual abilities. Subjects achieved 95% correct (87.5–100% range) on a word-to-picture matching task and 89% correct on a lexical decision task (78–94% range), indicating recognition of single words. However, they performed at near-chance levels on a sentence-to-picture matching task, with an average accuracy of 58% (53–69% range), suggesting severely compromised comprehension of sentences. RH, right-hemisphere-damaged patients, mean age 59.6 years. C, matched controls, mean age 60.2 years. Both RH and C groups had equal numbers of men and women, were matched with the LH patients for education and IQ scores, were patients at the Massachusetts General Hospital, and had given informed consent. UC, undergraduate controls.

The Neural Basis of Human Speech

- **Primary auditory cortex**
- **Wernicke's area** (word recognition)
- **Posterior language area** (connects Wernicke's area with perceptions and memories)
- **Broca's area** (speech production)
- Word meanings

Perceptions and memories

Image by MIT OpenCourseWare.
<table>
<thead>
<tr>
<th>Lesion</th>
<th>Broca's</th>
<th>Wernicke's</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>frontal</td>
<td>temporal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speech</th>
<th>Broca's</th>
<th>Wernicke's</th>
</tr>
</thead>
<tbody>
<tr>
<td>nonfluent,</td>
<td></td>
<td>fluent,</td>
</tr>
<tr>
<td>telegraphic</td>
<td></td>
<td>paraphasia, empty</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comprehension</th>
<th>Broca's</th>
<th>Wernicke's</th>
</tr>
</thead>
<tbody>
<tr>
<td>good</td>
<td></td>
<td>poor</td>
</tr>
</tbody>
</table>
Neural Basis of Language

Regardless of modality, sign & speech, recruit Wernicke & Broca regions; Deaf infants “babble” with their hands

- language is separable from speech

Petitto et al, PNAS (2000)
Recovery in Aphasia reflects right-hemisphere participation in language

Case study – left frontal injury – word stem completion (name a word that starts with STA____) activates right frontal region, compared to normal left frontal region

Language Acquisition

Photo courtesy of pohly on Flickr.
## Major Milestones in Language Acquisition

<table>
<thead>
<tr>
<th>Approximate age</th>
<th>Major Linguistic Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-3 Months</td>
<td>Perceive all phonemes; notice changes in phonemes</td>
</tr>
<tr>
<td>6 Months</td>
<td>Ignore distinctions between sounds not used in languages spoken around them; babbling begins</td>
</tr>
<tr>
<td>8 Months</td>
<td>Identify words in the continuous speech stream</td>
</tr>
<tr>
<td>1 Year</td>
<td>Babbling has adultlike intonation patterns; speaking begins</td>
</tr>
<tr>
<td>13 Months</td>
<td>Understand about 50 words</td>
</tr>
<tr>
<td>18 Months</td>
<td>Speak about 50 words</td>
</tr>
<tr>
<td>2 Years</td>
<td>Telegraphic speech</td>
</tr>
<tr>
<td>3 Years</td>
<td>Simple pragmatics</td>
</tr>
<tr>
<td>4 Years</td>
<td>Rules of grammar, such as plural</td>
</tr>
<tr>
<td>6 Years</td>
<td>Know about 10,000 words</td>
</tr>
<tr>
<td>9 Years</td>
<td>Subtle pragmatics</td>
</tr>
</tbody>
</table>
INFANTS & LANGUAGE

• sucking on a nipple (rate)/habituation
• within 2 hours of birth, chose mother’s voice over another voice (had not heard mother after birth)
• 3-day olds preferred language to other sounds like music
• 4-day olds noticed French/Dutch distinction
• 2 months phonemic distinctions (ba/ga), preference for own language
2-Day Old Infants Show Left Hemisphere Specialization for Speech

MOTHERESSE

- child-directed speech
- short, pauses, careful enunciation, exaggerated intonation in high pitch
- fits perfectly with infant perception

Photo courtesy of toomhe on Flickr.
CATEGORICAL PERCEPTION

NON-NATIVE LANGUAGES

6-12 MONTHS  (Werker & Lalonde 1988)

Ba   Ba   Ba    da    da    Da   Da   Da

16 Equal Steps from BA to DA

Eng Infants
10-12 mos
Eng Adults

Hindi Adults

Eng Infants
6-8 mos
Hindi Adults
Categorical Perception

Phoneme categorical perception (e.g., ba/da)

Universal “learner” up to 8 months
Native “learner” = 12 months

Behavioral Evidence:
Head Turn Procedure in Speech

http://www.youtube.com/watch?v=Ew5-xbc1HMk

Werker & Tees, 1992
Are Bilingual Children Delayed & Confused?

Babies “absorb” language easily!

BUT.... Isn’t 2 languages an overload?

THOUGHTS?
Bilingual Language Development

Language Delayed? NO!
Bilingual Groups - English/French, English/ASL, French/LSQ (ages 0-3) (Petitto & Kovelman, 2003; Petitto et al., 2001)

6 Months: Babbling
12 Months: First Words
18 Months: First 2 Words
24 Months: Morphology & Syntax

Image by MIT OpenCourseWare.
The Number of New Words Understood During the First Two Years of Life

Comprehension Score

Age in Months

Girls

Boys

Image by MIT OpenCourseWare.
Critical Period in Language Acquisition

Fragile & Resilient aspects of language

**FRAGILE** – phonology (production) & grammar
- age sensitive

**RESILIENT** - semantics/vocabulary learning -
  can be easily learned later in life
Critical Periods in Second Language Grammaticality Judgment Task

He go home
Grammar is ‘fragile’ = age sensitive

Fig. 1. The relationship between age of arrival in the United States and total score correct on the test of English grammar.

CRITICAL PERIOD?

Genie - locked in back room from 20 months until 13 years of age

Class watches 7:00 video clip from Secret of the Wild Child. PBS/NOVA, 1994.