

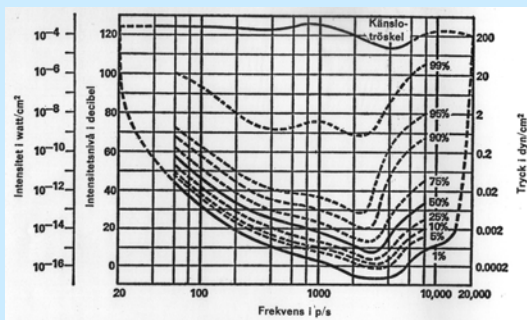
Psychoacoustics, speech perception, language structure and neurolinguistics

David House

Hearing acuity

- Sensitive for sounds from 20 to 20 000 Hz
- Greatest sensitivity between 1000-6000 Hz
- Non-linear perception of frequency intervals
 - E.g. octaves
 - 100Hz - 200Hz - 400Hz - 800Hz - 1600Hz
 - 100Hz - 800Hz perceived as a large difference
 - 3100Hz - 3800 Hz perceived as a small difference

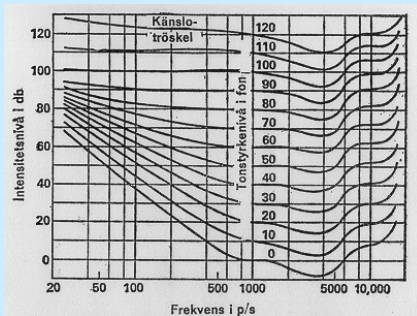
Absolute auditory threshold



Demo: SPL (Sound pressure level) dB

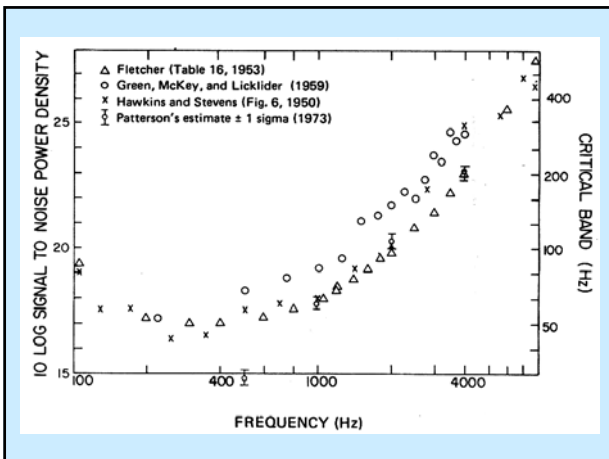
- Decreasing noise levels
 - 6 dB steps, 10 steps, 2*
 - 3 dB steps, 15 steps, 2*
 - 1 dB steps, 20 steps, 2*

Constant loudness levels in phons



Demo: SPL and loudness (phons)

- 50-100-200-400-800-1600-3200-6400 Hz
 - 1: constant SPL 40 dB, 2*
 - 2: constant 40 phons, 2*

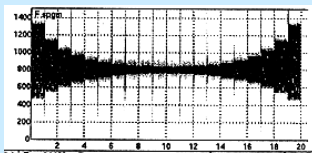


Critical bands

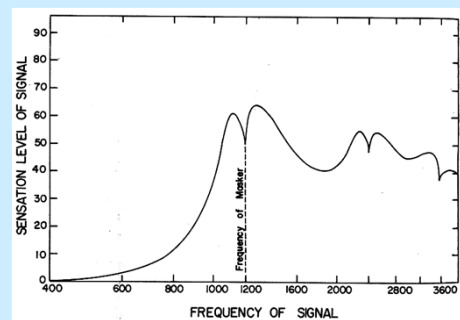
- Bandwidth increases with frequency
 - 200 Hz (critical bandwidth 50 Hz)
 - 800 Hz (critical bandwidth 80 Hz)
 - 3200 Hz (critical bandwidth 200 Hz)

Critical bands demo

- $F_m=200$ Hz (critical bandwidth 50 Hz)
 - B= 300,204,141,99,70,49,35,25,17,12 Hz
- $F_m=800$ Hz (critical bandwidth 80 Hz)
 - B=816,566,396,279,197,139,98,69,49,35 Hz
- $F_m=3200$ Hz (critical bandwidth 200 Hz)
 - B=2263,1585,1115,786,555,392,277,196,139,98 Hz

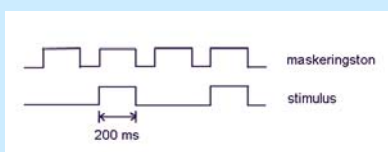


Effects of masking



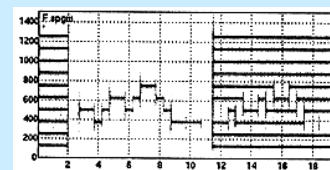
Effects of masking

- Low frequencies more effectively mask high frequencies
- Demo: how many steps can you hear?
 - a) masking tone 1200 Hz, stimulus 2000 Hz
 - b) masking tone 2000 Hz, stimulus 1200 Hz



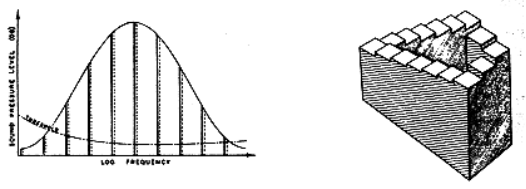
Holistic vs. analytic listening

- Demo 1: audible harmonics (1-5)
- Demo 2: melody with harmonics
- Demo 3: vowels and audible formants



Circularity in pitch

- R N Shepard
- J-C Risset
- J Liljencrants



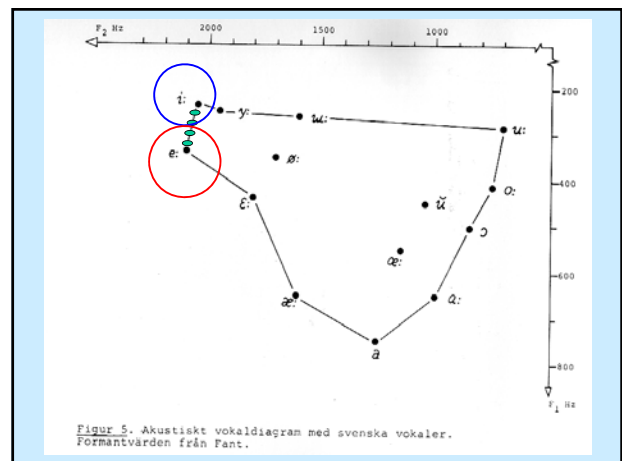
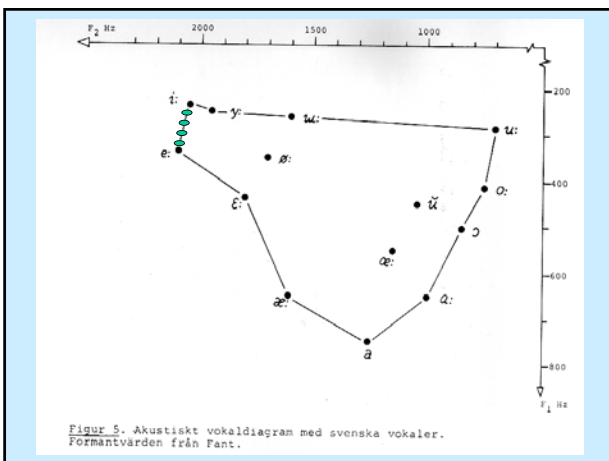
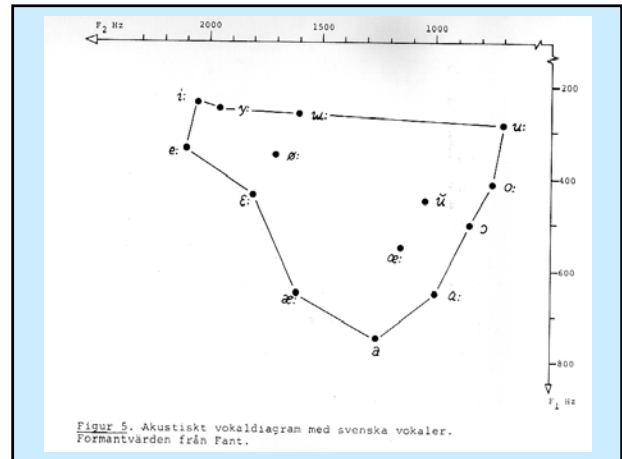
<http://asa.aip.org/sound.html>

Perception of vowels

- Formants (general relationship acoustics-articulation)
 - F1: information on jaw opening
 - higher F1= more open
 - F2: information on front-back
 - higher F2=more front
 - F3: information on lip rounding
 - lower F3=more rounded

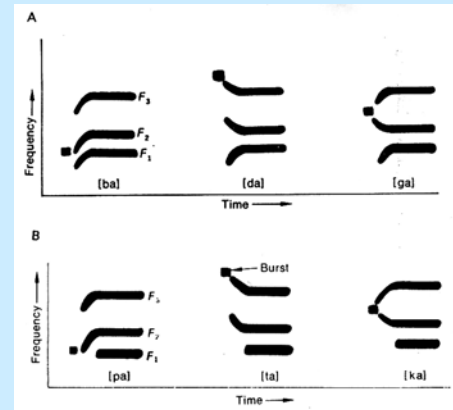
Perception of vowels

- Identification
 - Perceive which vowel is pronounced
- Discrimination
 - Hear that two vowel sounds are different
- Categorical perception
 - Difficult to discriminate within a category
 - Easy to discriminate between categories



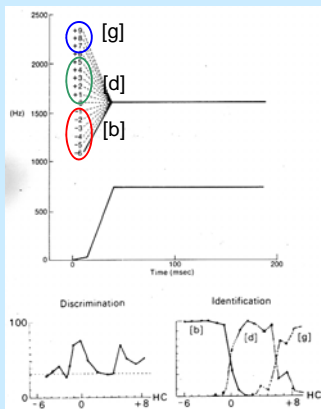
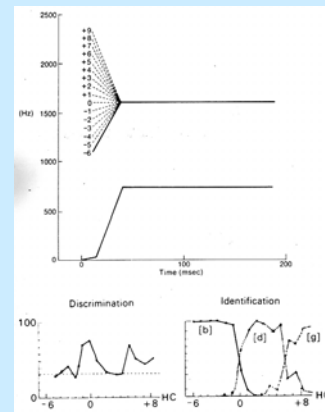
Perception of stops

- Frequency of the burst release
 - Provides information on place of articulation
- Formant transitions in adjoining vowels
 - Also information on place of articulation
- Voiced occlusion or aspiration
 - Provides information on manner of articulation

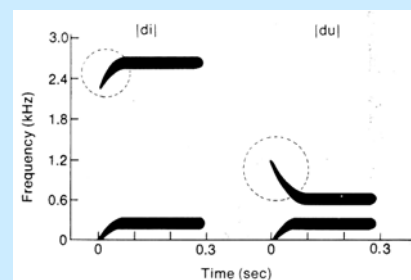


Perception of stops

- Early experiments with speech synthesis
 - Formant transitions alone were sufficient to identify place of articulation (ba-da-ga)
 - Identification and discrimination of stops
- Categorical perception of stops
 - Difficult to discriminate within a category
 - Easy to discriminate between categories



Invariance and segmentation problem



Invariance and segmentation problem

- The same phoneme has different cues in different contexts, e.g. F2-transitions for [di] [du].
- Where are the segment boundaries?
- Problem is a result of coarticulation
- Problem has inspired the classic perception theories

Classic theories of speech perception

- Invariance theory
 - The acoustic signal is the most important (invariant)
- Motor theory
 - Speaker's nerve impulses for speech motor control are calculated by the brain by analysing the acoustic signal.
 - Articulation is the most important
- Direct perception
 - The speaker's articulatory movements are directly perceived by the listener

Cognitive theories

- Top-down speech processing
 - Expectation and linguistic knowledge set the frame
 - Incoming words are compared to hypotheses
- Bottom-up processing
 - Acoustic signal is transferred to words
 - Message formed from words

Psycholinguistics

- The mental lexicon
- “Top-down” perception and context
 - experiments with phoneme detection (e.g. [s])
 - “They had been up all night and needed to sleep”
 - “They didn't know if they would be able to sleep”
 - experiments with filtered speech

Demo: *Low-pass filtered speech (speech below 300 Hz)* 🗣️

Original recording 🗣️

Speech acquisition theories

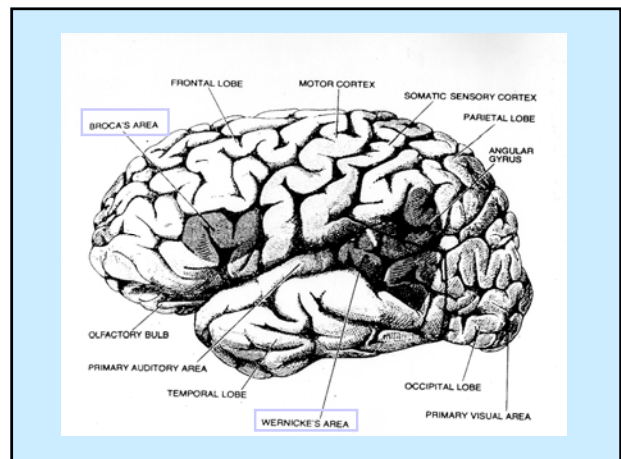
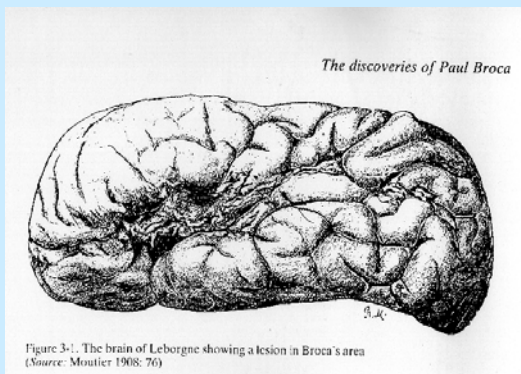
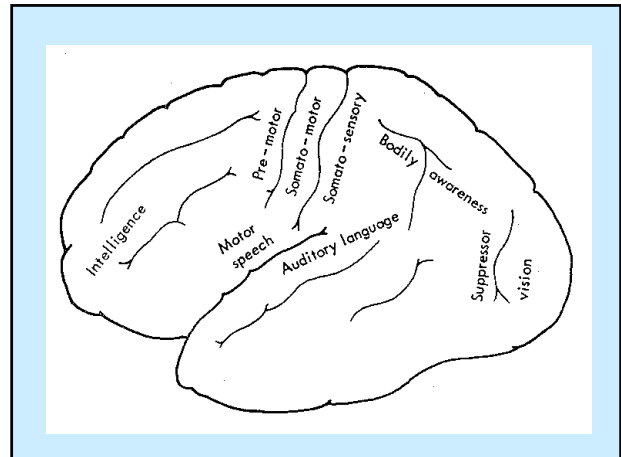
- Innate
 - Possible psychophysical limits
 - e.g. the number of vowels that can be discriminated
- Acquired
 - Language-specific categories
 - Several high, front vowels in Swedish: language categories develop making use of psychophysical limits
 - One high front vowel in Japanese: category differences are lost

Some of the main functions of language and speech

- Informative (provide information)
- Interrogative (obtain information)
- Influence (make someone perform an action)
- Social (make contact)
- Expressive (express feelings)
- Speaker-specific information (gender, age, background, identity)

Language and the brain

- Neurolinguistics
 - Language lateralization to the left hemisphere
 - Aphasia
 - Paul Broca, 1861
 - Carl Wernicke, 1874



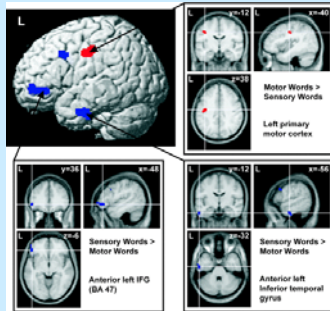
Semantics

- The linguistic sign (word) *Ferdinand de Saussure*
 - Arbitrary union between sound and meaning (e.g. hund, dog, chien)
 - But there are onomatopoeic words (sound imitation: e.g. whisper, mumble, susa, mumla)
- Homonyms
 - Two signs have the same form (e.g. vad-vad, bear-bear-bear)
- Lexicon
 - Semantic features (e.g. häst-sto-hingst, horse-mare-stallion)
 - Language dependent categories (e.g. tak, roof-ceiling)

Semantic representation in the brain

- PET-study (Positron Emission Tomography)
 - Cerebral blood flow
- Subjects listened to words (Italian)
 - Motor words (e.g. dive, skate)
 - Sensory words (e.g. darkness, shine)
- Used both nouns and verbs

Semantic representation in the brain

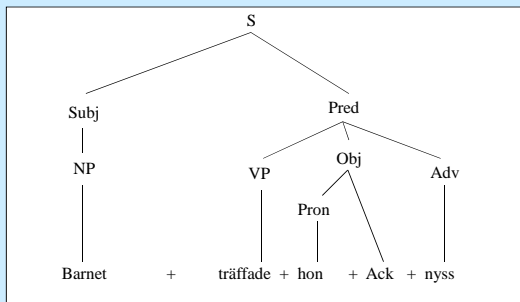


Vigliocco, G., Warren, J., Siri, S., Arculli, J., Scott, S.K., Wise, R. (2006). The role of semantics and grammatical class in the neural representation of words. *Cerebral Cortex* 16(12), 1790-1796.

Syntax and grammar

- Grammatical analysis
 - Word class (e.g. noun, verb, adverb)
 - function (e.g. subject, object)
- Position analysis
- Phrase structure rules (*Noam Chomsky*)
- Parsing (phrase structure analysis)
- Generative grammar

Phrase structure trees



Phrase structure rules

Den lille mannen på gatan.

1. np \rightarrow art + a + n + pp
2. art \rightarrow den
3. a \rightarrow lille
4. n \rightarrow mannen, gatan
5. pp \rightarrow p np
6. p \rightarrow på

Example of syntactic ambiguity

- *Igår sköt jag en hare med gevär på 100 meter.*
- *Hade du ett så långt gevär?*
- *Nej, jag menar att jag sköt med gevär en hare på 100 meter.*
- *Jaså, finns det så långa harar?*
- *Nej, jag sköt på 100 meter en hare med gevär.*
- *Då hade du tur att inte haren sköt först.*

Efter Sigurd: *Språk och språkforskning*

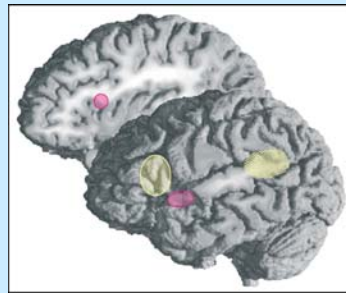
Example of syntactic ambiguity

- *Do you want to see my synthetic cow hide?*
- *I didn't know you had a synthetic cow.*
- *No, I mean do you want to see the cow hide.*
- *Oh, is she so shy?*
- *No, I mean a synthetic cow hide.*
- *Yes, I know, but what happened to the real one?*

Syntax in the brain

- Studies of aphasia
 - What kinds of linguistic problems do patients display? (e.g. problems with passive construction)
- fMRI-study (functional magnetic resonance imaging)
 - Subjects are asked to interpret complex syntactic structures

Syntax in the brain



pink=phrase structure, yellow=sentence constituents,
striped=integration:syntax/lexicon

Yosef Grodzinsky and Angela D Friederici, Neuroimaging of syntax and syntactic processing, *Current Opinion in Neurobiology* 2006, 16:240-246

Morphology

- Morpheme: the smallest unit of linguistic meaning
stol-en bord-et bord-en
se-r the table
- allomorph: variant of a morpheme (a, an) (-en, -et)
- Morpheme classes
 - Lexical/grammatical
 - Lexical morphemes (häst, horse)
 - Grammatical morphemes (-ar, -s)
 - Free/bound
 - Free morpheme (book, bok)
 - Bound morpheme (o-klart, un-happy)
 - (genetiv -s: Kungen-s, The King's)

Phonology

- Phoneme: The smallest distinctive unit of sound
e.g. /b/ /p/ in Swedish (bil pil)
- allophones: variants of a phoneme (t.ex. /r/ > [r], [R])
- minimal pairs (bil/pil, par/bar)
- commutation test (used to define phonemes in a language)
 - /r/ /R/ are two phonemes in Swedish and English but not in Japanese
- Distinctive features (e.g. voicing)
- Phonotactic structures (e.g. pferd, stone)
- Syllable structure

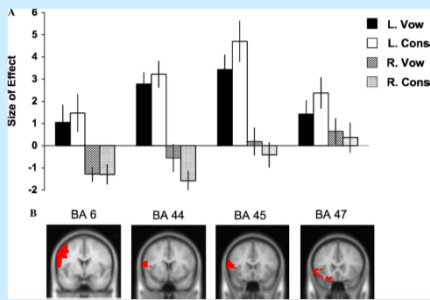
Vowels and consonants

- Speech production (phonetics)
 - Free air passage through the pharynx, mouth and the lips = vowel
 - Constricted or closed air passage = consonant
- Function (phonology)
 - Nuclear in the syllable = vowel
 - Marginal in the syllable = consonant
- Exceptions
 - Some voiced consonants (e.g. syllabic nasal)
 - Approximants or semi-vowels (e.g. [j] [w])
- Information
 - Consonants carry more information than vowels

Representation of phonemes in the brain

- PET-study (Positron Emission Tomography)
 - Cerebral blood flow
- Subjects had to reconstruct words
 - Real words (repeat the word)
 - Non-word (wrong vowel, say the real word)
 - Non-word (wrong consonant, say the real word)
- Left hemisphere (Words with wrong consonants produced more brain activity)

Representation of phonemes in the brain



Sharp, D., Scott, S.K., Cutler, A., Wise, R.J.S. (2005). Lexical retrieval constrained by sound structure: The role of the left inferior frontal gyrus. *Brain and Language* 92, 309-319.

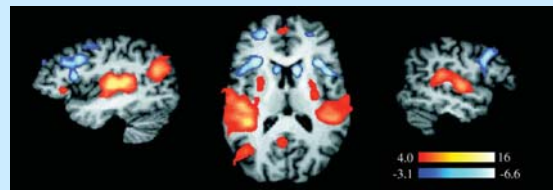
Prosody

- Functions of prosody
 - Lend prominence (emphasize, de-emphasize)
 - Grouping function (combine, separate)
 - Facilitate dialogue: turntaking and feedback
 - Signal attitude and emotion
- Word prosody
 - quantity, intensity (stress), accent
- Phrase prosody
 - Focus, emphasis, intonation

Prosody in the brain

- Prosody lateralized to the right hemisphere?
- Studies of aphasia
 - Lesions or injuries to the right hemisphere can result in deviant prosody
- fMRI-study
 - Subjects listened to emotional speech
 - Complex prosodic stimuli seem to activate several areas in the brain (not exclusively right hemisphere)

Prosody in the brain



Normal speech = red Prosodic speech = blue

Sonja A. Kotz, Martin Meyer, Kai Alter, Mireille Besson D., Yves von Cramon, and Angela D. Friederici. *On the lateralization of emotional prosody: An event-related functional MR investigation. Brain and Language* 86 (2003) 366-376

Transcription

- Phonetic transcription
 - What are the speech sounds?
 - Transcription of allophones []
- Phonological (phonemic) transcription
 - What is the function in the phoneme system?
 - Only phonemes are transcribed / /
- IPA chart

THE INTERNATIONAL PHONETIC ALPHABET (revised to 2005)

Category	Symbol	Approximate	Symbol	Approximate	Symbol	Approximate	Symbol	Approximate
Plosives	p	voiceless	b	voiced	t	voiceless	d	voiced
...

IPA chart showing various phonetic symbols and their approximate positions on a vowel chart.

IPA charts from the International Phonetic Association (Department of Theoretical and Applied Linguistics, School of English, Aristotle University of Thessaloniki, Thessaloniki 54124, GREECE).

References

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