

Sentence Processing

moving from syntax to semantics

Psycholinguistics

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last time...

we looked at some simple, low-level computational models of parsing:

- purely top-down and purely bottom-up strategies
- hybrid **left-corner** parsing technique seems to align with human intuitions of processing difficulty

today:

we examine key theoretical debates and models in sentence processing; syntactic *and* semantic considerations

agenda for today (Tues.)

1. experimental paradigms in sentence processing
(interleaved throughout)
2. The Garden Path Theory (Frazier et al.)
3. competing models of sentence processing
 - >> serial/parallel
 - >> modular/interactive
 - >> single- or multi-stage
4. the semantic side of sentence processing
 - >> factors that affect processing difficulty
 - >> reading versus verbal comprehension

theories of sentence processing

motivating observations:

- there are fast and slow cognitive systems
- sentence processing appears to be one of the fast systems
- we know that fast systems are error-prone and based on shallow, imperfect heuristics

Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

85%* say 2. is more likely

Which of the following two alternatives is more probable?

(wrong!)

1. Linda is a bank teller.
2. Linda is a bank teller and active in the feminist movement.

garden path effects show that the sentence processor is also error-prone

*...of participants in an experiment from Tversky & Kahneman (1983)

theories of sentence processing

considerations like these led to development of **The Garden Path Theory** of sentence processing

key tenets of The Garden Path Theory:

- parsing is **serial** -- we consider one candidate structure at a time
- parsing is **modular** -- only syntactic information is available to guide the initial parse (no semantic/contextual considerations)
- there are **two stages** of parsing -- initial parse is fast and blind, second stage evaluates parse w/outside info (reanalysis needed?)
- initial parse is guided by **heuristics** -- shallow rules of thumb meant to speed up processing (but fallible)

recall whole-object bias, mutual exclusivity assumption from Markman (1992) -- these are heuristics for word learning

The Garden Path Theory

two important parsing heuristics

- **late closure:** integrate incoming words into the constituent currently being built
- **minimal attachment:** assume the "simplest" structure compatible with the input

what do these heuristics predict about...

Since Jay always runs a mile and a half is nothing to him.

Being as smart as she is, of course Mary knew the answer was wrong.

The dangerous poacher shot at the lion with the scars.

The horse raced past the barn fell.

The Garden Path Theory

*Since Jay always runs a mile and a half **is nothing** to him.*

*Being as smart as she is, of course Mary knew the answer **was wrong**.*

*The dangerous poacher shot at the lion with **the scars**.*

*The horse raced past the barn **fell**.*

evidence of reading difficulty in the critical regions (of a wide variety of these kinds of sentences) interpreted as evidence that people use **late closure** and **minimal attachment** as guiding principles for the initial pass at a sentence

GPT offers an intuitive explanation of why we backtrack and how we are able to process sentences so fast

methodology in sentence proc.

some important questions:

>> so how do you measure "processing difficulty" anyway?!

>> how do we know when someone backtracks??

the answers will depend on whether we're studying reading or verbal comprehension

early research in sentence processing mostly studied reading, via

- self-paced reading [link] (moving window)
- other self-paced reading (word-by-word or chunks; centered or cumulative)
- eye-tracking during reading [link]

dependent measures can be:

>> **reading time** (RT) at some critical region of interest (ROI);

>> **regressions** (right-to-left);

>> **fixation time** per saccade;

>> **accuracy** on comprehension questions, and others

some problems for a modular theory

consider the following sentences:

The dog walked to the park wagged its tail happily.

The treasure buried in the sand was never found.

GPT predicts that *all* sentences with dispreferred structures should lead to processing lags (and should do so equally)

the observation that garden pathing can be sensitive to non-syntactic information is the primary evidence for so-called **constraint-based theories** of sentence processing

constraint-based approaches

key tenets of (some) **constraint-based theories** of sentence processing:

- **interactive** -- diverse kinds of information accessed during parsing
- **parallel** -- more than one structure considered simultaneously (with varying degrees of activation)
- **single-stage** -- brute-force, "everything but the kitchen sink" approaches (world knowledge, context, statistical learning of frequencies/co-occurrences/etc.)

note: "constraint-based approach" often used as a catch-all ("catch-most"?!) term for processing models opposed to the GPT MacDonald; Trueswell; Chambers; Tanenhaus; others (1990s--present)

constraint-based approaches

a nice example -- **syntactic priming***

obtain --> NP direct object

accept --> NP d.o. bias, S also possible

realize --> S bias, NP d.o. also possible

Trueswell & Kim (1998): subconscious exposure to S-prime verb (*realize*) or NP-prime verb (*obtain*) just prior to main verb in sentence

The photographer accepted the fire could not be put out.



39ms of ***obtained*** or ***realized***

greater garden path effects
for NP-verb prime (*accept*)
than for S-verb prime (*realize*)

*fits nicely with the idea of parallel processing (just btw)

adjudicating between the theories

several kinds of information seem to affect processing difficulty

- syntactic subcategorization frame and thematic info of verbs

The treasure/pirate buried/put/left in the sand was lost forever.

- frequency of competing structures

question: relative frequency of reduced RC versus main verb construction?

- syncretism in morphology

The horse raced past the barn fell. The horse ridden past the barn fell.

race ~ raced ~ raced (regular) ride ~ rode ~ ridden (irregular)

- lexical ambiguity

The government plans to raise taxes were defeated.

- contextual information

the horse that was walked past the barn was fine, but the horse raced past the barn fell.

- interactions between **frequency** and all of these things!

from reading to listening

so far we've been theorizing on the basis of reading studies -- reading studies carried out under non-typical circumstances

also: not all languages are written, so unclear degree to which these phenomena reflect linguistic processing independently of visual pattern recognition

also: real-life linguistic behavior involves reference to language-external objects, but in reading everything is a piece of language

question: how can we measure *auditory* language comprehension in real time?

from reading to listening

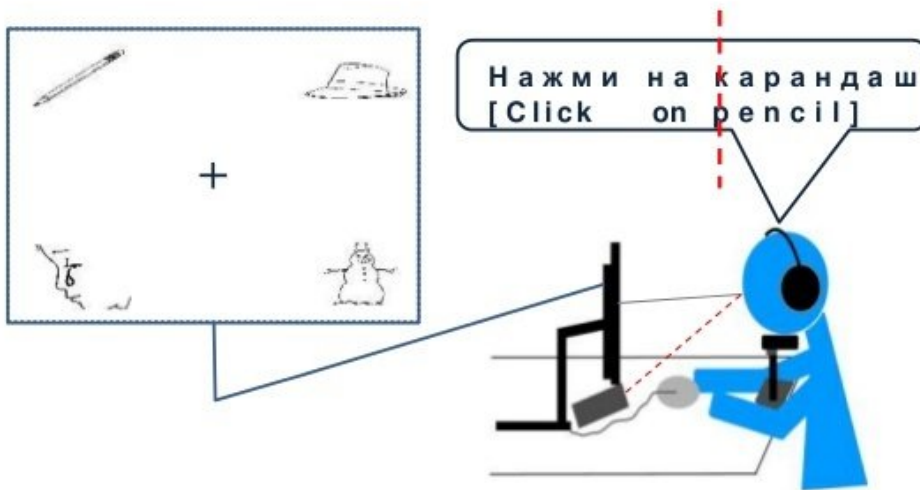
one answer:

1. construct a mini-world containing collections of objects
2. selectively refer to those objects in auditory stimuli
3. manipulate properties of the stimuli *and* of the visual displays
4. measure eye-movements, looking times, or latencies to different visual objects across different experimental conditions
5. make inferences about how particular manipulations of linguistic stimulus and context affect processing time

from reading to listening

this is the basic approach of
the visual world paradigm

Eye movements monitored
in Visual World Paradigm



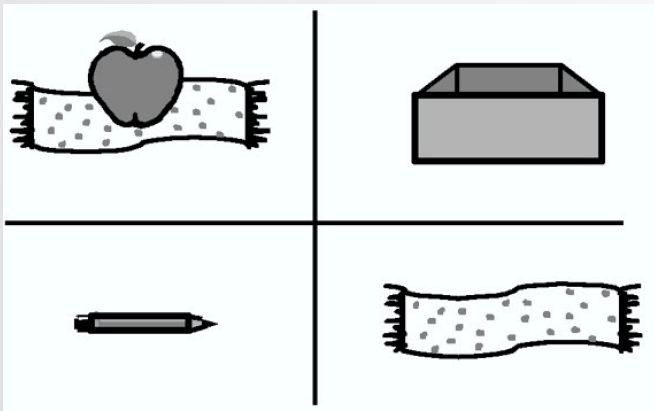
- method for studying incremental syntactic and semantic processing
- made possible by the fact that people automatically, incrementally, and unconsciously try to relate visible objects in their surroundings to chunks of linguistic material

the visual world paradigm

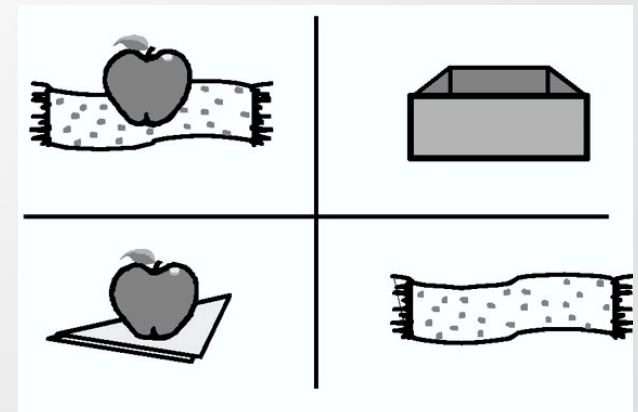
question: how do we know if someone has mis-analyzed this sentence?

Put the apple on the towel in the box.

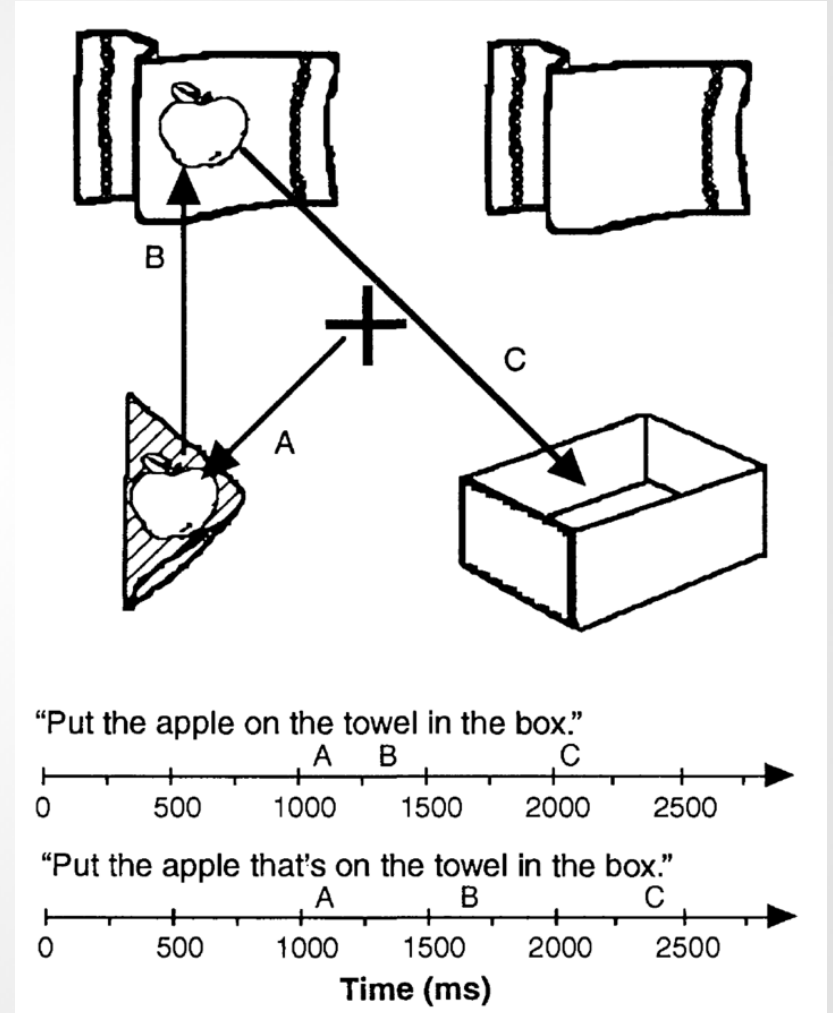
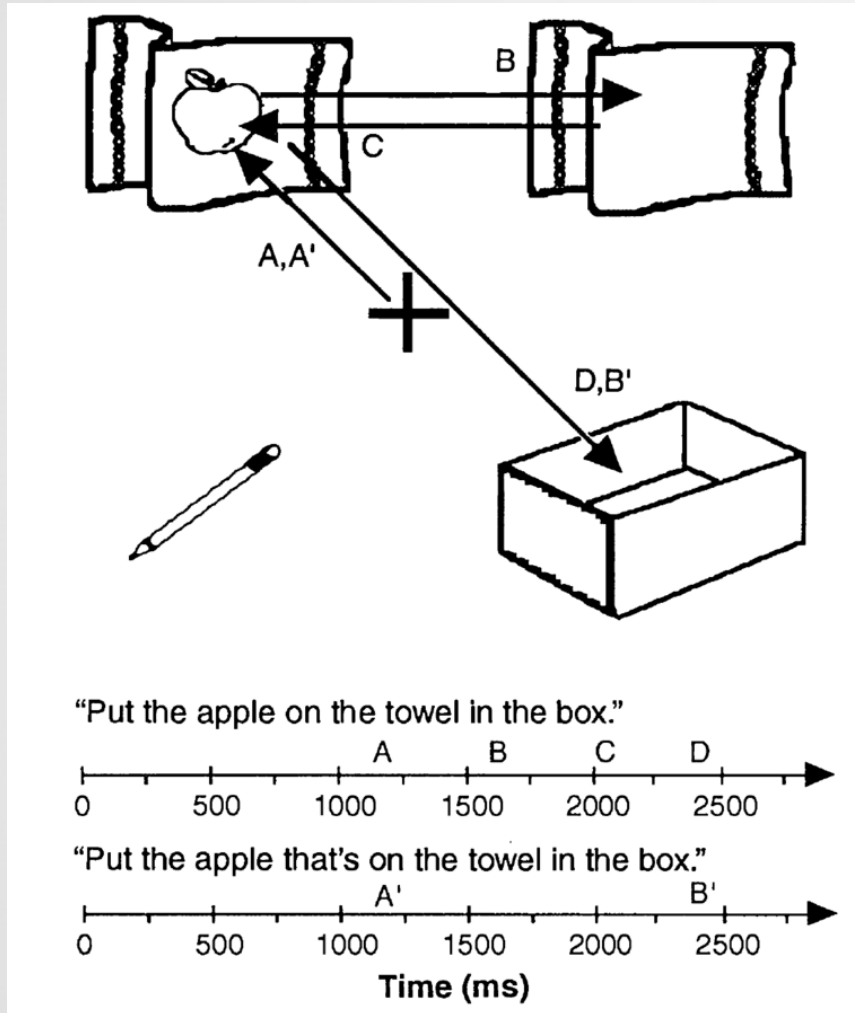
what about given this context?



what about this one?



the visual world paradigm

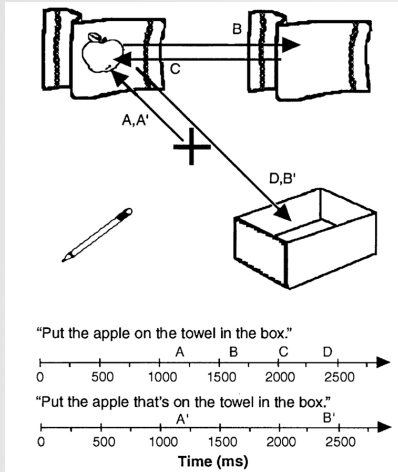


seminal study of Tanenhaus et al. (1995)

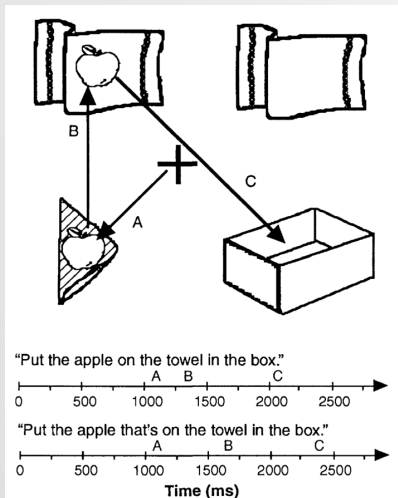
the visual world paradigm

Tanenhaus et al. (1995)

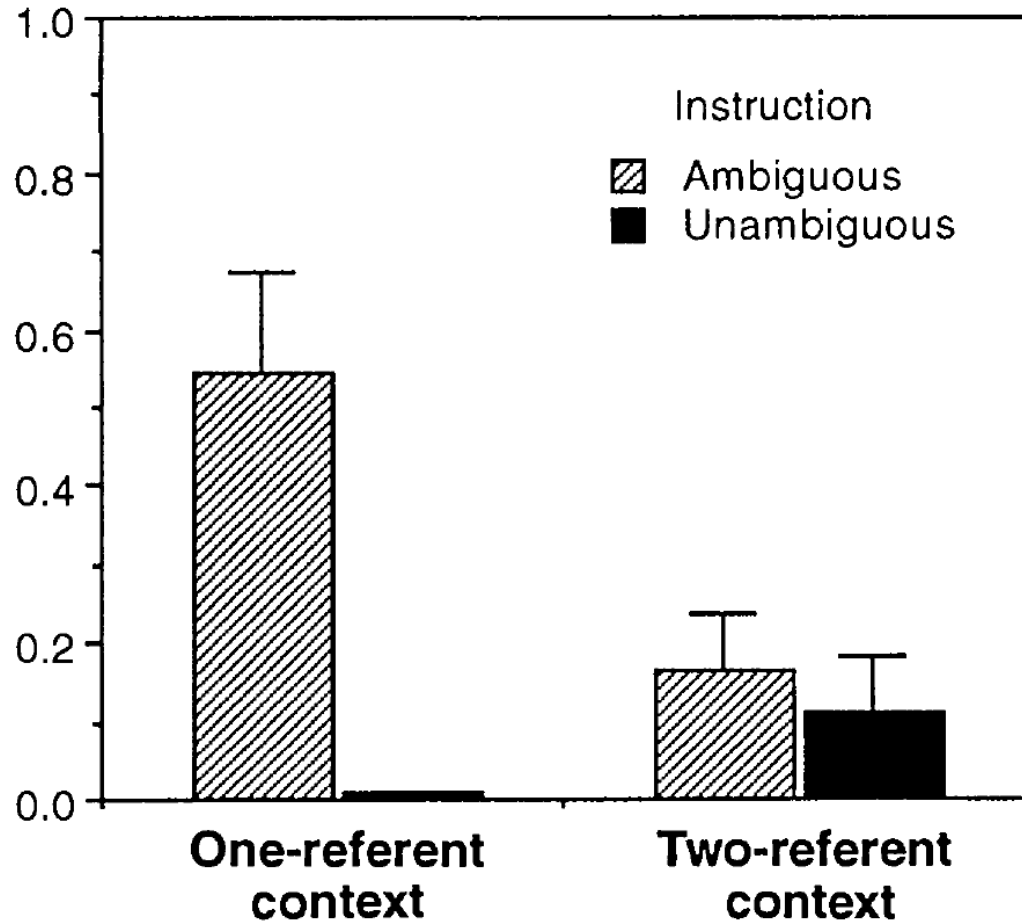
one-referent



two-referent



Proportion of trials with eye movements to incorrect destination



the visual world paradigm

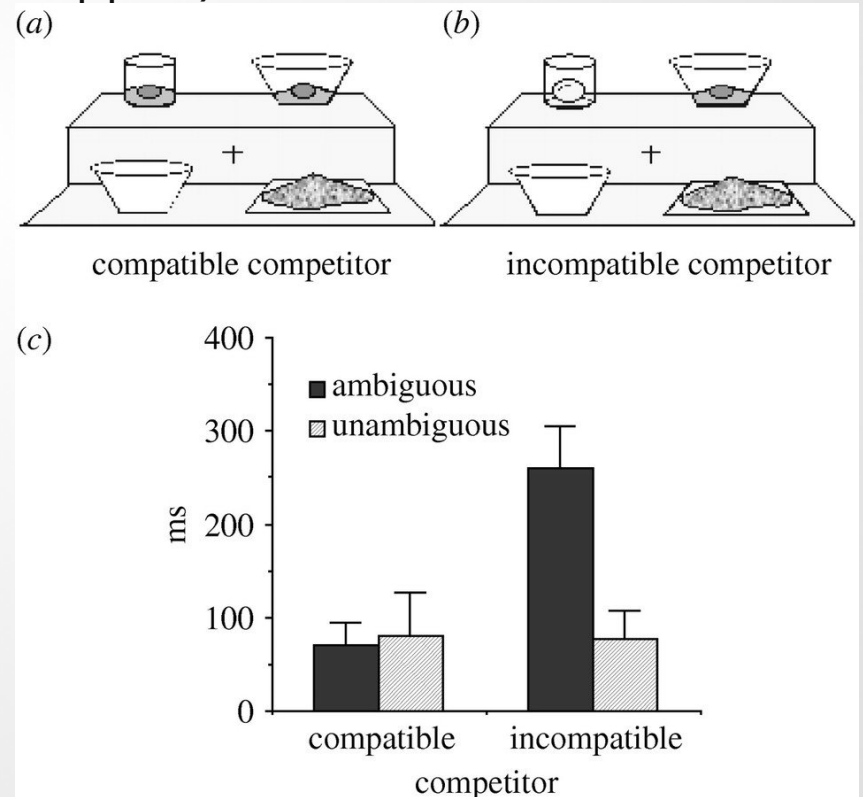
Tanenhaus et al. (1995):

- contextual information is taken into account *incrementally* during on-line sentence processing
- semantic information appears to be rapidly integrated (e.g. that *on the towel* signals multiple apples)

Chambers et al. (2004)

- rapid integration of verb-specific world knowledge during on-line processing of temporarily ambiguous sentences

"pour the egg (that's) in the bowl over the flour"



what's coming next...

on Thursday, we will...

- look at some key experimental results in the semantic processing literature;
- look further into how context can affect/guide sentence-level and word-level processing;
- survey some evidence of *predictive processing*, from neuro-imaging and eye-tracking studies; and finally,
- try to philosophize a bit about what all this tells us about the nature of language and human cognition in general