Human Language Processing
Lecture 2
Introduction to Psycholinguistics

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Psycholinguistics

"To understand and model the processes that underlie the human capacity to understand language"

- How does the human language processor work?
- How is it realized in the brain?
- How is linguistic knowledge represented in the brain?
- How can we understanding computationally?
- Where does our capacity for language emerge from?

Human language processing: Function

What does it *do*?

- **Comprehension:** Maps from "sound to meaning"
  - speech/orthography to words
  - words to structures
  - structure to meanings
- **Production:** Maps from "message to speech"
  - Meaning to grammatical encoding
  - Phonological encoding
  - Articulation

Competence versus Performance

Competence: Knowledge of Language

- Linguistic theories at all levels
  - Phonetics/phonology, morphology, syntax, semantics ...
- Rules and representations

Performance: How Language is Processing

- Use of Knowledge of Language
  - Processes for comprehension and production
- Architectures and Mechanisms

Why Distinguish Competence & Performance?

Sometimes what we do differs from what we know.

Production: we say things we know are wrong

- Spoonerisms: "Mental lexicon" spoken as "Lentil Mexican"
- Agreement: "The friend of the two girls are laughing"

Comprehension: we can't understand things we know are ok

- Centre embedding:
  - "The mouse that the cat that the dog chased bit fled"
- Garden paths:
  - "The horse raced past the barn fell"

The Competence Hypothesis

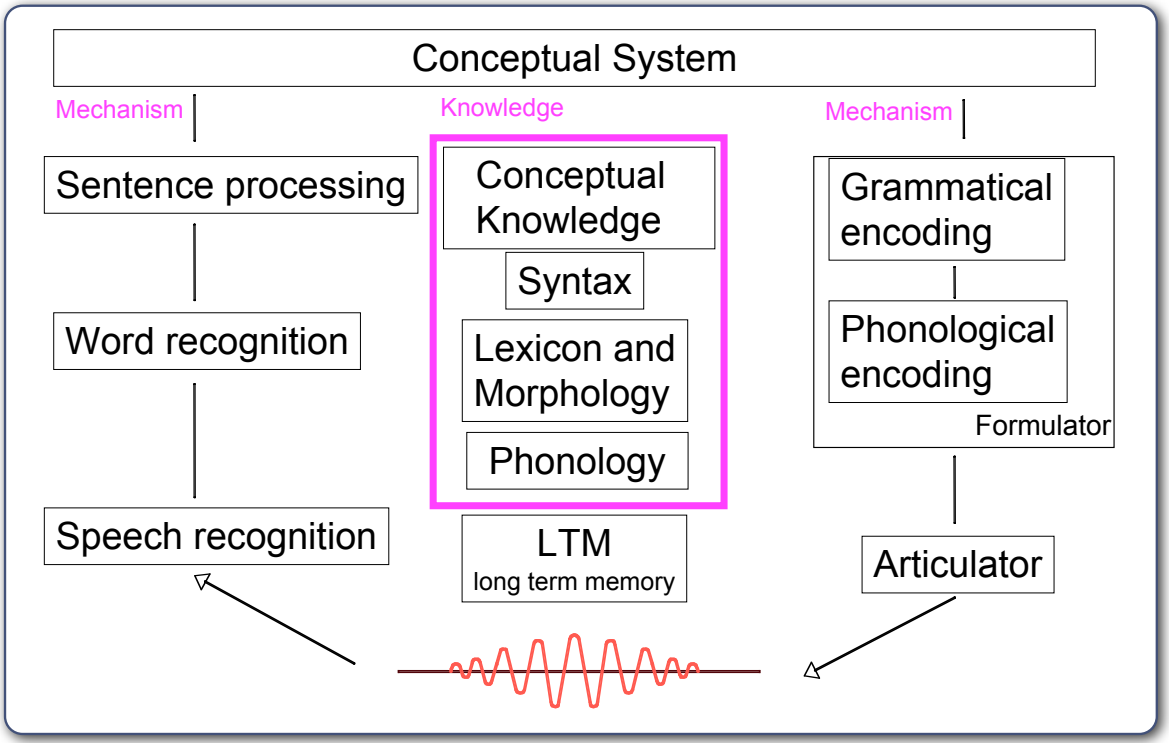
Knowledge: Competence hypothesis

- Need to recover the meaning of sentences/utterances
- Assumptions about (levels of) representations
  - Linguistic theory is isomorphic to human linguistic knowledge
  - Comprehension and production share same knowledge

Weak competence: people recover *representations* that are isomorphic to those of linguistic theories

Strong competence: people *directly use* the grammatical knowledge & principles of linguistic theories

Speech Processing Model (Dijkstra & Kempen, 1993)



The Modularity Issue

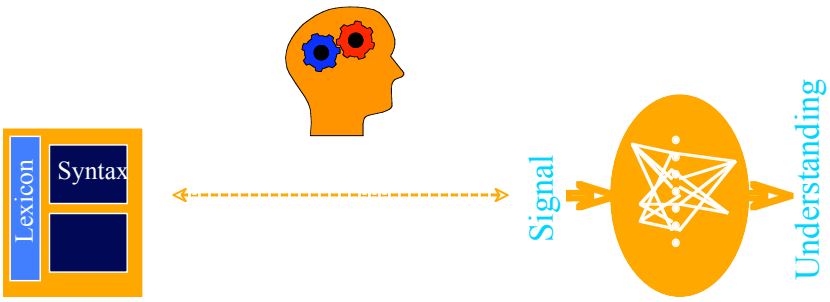
Is language distinct from other other cognitive processes?

- e.g. vision, smell, reasoning ...

Do distinct modules exist *within* the language processor?

- e.g. word segmentation, lexical access, syntax ...

What is a module anyway!?



Architectures and Mechanisms

What does "distinct" mean:

- Representational autonomy: e.g. phonological versus syntax representations
  - Possibly interactive processes
- Procedural autonomy: e.g. lexical access versus syntax
  - Possibly shared representations

How are any such "distinct subsystems" for language processing organised? How do they interact?

- Does organisation affect possible mechanisms?
- Theoretical, computational and empirical arguments for and against 'modularity'?

Modularity and Computation

The brain is the natural computer, par excellence:

- Perception occurs in real time, and is highly strategic

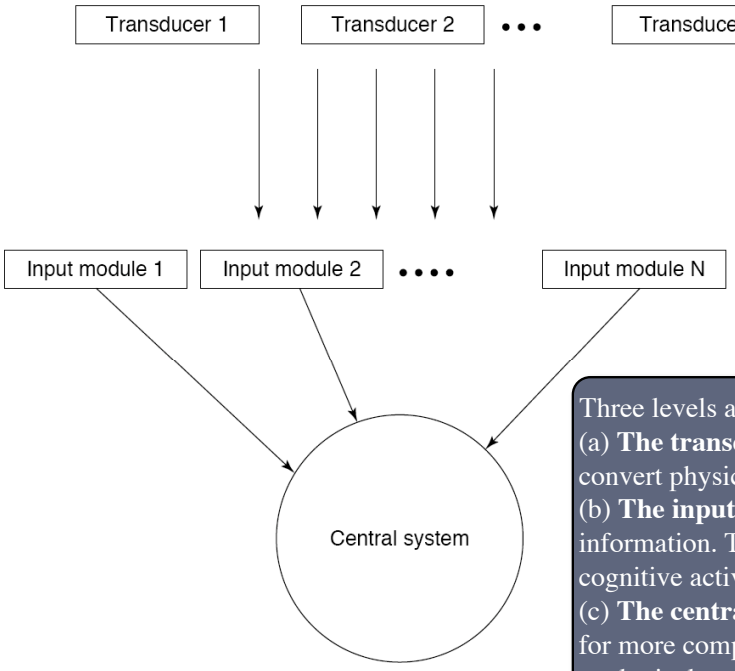
Traditional views on human perception

- Cognitivist: inferential, unencapsulated
  - cognitive penetration of perceptual processes
- Behaviourist: non-inferential, encapsulated
  - perception reduces to conditioned reflexes

Fodor: inferential but encapsulated

- perception is performed by: *"informationally encapsulated systems which may carry out complex computations"*

Fodor's Modularity



Modules are:
- domain specific
- innately specified
- informationally encapsulated
- fast
- hardwired (neurally specific)
- autonomous
- not assembled

Three levels are distinguished:
(a) **The transducers**, whose function is to convert physical stimulation into neural signals.
(b) **The input systems**, interpret transduced information. They are responsible for basic cognitive activities and are modular.
(c) **The central system**, is responsible for more complex cognitive activities such as analogical reasoning, and is not modular.

Reference

a Fodor, J.A. (1983) *The Modularity of Mind*, MIT Press/Bradford Books

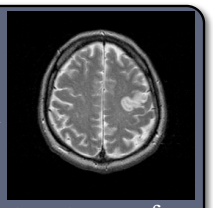
Proving Modularity

The best proof of Modularity would be evidence for a "Double Dissociation":

#1 Damaged linguistic abilities, but intact general cognition

#2 Damaged cognitive abilities, but intact language

#1 Broca's aphasia
- normal IQ
- language comprehension is relatively unimpaired
- language production is non-fluent, few words, short sentences, few function words, no intonation



#2 Williams Syndrome
(Genetic defect in .001% births)
- low IQ, overly social, poor spatial reasoning
- good language ability, nearly age appropriate

#1 Specific Language Impairment
- normal IQ and hearing
- language is meaningful, appropriate
- problem with grammatical morphemes

#2 Senile Dementia
- poor memory and diminished general cognitive function
- language production and comprehension remain intact

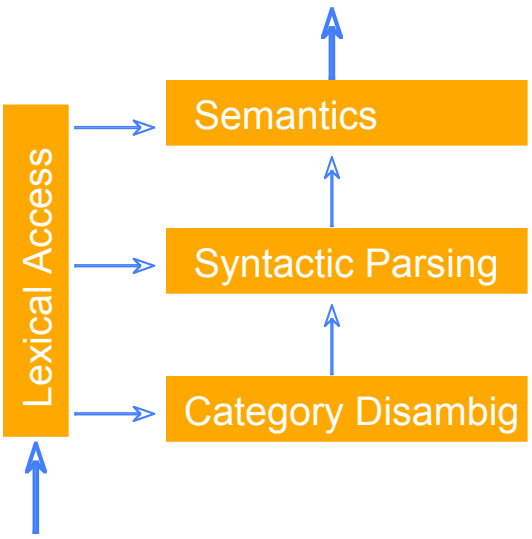
Strong competence and linguistic modularity

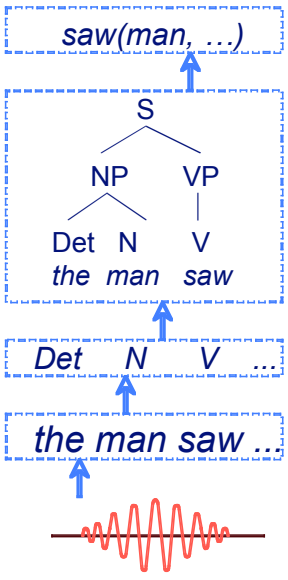
Fodor's proposals emphasis language as a module, distinct from other perceptual cognitive abilities

Linguistic theories suggest that language itself may consist of sub-levels: phonology, morphology, syntax, semantics ...

- Each with different rules and representations
- Do these correspond to distinct processes?
- Are these processes modules?
- Which of Fodors characteristics do the have/not have?

A Modular Architecture





Support for Sub-linguistic Modularity

Modular lexical access versus syntax: Forster

- all possible word meanings temporarily available
- not initially influenced by syntactic context

Modular syntax versus semantics: Frazier

- initial attachment ambiguities resolved by purely structure strategies/preferences
- no initial ("first pass") effect of semantics

Dissociation in language impairment at different levels

- lexical, syntactic, semantic
- production and comprehension

Human Language Processing: Observations

Features of the human comprehension system

- People are highly adaptive, and context sensitive
- People are accurate and fast
- Incremental, word-by-word
- Some limitations that computers don't have: memory

In addition to understanding language, we want to model *on-line human behaviour,* or "performance"

So what ...

Speech streams include no discrete boundaries to indicate where one word ends and another begins.

We understand stammering non-fluent politicians and non-native speakers. Incomplete sentences are no problem for us.

We deal with ambiguity all the time without breaking down. Computer parsers often maintain thousands of possible interpretations.

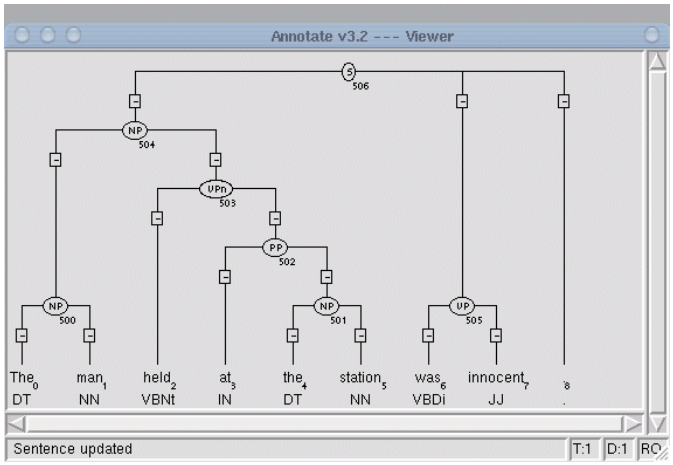
We have a vocabulary of about 60,000 words. We access somewhere between 2-4 words/second (error rates around 2/1000 words)

We understand speech even faster than we can produce it. We are so fast, we can even finish each others sentences.

The Problem

How do people recover the meaning of an utterance, with respect to a given situation, in real-time?

"The man held at the station was innocent"



Crocker & Brants, *Journal of Psycholinguistic Research*, 2000.

Human Language Processing

We understand language incrementally, word-by-word

- How do people construct interpretations

We must resolve local and global ambiguity

- How do people decide upon a particular interpretation

Decisions are sometimes wrong!

- What information is used to identify we made a mistake
- How do we search for an alternative

Investigating real-time language processing

How do we know people understand language incrementally?

- Speech shadowing task: the participant repeats back speech as he hears it
  - Close shadowers (~10% of people) can repeat what they hear at a delay of only 250 ms (normal ~500 ms)
  - 250 ms = 1 syllable, i.e. close shadowers are processing the incoming material at the level of individual syllables

Marslen-Wilson, *Nature*, 1973.

Speech Showing

Analysis of "constructive" errors by shadowers:

- In almost all cases in which the participant changed/ omitted/added a word or its part, the change was structurally appropriate

Examples

Original: It was beginning to be light enough so I could see...
Repeated: It was beginning to be light enough so that I could see...

Original: He had heard at the brigade...
Repeated: He had heard that at the brigade ...

- Speakers analyze the input at higher levels without waiting till the end of the phrase/constituent

Reading time studies

We can use controlled experiments of reading times to investigate local ambiguity resolution

(a) The man held at the station was innocent (LA)

(b) The man who was held at the station was innocent (UA)

We can compare the reading times of (b) where there is no ambiguity, with (a) to see if & when the ambiguity causes reading difficulty.

- Need a "linking hypothesis" from theory to measures
- Can then manipulate other linguistic factors to determine their influence on on RTs in a controlled manner

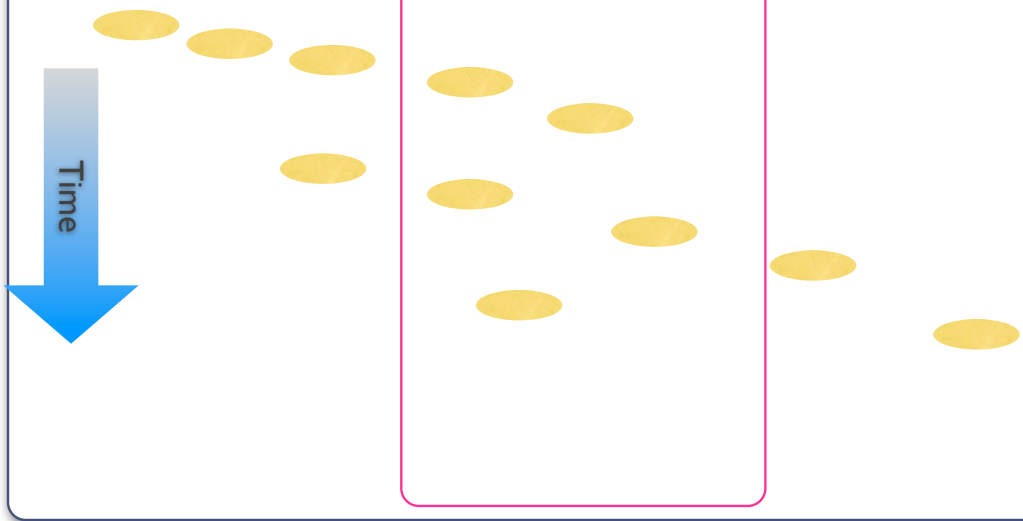
Methods for Investigating Human Behaviour

The man held at the station was innocent

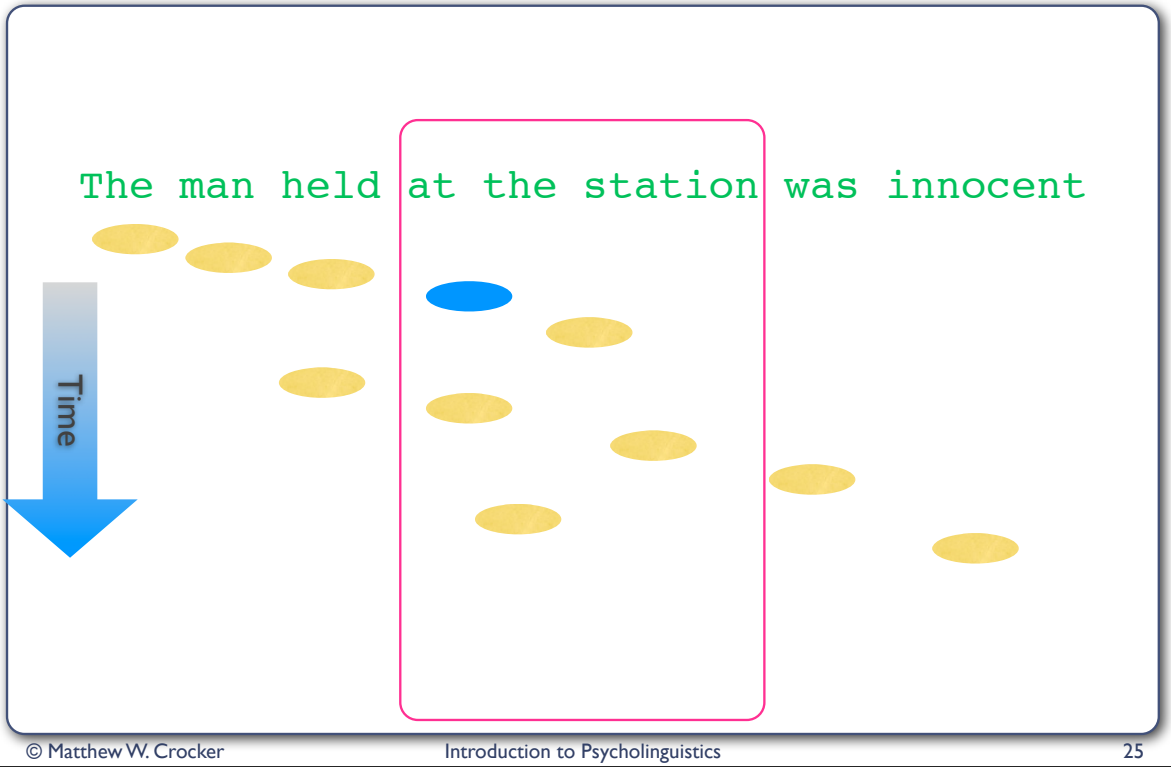
~~The man held at the station was innocent~~

Eye-tracking: Difference Measures

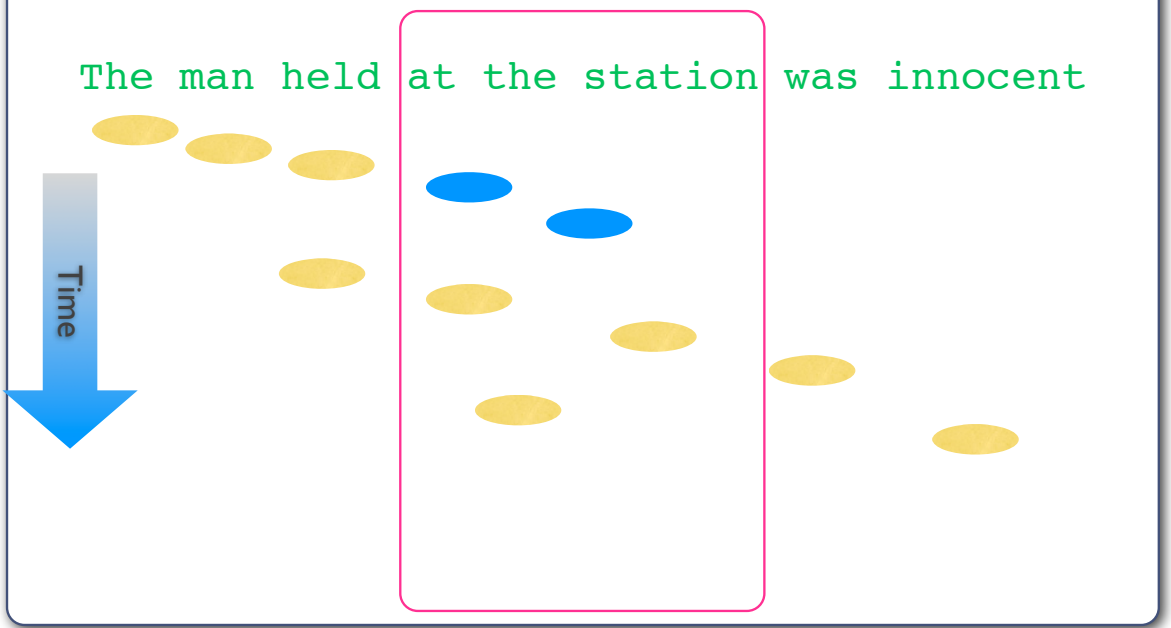
The man held at the station was innocent



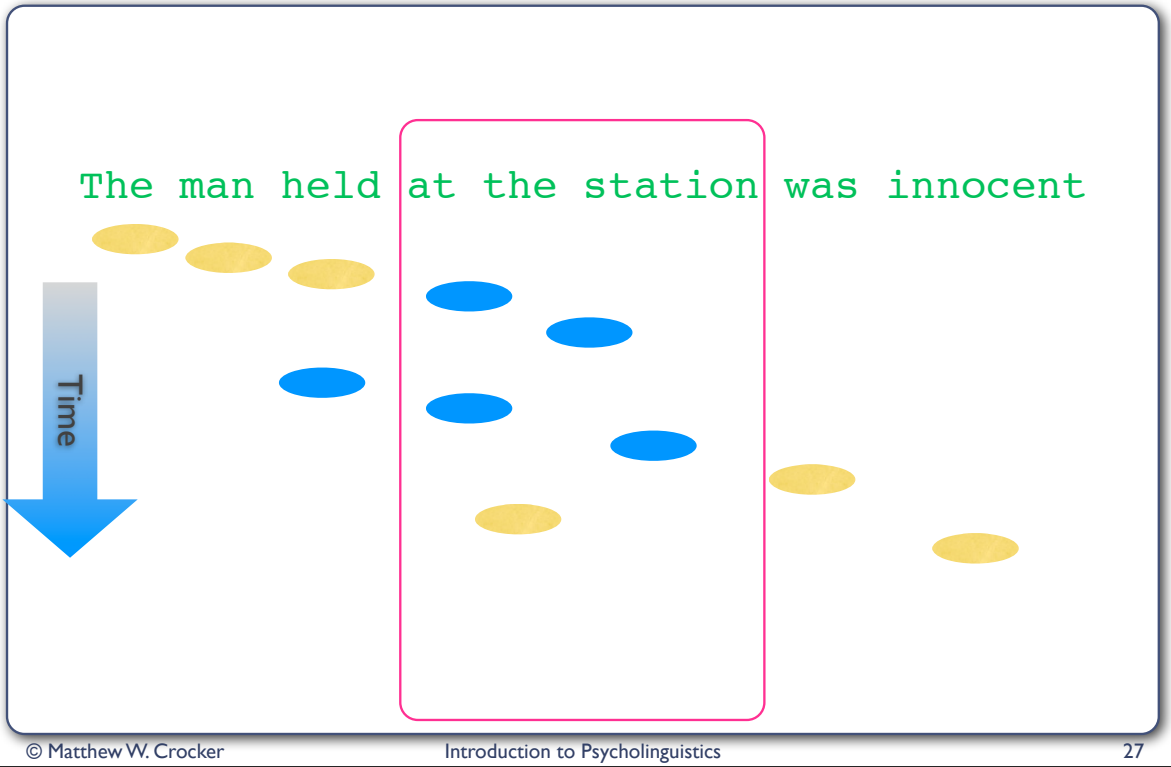
Eye-tracking: First Fixation



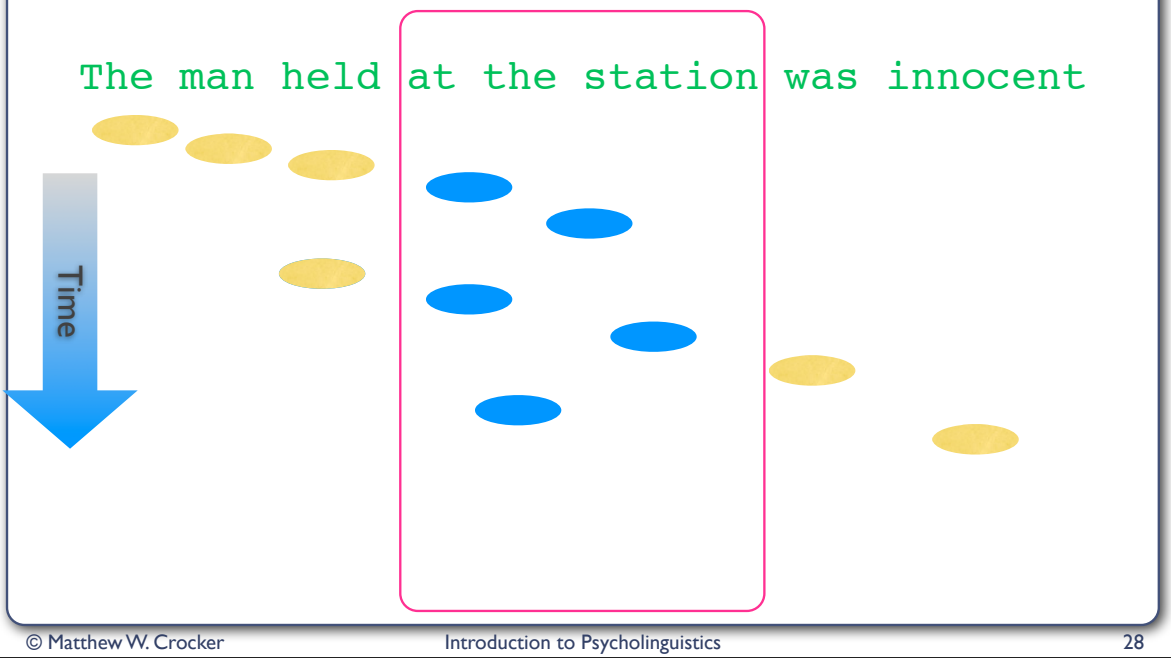
Eye-tracking: First Pass



Eye-tracking: Regression Path



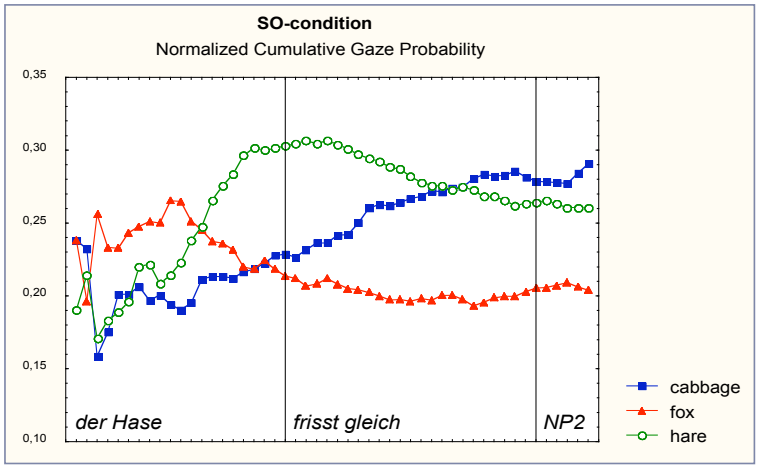
Eye-tracking: Total time



Spoken comprehension in visual scenes

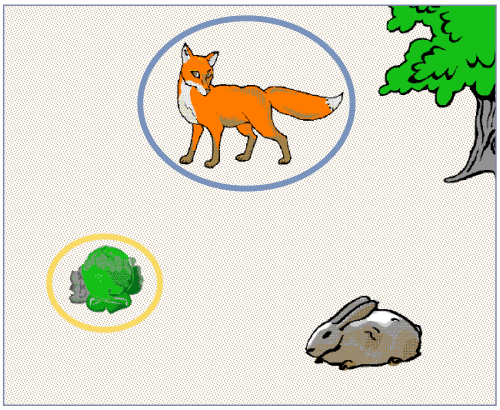
Monitor gaze in the scene as people hear a spoken utterance

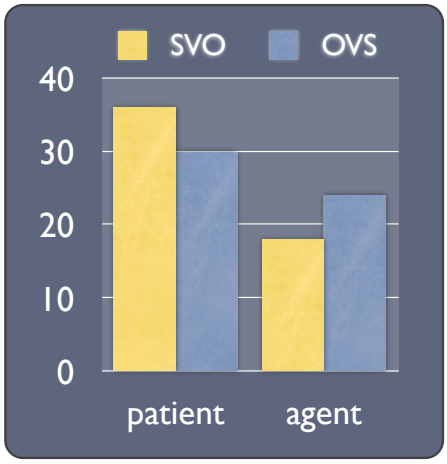
- Listeners fixate objects which are mentioned (180ms)
- Anticipatory eye-movements reflect interpretation



Anticipation in Visual Worlds

Anticipatory eye-movements in visual scenes





SVO: *Der Hase frisst gleich den Kohl*

OVS: *Den Hasen frisst gleich der Fuchs*

Kamide, Scheepers & Altmann, *JPR*, 2003

Modularity revisited

Does incremental language processing challenge the notion of modularity?

What does the close mapping from speech to visual attention imply for the modularity thesis?

Read: Coltheart, M. Modularity and Cognition. *Trends in Cognitive Sciences*, 3:3, 1999.

- Misguided arguments made against Modularity
- Main problems with Fodor's proposals
- Knowledge vs. Processing modules
- New definition of Modularity