Resource use and sentence comprehension

9.591; 24.945

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Ted Gibson

What sources of information do people use in processing sentences?

- Syntactic structure
- Word frequency
- Plausibility
- Discourse context
- Intonational information

The use of these information sources is constrained by the amount of **working memory** resources that are available.

Hard to process unambiguous sentences
Nested (or *center-embedded*) structures

The reporter disliked the editor.

The reporter [who the senator attacked] disliked the editor.

\# The reporter [who the senator [who John met] attacked] disliked the editor.

Right-branching (non-nested) control:

John met the senator who attacked the reporter who disliked the editor.

Cross-linguistic generalization: Nested structures are hard; left- and right-branching structures are not.

Japanese:

Obasan-wa [bebiisitaa-ga [ani-ga imooto-o ijimeta] to itta] to omotteiru

aunt-top babysitter-nom older-brother-nom younger-sister-acc bullied that said that thinks

"My aunt thinks that the babysitter said that my older brother bullied my younger sister"

Less nested version: easier to understand

[bebiisitaa-ga [ani-ga imooto-o ijimeta to] itta to] obasan-wa omotteiru

Syntactic information use in sentence processing: The Dependency Locality Theory (DLT, Gibson, 1998, 2000)

Resources are required for two aspects of language comprehension:

(a) Integration: connecting the current word into the structure built thus far;

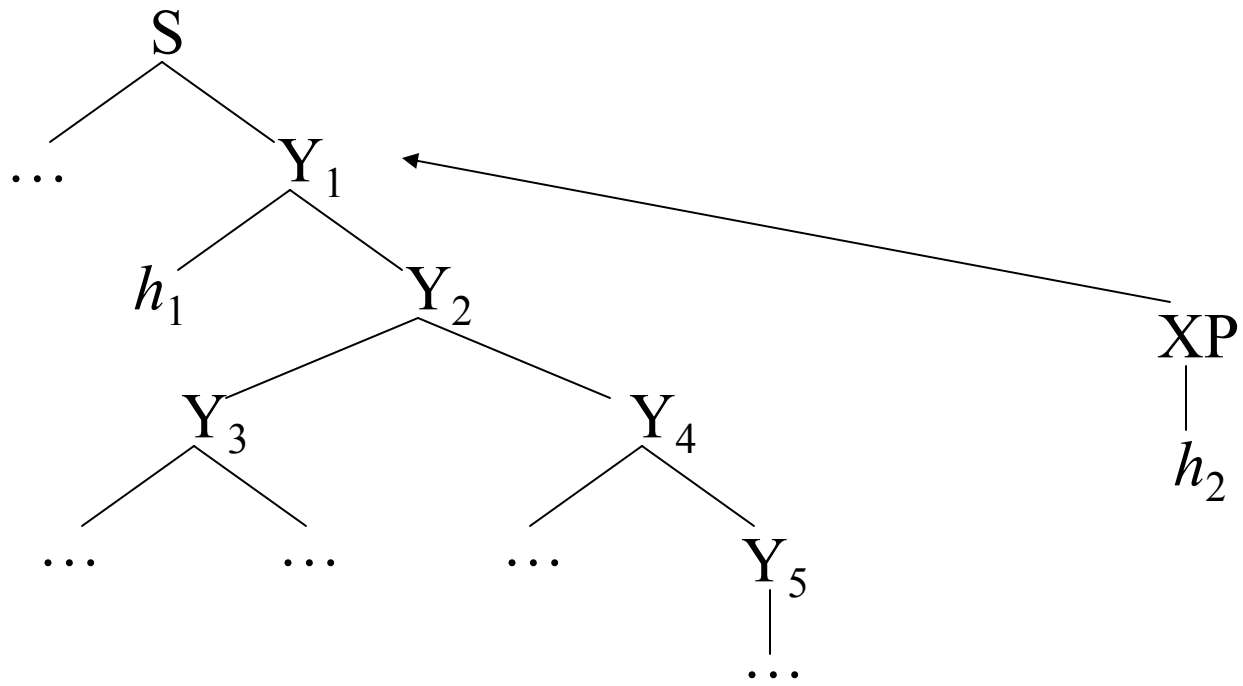
(b) Storage / Expectations: Predicting categories to complete the current structure.

Syntactic resource hypotheses

- Frazier (1978): Minimal Attachment & Late Closure:
  - Ambiguity resolution only
  - Assumed to be modular: Applying before other sources of information use

- Gibson (1998; 2000): Syntactic storage and integration
  - Apply in both ambiguous and unambiguous sentences
  - Assumed to be non-modular: Interact immediately with other sources of information (but this is not a crucial part of the theory).

Integration complexity depends on the *distance* or *locality* between the head and dependent being integrated.



Computational motivation: Integrating h_2 to h_1 involves reactivating h_1 to a target level.

Two possible sources of locality effects:

1. Decay of h_1: h_1's activation will have decreased for all the integrations that have taken place since it was last highly activated.
2. Interference of similar items between h_1 and h_1 may make h_1 hard to reactivate.

Integration complexity depends on the *distance* or *locality* between the head and dependent being integrated.

Motivations:

1. Linguistic elements are perceived serially.
2. Language comprehension is incremental.

Locality effects in ambiguous structures

Right Association (Kimball, 1973); Late Closure (Frazier, 1979, 1987); Recency (Gibson, 1991)

(1) The bartender told the detective that the suspect left the country yesterday.

Yesterday is preferred as modifying *left* rather than *told*

Experimental evidence: Frazier & Rayner, 1982;
Gibson et al., 1996; Altmann et al., 1998; Pearlmutter & Gibson, 2001.

Local attachment preference

Comic strip removed for copyright reasons.

Initial Integration Distance Hypothesis

The difficulty of integrating a new word h_2 to h_1 is proportional to the number of discourse objects and events (nouns and verbs, roughly) which were introduced since h_1 was last processed.

Locality effects in unambiguous structures

Experiment 1:

Object-extracted relative clause:

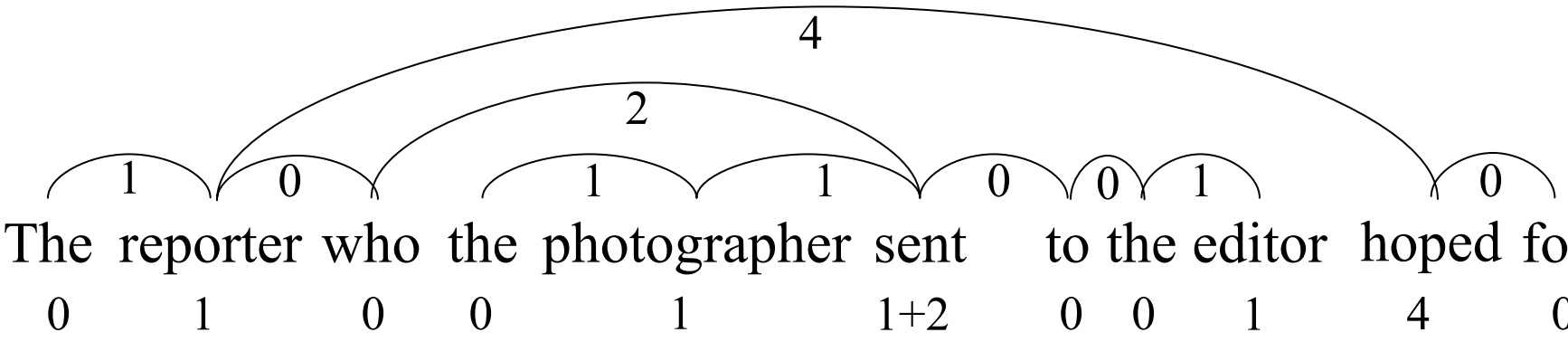
The reporter who the photographer sent to the editor hoped for a good story.

Subject-extracted relative clause:

The reporter who sent the photographer to the editor hoped for a good story.

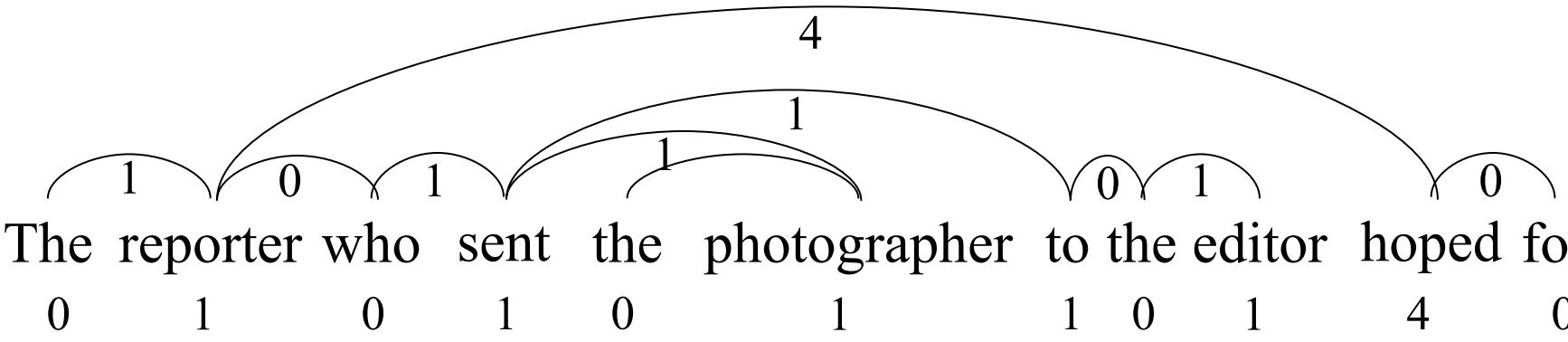
Locality effects in unambiguous structures

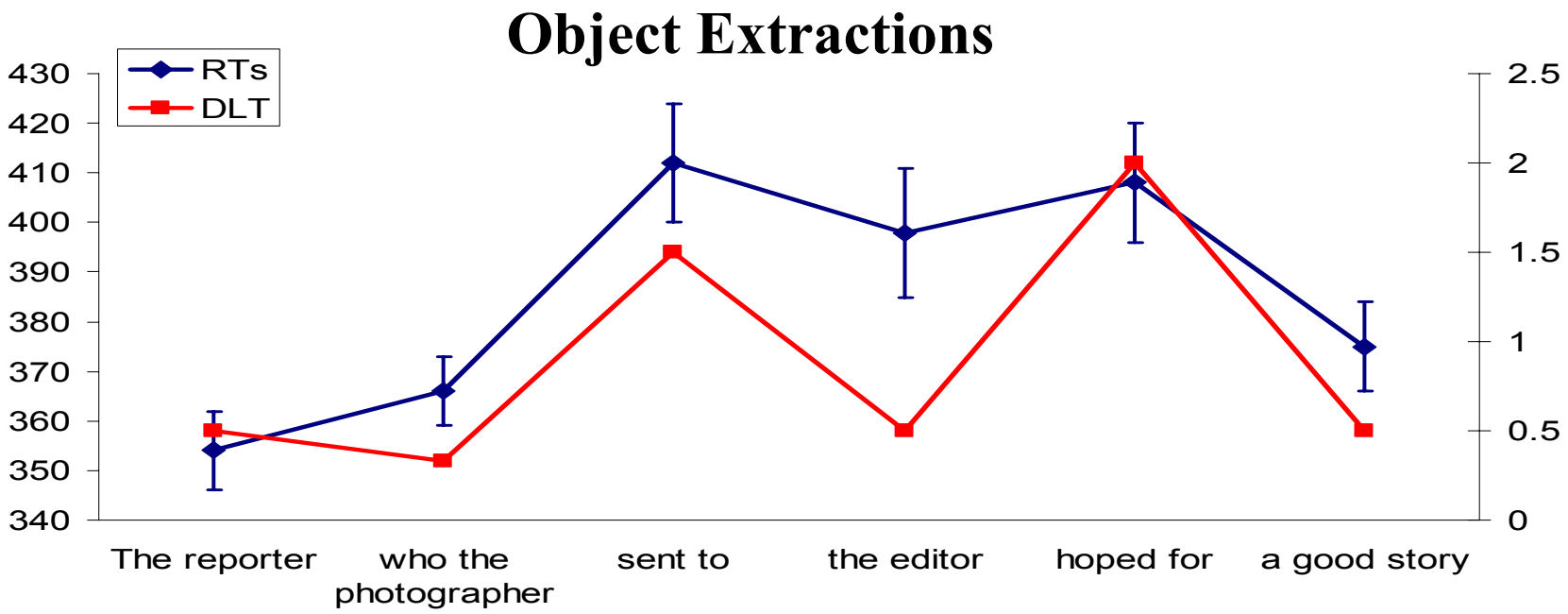
Object-extracted relative clause:
The reporter who the photographer sent to the editor hoped for a story.

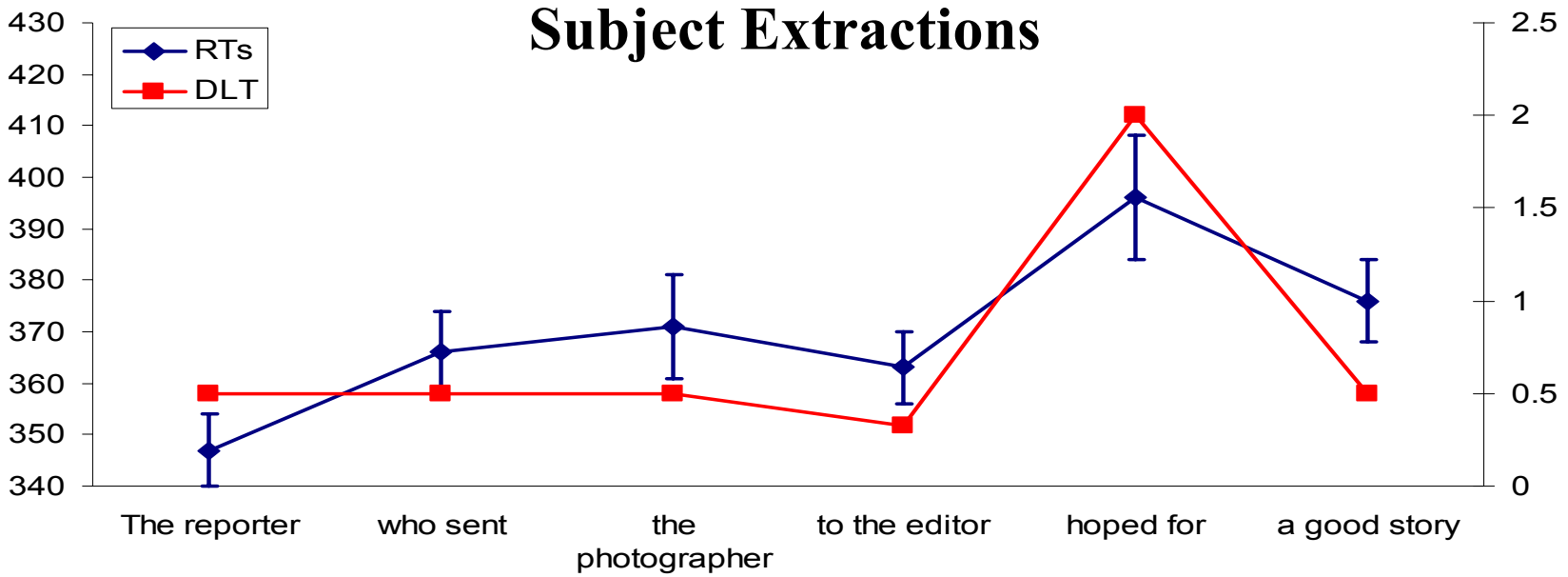


Locality effects in unambiguous structures

Subject-extracted relative clause:
The reporter who sent the photographer to the editor hoped for a story.



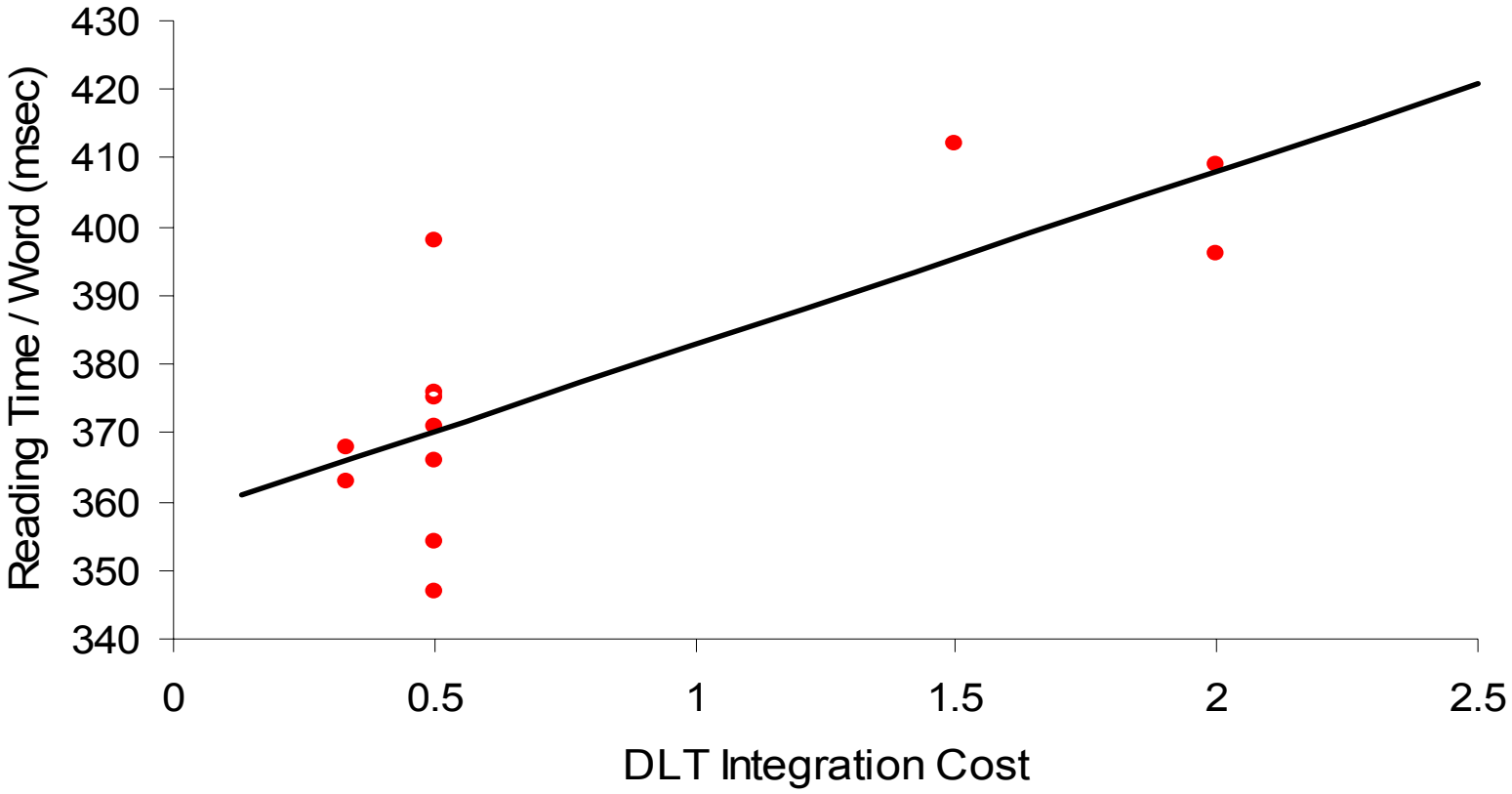

Object Extractions
RTs
DLT
430
420
410
400
390
380
370
360
350
340
2.5
2
1.5
1
0.5
0
The reporter
who the photographer
sent to
the editor
hoped for
a good story


Subject Extractions
RTs
DLT
430
420
410
400
390
380
370
360
350
340
2.5
2
1.5
1
0.5
0
The reporter
who sent
the photographer
to the editor
hoped for
a good story

Experiment 1: DLT vs. RTs

(Grodner & Gibson, in press)

Linear model: $r^2 = .582$, $p < .001$



Experiment 2 Materials

Matrix – Unmodified Subject

The nurse supervised the administrator while ...

0 1 1 0 1 1

Matrix – PP Modified Subject

The nurse from the clinic supervised the administrator while ...

0 1 0 0 1 2 0 1 1

Matrix – RC Modified Subject

The nurse who was from the clinic supervised the administrator while ...

0 1 0 1 0 0 1 3 0 1 1

Embedded – Unmodified Subject

The administrator who the nurse supervised scolded the medic while...

0 1 0 0 1 3 3 0 1 1

Embedded – PP Modified Subject

The administrator who the nurse from the clinic supervised scolded the medic…

0 1 0 0 1 0 0 1 5 4 0 1

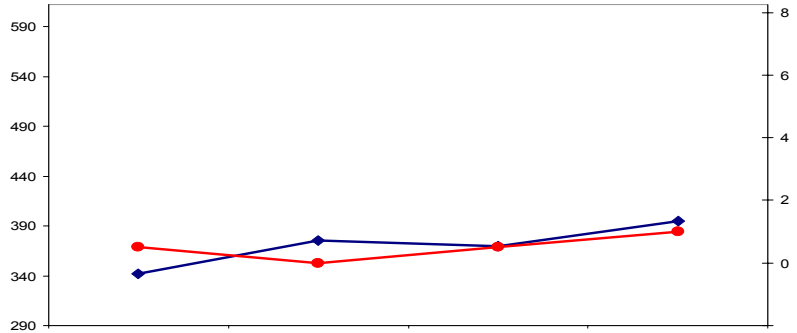
Embedded – RC Modified Subject

The administrator who the nurse who was from the clinic supervised scolded the medic…

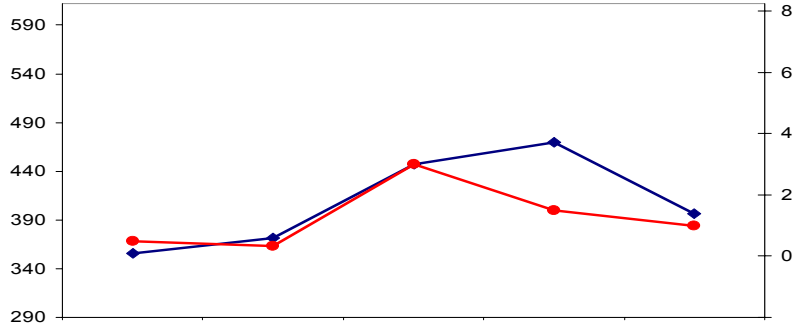
0 1 0 0 1 0 1 0 0 1 7 5 0 1

Experiment 2: DLT vs. RTs by Regions

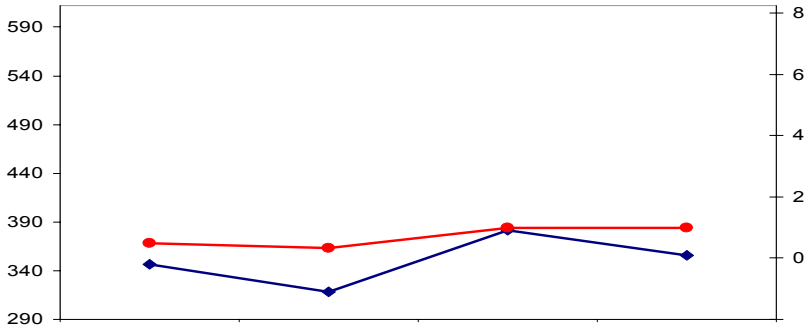
Matrix – Unmodified Subject



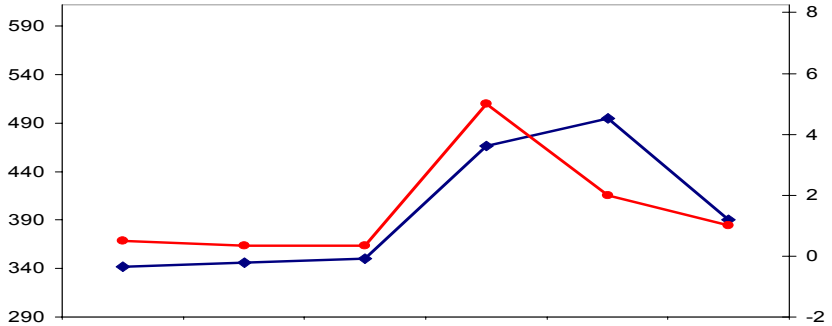
Embedded – Unmodified Subject



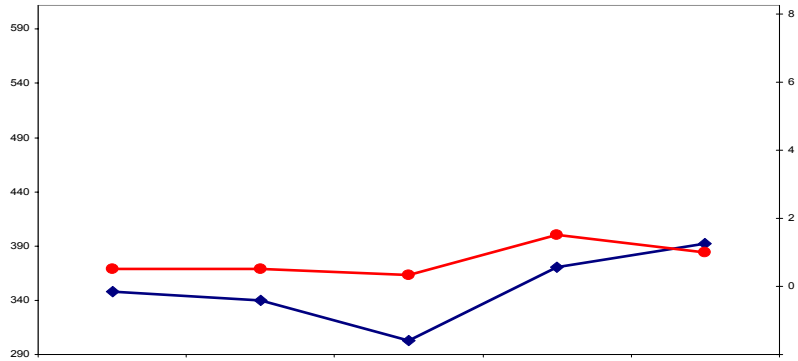
Matrix – PP Modified Subject



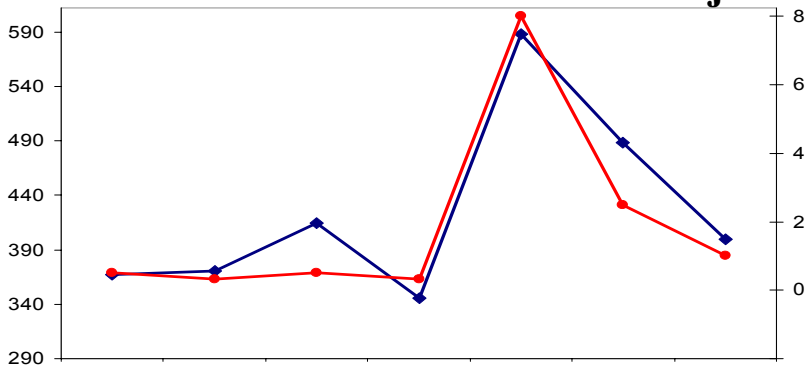
Embedded – PP Modified Subject



Matrix – RC Modified Subject

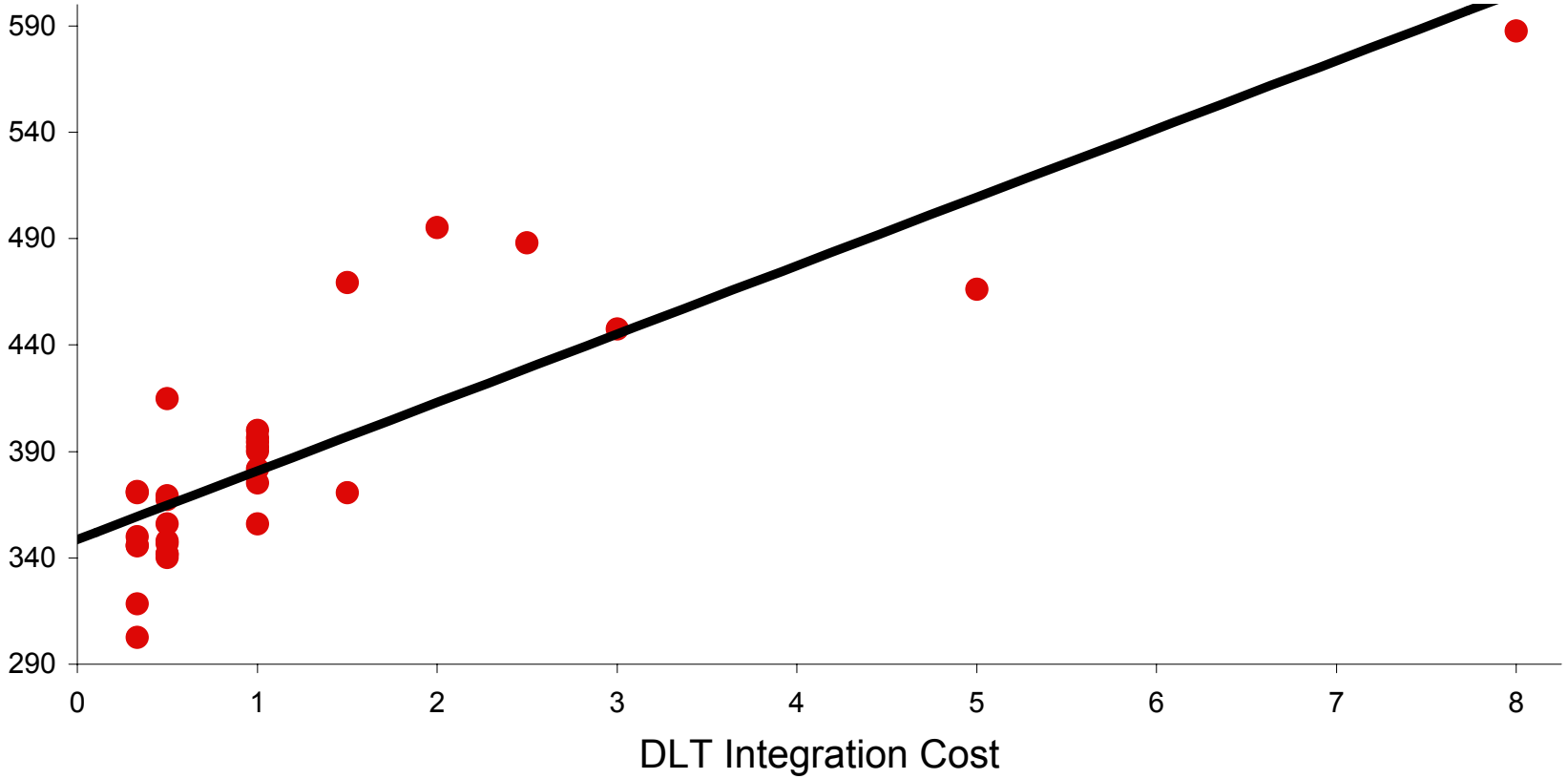


Embedded – RC Modified Subject

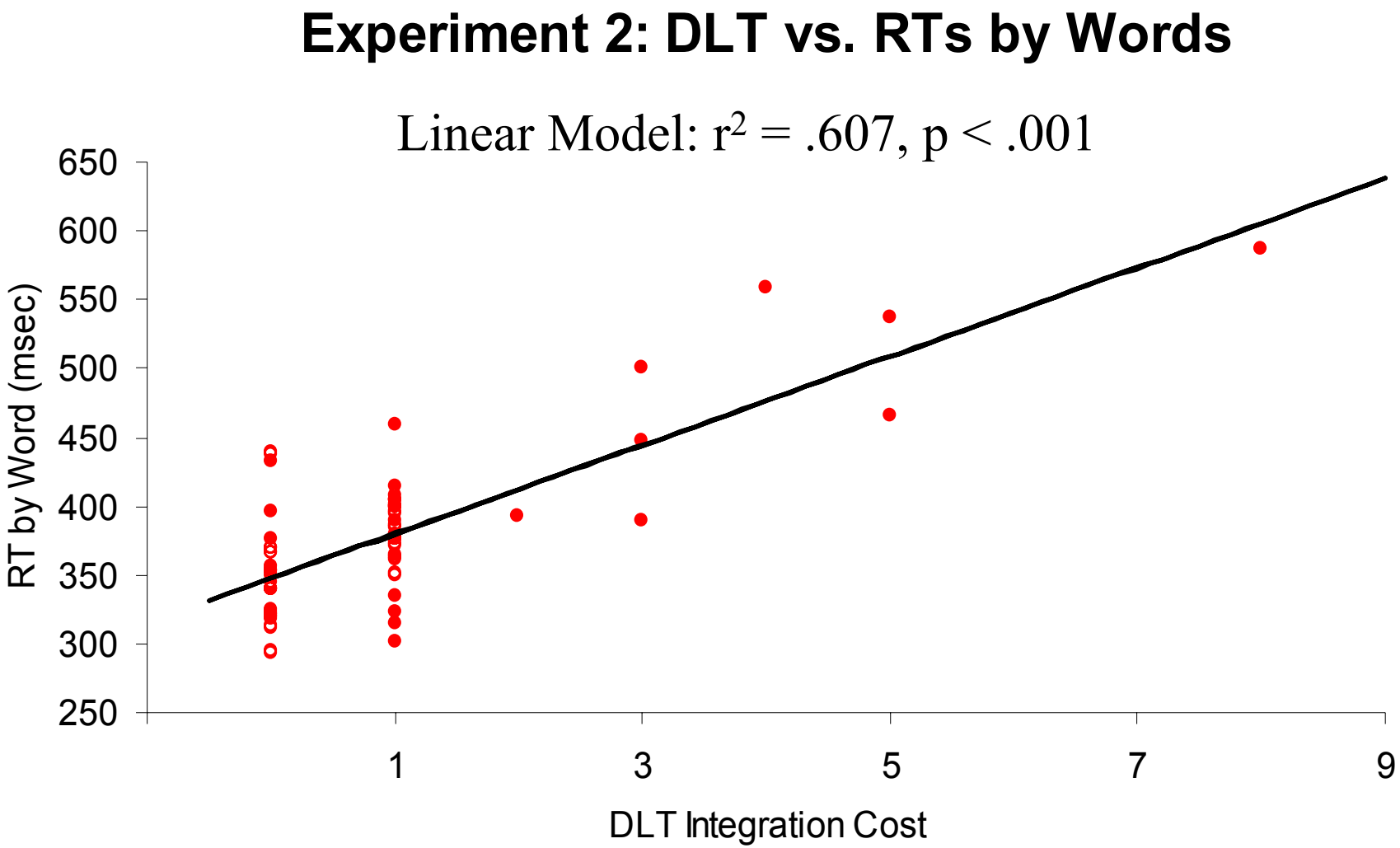


Experiment 2: DLT vs. RTs by Regions

Linear Model: $r^2 = .721$, $p < .001$



Experiment 2: DLT vs. RTs by Words



Nesting complexity effects

(1) The reporter disliked the editor.

(2) The reporter [who the senator attacked] disliked the editor.

(3) The reporter [who the senator [who John met] attacked] disliked the editor.

(4) John met the senator [who attacked the reporter [who disliked the editor]].

Locality account of nesting complexity

Nested structures have longer distance dependencies than non-nested structures.

An alternative account of nesting complexity

Nested structures have parse states with more incomplete dependencies (e.g., Yngve, 1960; Chomsky & Miller, 1963).

Puzzle: Nested pronoun generalization (Bever, 1974; Kac, 1981)

The lower complexity of examples like:

(1) The reporter who everyone that I met trusts said the president won't resign yet. (Bever, 1974)

(2) A book that some Italian who I've never heard of wrote will be published soon by MIT Press. (Frank, 1992)

Null contexts:

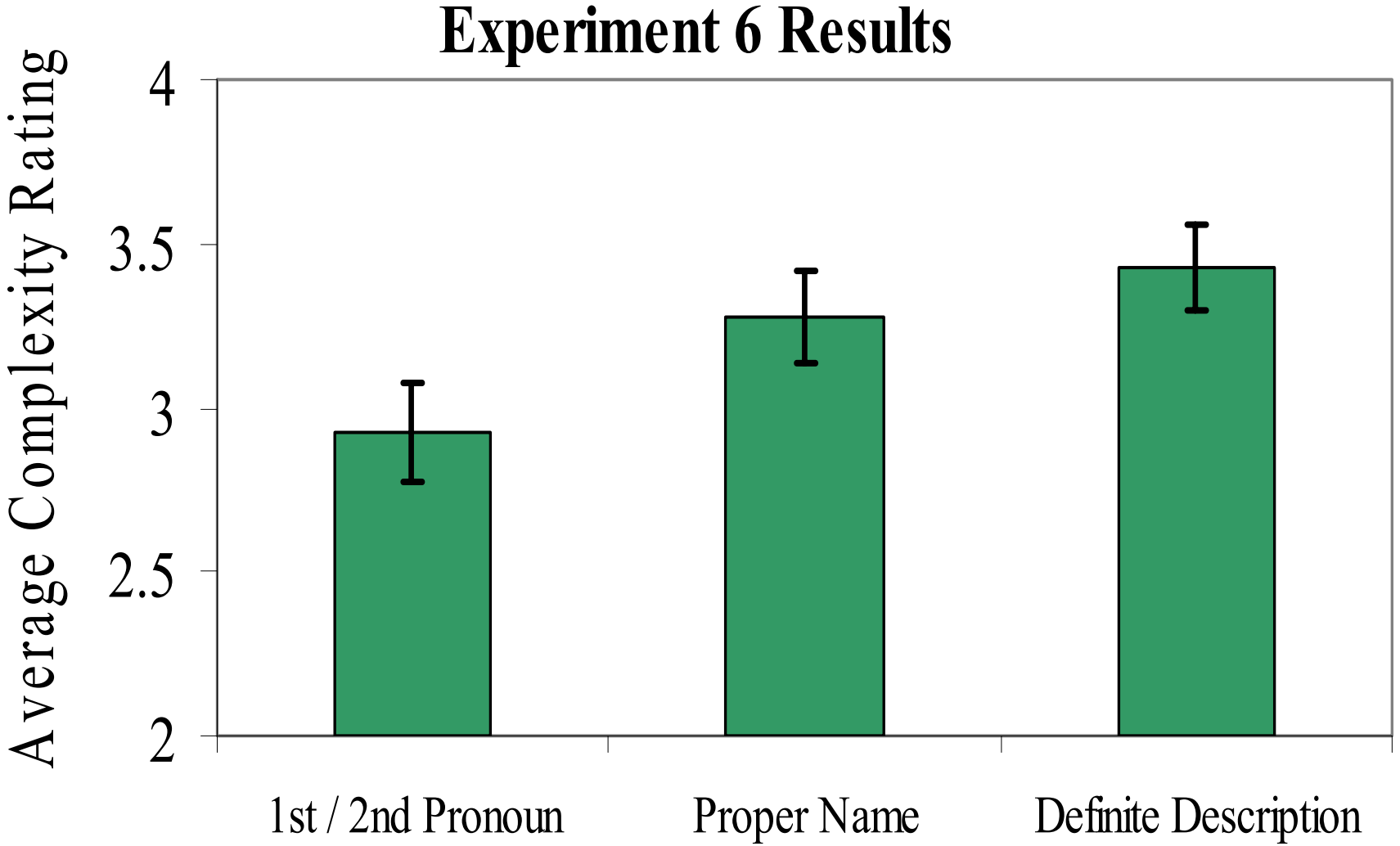
The low complexity of nested pronouns

Experiment 6 Materials

First / second person pronoun
The reporter who the senator who you met attacked disliked the editor.

Proper name
The reporter who the senator who John met attacked disliked the editor.

Definite description
The reporter who the senator who the professor met attacked disliked the editor.


Experiment 6 Results
Average Complexity Rating
4
3.5
3
2.5
2
1st / 2nd Pronoun
Proper Name
Definite Description

Japanese nested structures (Nakatani, Babyonyshev & Gibson, 2000)

[NP1-topic [NP2-nom [NP3-nom

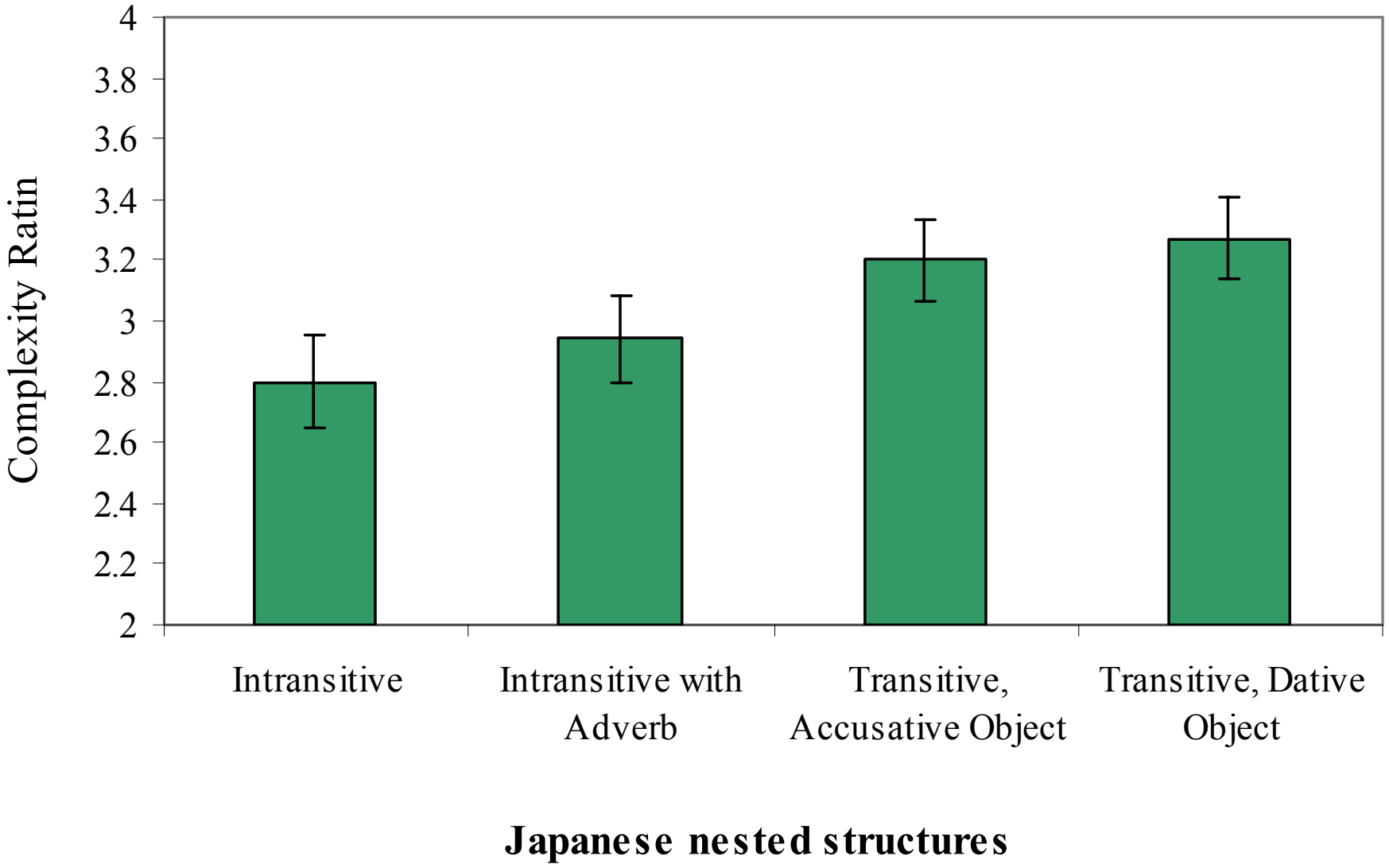
{ null / Adv / NP-accusative / NP-dative }

V1 Comp] V2 Comp] V3

Japanese nested structures (Nakatani, Babyonyshev & Gibson, 2000)

"Tuma-wa uranaisi-ga otto-ga syoosinsuru to tugeta to zimansita"

"The wife boasted that the fortune teller said that her husband would be promoted / suddenly promoted / surpass the chief clerk / catch up with the chief clerk."


Complexity Ratin
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
Intransitive
Intransitive with Adverb
Transitive, Accusative Object
Transitive, Dative Object
Japanese nested structures

Open question: How to quantify distance?

- Words?
- Discourse structure? (Gibson, 1998; 2000; Warren & Gibson 2002)
- The accessibility of the types of embedded NPs? (Warren & Gibson, 2002)
- Intervening interfering NPs? (Gordon et al. 2001, 2002; cf. Lewis, 1996)
  - Similar NPs (syntactic, semantic) cause more interference

Nested pronoun generalization (Bever, 1974; Kac, 1981)

The low complexity of doubly-nested examples like:

(1) The reporter who everyone that I met trusts said the president won't resign yet. (Bever, 1974)

(2) A book that some Italian who I've never heard of wrote will be published soon by MIT Press. (Frank, 1992)

Cf. (3) The reporter who the senator who (you / # John) met trusts said that the president won't resign yet.

The relative ease of (1) and (2) can be explained in many ways by an integration distance metric: e.g., discourse-based, or interference-based.

The cognitive status of NPs
(Warren & Gibson, 2002)

The Givenness Hierarchy (Gundel et al., 1993; Ariel, 1990) is hypothesized to link the type of an NP and the degree to which its antecedent is accessible in discourse

pronouns < first names < full names < definite NPs

Central Peripheral

Prediction of accessibility-based theory: Greater difficulty in processing more peripheral NPs, especially in nested positions

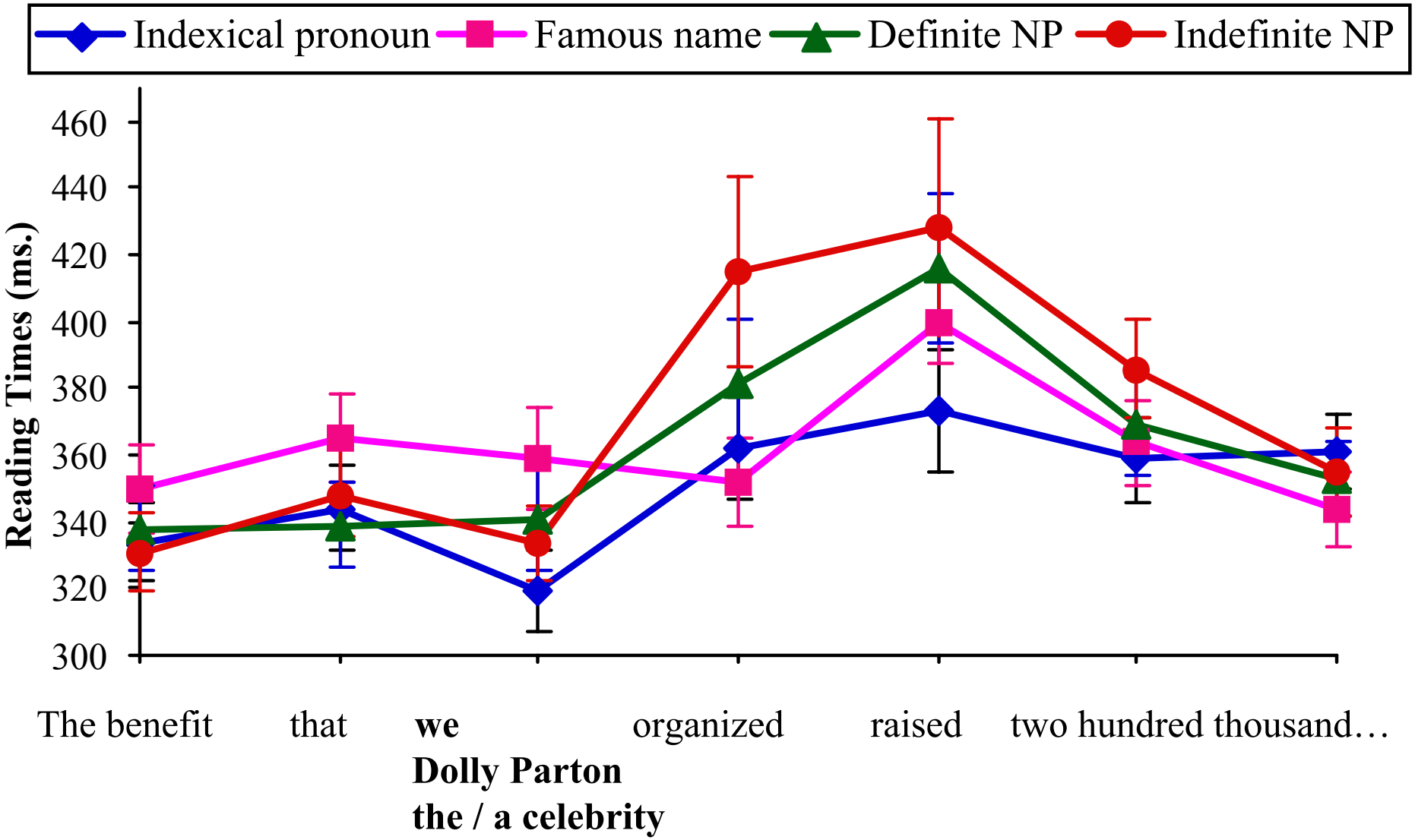
Warren & Gibson (2002): An on-line test of cognitive status differences

Four conditions, controlled for plausibility in an off-line norming task:

1st/2nd person pronouns, full names, definite NPs, indefinite NPs

The benefit that {**we, Dolly Parton, the celebrity, a celebrity**} organized raised two hundred thousand dollars for cancer research.

Warren & Gibson (2002)



Gordon et al. (2001): An alternative distance metric

- The syntactic / semantic similarity of intervening NPs: More similar NPs, slower processing

- Prediction: Same kinds of NPs as head noun and embedded NP in an objected-extracted RC will lead to most processing difficulty, independent of the NP type

Gordon et al. 2001, Experiment 4

- Clefts:

  It was (the barber / John) that (the lawyer / Bill) saw in the parking lot.

  It was (the barber / John) that saw (the lawyer / Bill) in the parking lot.

Graph removed for copyright reasons.

Gordon et al. 2001, Experiment 4

- Conclusion: Syntactic interference of the intervening words leads to integration difficulty.

- Problems with this interpretation:
  - Odd method: self-paced reading **center-screen presentation**; with only 50% target sentences, and questions always about the cleft predication: This could have led to a memorization strategy.
  - Very slow RTs for normal reading: 500-800 msec / word
  - Hard to generalize to pronouns: No pronouns in their test conditions

New Experiment:
Warren, Gibson, Jamison & Hirsch

- Self-paced reading, normal presentation
- 3x3 design in object-extracted materials, crossing (definite description, name, pronoun) x (definite description, name, pronoun)

- Materials:

  It was (the lawyer / Patricia / you) who (the businessman / Dan / we) avoided at the party.

  Predictions:

  Gordon's interference theory: DD, NN, PP should all be slowest than the rest.

  Warren & Gibson's nominal reference type theory:

  D in the middle should be worst, then N, then P.

  On the outside, D should be worst, then N, then P.

  The inside NPs should have more of an effect than the outside NPs.

New Experiment:
Warren, Gibson, Jamison & Hirsch

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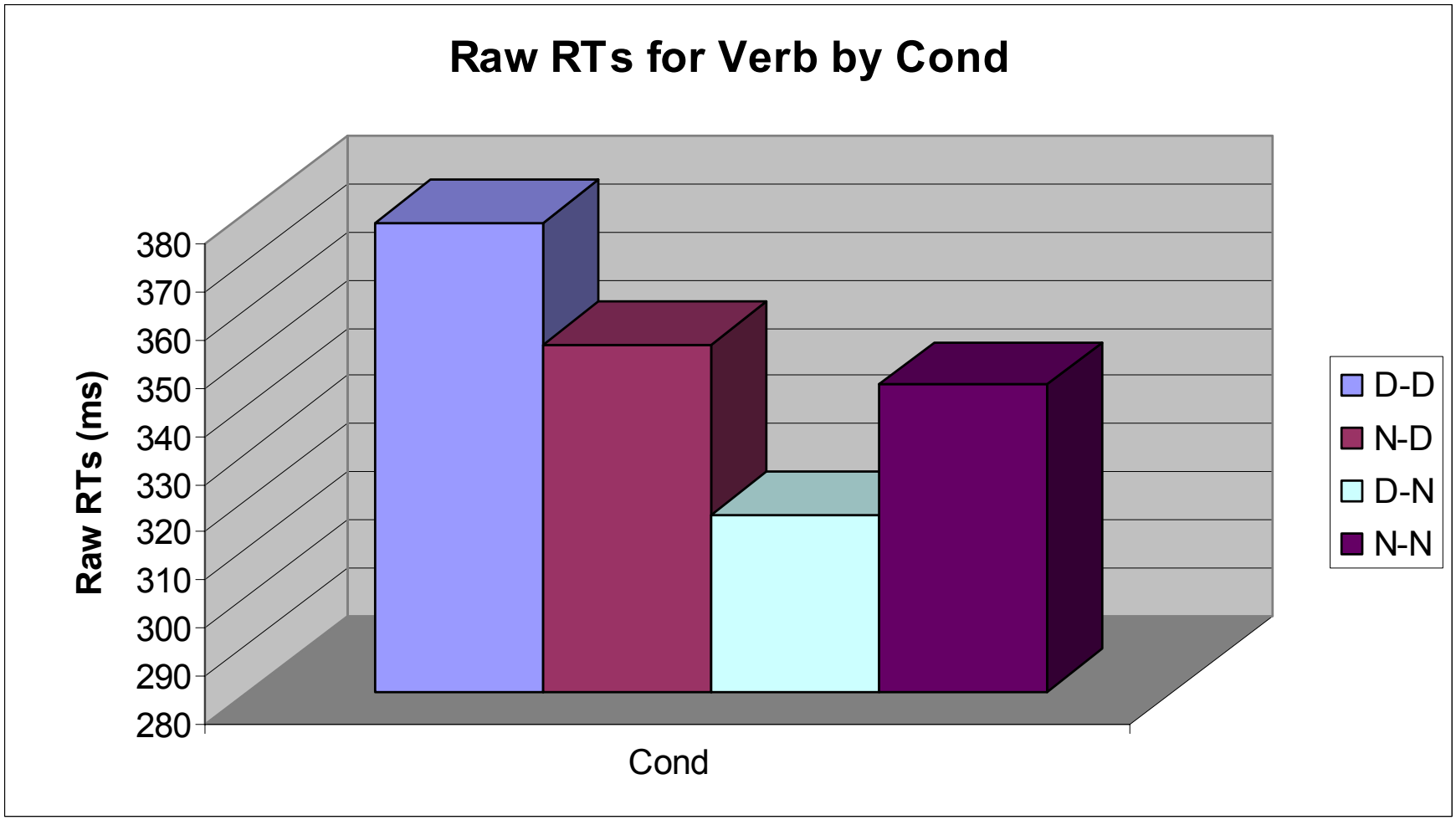
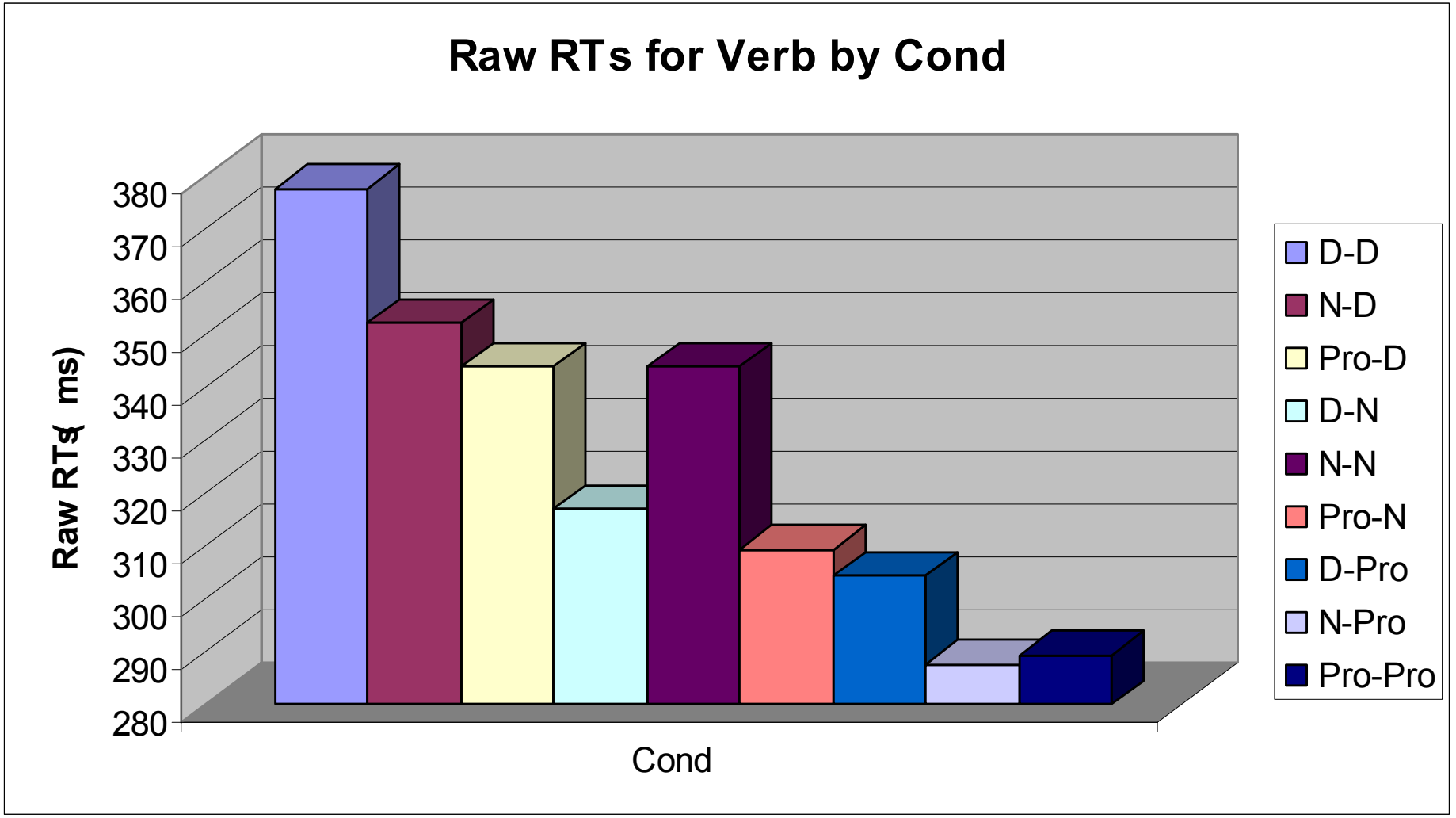
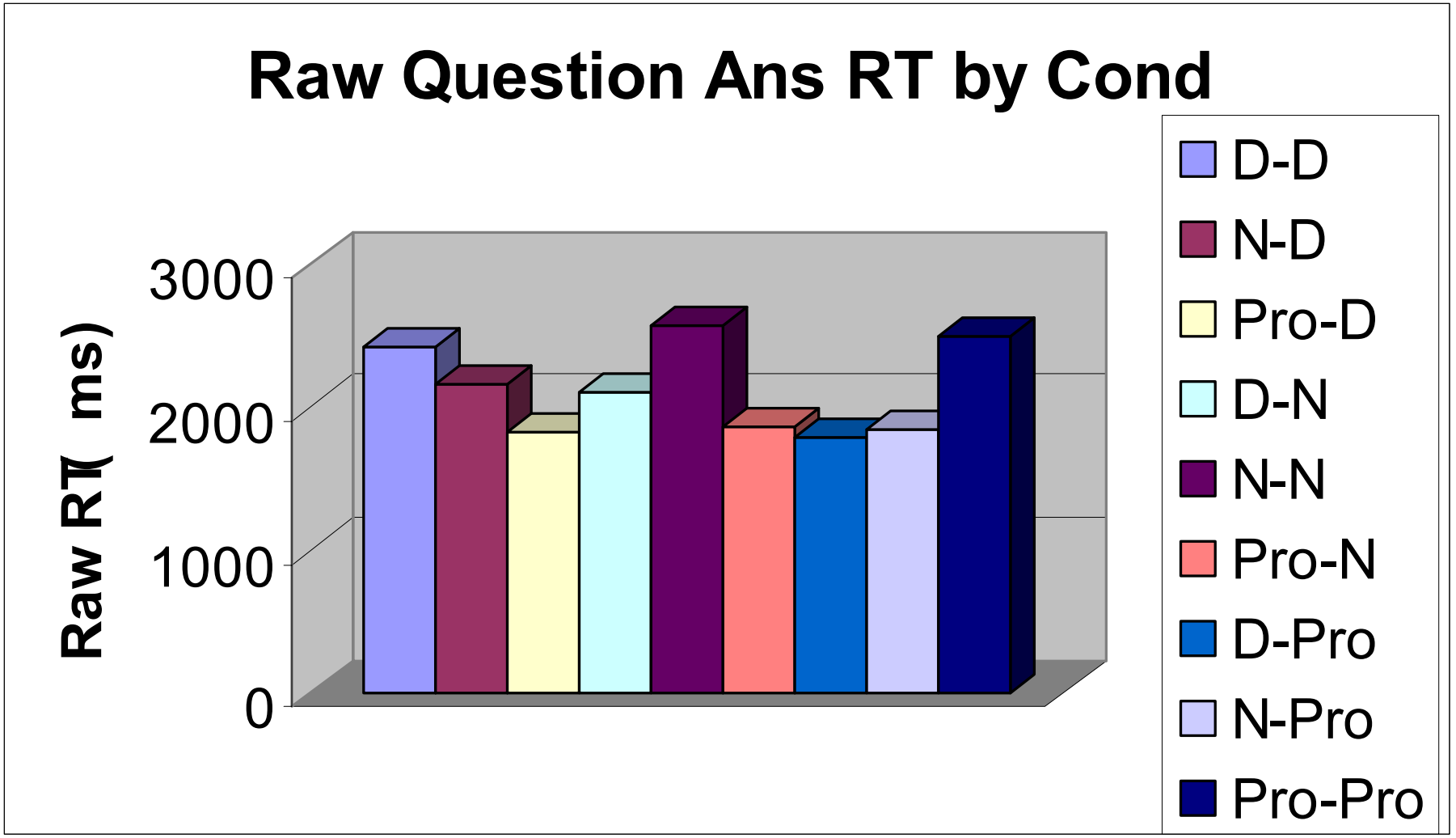
New Experiment:
Warren, Gibson, Jamison & Hirsch



New Experiment:
Warren, Gibson, Jamison & Hirsch



New Experiment:
Warren, Gibson, Jamison & Hirsch



New Experiment: Warren, Gibson, Jamison & Hirsch

- Conclusion:
  - Aspects of both Gordon et al.'s hypothesis and Warren & Gibson's hypothesis are correct. Warren & Gibson's hypothesis appears to apply more immediately, whereas Gordon et al.'s appears to apply later.

More Locality effects: Length / heaviness effects

See e.g., Bever (1970), Hawkins (1994):

"Save the hardest for last."

(1) ? I gave [the beautiful green pendant that's been in the jewelry store window for weeks] [to my mother].

(2) I gave [my mother] [the beautiful green pendant that's been in the jewelry store window for weeks].

Length / heaviness effects

(3) # [That the administrator who supervised the nurse had lost the medical reports] bothered the intern.

(4) It bothered the intern [that the administrator who supervised the nurse had lost the medical reports].

An old puzzle: relative clauses (RCs) and complement clauses (CCs)

RC within CC: difficult, but processable

The fact [that the employee [who the manager hired] stole office supplies] worried the executive.

CC within RC: unprocessable

The executive [who the fact [that the employee stole office supplies] worried] hired the manager.

RCs and SCs: Gibson & Thomas (1997)

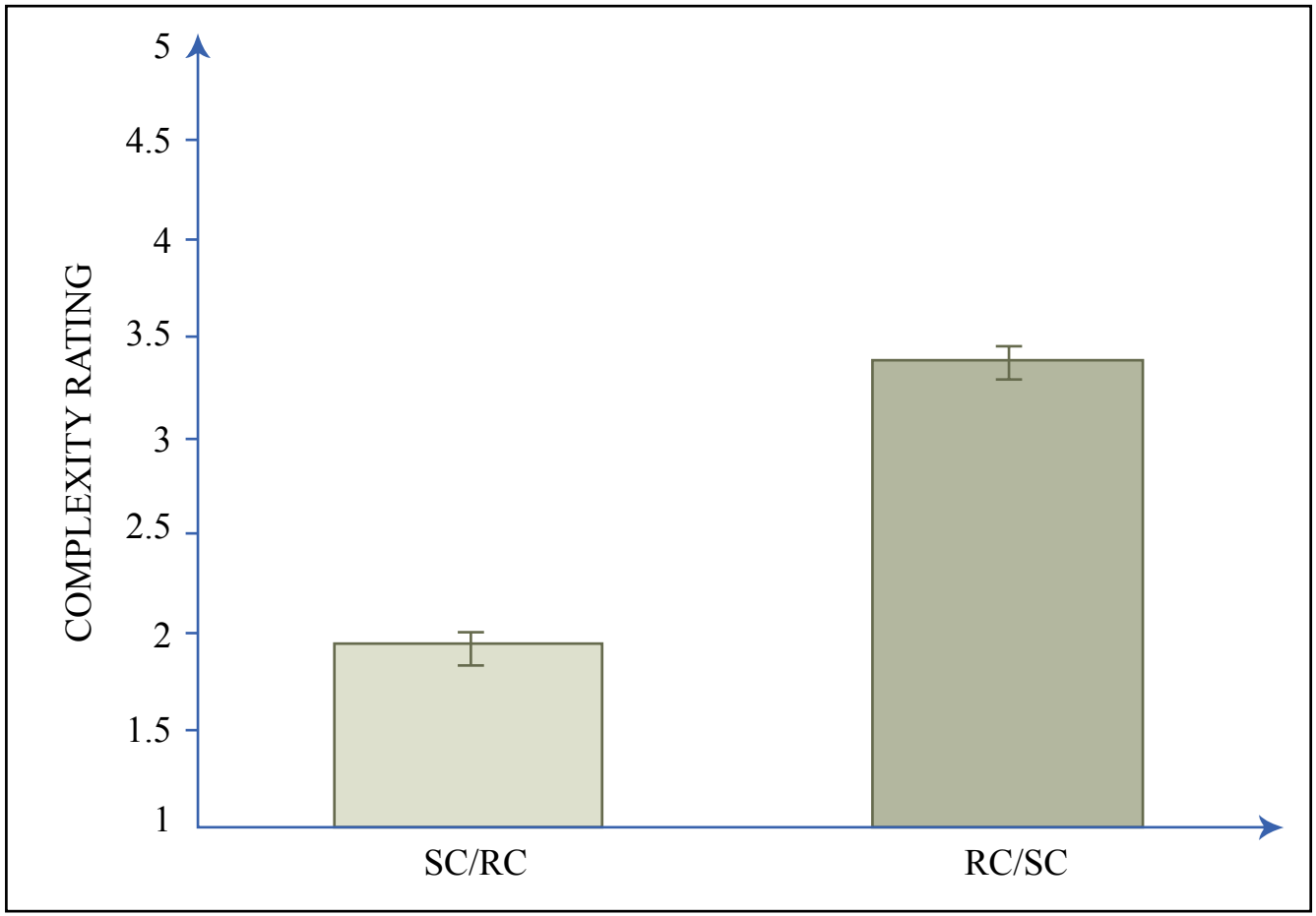


Figure by MIT OCW.

Nested vs. Cross-serial dependencies

Cross-serial dependencies are easier to process than nested dependencies (Bach, Brown & Marslen-Wilson, 1986)

Nested vs. Cross-serial dependencies

Nested (German)

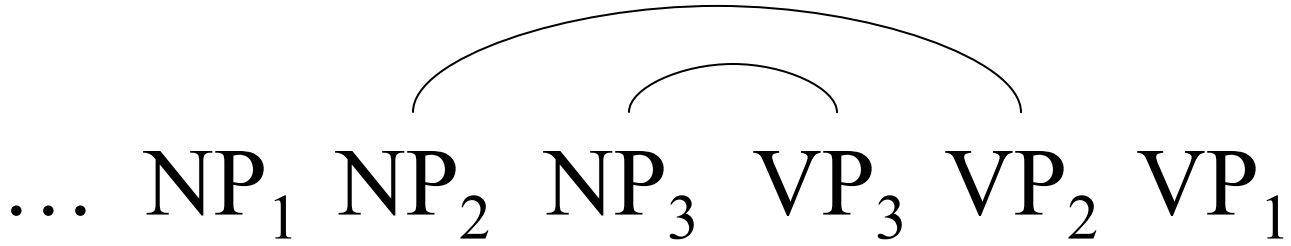
$$\ldots \; NP_1 \; NP_2 \; NP_3 \; VP_3 \; VP_2 \; VP_1$$

Nested vs. Cross-serial dependencies

Nested (German)

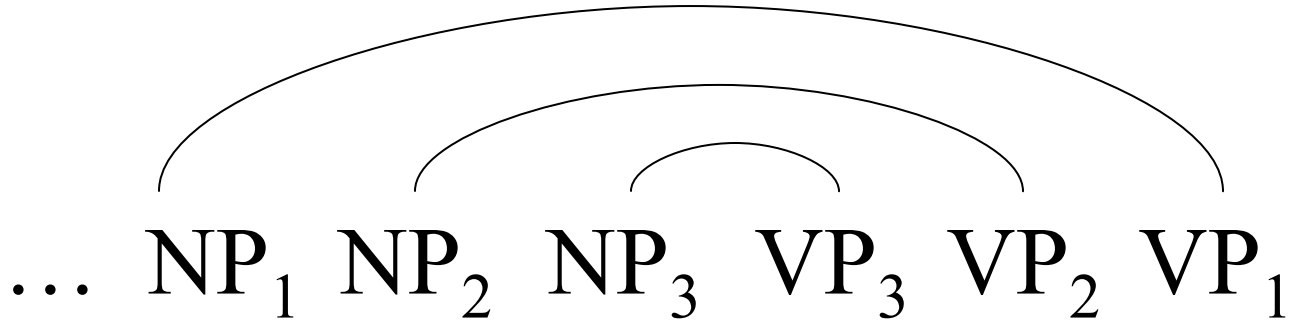
Nested vs. Cross-serial dependencies

Nested (German)



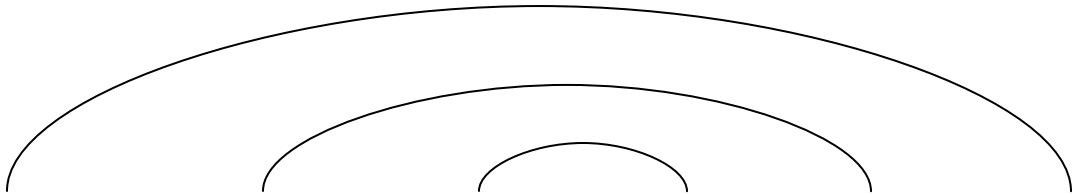
Nested vs. Cross-serial dependencies

Nested (German)



Nested vs. Cross-serial dependencies

Nested (German)



Johanna hat den Männern Hans die Pferde füttern lehren helfen.

Joanna has the men Hans the horses feed teach helped

“Joanna helped the men teach Hans to feed the horses.”

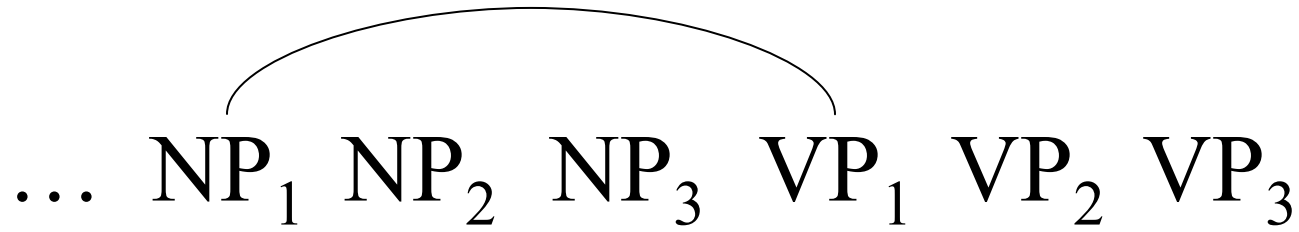
Nested vs. Cross-serial dependencies

Cross-serial (Dutch)

$$\ldots \; NP_1 \; NP_2 \; NP_3 \; VP_1 \; VP_2 \; VP_3$$

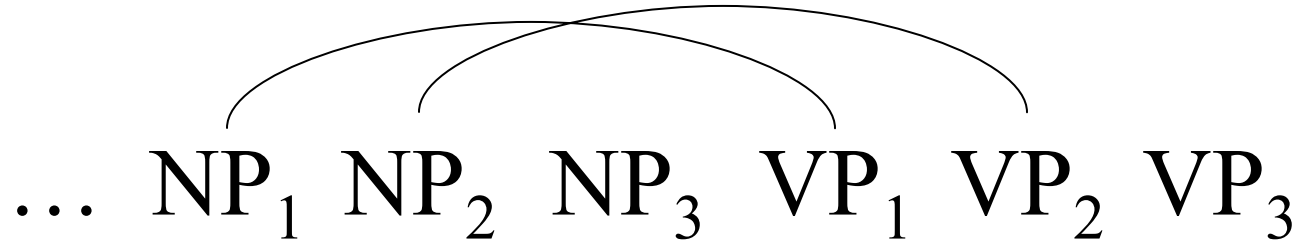
Nested vs. Cross-serial dependencies

Cross-serial (Dutch)



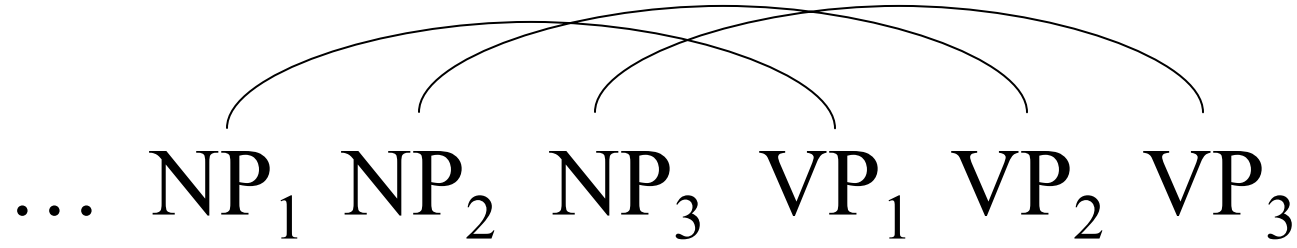
Nested vs. Cross-serial dependencies

Cross-serial (Dutch)



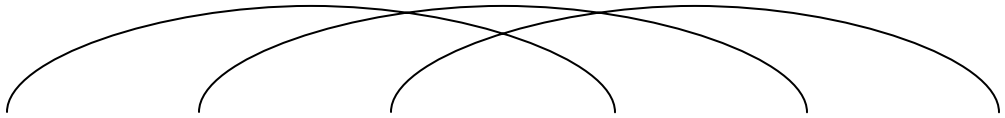
Nested vs. Cross-serial dependencies

Cross-serial (Dutch)



Nested vs. Cross-serial dependencies

Cross-serial (Dutch)



Jeanine heeft de mannen Hans die paarden helpen leren voeren.

Joanna has the men Hans the horses helped teach feed

“Joanna helped the men teach Hans to feed the horses.”

Application to technical writing

- To help the reader, keep syntactic dependencies close together.

Earlier accounts of nesting complexity

Nested structures have parse states with more incomplete dependencies (e.g., Yngve, 1960; Chomsky & Miller, 1963).

Unacceptable nestings: 4 or more incomplete dependencies at their worst states

Problems with the incomplete dependency account

1. doubly-nested clauses in SOV languages are unacceptable, even with only at most three incomplete dependencies.

Japanese:

Obasan-wa [bebiisitaa-ga [ani-ga naita] to itta] to omotteiru

aunt-top babysitter-nom older-brother-nom cried that said that thinks

"My aunt thinks that the babysitter said that my older brother cried"

Problems with the incomplete dependency account

2. Singly-nested clauses in SOV languages are acceptable, even with four or five incomplete dependencies.

Japanese:

Taroo-ga Hajime-ni Akira-ga Hanako-ni Sigeru-o syookai sita to itta

Taroo-nom Hajime-dat Akira-nom Hanako-dat Sigeru-acc introduced that said

"Taroo said to Hajime that Akira introduced Shigeru to Hanako"

Kimball (1973):
The principle of two sentences

Count only incomplete subject-verb dependencies.

Two or fewer incomplete sentences: acceptable

Three or more: unacceptable

Problems for the principle of two sentences

Relative clauses within sentential subjects:

[That the employee [who the manager hired] stole office supplies] worried the executive.

Lewis (1993): Interference between similar X-bar positions

Unacceptability: Three similar incomplete X-bar relationships

E.g., three incomplete spec-IP relationships

Relative clauses within sentential subjects:

[That the employee [who the manager hired] stole office supplies] worried the executive.

Sentential subjects have been argued to be in spec-CP, not spec-IP (Koster, 1978)

Therefore, there are only at most two incomplete spec-IP relationships here, and two incomplete spec-CP relationships

Problems for all earlier theories

1. The acceptability of relative clauses within sentential complements:

   The fact [that the employee [who the manager hired] stole office supplies] worried the executive.

2. The unacceptability of the reverse embedding:

   # The executive [who the fact [that the employee stole office supplies] worried] hired the manager.

Problems for all earlier theories **Nested pronoun generalization** (Bever, 1974; Kac, 1981)

The acceptability of doubly nested RC examples like:

(1) The reporter who everyone that I met trusts said the president won't resign yet. (Bever, 1974)

(2) A book that some Italian who I've never heard of wrote will be published soon by MIT Press. (Frank, 1992)

Cf. (3) # The reporter [who the senator [who John met] attacked] disliked the editor.

A second resource factor: **Syntactic storage**

Syntactic predictions: processing cost for each head that is required to complete the current string as a grammatical sentence

(1) The reporter claimed that **the baseball player would hold out for more money**.

(2) The reporter's claim that **the baseball player would hold out for more money** turned out to be true.

Syntactic storage

- Syntactic predictions: processing cost for each head that is required to complete the current string as a grammatical sentence

  E.g., after processing the word “the” sentence initially, the parser predicts 2 syntactic heads: a noun and a verb.

Syntactic storage

(1) The employee realized that the boss implied that **the company planned a layoff** and so he sought alternative employment.

(2) The employee realized that the implication that **the company planned a layoff** was not just a rumor.

(3) The realization that the implication that **the company planned a layoff** was not just a rumor caused a panic.

RTs in the bold region are fastest in (1), intermediate in (2), and are slowest in (3). (Chen, Gibson & Wolf, in press)

Gibson, Chen & Wolf (in progress): Preliminary Experiment 1 results

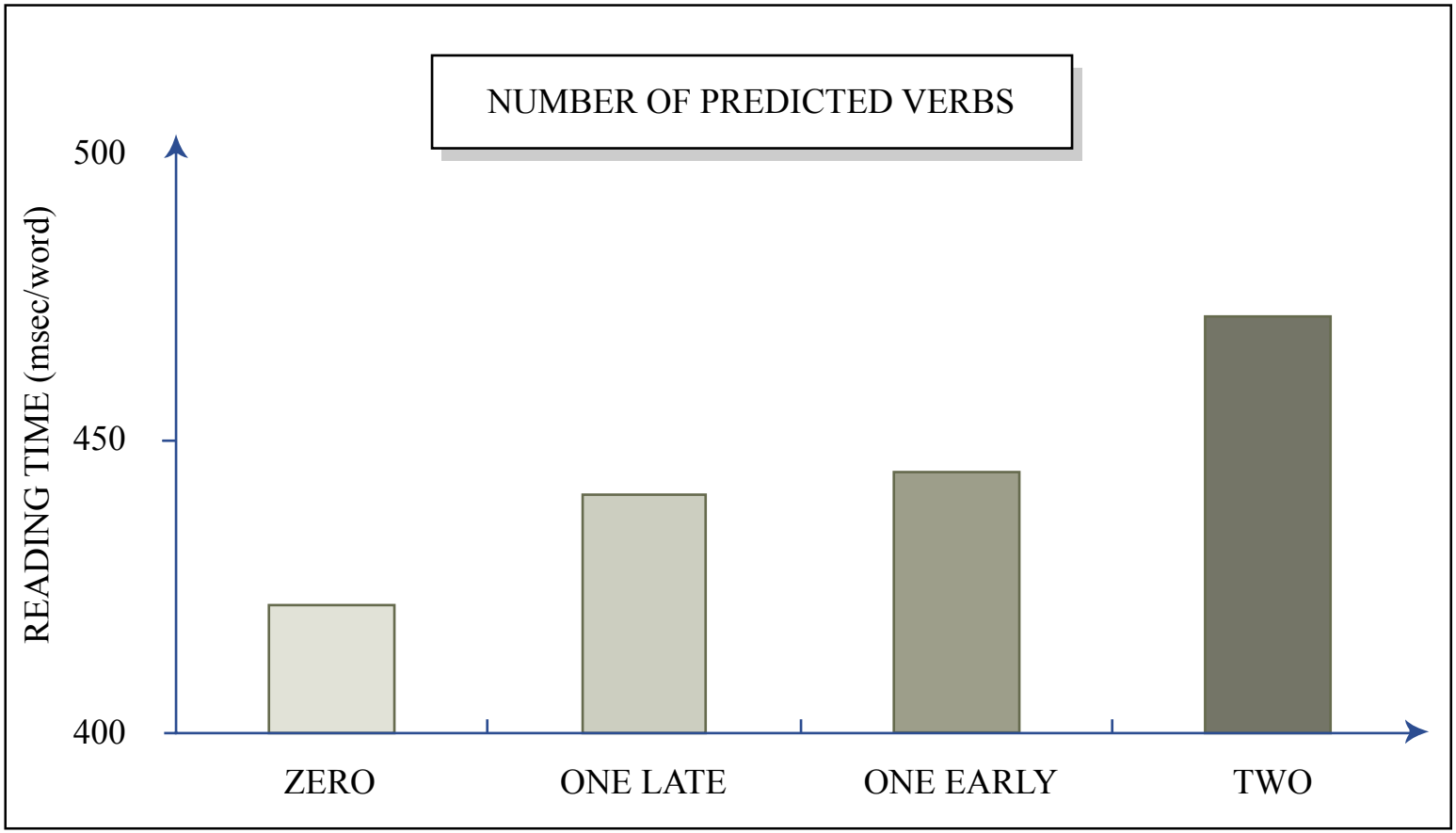


Figure by MIT OCW.

Chen, Gibson & Wolf (in press)

The results from Experiment 1 suggest that there is storage cost associated with predicted verbs / incomplete verbal dependencies.

Predictions of other categories associated with storage cost?

Chen, Gibson & Wolf (in press)
Experiment 2

Do predictions of empty categories in wh-dependencies incur storage costs?

Sentential complement of a noun:

The claim (alleging) that **the cop who the mobster attacked** ignored the informant might have affected the jury.

Relative clause modifying a noun:

The claim which / that **the cop who the mobster attacked** ignored might have affected the jury

Chen, Gibson & Wolf (in press)
Experiment 2 results

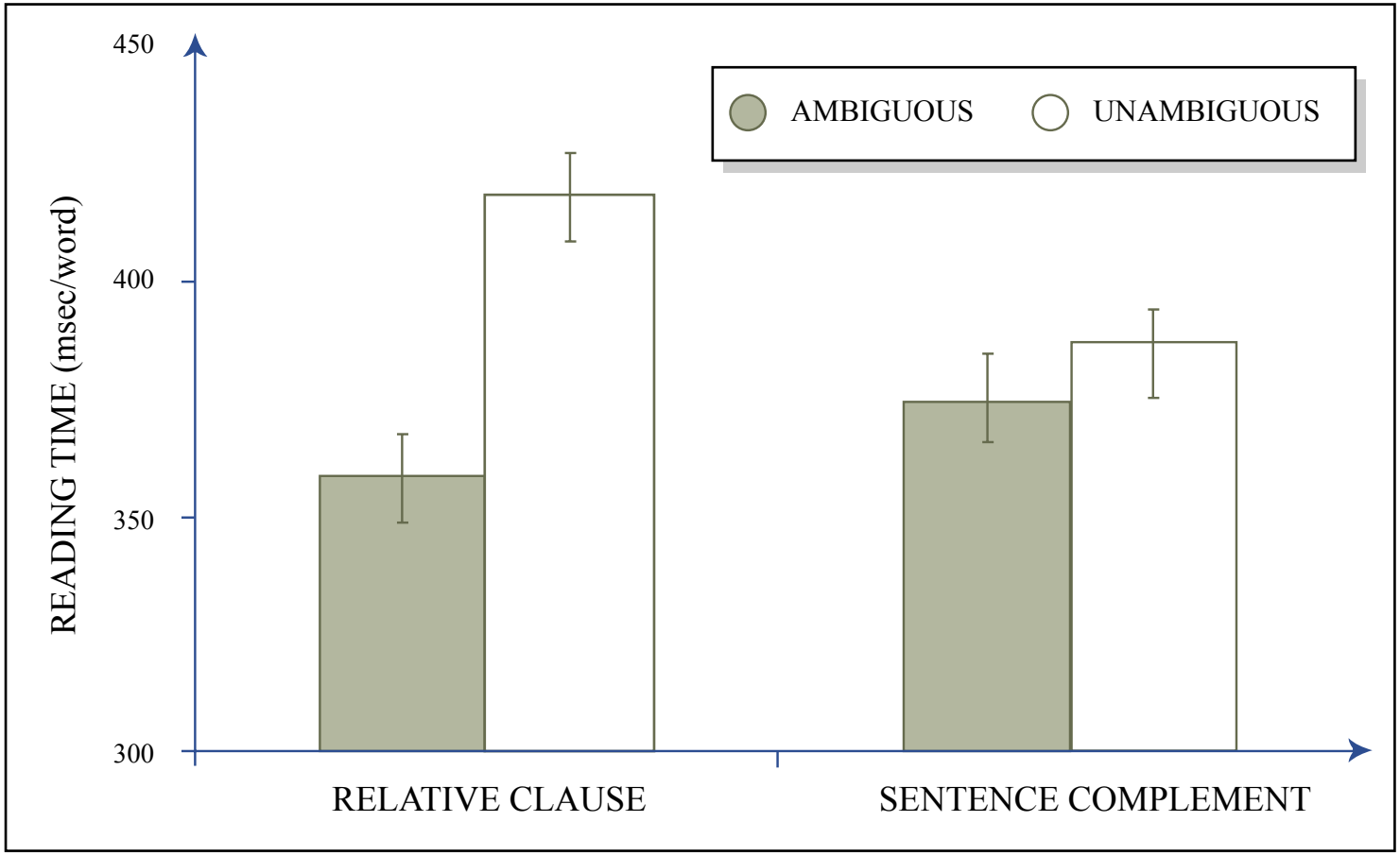


Figure by MIT OCW.

Chen, Gibson & Wolf (in press)
Experiment 2 results

- Unambiguous RCs were read slower than any of the other three conditions

- This result suggests that predicted empty categories in wh-dependencies incur storage costs.

Experiment in progress: Predicted arguments of verbs

Obligatory ditransitive: "give"

Mary gave a book **which had impressed some critics who worked for a magazine** to a young child.

Optional ditransitive: "read"

Mary read a book **which had impressed some critics who worked for a magazine** to a young child.

Unlikely ditransitive: "publish"

Mary published a book **which had impressed some critics who worked for a magazine**.

Results:

Slow during target region for obligatory ditransitive verbs; faster for the other two.

Conclusion: There is a storage cost for the predicted PP argument of verbs like "give".

Experiment in progress: Predicted arguments of verbs

Graph removed for copyright reasons.

Chen, Gibson & Wolf (in press)

Potential explanations of the pattern of data:

- Incomplete clauses? No: Expts 2 & 3 results.

- Incomplete dependencies? OK for these data
  - Incomplete thematic role assignments
- Predicted syntactic heads? OK for these data

- Data from the processing of head-final languages strongly support the predicted-head view (German: Konieczny, 2000; Hindi: Vasishth, 2002; Japanese: Nakatani & Gibson, 2003)

Chen, Gibson & Wolf (in press)

Taken together with the processing results from the literature, the results of Gibson, Chen & Wolf therefore support a syntactic-head prediction theory of syntactic storage over and incomplete-dependency theory.

The results of Experiment 2 can only be accounted for with the inclusion empty categories mediating long-distance dependencies.

Therefore, these results provide **processing evidence in support of the existence of wh-traces in wh-dependencies**.

Another test of resource theories: Chinese Relative Clauses Hsiao & Gibson (2003)

Observation:

Subject-extracted RCs are less complex than object-extracted RCs in English:

The reporter [who the senator attacked] hoped for a good story.

The reporter [who attacked the senator] hoped for a good story

RC complexity processing theories

- Resources: more resources for object-extracted RCs than subject-extracted RCs, both integration and storage.

- Accessibility of syntactic positions: Subject position is more accessible than object position (Keenan & Comrie, 1977)

- Perspective shift: Fewer perspective shifts in subject-extractions (MacWhinney, 1977)

Test case: Chinese RCs

Chinese: Subject-Verb-Object word order, with RCs before the head noun:

Object-extraction:

[Subject-NP V e Comp] NP V NP

[the senator attacked who] the reporter admitted the error.

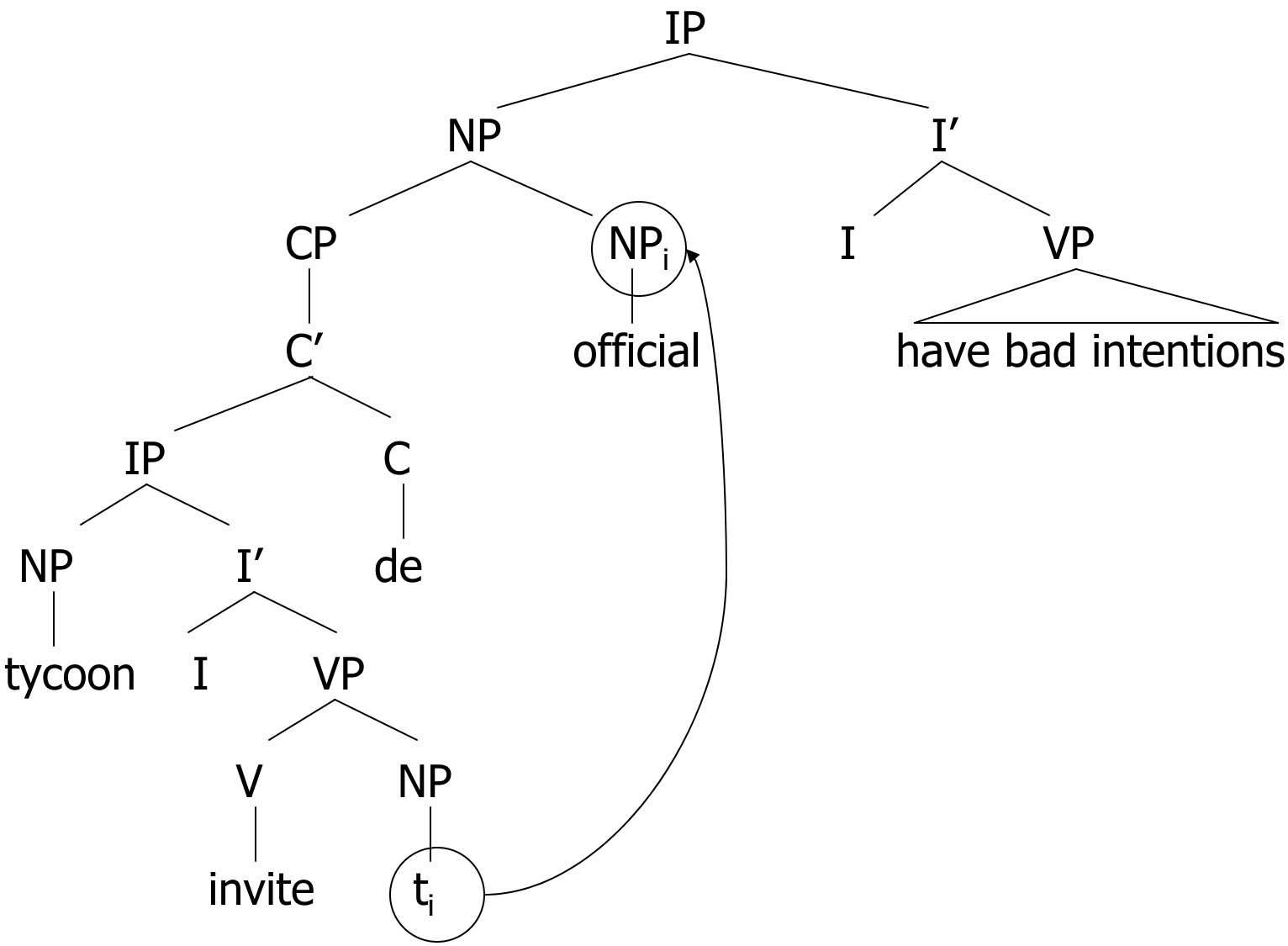
"The reporter who the senator attacked admitted the error."

Subject-extraction:

[e V Object-NP Comp] NP V NP

[attacked the senator who] the reporter admitted the error.

"The reporter who attacked the senator admitted the error.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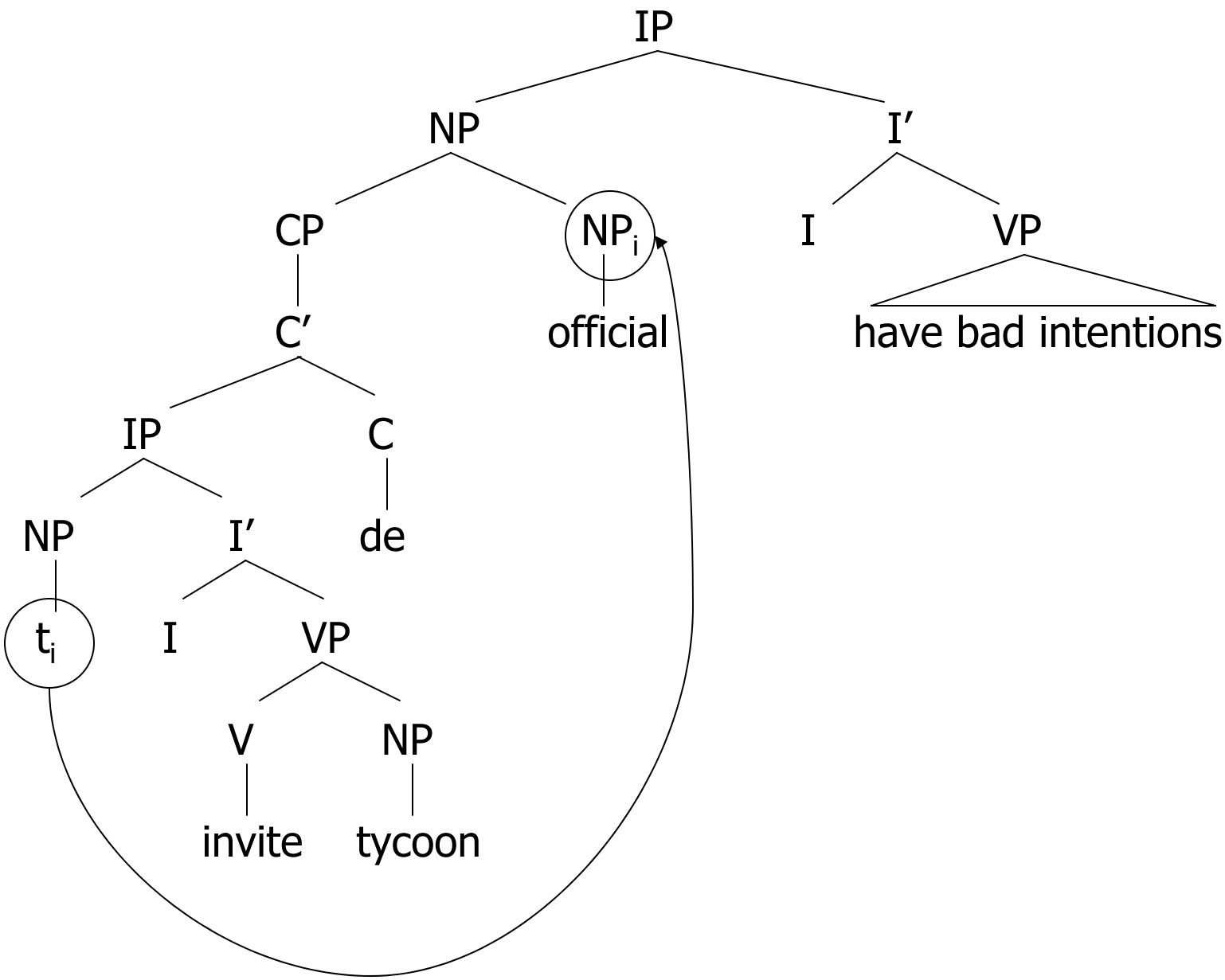
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RC complexity processing theories: Predictions for Chinese RCs

- Resources: more resources for subject-extracted RCs than object-extracted RCs: both integration and storage.

- Accessibility of syntactic positions: Subject-extractions easier than object-extractions

- Perspective shift: Subject-extractions easier than object-extraction

  Note: There is a temporary ambiguity in the object-extracted RC, but less so in the subject-extracted RC. Thus processing evidence for a resource theory would come in spite of potential opposing ambiguity effects.

Hsiao & Gibson (2003): Results for singly-embedded structures

Graph removed for copyright reasons.

Hsiao & Gibson (2003): Doubly embedded structures

Chinese doubly embedded object-extracted RC:

fuhao yaoching t-i de faguan-i gojie t-k de guanyuan-k shinhuaibugui

N1 **V1** **de1** **N2** **V2** **de2** N3 **…**

tycoon invite judge conspire official have bad intentions

'The official who the judge who the tycoon invited conspired with has bad intentions.'

Chinese doubly embedded subject-extracted RC

t-i yaoching t-k gojie faguan de fuhao-k de guanyuan-i shinhuaibugui

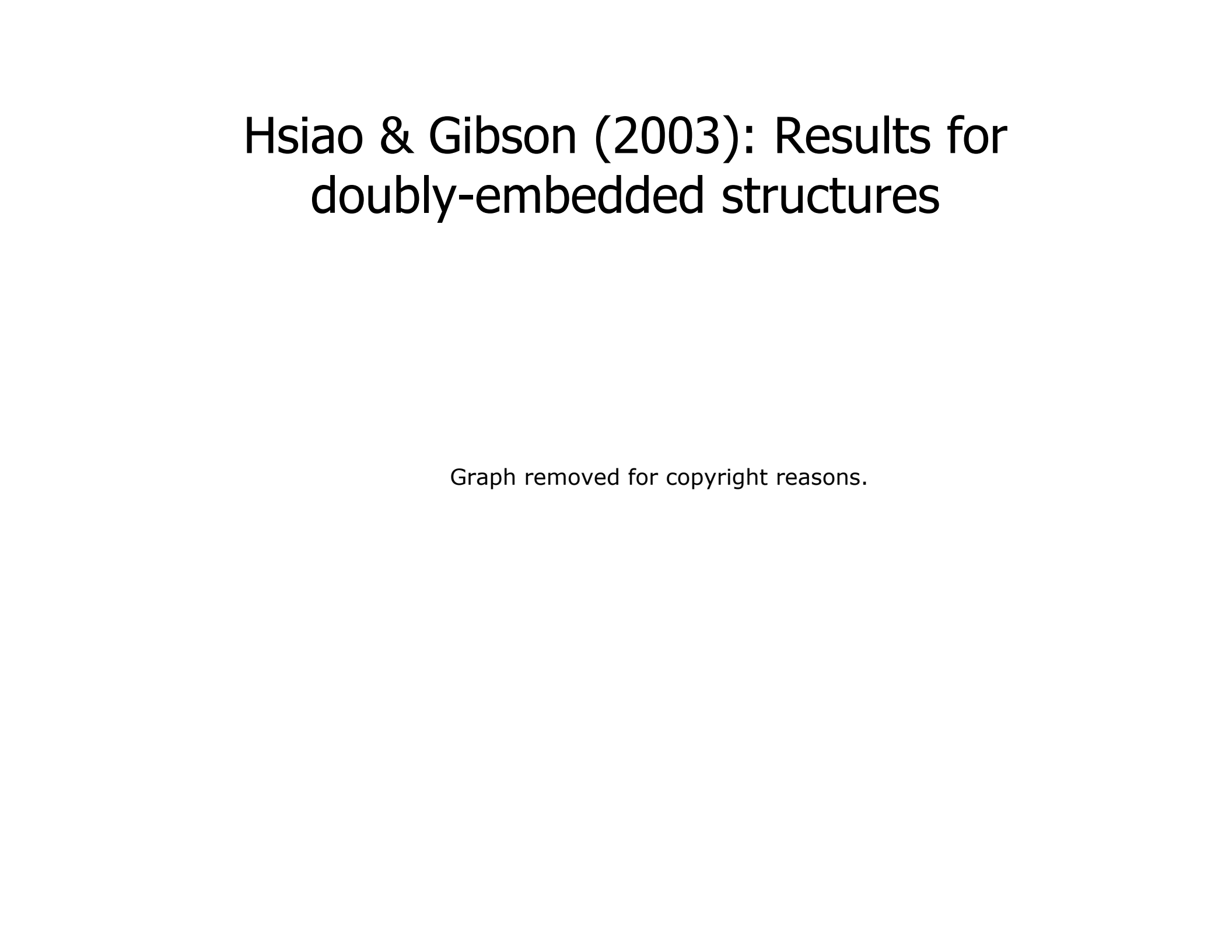
V1 **V2** **N1** **de1** **N2** **de2** N3 **…**

invite conspire judge tycoon official have bad intentions

'The official who invited the tycoon who conspired with the judge has bad intentions.'

Diagrams removed for copyright reasons.

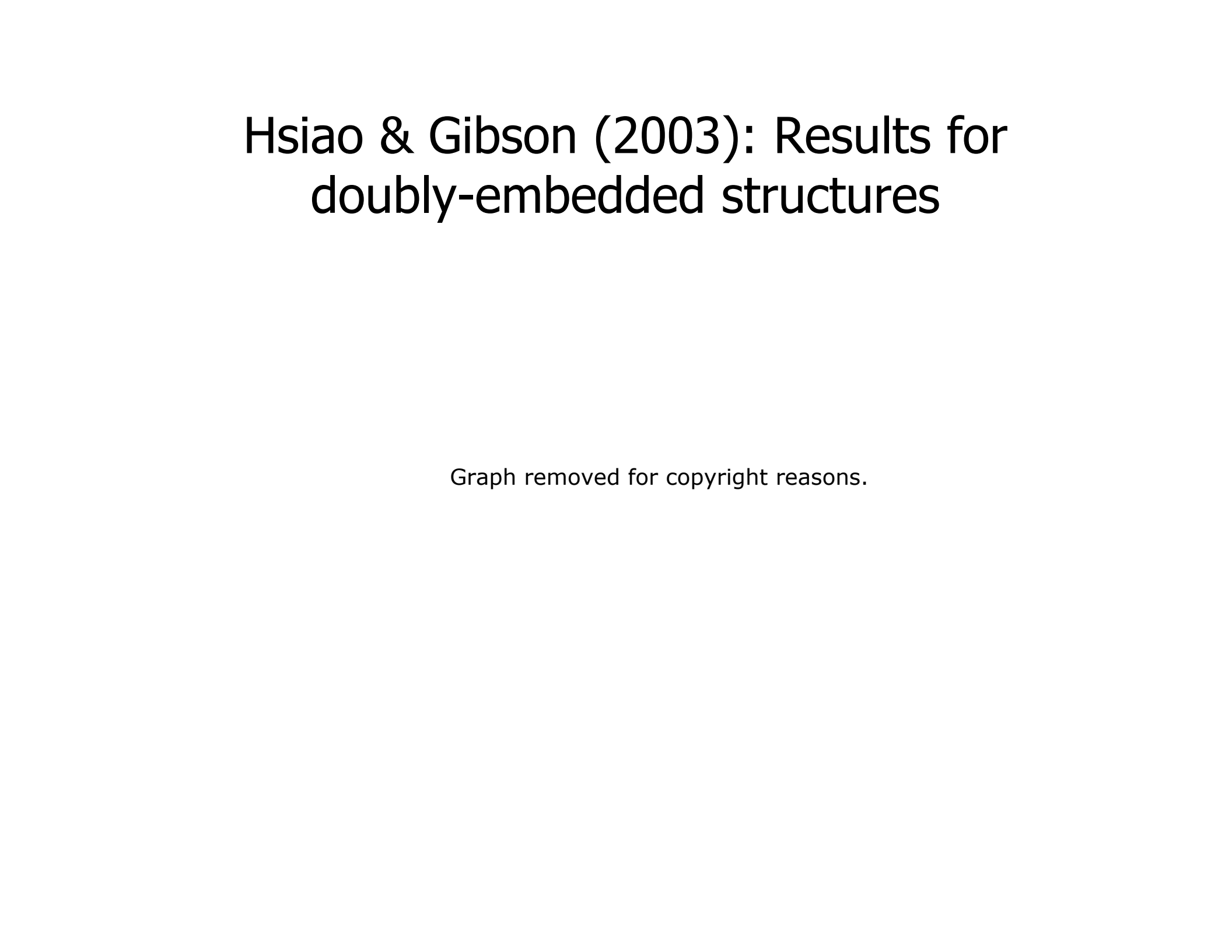
Hsiao & Gibson (2003): Results for doubly-embedded structures



- A potentially confounding influence: different words are being compared in the two conditions.

- Length control: Compute residual RTs

Hsiao & Gibson (2003): Results for doubly-embedded structures



Processing Chinese RCs: Conclusions

- Resource theories account for the pattern of data: Both storage and integration
- These data are also compatible with a canonical-word-order based theory of complexity (e.g., Bever, 1970; MacDonald & Christiansen, 2002)
- Accessibility, perspective-shifts make the wrong predictions
- Consequences for theories of the representation of RCs in Chinese: Probably no operator on the left of a Chinese RC.

Ambiguity resolution

- Minimize integration distances
- Minimize storage costs

- Small differences: easy ambiguity
- Big differences: hard ambiguity

Ambiguity resolution: Storage costs

- Small (no) difference:
  The desert trains young people to be tough.
  The desert trains are tough on young people.

  (Both readings involve local integrations of “trains”.)

  Noun-noun reading of “the desert trains”:
  one category needed to form a sentence : a verb

  Noun-verb reading of “the desert trains”:
  one category needed to form a sentence : a noun

Ambiguity resolution: Storage costs

- Big difference:
  # The cotton clothing is made of comes from Mississippi.

  Noun-noun reading of “the cotton clothing”:
  one category needed to form a sentence : a verb

  Relative clause reading of “the cotton clothing”: three categories needed: two verbs and a position in the relative clause for “cotton”.

Grodner, Gibson & Tunstall (2002): Noun-noun (NN) / Relative clause (RC) ambiguity

Item set 1: Plausibility and frequency factors were biased strongly for the RC:

The tool (which) plumbers need to have is
a good monkey wrench for loosening rusty pipes.

Grodner, Gibson & Tunstall (2002): Noun-noun (NN) / Relative clause (RC) ambiguity

Item set 1: Plausibility and frequency factors were balanced between the RC and the NN:

The alley (which) mice run rampant in is damp and dimly lit but relatively clean.

NN/RC (Grodner et al. 2002)

Graph removed for copyright reasons.

NN/RC (Grodner et al. 2002)

Ambiguity effects for both the balanced items and for the NN-biased items

Conclusion: storage cost is an important factor in resolving ambiguity

NN continuations:

(The) tool plumbers need to have big toolboxes because unforeseen problems often arise on the job.

(The) alley mice run rampant in dark streets because there isn't much traffic there to scare them away.

Application of DLT to the MV/RR ambiguity

The defendant examined …

MV …the evidence.

RR … by the lawyer turned out to be unreliable

Integration costs: both the MV and RR are local integrations.

Application of DLT to the MV/RR ambiguity

The defendant examined …

Storage costs: no difference

MV structure: 1 head is required:

a noun (object of the verb "examined")

RR structure: 1 head is required:

the matrix verb

Application of DLT to the MV/RR ambiguity

The defendant examined …

Integration and storage costs: no differences

Therefore, lexical frequency and plausibility information play a major role in this ambiguity

Application of DLT to the MV/RR ambiguity

MV/RR ambiguity embedded within an RC:

The witness who the defendant examined …

MV: …turned out to be unreliable.

RR: …by the lawyer implicated turned out to be unreliable.

Application of DLT to the MV/RR ambiguity

The witness who the defendant examined …

Storage costs:

MV: 1 head is required:

the matrix verb.

RR: 3 heads are required:

(1) the embedded verb (“implicated”), (2) a gap-site for the wh-pronoun “who”, (3) the matrix verb

Application of DLT to the MV/RR ambiguity

The witness who the defendant examined …

Storage costs: 3 heads vs. 1 head: MV preferred

Control ambiguity:
The witness said that the defendant examined …

Storage costs: 1 head vs. 1 head: no storage cost preference

Application of DLT to the MV/RR ambiguity
Grodner, Gibson & Tunstall (2002)

MV/RR embedded in relative clause:

The witness who the evidence (that was) examined by the lawyer implicated turned out to be unreliable.

MV/RR embedded in a sentence complement:

The witness said that the evidence (that was) examined by the lawyer was unreliable.

Reading times at the disambiguating region "by the lawyer"

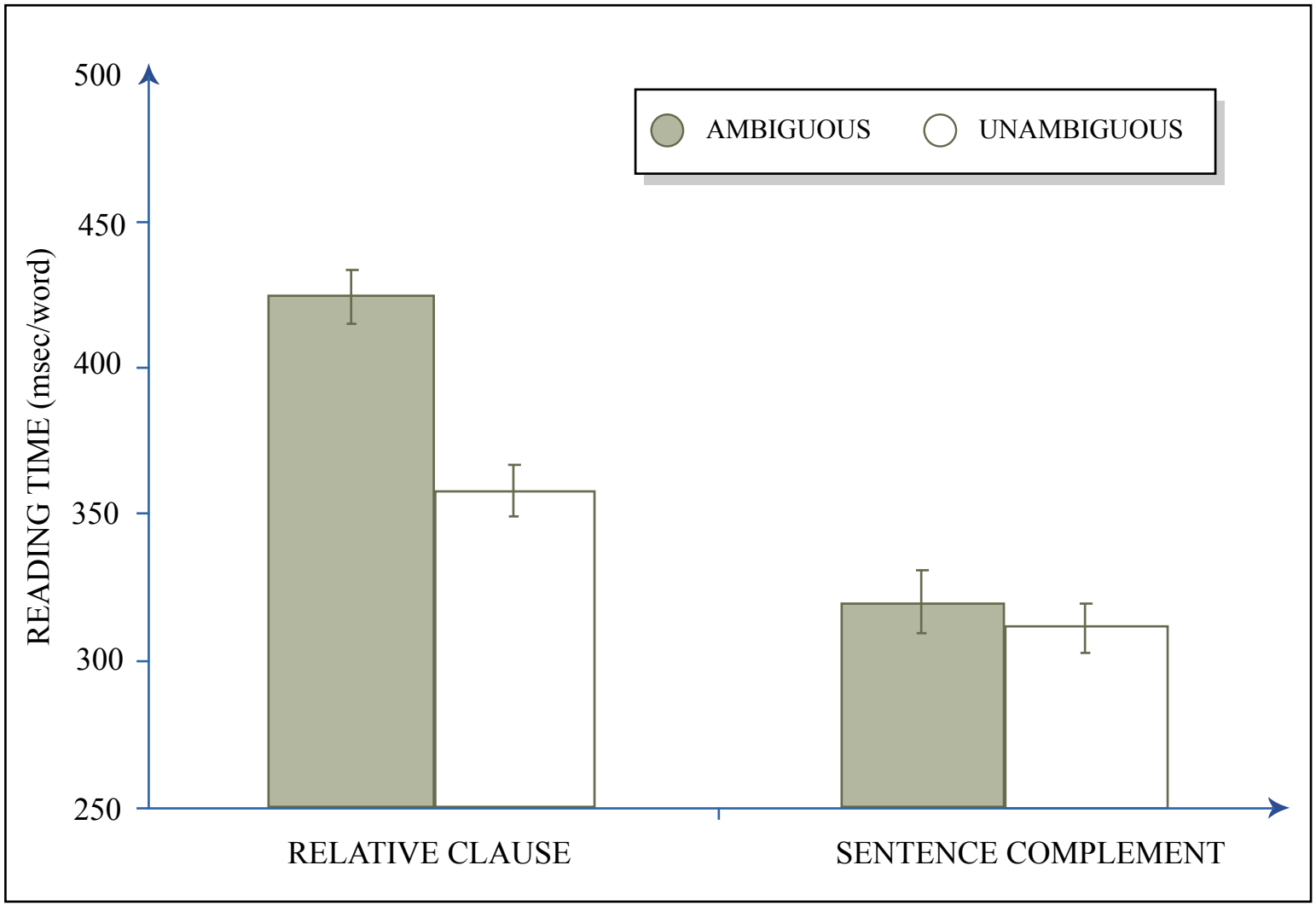
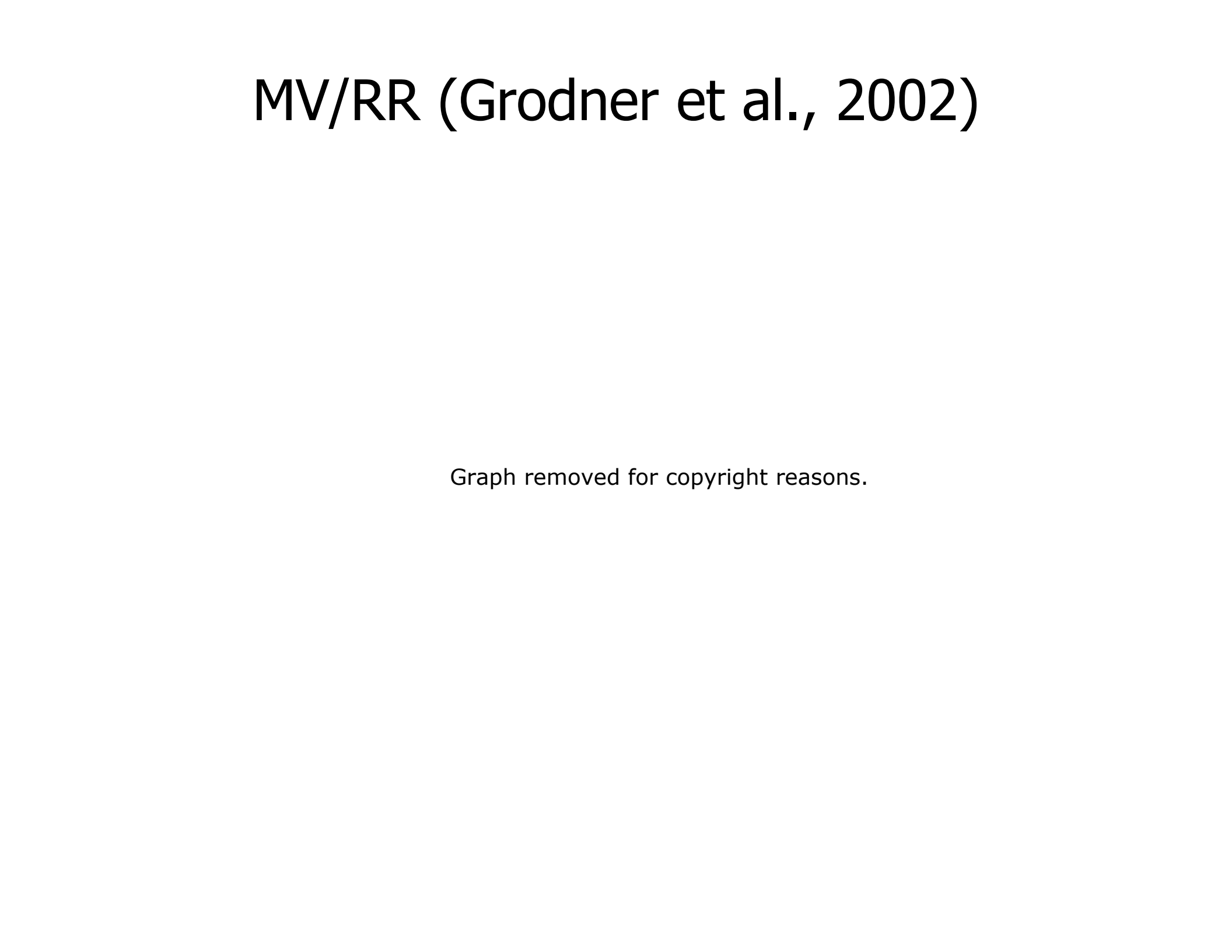


Figure by MIT OCW.

MV/RR (Grodner et al., 2002)



Conclusions

Storage and integration apply in accounting for the processing of both unambiguous and ambiguous structures, including:

- On-line reading times in unambiguous sentences
- The complexity of nested structures cross-linguistically
- Heaviness effects: putting heavy constituents at the end
- Numerous ambiguity effects cross-linguistically

Note: Even though syntactic integrations are being performed, non-syntactic information in the interim affects the complexity of the integrations.

Sentence processing: Summary

- Multiple factors are involved in sentence processing:
  - Syntactic structure:
    - Keep dependencies close
    - Syntactic storage: minimize predicted categories
  - Word frequencies
  - Plausibility of the resultant structures
  - Discourse context
  - Intonation