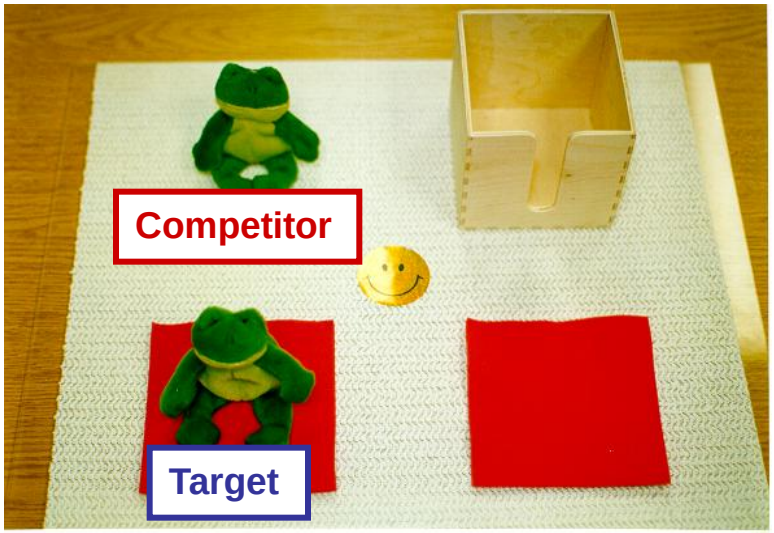
Using eye movements to study spoken sentence processing

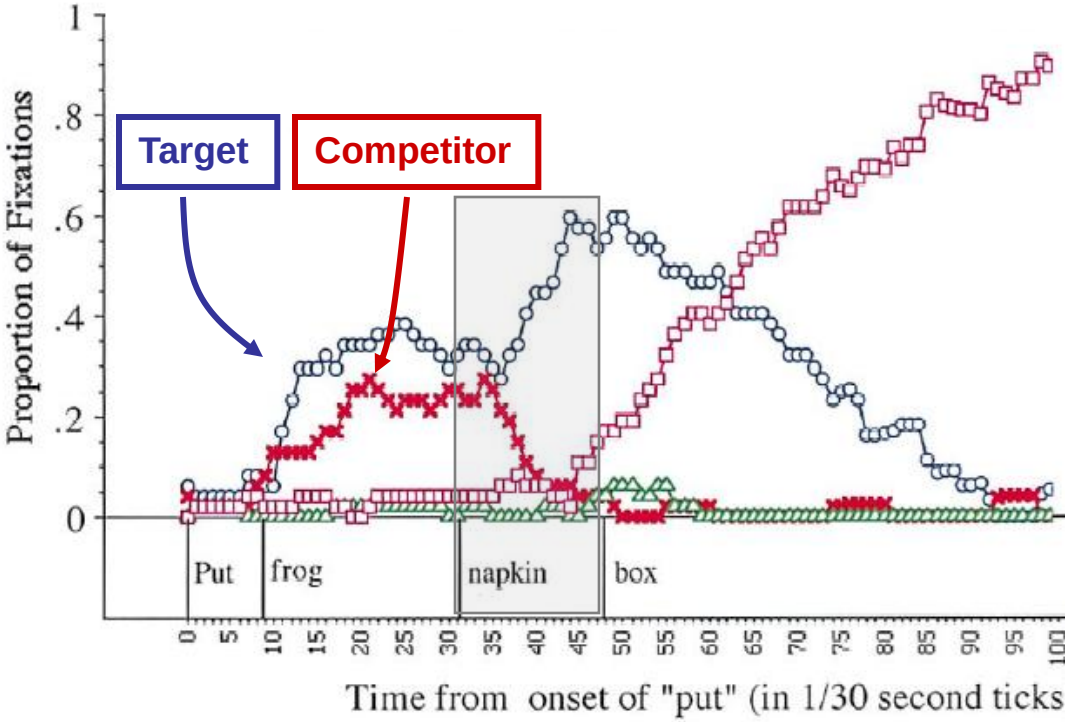
John Trueswell

LSA 363

Can we use eye movements to study sentence-level processes?

Put the frog that's on the napkin into the box.



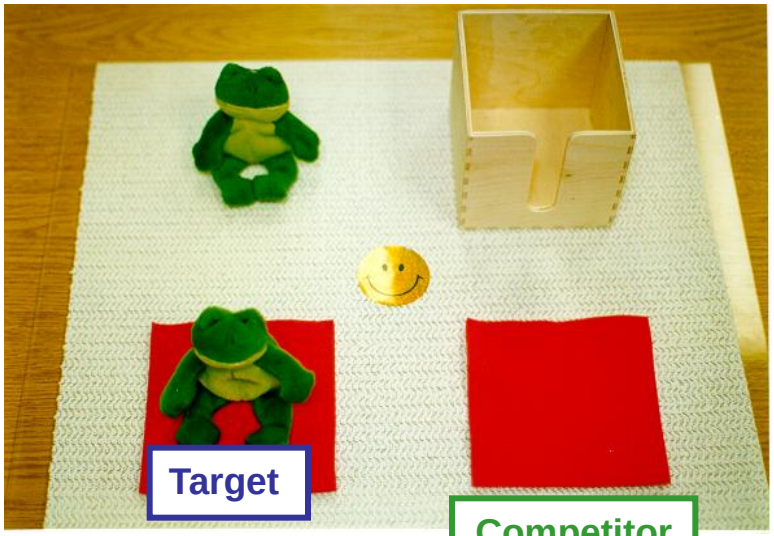


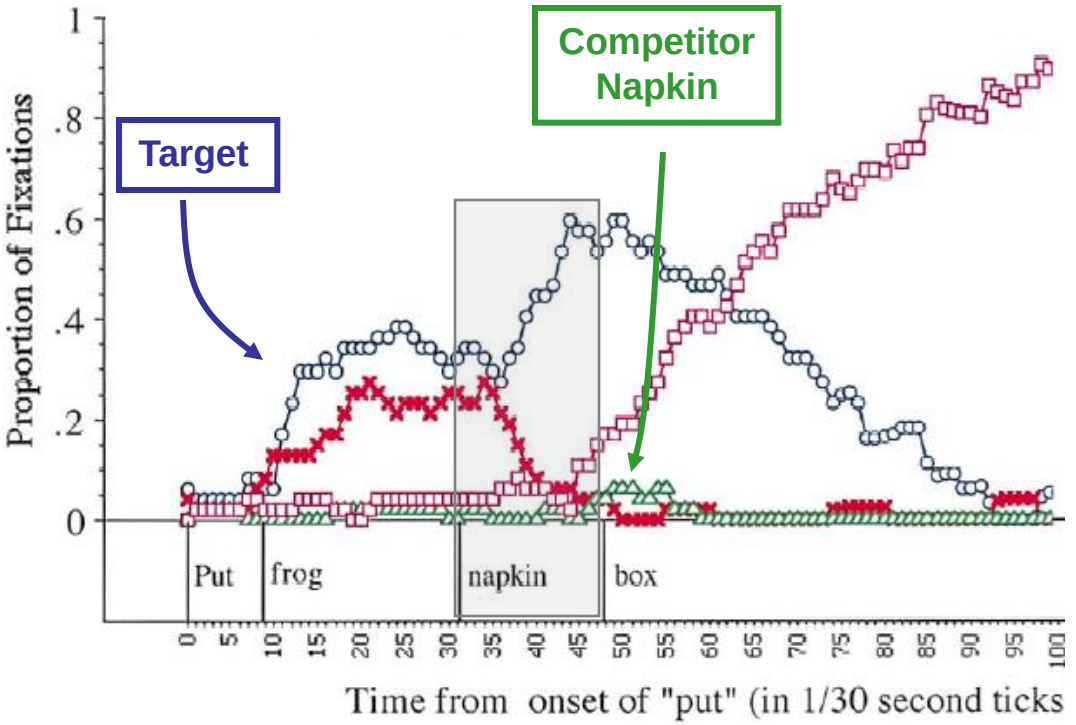
Tanenhaus et al. (1995); Trueswell et al. (1999)

Point 1. The presence & absence of **competitor effects** can be used to study parsing decisions.

No…

Put the frog that's on the napkin into the box.



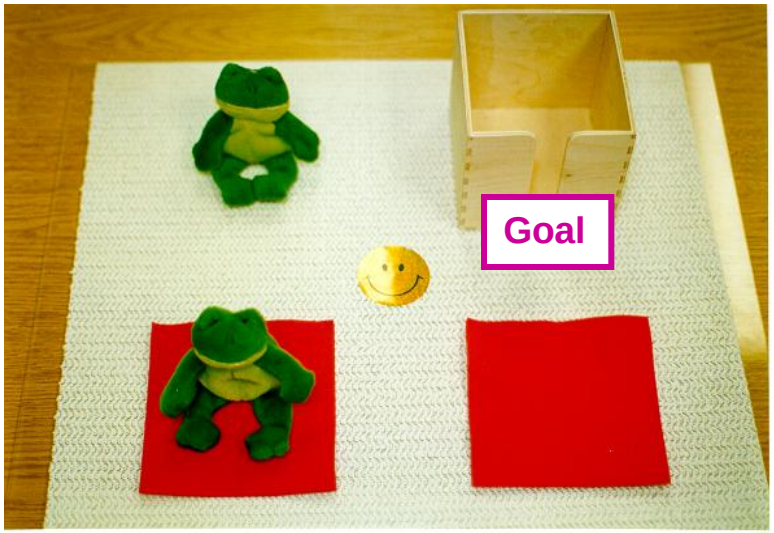


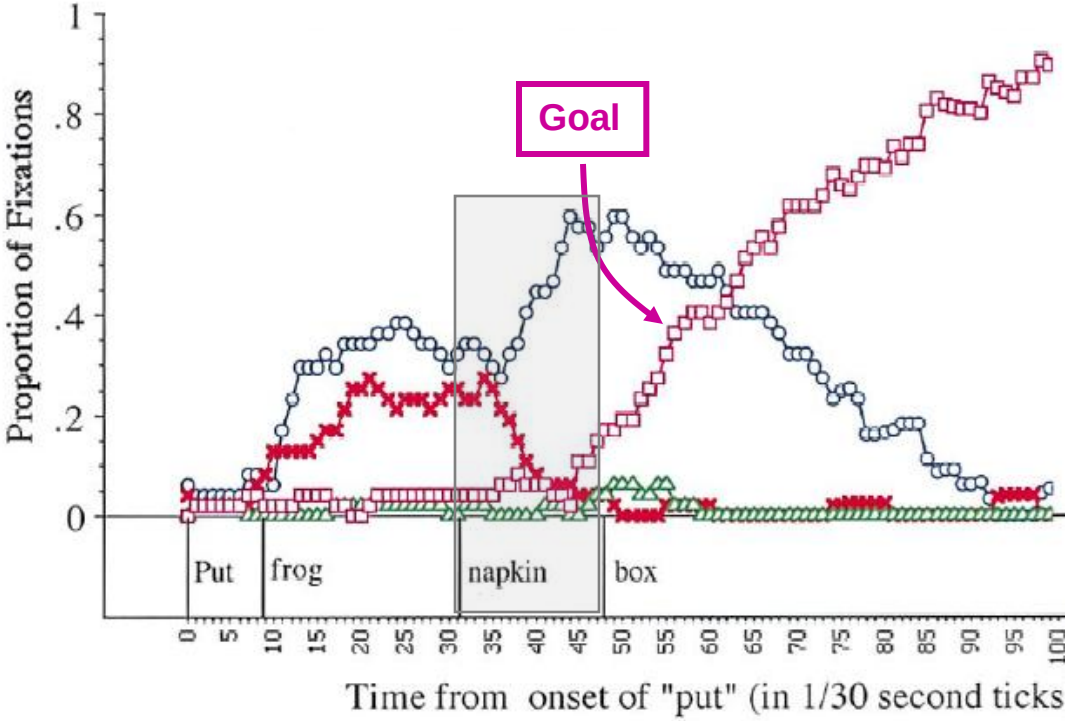
Tanenhaus et al. (1995); Trueswell et al. (1999)

Point 2. **Anticipatory effects** can be used to study parsing and interpretation as well.

No...

Put the frog that's on the napkin into the box.





Tanenhaus et al. (1995); Trueswell et al. (1999)

Outline

- Using **competitor effects** to study parsing and interpretation in spoken sentence processing
  - Referential constraints
  - Lexico-syntactic and lexico-semantic constraints
  - Prosody
  - Pragmatic/real-world constraints
- Using **anticipatory effects** to study parsing and interpretation in spoken sentence processing
  - Lexical representations & contextual sensitivity
    - Spatial prepositions
    - Verbs
  - Discourse implications of structure
    - Finnish word order

Real-time Sentence Processing

- Sentence interpretation is rapid and unfolds over course of perceiving each sentence.
  - Semantic Anomaly Effects
  - Garden-Path Sentences
- Requires rapid structure building
  - Phonological
  - Syntactic
  - Semantic
  - Referential

Real-Time Sentence Processing
Classic Distinctions / Debates

Modular (Encapsulation)	vs.	Interactive
Principle-Based Decisions	vs.	Probabilistic
Phrase-Structure-Like Representations	vs.	Lexicalist

Syntactic Ambiguity Resolution
(30 years of research on a single slide)

- Early reading studies found general structural biases (e.g., Frazier & Rayner, 1982; Rayner et al., 1983)
  - Minimal Attachment: Prefer the simplest structure
    - ***Ann hit the thief with the stick. Ann hit the thief with the scar.***
- Better controlled studies found a highly-tuned linguistic processor that is sensitive to context
  - Lexical Effects (e.g., Taraban & McClelland, 1988;Trueswell et al., 1994;Garnsey et al., 1998)
    - ***Ann hit/recognized the thief with the stick…***
  - Referential Effects (e.g., Crain & Steedman, 1983; Altmann & Steedman, 1988)
    - **Story about two thieves, one holding a stick….**
  - Interactive Combination (Britt, 1994; Spivey-Knowlton & Sedivy, 1998)
    - **Referential and Lexical Evidence show simultaneous effects**

Levels of Representation and Interface Issues

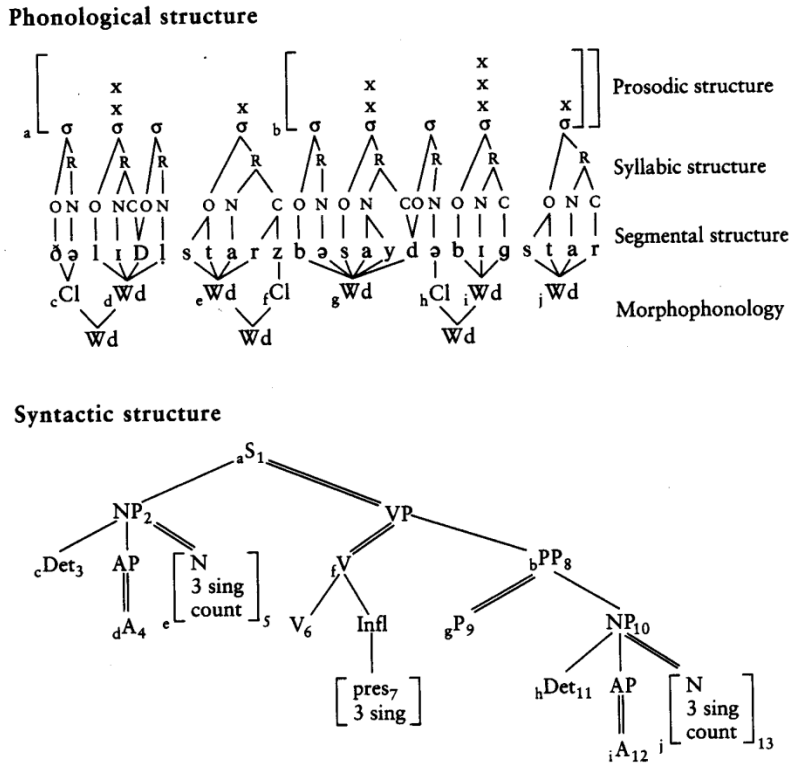
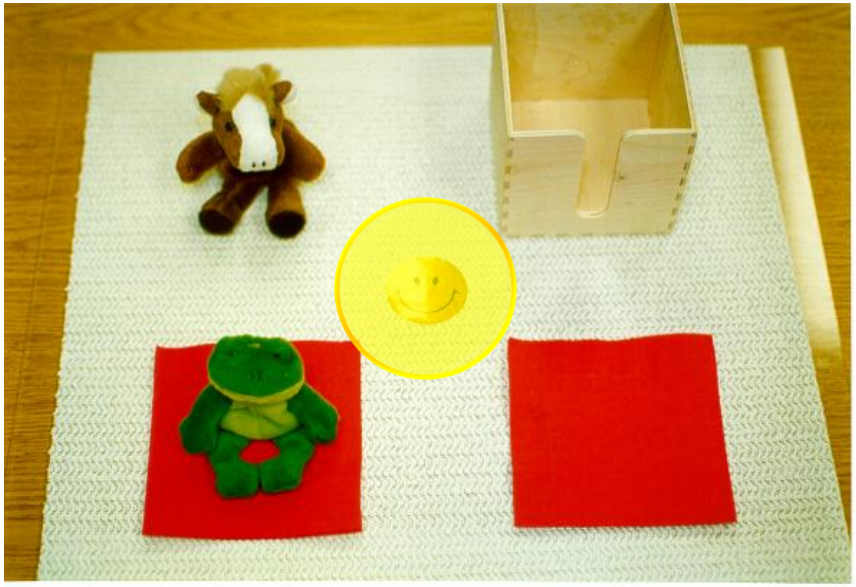


Fig. 1.1. Structure of *The little star's beside a big star*

Jackendoff (2002)

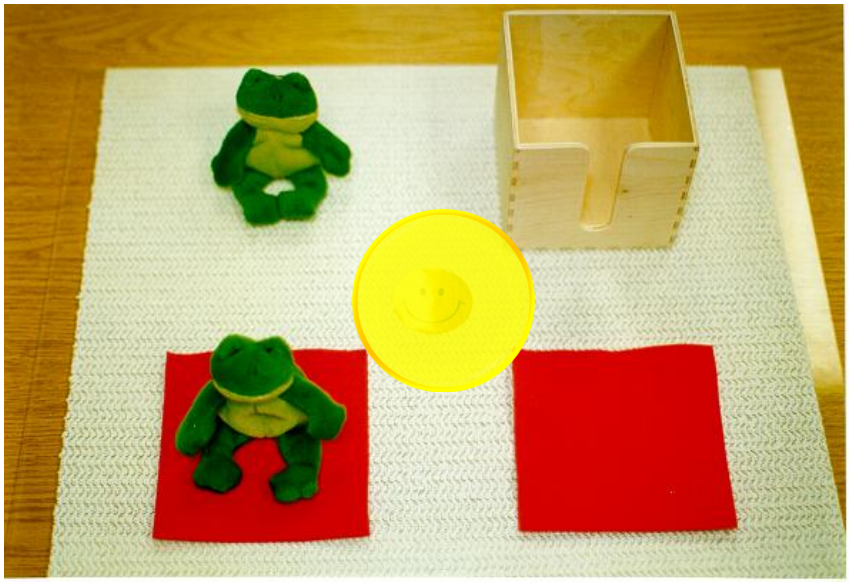
Effects of visual world on parsing decisions

(Tanenhaus et al., 1995; Spivey et al., 2002; Trueswell et al., 1999)



1-Referent Context

Supports
Destination Interp.
(VP-Attach)



2-Referent Context

Supports
Modifier Interp.
(NP-Attach)

Percentage of looks to Competitor Goal

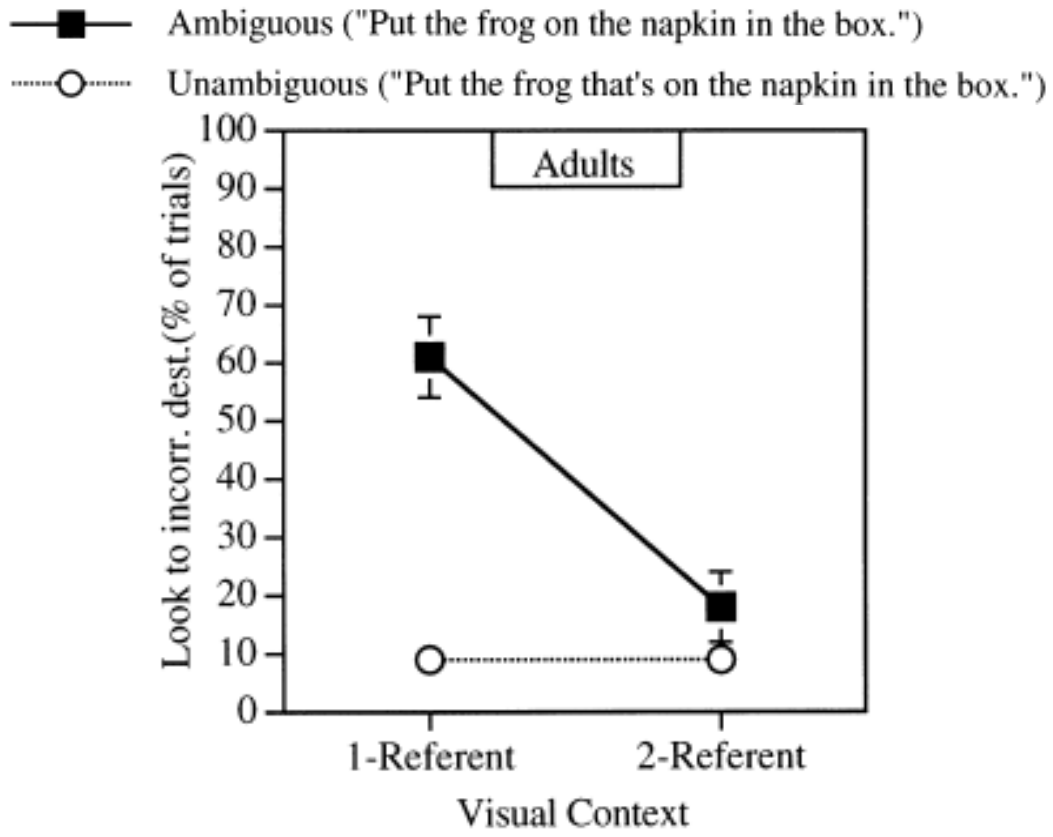


Fig. 3. Percentage of trials in which there was a look to the Incorrect Destination, e.g. the empty napkin, as measured for the onset of ambiguous phrase, e.g. ''on the napkin''

Which information sources drive parsing decisions? And how do they combine?

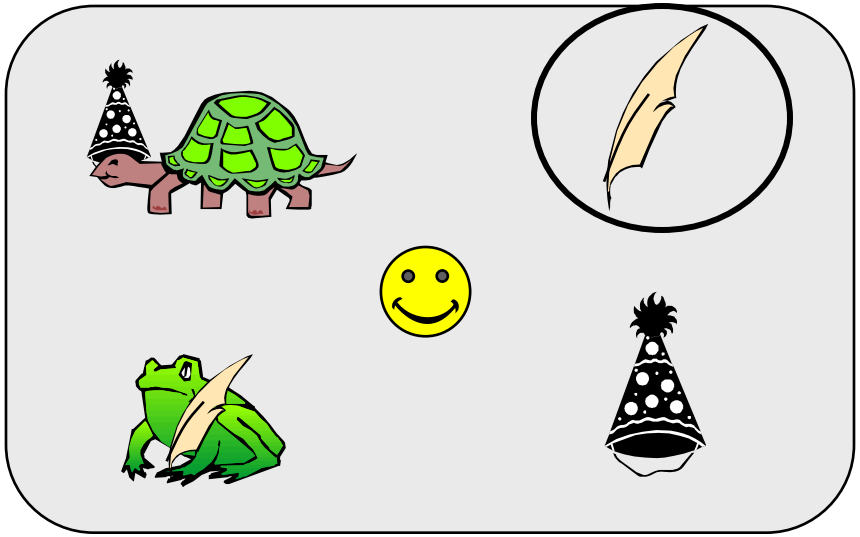
- *Put the frog on the napkin…*
  - *Parsing Principles (Minimal Attachment)?*
  - *Lexico-syntactic tendencies?*
  - *Lexico-semantic tendencies?*
  - *Prosody?*
  - *Referential/pragmatic constraints?*

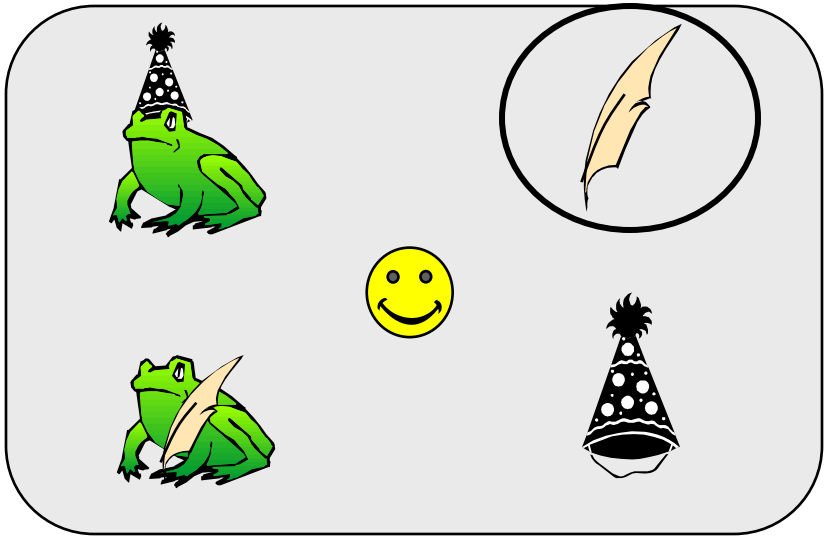
Constraint-Based Lexicalist (CBL)

Lexical constraints

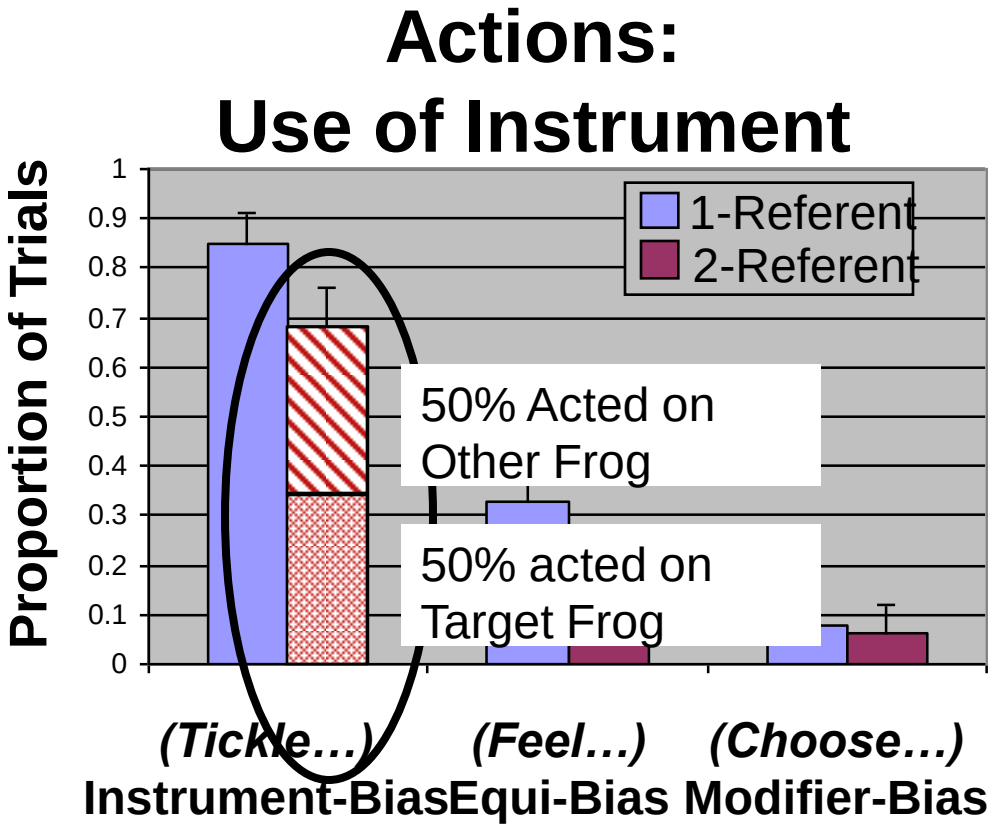
(**Snedeker & Trueswell, 2004**)

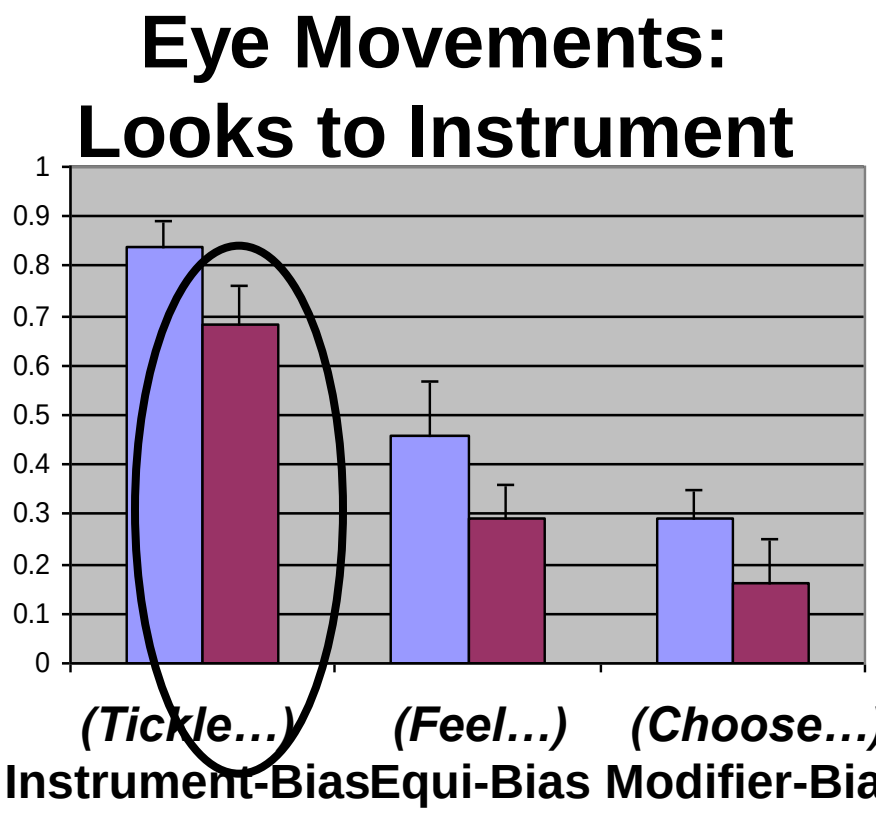
- Adults in Eye-Gaze Listening
- Global Syntactic Ambiguity, Manipulate V-bias:
  - *Tickle the pig with the fan.* (Instrument Bias)
  - *Feel the frog with the feather.* (Equi Bias)
  - *Choose the cow with the stick.* (Modifier Bias)
- Crossed with Referential Scene...





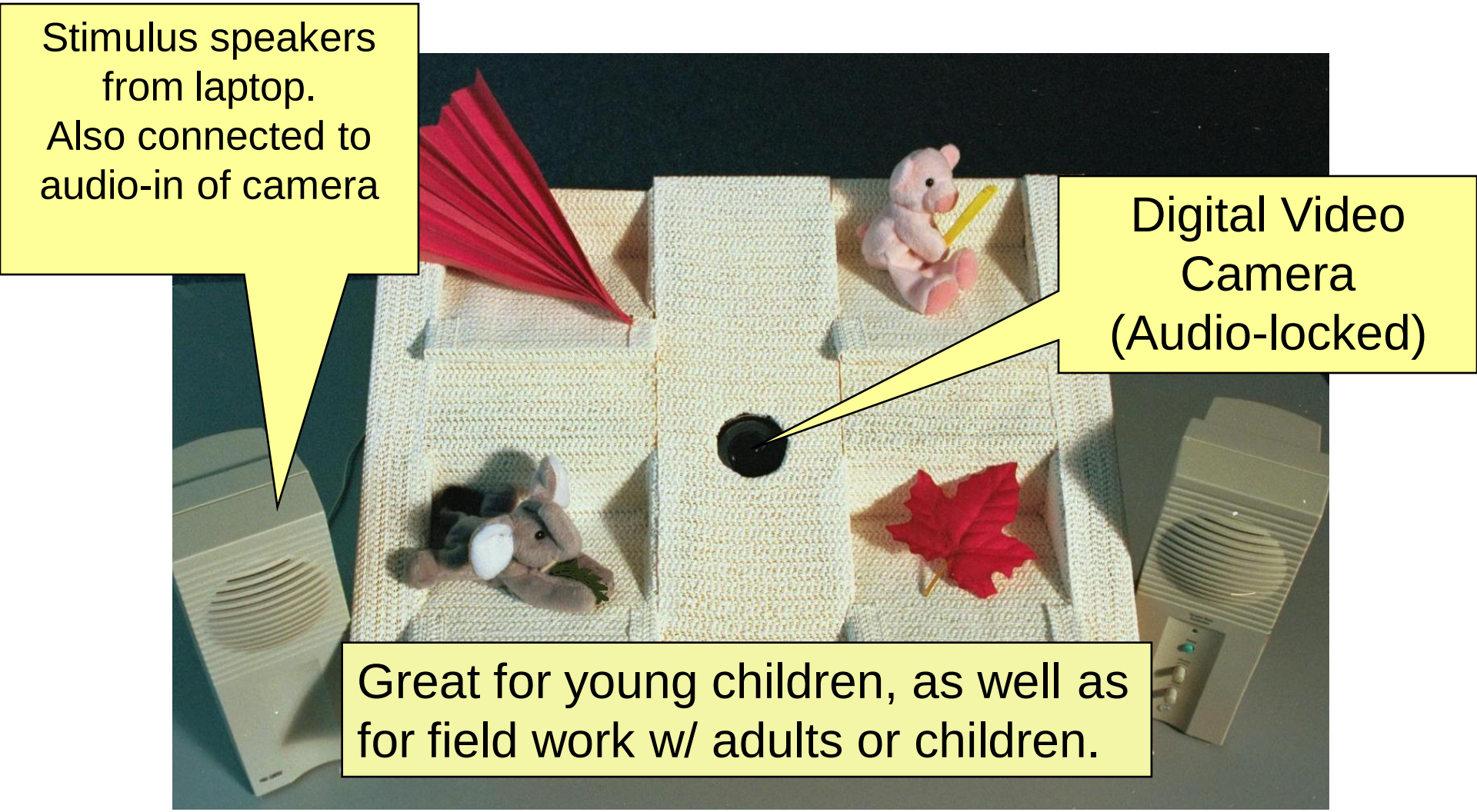
Adults show Referential and Verb-bias effects





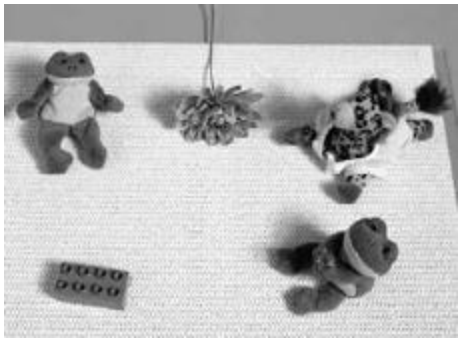
Tracking without an eye tracker

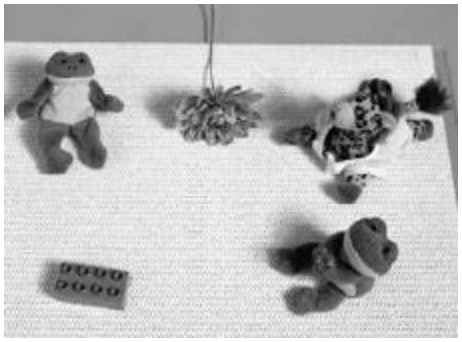
(see Snedeker & Trueswell, 2004)



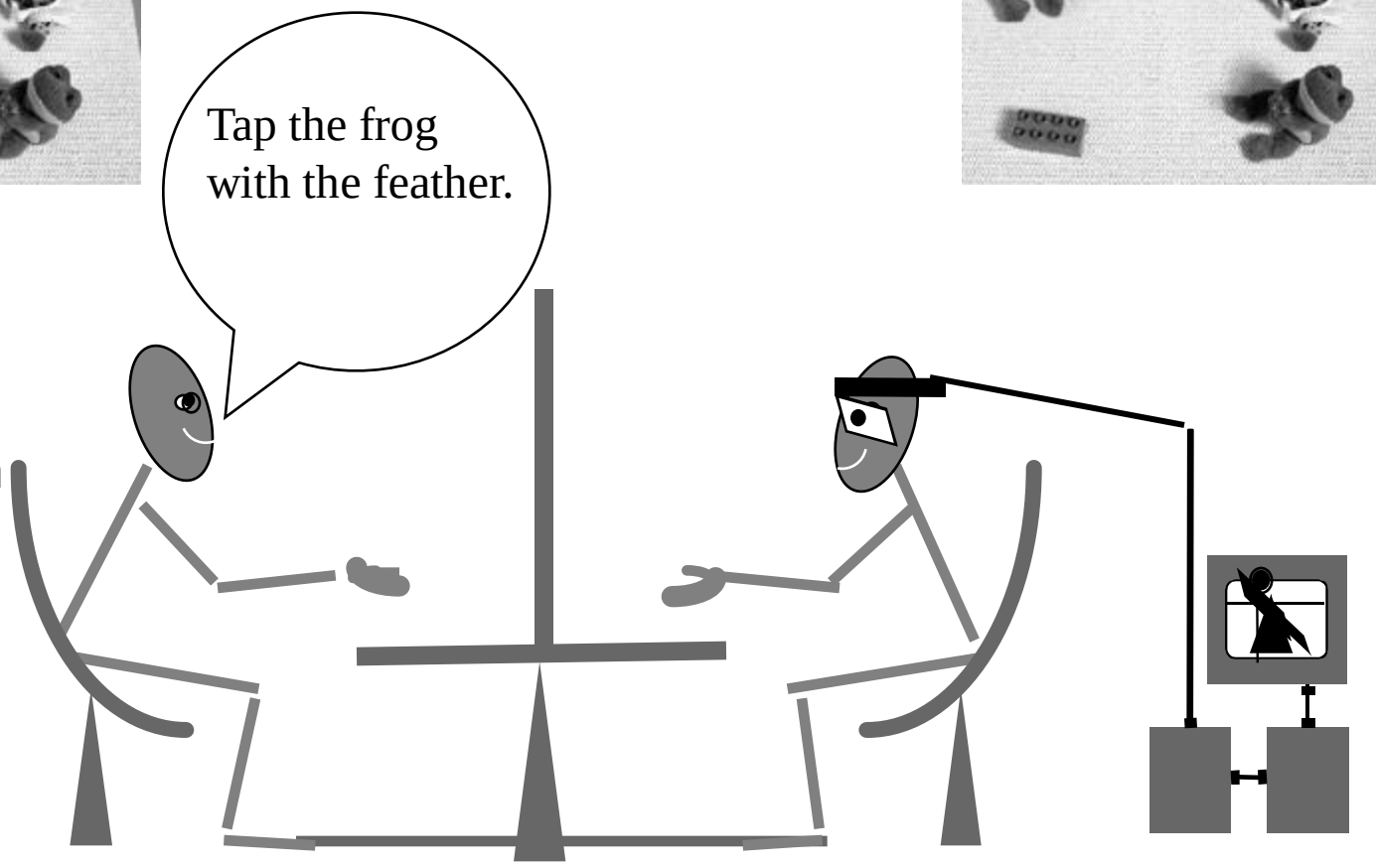
Role of Prosody
(Snedeker & Trueswell, 2003)

- Pairs of participants
  - ‘Speaker’
  - ‘Listener’
- (Highly constrained) referential communication task…





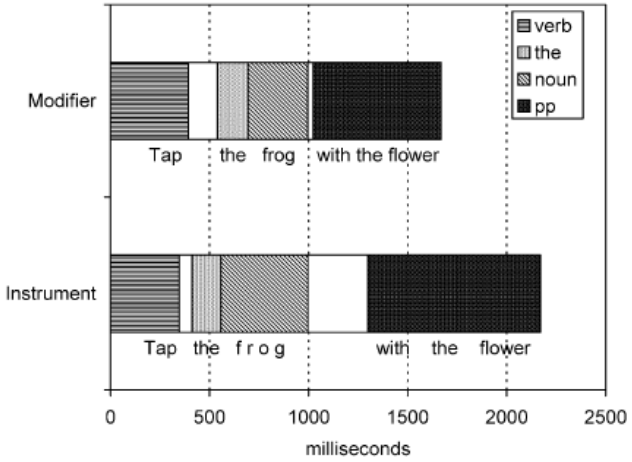
Exp. demonstrates either instrument or modifier action to speaker.



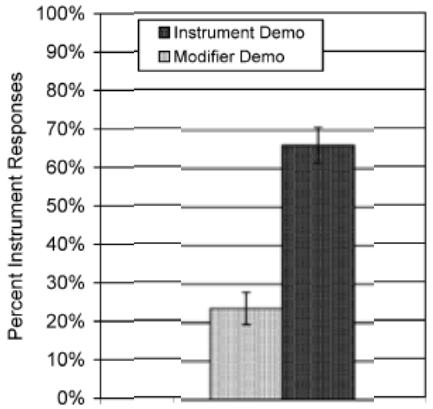
Speaker

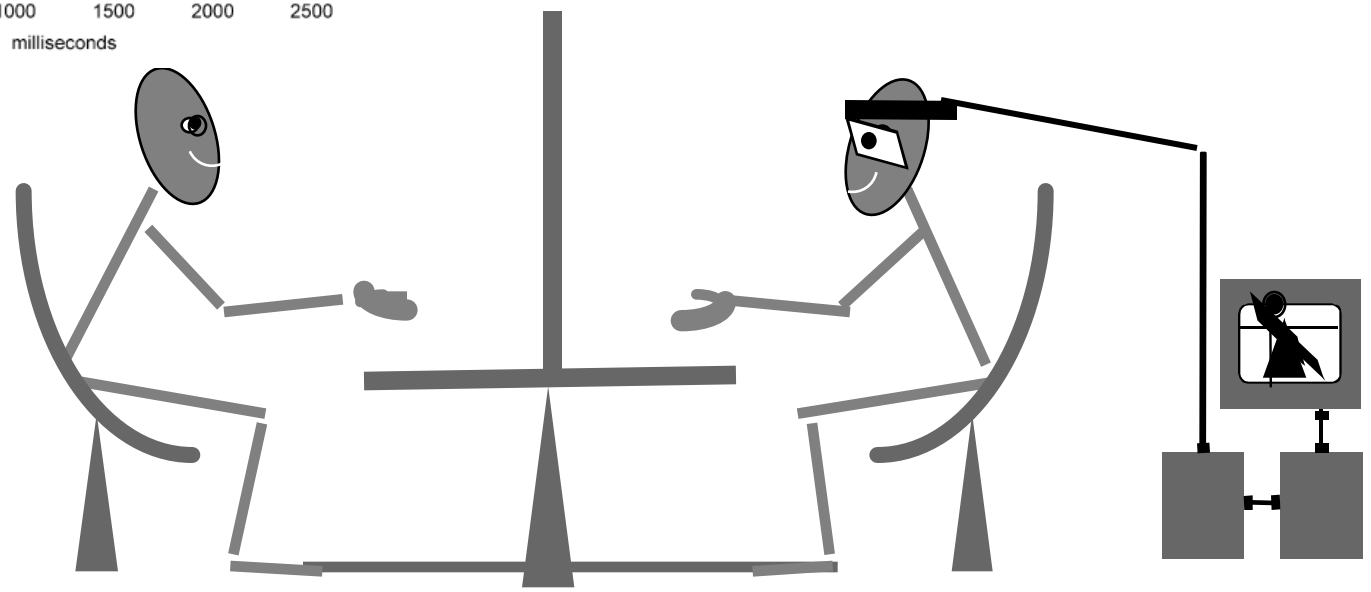
Listener

Speaker Word Durations



Listener Instrument Actions

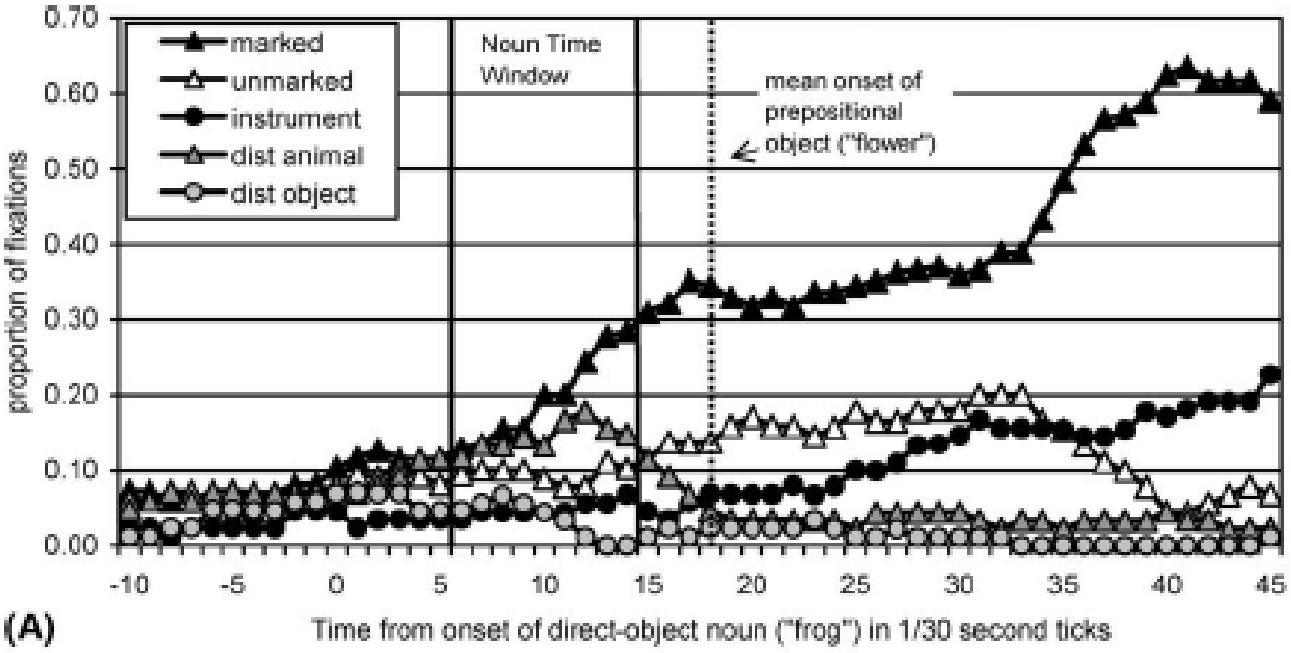




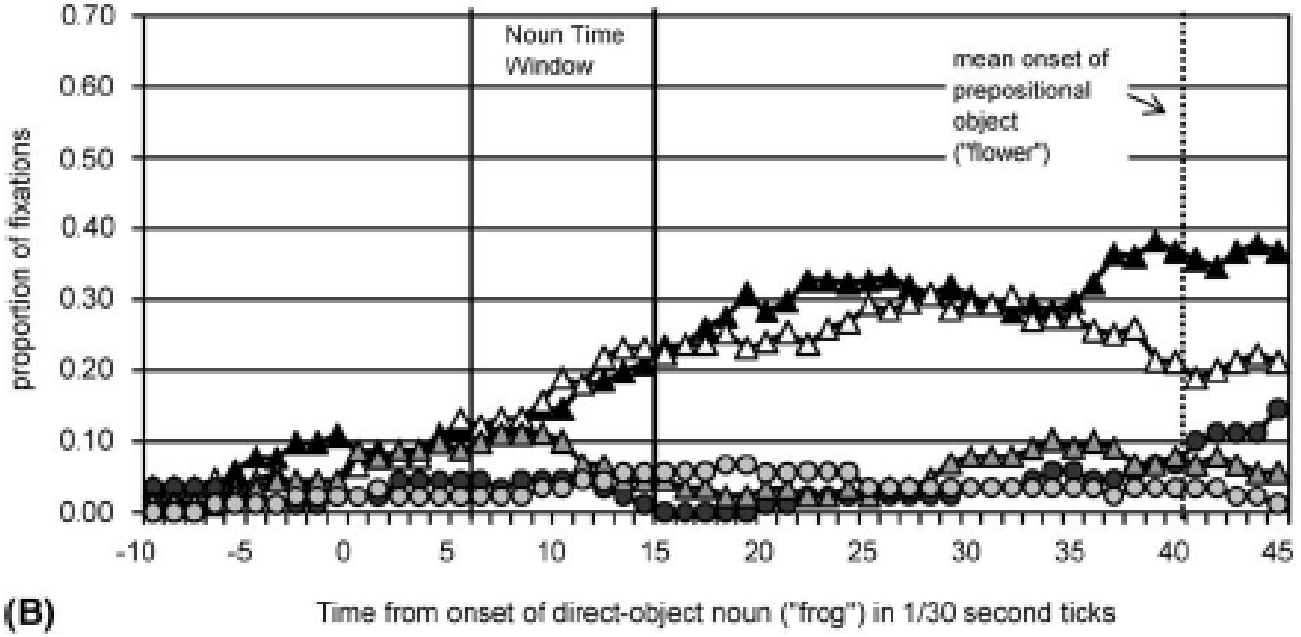
Speaker

Listener

Speaker had seen Modifier Demo.



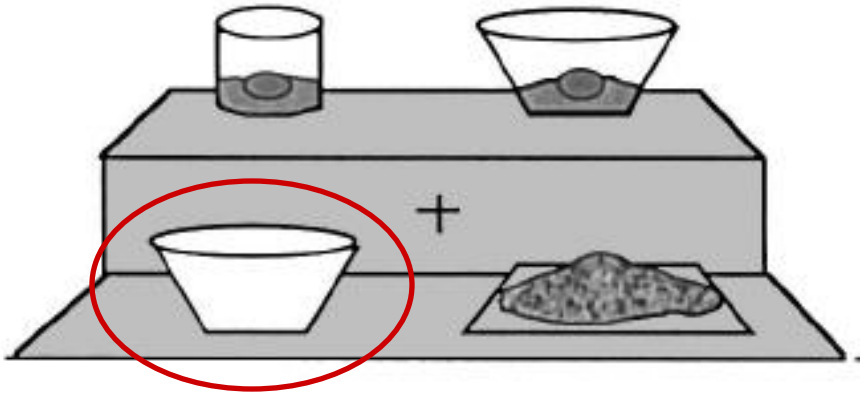
Speaker had seen Instrument Demo.



Chambers, Tanenhaus & Magnuson (2004)

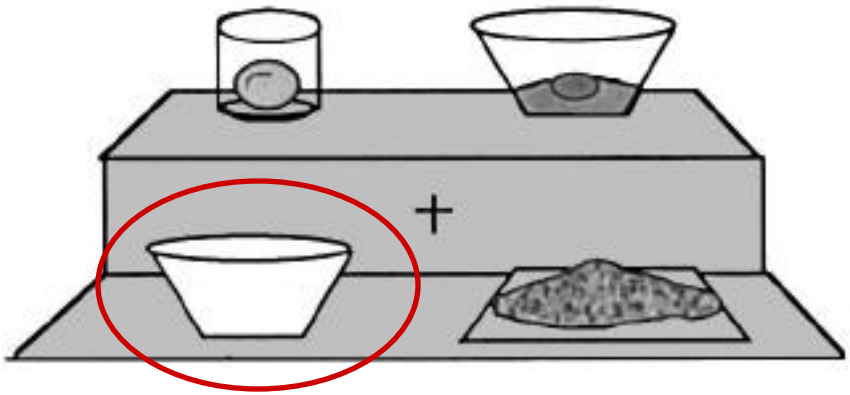
Pour the egg in the bowl onto the flower.

Compatible competitor



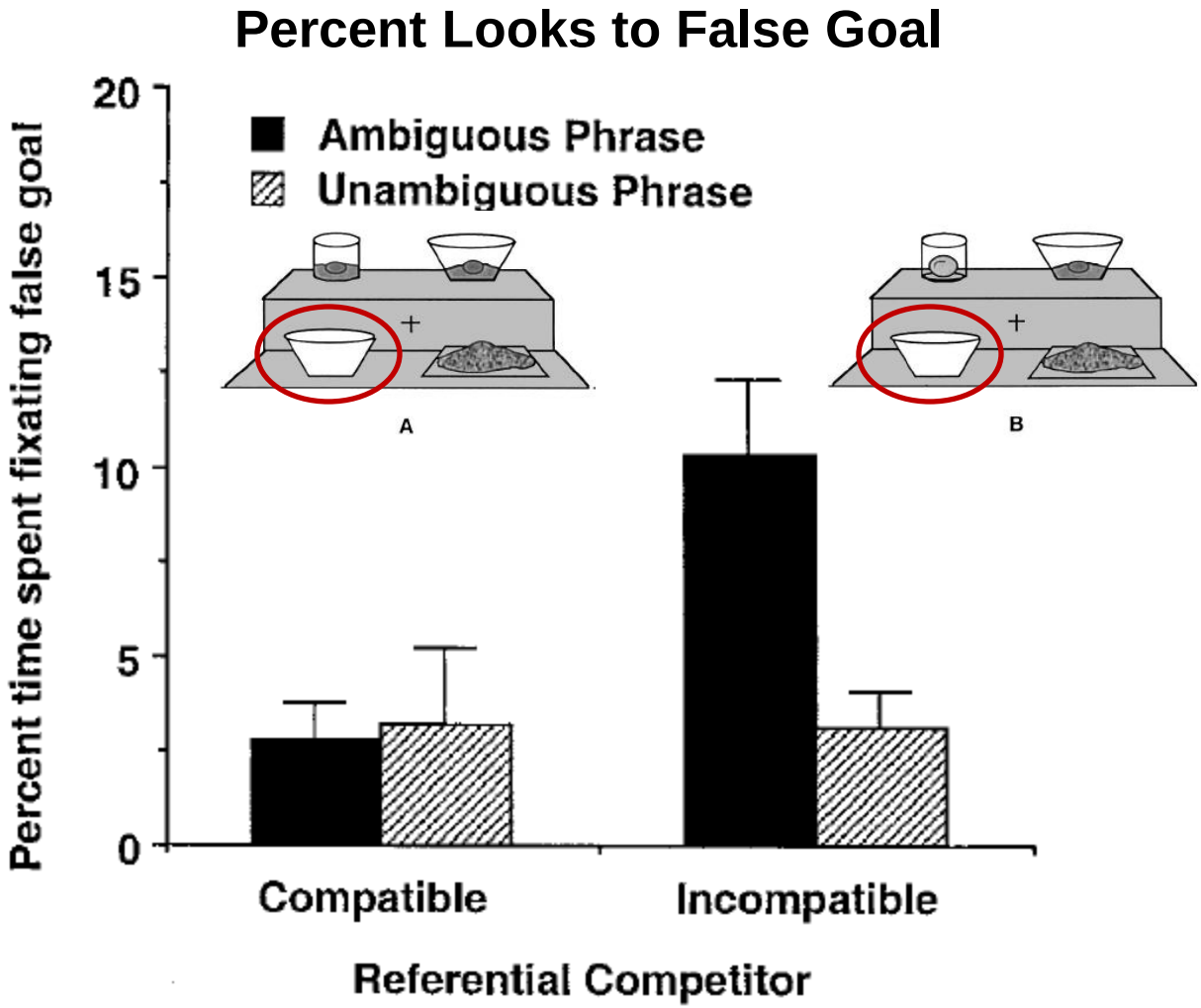
A

Incompatible competitor



B

Chambers, Tanenhaus & Magnuson (2004)



Which information sources drive parsing decisions?

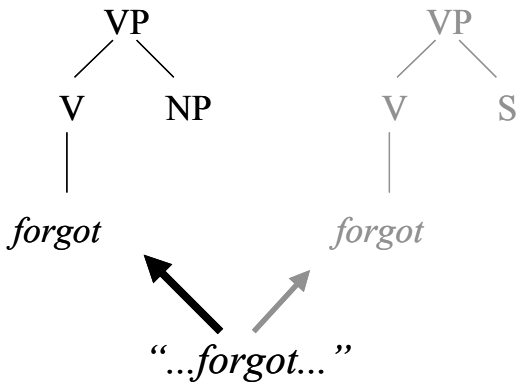
- *Put the frog on the napkin…*
  - *Parsing Principles (Minimal Attachment)?* ***No.***
  - *Lexico-syntactic tendencies?* ***Yes.***
  - *Lexico-semantic tendencies?*
  - *Prosody?* ***Yes.***
  - *Referential/pragmatic constraints?* ***Yes.***

Constraint-Based Lexicalist (CBL)

Constraint-based lexicalist theory

(Trueswell & Tanenhaus, 1994; MacDonald et al., 1994)

- Comprehension process is inherently a <u>perceptual guessing game</u>
- Multiple probabilistic cues to recover detailed linguistic structure
- Parsing is a *recognition* process, with temporary parallelism



Anticipatory Effects

(e.g. Chambers, Tanenhaus, Eberhard, Filip & Carlson, 2002)

Put the duck <u>inside</u> the can.

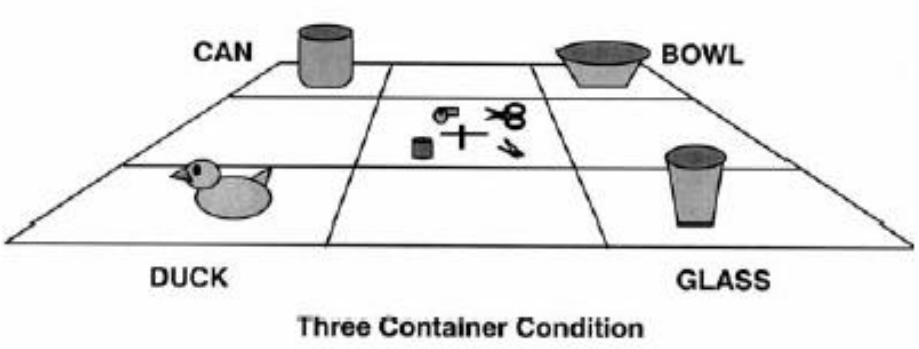
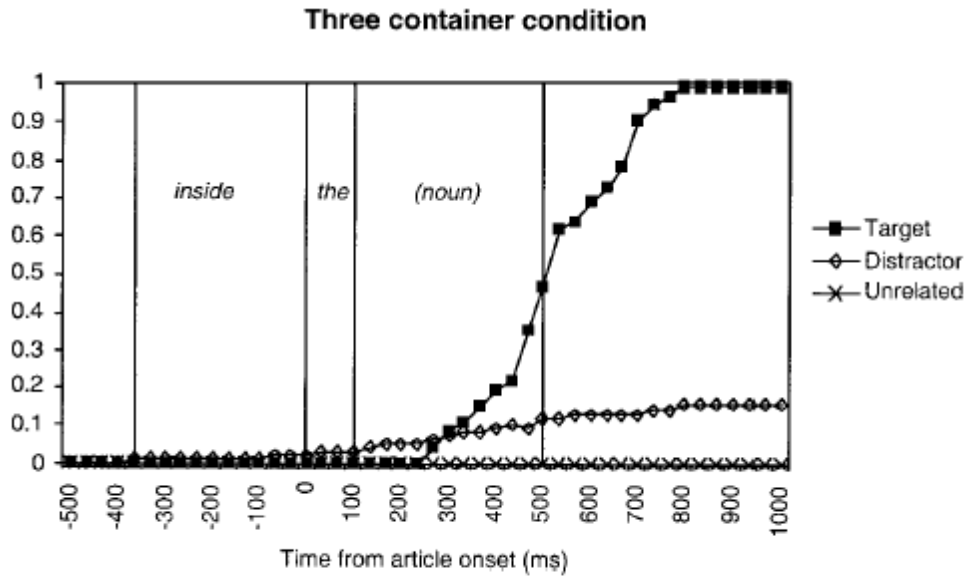
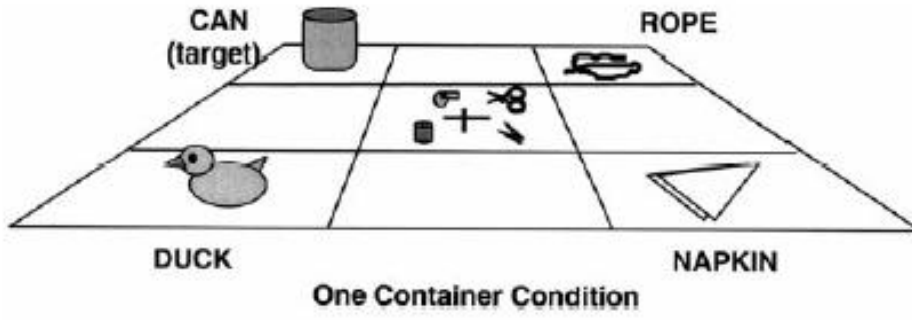
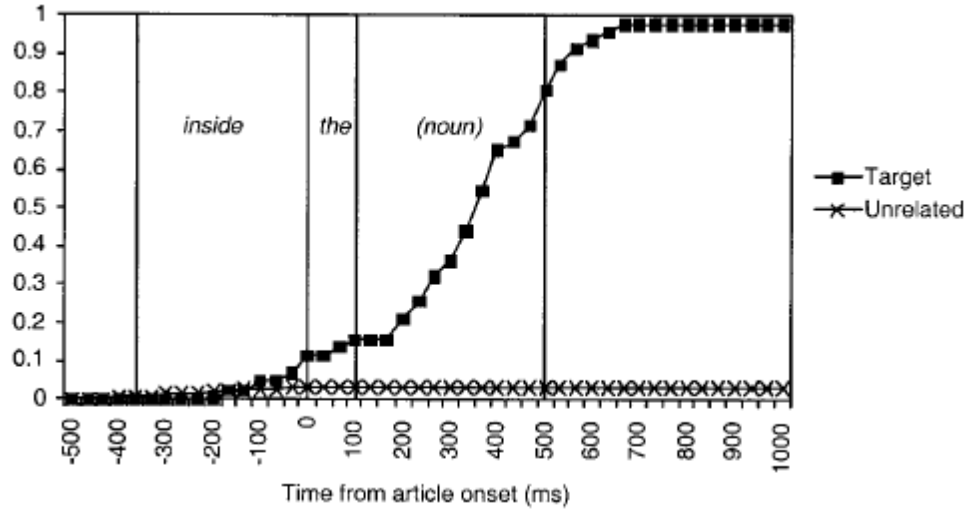


FIG. 1. Examples of experimental displays (Experiment 1).





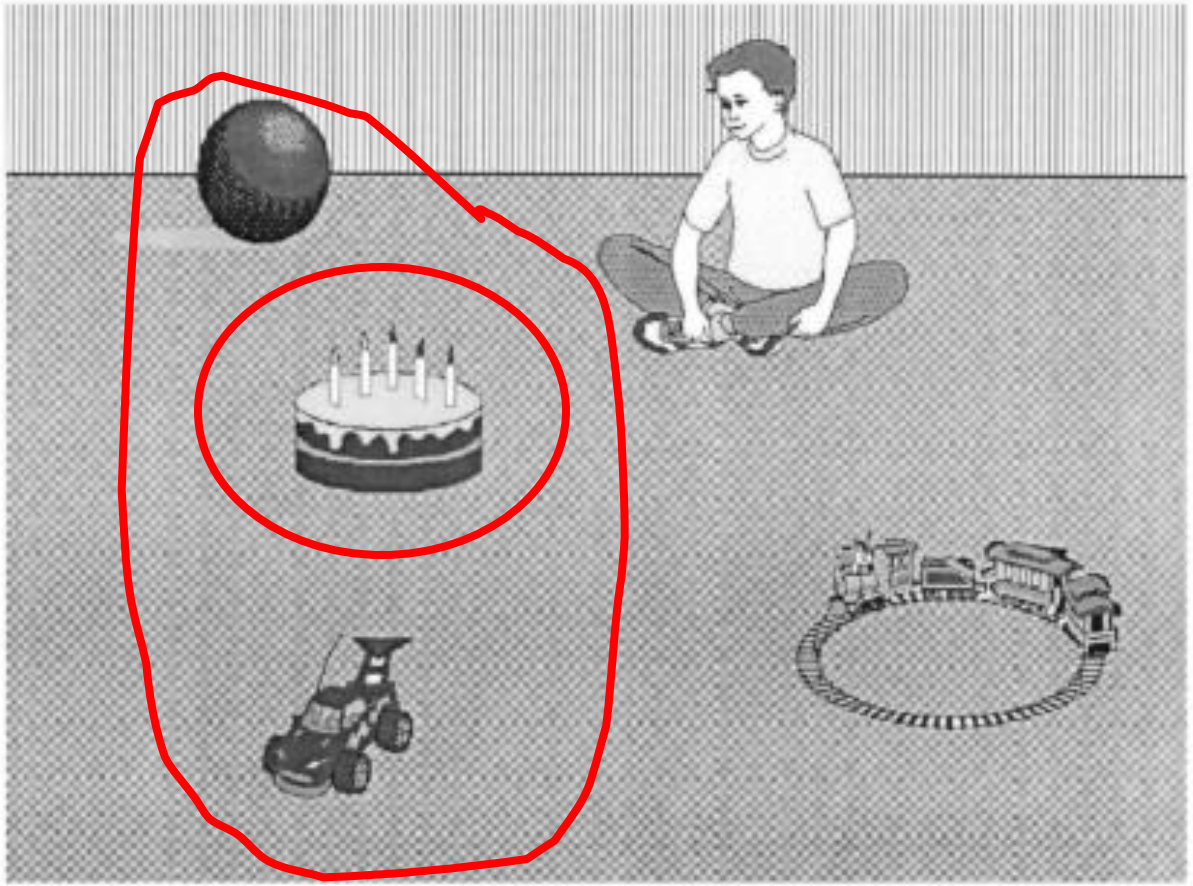


Verb Semantic Restrictions

(Altmann & Kamide, 1999)

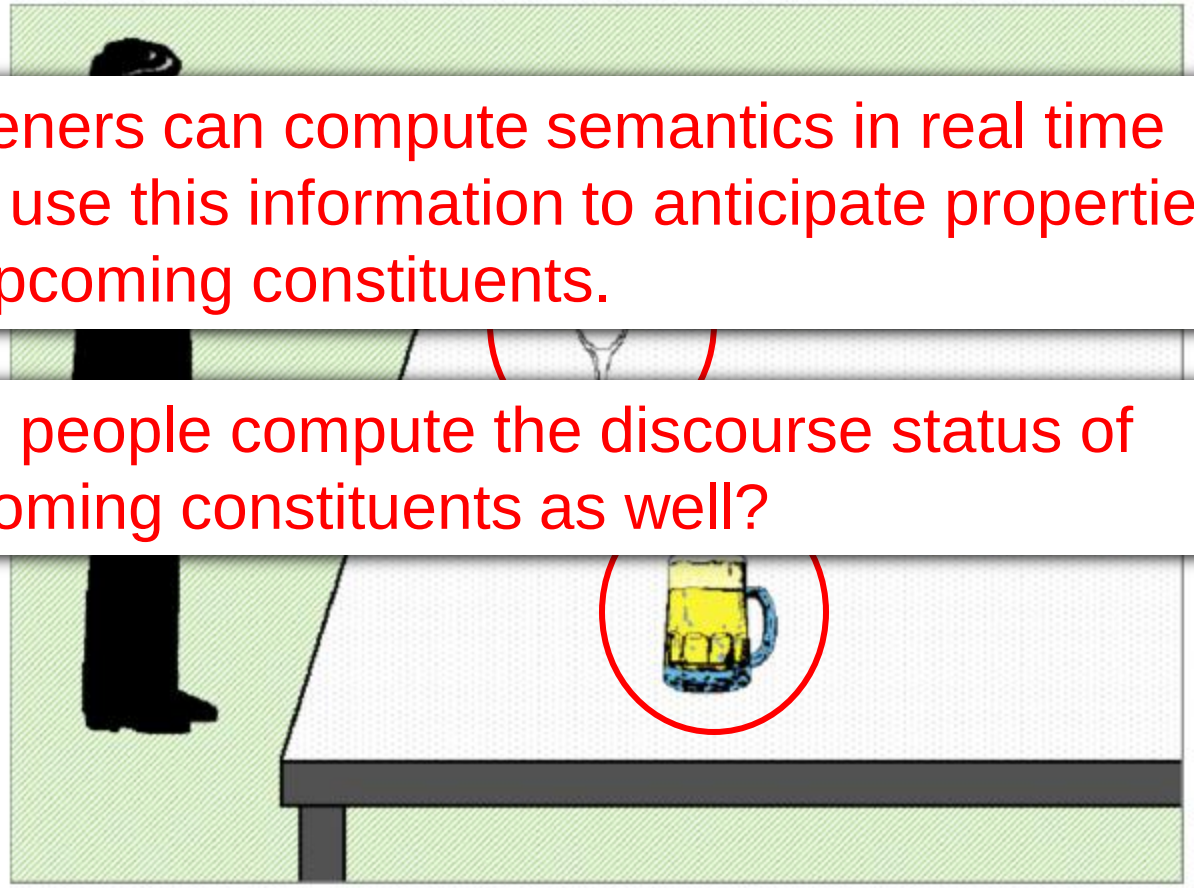
Boland (2004): Only arguments are predicted, not adjuncts.

The boy will move the cake. *The boy will eat the cake.*



Altmann & Kamide (in press, JML)

The man will drink all of the…
The man has drunk all of the…



Listeners can compute semantics in real time and use this information to anticipate properties of upcoming constituents.

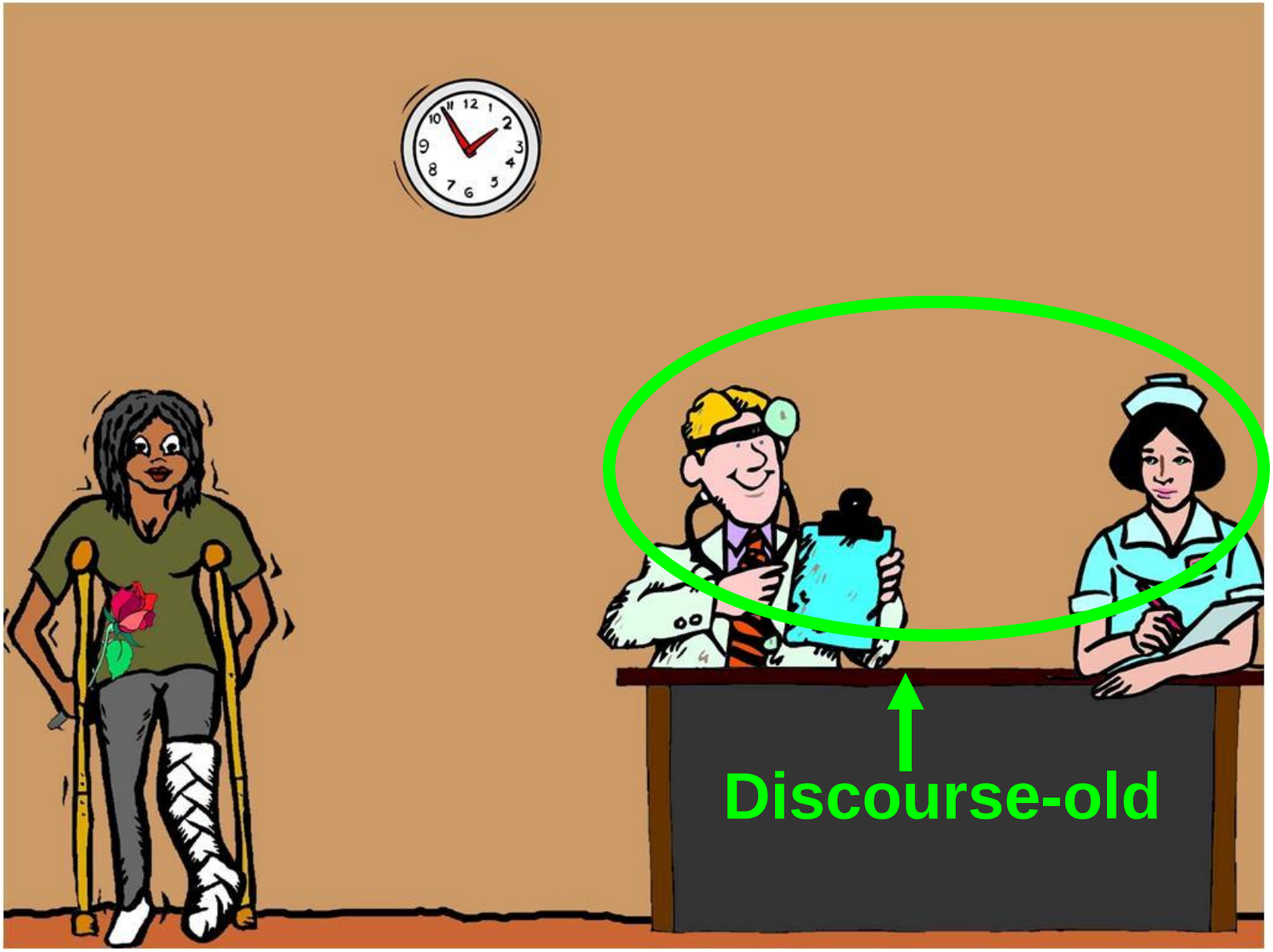
Can people compute the discourse status of upcoming constituents as well?

Sentence processing in Finnish
Kaiser & Trueswell (2004)

- Finnish
  - Case Marking
  - Flexible word order
  - No articles (*the, a*)
  - SVO canonical order
  - OVS order:
    - Object is discourse old
    - Subject is discourse new
  - Prediction: When Finnish listeners hear OV… they should expect a discourse NEW subject.

Participants hear:

At the hospital, behind a desk, are a doctor and a nurse. ….


Discourse-old


And it’s almost two o’clock.

Target sentence (OVS):

Then doctor-obj greets …

Target sentence (OVS):

Then doctor-obj greets…

Anticipatory looks to new ref after hearing OV….

Target sentence (OVS):

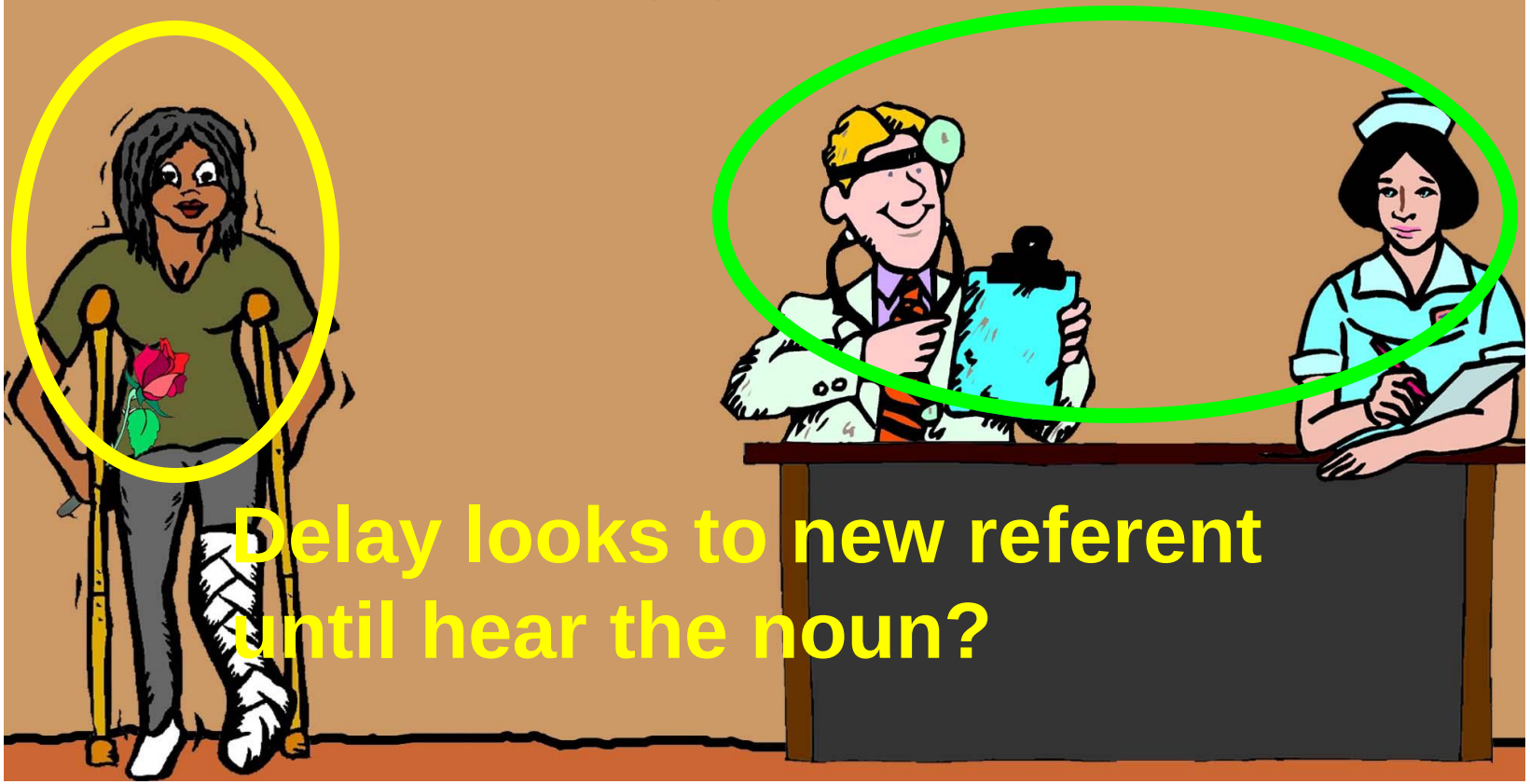
Then doctor-obj greets patient-subj.

Target sentence (SVO):

Then doctor-subj greets…

Target sentence (SVO):

Then doctor-subj greets…



Delay looks to new referent until hear the noun?

Target sentence (SVO):

Then doctor-subj greets patient-obj

AMBIGUOUS SECOND NOUN

Target sentence (OVS):

Then doctor-obj greets ….

AMBIGUOUS SECOND NOUN

Target sentence (OVS):

Then doctor-obj greets ….

Anticipatory looks to new nurse after hearing OV….

AMBIGUOUS SECOND NOUN

Target sentence (OVS):

Then doctor-obj greets nurse-subj

AMBIGUOUS SECOND NOUN

Target sentence (SVO):

Then doctor-subj greets nurse-obj

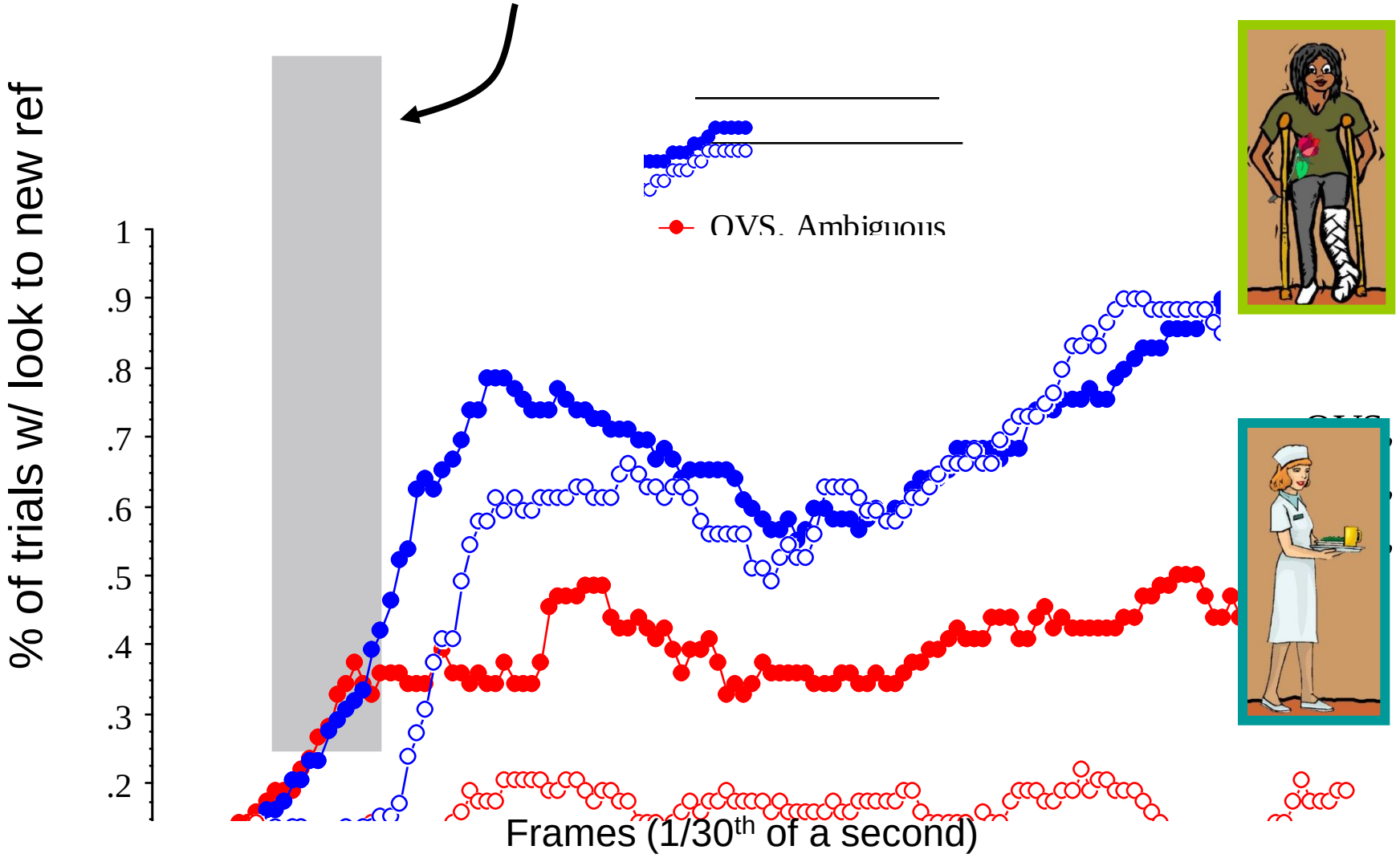
Less looks to new nurse?

Summary of Design and Predictions

- OVS unambiguous
  - Early looks to New Referent upon hearing [OV…]
- SVO unambiguous
  - Looks to New Referent delayed until hearing N2
- OVS ambiguous
  - Early looks to New Referent upon hearing [OV…]
  - Prefer New Referent, though ambiguous
- SVO ambiguous
  - Few looks to New Referent? (Prefer Old Referent?)

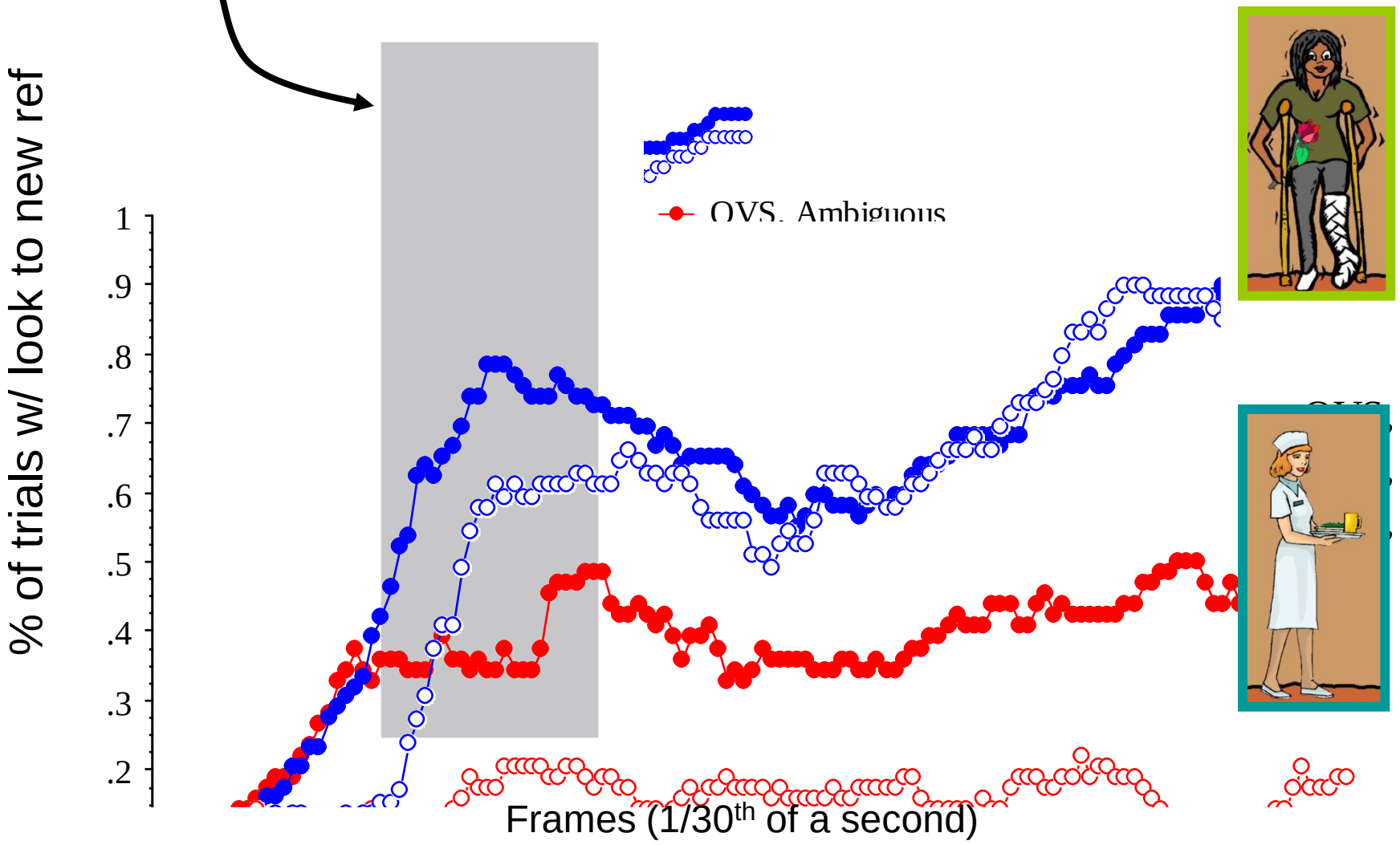
Looks to discourse-new referent from onset of 2nd Noun

Main effect of structure (first 400 ms, p<0.05)



Effects of Phonological Content of Noun

Effects of Ambig. And Structure (400 ms and onward, p<0.05)



Summary of Parsing

- Two tricks of the trade:
  - Competitor effects
  - Anticipation effects
- Results show listeners dynamically structure input into semantic + referential characterization of input.
  - Done in real-time
  - Done at multiple levels simultaneously
  - Highly interactive

Open questions

- Importance of lexical generated structure building vs. contextual dependencies
- Interface Issues
  - What are the limitations (if any) on interactions across levels of representation
  - Are complete linguistic characterizations computed & operated on?

Language Development (next Thurs.)

- The two tricks of the trade, **competitor effects** and **anticipatory effects**, are being used to study:
  - Phonological & Lexical development
    - Fernald, Swingley, Aslin and colleagues
  - Syntax & Semantics
    - Trueswell, Snedeker, Gleitman, Lidz, Musolino and colleagues
  - Discourse & Conversation
    - Sedivy, Eply, Keysar and colleagues