Information in Spoken Language
A quantitative approach

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LOT winterschool 2006
1 Information Structure

- Introduction
- Reaction time experiments
- Syllable and Lexical stress
- Word segmentation
- Focus and prominence
- Bibliography

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Introduction

There is more in speech than lexical information

- Speech is \textit{sequential}!
  - Lexical information is unevenly distributed
  - Words have to be isolated to be recognized
  - Some words are less important than others
  - Words come in groups
  - Semantic and syntactic structure should be reflected in the speech
  - These are questions about recognition and processing
  - How to study them?
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How do humans process speech?

Time the difference between stimulus and response
- Model perception, processing, and motor reaction
- Manipulate one of the steps using the stimulus
- Find timing difference
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How do humans process speech?

- Stimulus
- \[ 1 \rightarrow 2 \rightarrow \ldots \rightarrow n-1 \rightarrow n \]
- Response
- Reaction Time (ms)

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Three temporal stages in Reactions to Stimuli:

- Perceptual (P) and motor (M) component
- Both with deterministic response-times ($t_p$ and $t_m$)
- Central decision making component (C) characterized by a random walk to a decision threshold

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Reaction time experiments: Decision component

Random walk in the Central Component

- Deterministic $t_0 = t_p + t_m$
- Variable $RT = t_0 + \text{RandomWalk}$
- Integration time $\tau = \frac{1}{\alpha}$

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Reaction time experiments: Relative integration time $\frac{\tau_1}{\tau_2}$

$\frac{\tau_1}{\tau_2}$ determined from RT variances

- $\text{Mean}(RT) = t_0 + \tau$
- $\text{Var}(RT) = \sigma^2 \tau^3$ (where $\sigma$ is a modeling parameter)
- $\frac{\tau_1}{\tau_2} = \sqrt[3]{\frac{S_1^2}{S_2^2}}$

with ($S^2 =$ variance)

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Syllable and Lexical stress

Stressed syllables are special

- English and Dutch words tend to start with a stressed syllable
- The stressed syllable tends to be the most complex (informatics)
- Words can be identified fairly well with only the stressed syllable and its position in the word
- Eg, in CELEX, only 15 Dutch words with a total of 577 tokens have the structure "*-kOn-*-*", like 'verkondiging' (proclamation)
- This is also true if only the broad phoneme classes are used

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Dutch stress position in words of 3 and more syllables (CELEX)

If some syllables contain more information, it would be advantageous to emphasize them

- **Speed up recognition** by starting words with a *distinctive* stressed syllable
- Most English, and Dutch, words start with a stressed, or informative, syllable
- Even stronger with common prefixes, e.g., /ɛə-/ removed

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What distinguishes lexical stress? (in English and Dutch)

- Less reduction (and coarticulation)
- Longer phoneme durations
- Louder
- In short: Emphasis
- No pitch marking

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- Not all languages have lexical stress
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Syllable and Lexical stress:
Example: Word Spotting in Dutch

Press button when you hear a word
Present words and measure Reaction Times to spotting the embedded word, e.g., zee (sea):

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Explanation:

muzee starts an existing Dutch word, museum, if the stress is right. luzee does not. Listeners cannot recognize a word while there are still alternatives.

[Cutler(1997)]
Word recognition works phoneme by phoneme

- Word boundary markers would prevent word-in-word ambiguity
- The segmentation problem
- Primary cue is rhythm
- Rhythmic groups are isolated and used as “first guess”
- Three options (examples):
  - Mora timed: Japanese
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Fragment detection response times (msec) of English (left), Japanese (center), and French (right) listeners to CV and CVC targets in words with closed initial syllables. [Cutler(1997)]

**Single rhythmic units are identified faster**

- **English** (*ba/bal in balcony*): No effect (same stress)
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Word spotting response times (msec) of Finnish listeners to Finnish words with preceding (left) or following (right) contexts containing harmonically mismatching versus matching vowels. [Cutler(1997)]

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A vowel harmony mismatch marks the start of a new word (left). The end, however, is ignored (right)
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![Graph showing response times for words with and without vowel harmony mismatches]

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Other prosodic boundaries are also articulatory marked

- Levels: Word, intermediate phrase, intonational phrase, and utterance
- Higher levels marked by pitch “movements”
- Domain initial phonemes are emphasized
- Domain final phonemes are de-emphasized
- Emphasis by less reduction etc.
- De-emphasis by more reduction etc.
- Also very efficient:
  - The first phoneme(s) of a domain will be informative
  - The last phoneme(s) of a domain are often redundant

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In any utterance, some words convey new, important information, and others give less or repeat old information.

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- *The background* sets the stage
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- “*Walking in the park, I saw a dog*”
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Focus and prominence: Given and New information

Given information is redundant, new information important

- The prominence of a word decreases with its "givenness"
- New information is almost always prominently put in focus
- There is a lexical dimension, i.e., repeated words
- There is also a semantic dimension, i.e., repeated concepts
- The latter involves priming, e.g., names and roles
- That is, referring to a *president* primes her/his *name* as given
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The smooth signal redundancy hypothesis [Aylett and Turk(2005)]

- Redundancy in the language affects prosody
  - Prosody *reduces* redundant articulation
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