



Information in Spoken Language

A quantitative approach

Rob van Son

Chair of Phonetic Sciences
ACLC
University of Amsterdam

LOT winterschool 2006



AMSTERDAM CENTER
FOR LANGUAGE AND
COMMUNICATION

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1 Information Structure

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



There is more in speech than lexical information

- Speech is **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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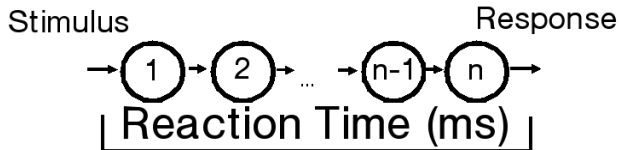
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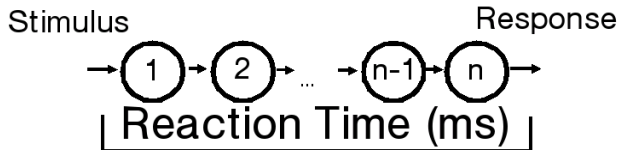
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Time the difference between stimulus and response

- Model perception, processing, and motor reaction
- Manipulate one of the steps using the stimulus
- Find timing difference
- Extremely sensitive probe

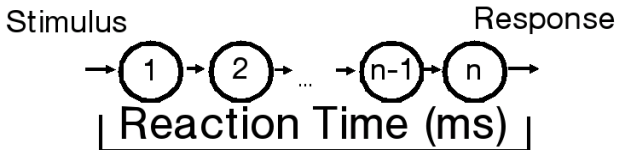
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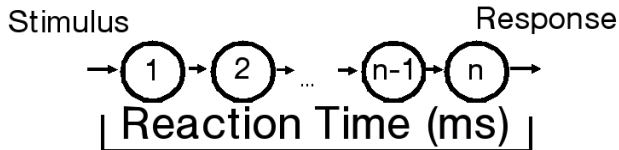
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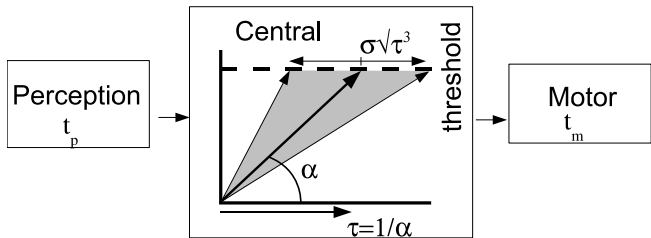
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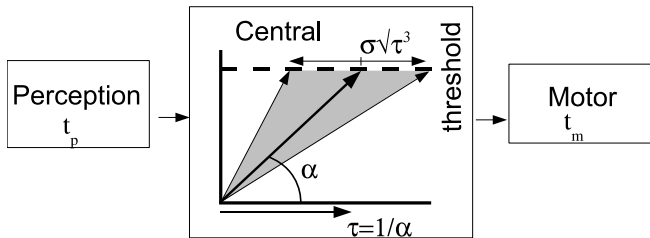
Reaction time experiments: Model



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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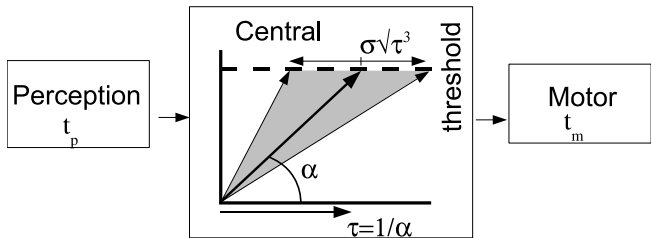


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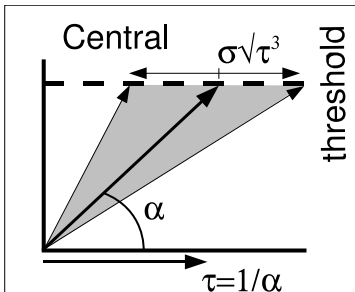
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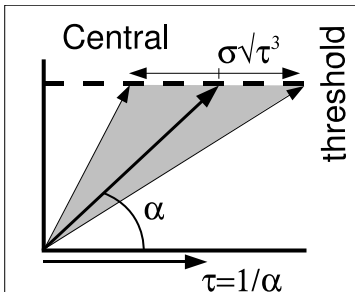
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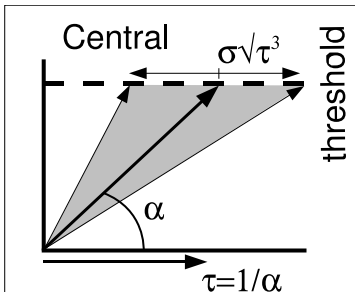
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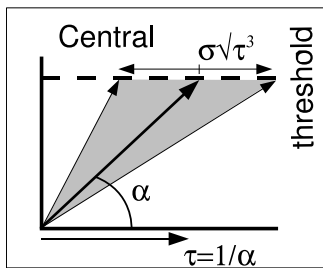
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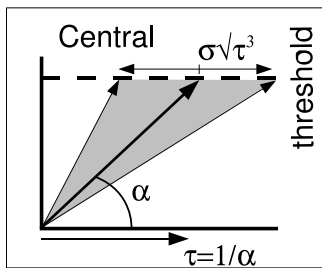
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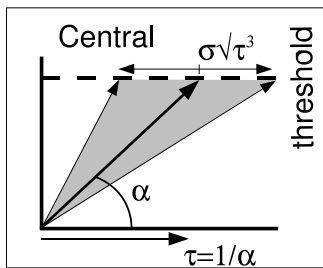
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Syllable and Lexical stress



Stressed syllables are special

- English and Dutch words tend to start with a stressed syllable
- The stressed syllable tends to be the most complex (= informative)
- 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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Stress	Words	Tokens	no /xə -/	Words	Tokens
+ - -	143,031	2,326,745		150,553	2,792,217
- + -	60,970	2,385,914		54,605	1,944,693
- - +	37,750	1,132,019		36,593	1,107,768

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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, eg, /xə -/, removed

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- In short: Emphasis
- No pitch marking

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Question: Do listeners actually use lexical stress for word recognition?

- Not all languages have lexical stress
 - Among others, *English* and *Dutch* have lexical stress
 - Experiment: Lexical competition increases RT
 - But only if stress pattern is correct
 - English listeners do not use lexical stress
 - In English, vowel quality (full vs schwa) replaces 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*):

	RT		RT
lu ZEE	< 600ms	LU zee	< 600ms
mu ZEE	> 700ms	MU zee	≈ 650ms

Explanation:

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

[Cutler(1997)]

Word segmentation



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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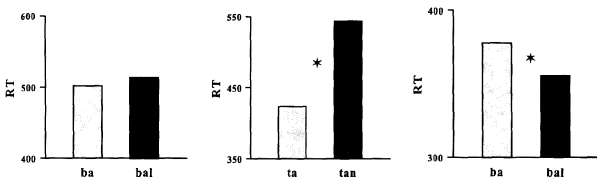


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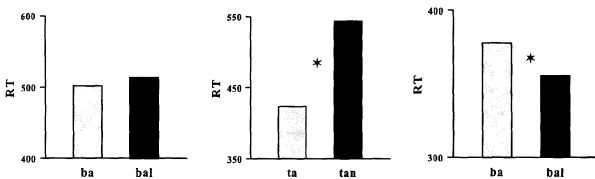


Fragment detection response times (msec) of **English** (left), Japanese (center), and French (right) listeners to CV and CVC targets in words with closed initial syllables. [Cutler(1997)]

Single rhythmic units are identified faster

- **English** (*ba/bal* in *balcony*): **No effect** (same stress)
- Japanese (*ta/tan* in *tanshi*): Faster for mora
- French (*ba/bal* in *balcon*): Faster for syllable

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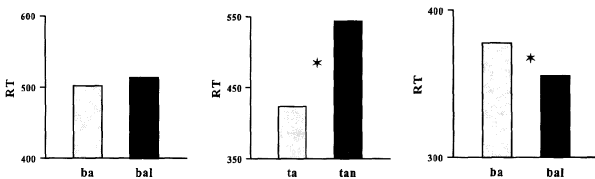


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- *Japanese* (ta/tan in tanshi): Faster for mora
- *French* (ba/bal in balcon): Faster for syllable

Word segmentation

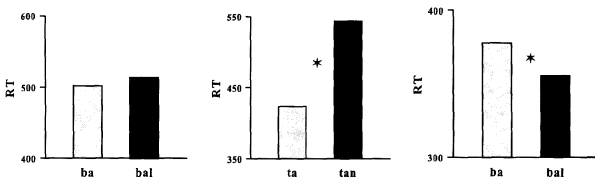


Fragment detection response times (msec) of *English* (left), *Japanese* (center), and *French* (right) listeners to CV and CVC targets in words with closed initial syllables. [Cutler(1997)]

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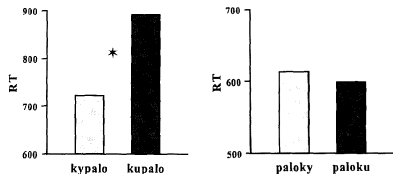


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Word segmentation: Vowel harmony

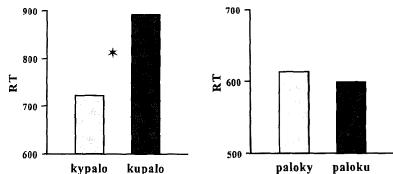


Word spotting response times (msec) of Finnish listeners to Finnish words with preceding (left) or following (right) contexts containing harmonically mismatching versus matching vowels. [Cutler(1997)]

Finish vowel harmony: /a o u/ and /æ œ y/ are excluded from the same word

A vowel harmony mismatch marks the start of a new word (left). The end, however, is ignored (right)

Word segmentation: Vowel harmony



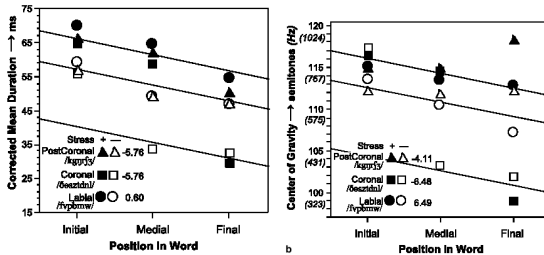
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Word segmentation



Marking word boundaries and stressed syllables US English

- Emphasize initial and reduce final consonants
- Reduce unstressed consonants
- Both in duration and spectrally (CoG)
- Coronals, /s z t d n l/, are special

[Van Son and Van Santen(2005)]

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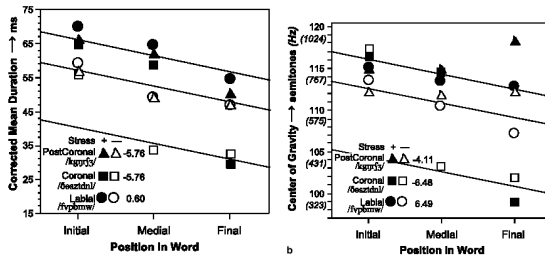
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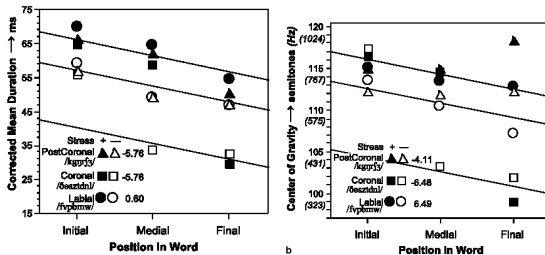
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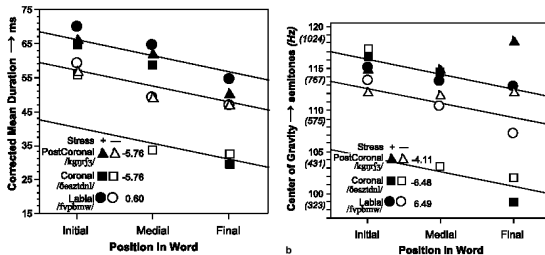
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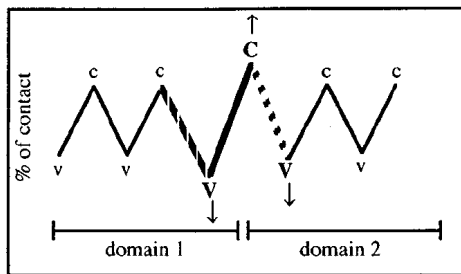


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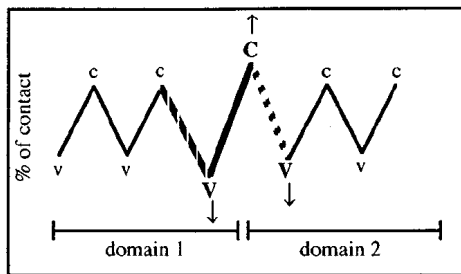
Word segmentation: Prosodic boundaries



Strengthening of prosodic boundaries

- More linguo-palatal contact after a boundary than before
- In *CV CV CV CV* utterances
- Start is strong, end is weak

Word segmentation: Prosodic boundaries



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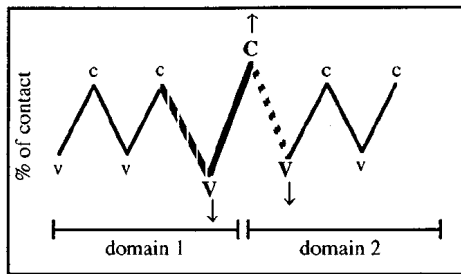
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Word segmentation



Other prosodic boundaries are also articulatory marked

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- 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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Focus and prominence



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

- The focus refers to the new, unpredictable words
- The words in focus are often marked in prosody and articulation
- These words are made prominent
- Prominence means *longer, louder, less reduced*
- Prominent words can also be accented (F_0 movements)
- In general: Informative → Emphasized
- Pitch accents mark prominent words
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Focus and prominence: Foreground/Background



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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, ie, repeated words
- There is also a semantic dimension, ie, repeated concepts
- The latter involves priming, eg, names and roles
- That is, referring to a *president* primes her/his *name* as given
- Prosody marks new information and de-emphasizes given information

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- The latter involves priming, eg, names and roles
- That is, referring to a *president* primes her/his *name* as given
- Prosody marks new information and de-emphasizes given information

[Aylett and Turk(2005)]

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
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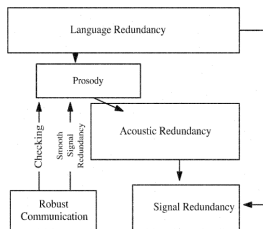


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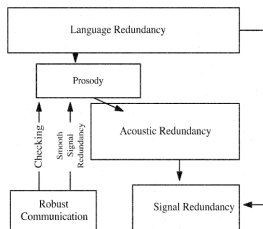
Focus and prominence: *information structure*



The smooth signal redundancy hypothesis [Aylett and Turk(2005)]

- Redundancy in the language affects prosody
- Prosody *reduces* redundant articulation
- Acoustic reduction → Robust and efficient communication
- But: Is prosody the only *compressor*?

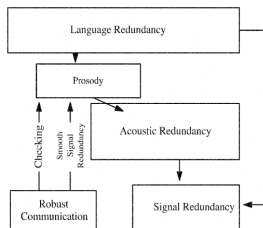
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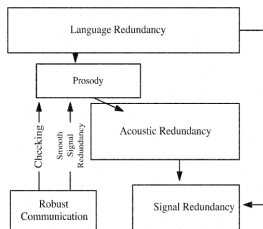
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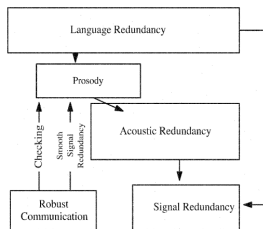
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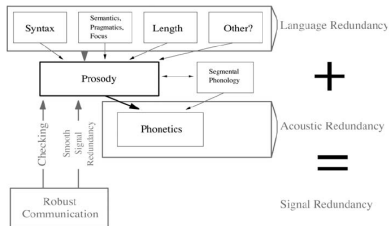
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The smooth signal redundancy hypothesis combined with traditional phonology

- Language and lexicon evolution favor efficient structures
- Speaker might evaluate intermediate structures for comprehension?
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Focus and prominence: *information structure*



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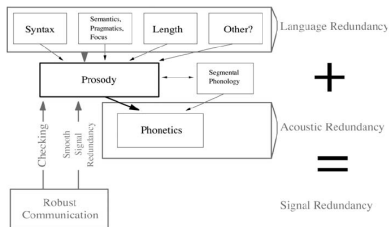
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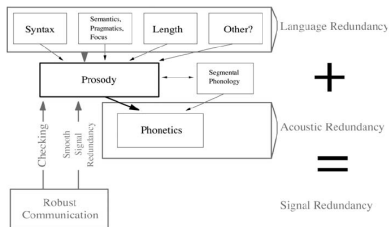
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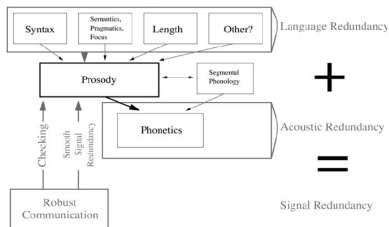
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