Quantifiers in Object Postion

Evidence from Sentence Processing

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Quantifiers do not Refer

- A fundamental fact about quantifiers is that they do not refer.
- How do we combine quanifiers with expressions whose conceptual core is that of an n-place relation between individuals?

(1)	Mary laughed.	$L(m)$
(2)	Everybody laughed.	$\forall x[L(x)]$; $^{*}L(\forall x)$
(3)	Mary hates John.	$H(j)(m)$
(4)	Mary hates every boy.	$\forall x[B(x) \rightarrow H(x)(m)]$

Quantifiers and Compositionality

What accounts for the (surface-) distributional uniformity of quantificational and referential DPs (in languages like English)?

- Is the Computational System (CS) sensitive to the *semantic* fact that quantifiers don't refer?
- If so, what are the mechanisms employed by CS to integrate quantifiers into a larger structure?

Quantifiers versus Referring Expressions

Do quantifiers have different combinatorial properties than referring expressions?

- Quantifiers are 2nd order predicates, proper names and definite descriptions are not (e.g. Heim&Kratzer 1998)

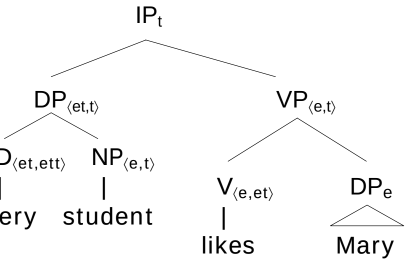
(1)	$[\![$every student$]\!] = \lambda X \in D_{et}.\ X \subseteq \{x\text{: x is a student}\}$	type $\langle$et,t$\rangle$
(2)	$[\![$Mary$]\!]$ = m	type e
(3)	$[\![$the student$]\!] = \iota x$: x is a student	type e

- All DPs are arity-reducing functions, type $\langle e_{n+1}t, e_nt\rangle$ (n = 0,1, ...)
  ex.: $\langle$et,t$\rangle$, $\langle$eet,et$\rangle$, $\langle$eeet,eet$\rangle$,... (Keenan'05)
- All DPs are syntactically type e (Kempson et al '01)

Quantifiers in Object Position (QOb)

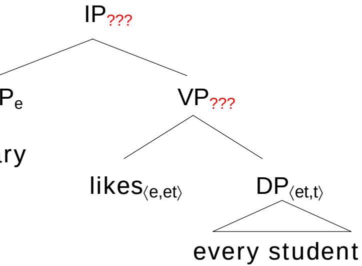
- Quantifiers in subject position take the VP as argument.

(1)



- Quantifiers in object position cannot combine with the verb.

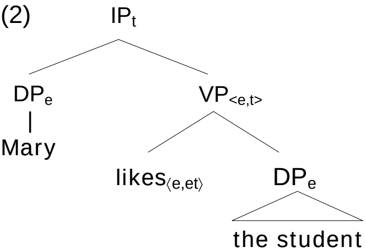
(2)



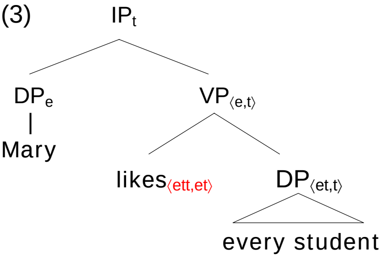
Semantic Solution: Type-shifting

- The type of the verb (or determiner) is shifted so that it can combine directly with a quantifier (or verb).

(2)



(3)



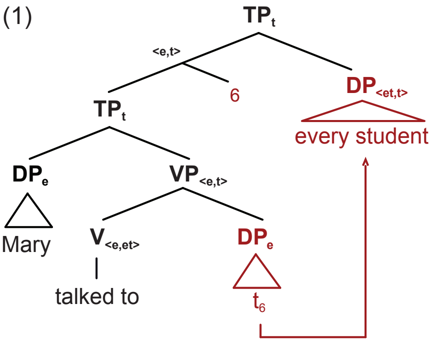
$[\![\text{likes}_1]\!] = \lambda x : x \in D_e . \lambda y : y \in D_e . \text{y likes x.}$

$[\![\text{likes}_2]\!] = \lambda f : f \in D_{\langle ett \rangle} . \lambda y : y \in D_e .$
$f(\lambda x . [\![\textbf{likes}_1]\!](x)(y) = 1) = 1$

Syntactic Solution: Quantifier Raising

- The quantifier is moved by a syntactic operation to the top of the clause (like PL: $\forall x[L(x)(m)]$ not $*L(\forall x)(m)$).

(1)

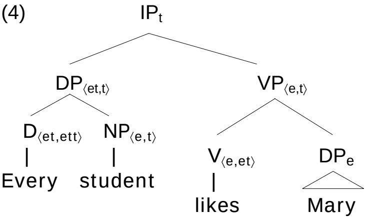


The Rich DP Hypothesis - Keenan 2005

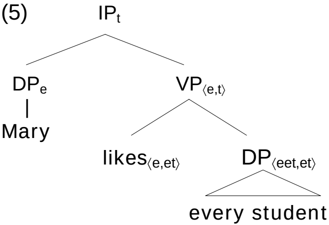
- DPs are arity-reducing functions, type $\langle e_{n+1}t, e_n t\rangle$

(n=0,1,...) ex.: $\langle et, t\rangle, \langle eet, et\rangle, \langle eeet, eet\rangle ...(c.f. Keenan'05)$

(4)



(5)



$[\![\text{every student}_1]\!] = \lambda f: f \in D_{et}.$
$\forall x[(x \text{ is a student} \rightarrow f(x)=1].$

$[\![\text{every student}_2]\!] = \lambda f: f \in D_{eet}. \lambda y: y \in D_e.$
$[\![\textbf{every student}_1]\!](\lambda x. f(x)(y)=1)=1.$

$[\![\text{every student}_3]\!] = \lambda f: f \in D_{eeet}. \lambda y: y \in D_e. \lambda z: z \in D_e.$
$[\![\textbf{every student}_1]\!](\lambda x. f(x)(y)(z)=1)=1.$

The "Simple DP Hypothesis" - Kempson et al. 2001

All DPs (quantificational or not) are of type e. Hence, there is never a case of type mismatch when the CS combines n-place relations of individuals with a quantifier.

- The semantic difference between quantifiers and referring expressions does not affect their combinatorial properties.
- The semantic properties that distinguish quantifiers from referring DPs become only relevant post LF.

(1) $[\![\text{laughed}]\!] = \lambda x \in D_e.\ \text{x laughed}$ type $\langle e,t \rangle$

(2) $[\![\text{smiled}]\!] = \lambda x \in D_e.\ \text{x smiled}$ type $\langle e,t \rangle$

Three Empirical Questions

Are there compositional differences between ...

- Quantifiers in object position and quantifiers in subject positions?
- Quantifiers in object position and definite descriptions in object position?
- Quantifiers in subject position and definite description in subject position?

Plan for the remainder of the talk

Studying processing of quanifiers in real-time can contribute important data that can help sort out these questions.

- Experiment 1a shows that the semantic status of a DP is a factor is local ambiguity resolution during first pass parsing.
- Experiment 2 argues in favor of a syntactic mechanism to resolve QOb and against purely semantic accounts.
- Experiment 3 argues that "transparent" interpretations of object DPs in intensional environments (e.g. look for) are due to the object DP scoping over the intensional verb at LF.
- Appendix I: Experiment 4 shows that indefinite objects can be interpreted in situ even in extensional contexts.
- Appendix II: Experiments 1b,c support the interpretation of the data observed in Experiment 1a.

Local Ambiguity Resolution with Quantifiers

The basic idea

- If quantifiers in object position aren't directly interpretable but quantifiers in subject position are and ...
- if this difference is visible to the parser we expect that
- Subject QPs are easier to process than object QPs.

The Basic Idea: NP/S-Ambiguity Resolution with QPs

- QPs can be a factor in local ambiguity resolution.
- Example: NP/S Ambiguity

```
(1) The judge believed every witness ...
    a.  ...was at the scene of the crime.
    b.  ...who was at the scene of the crime.
```

- A direct comparison of (1)a and b won't be informative!

NP/S-Ambiguity with Quantifiers.

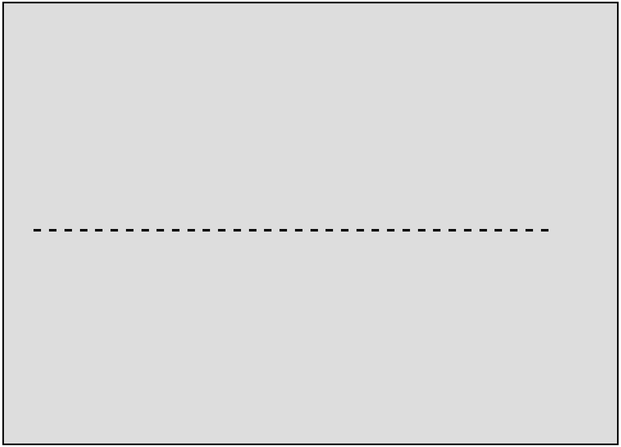
- 2x2 Design: "Determiner by Attachment"

```
(1) The judge believed the witness ...
    a.  ...was at the scene of the crime.
    b.  ...who was at the scene of the crime.

(2) The judge believed every witness ...
    a.  ...was at the scene of the crime.
    b.  ...who was at the scene of the crime.
```

- We expect an interaction between Determiner type and Attachment type: Object QPs should be relatively harder.

Self-Paced Reading



Self-Paced Reading

John -

Self-Paced Reading

`-----talked------------------------`

Self-Paced Reading

```
------------to--------------------
```

Self-Paced Reading

```
---------------every---------------
```

Self-Paced Reading

---------------------boy----------

Self-Paced Reading

```
-------------------------Mary-----
```

Self-Paced Reading

`------------------------------did.`

Self-Paced Reading

- Measures RT as intervals between button presses
- We analyze residual RTs for each word
- Length of rRT is a measurement of processing difficulty for each position (longer rRTs = more processing difficulty)

Self-Paced Reading Studies of QOb

- To get a handle on possible interference from verb preferences (cf. Trueswell et al.'93, etc.) we ran two versions of the experiment:
    - Experiment 1a: S-biased verbs
    - Experiment 1b: NP-biased verbs
- Methods
    - 20 undergraduates from Claremont Colleges, native speakers of English.
    - Single word, self-paced, moving window reading paradigm.
    - 32 target items (8 in each cell), 92 filler items.
    - Each sentence was followed by a comprehension question.

Experiment 1a: S-bias

Materials

- 4 versions of target sentences were constructed as exemplified below.
- S-biased verbs were chosen from Trueswell et al.'93 (verb bias was checked against Brown and Wall Street Journal Corpus of Penn Tree Bank).

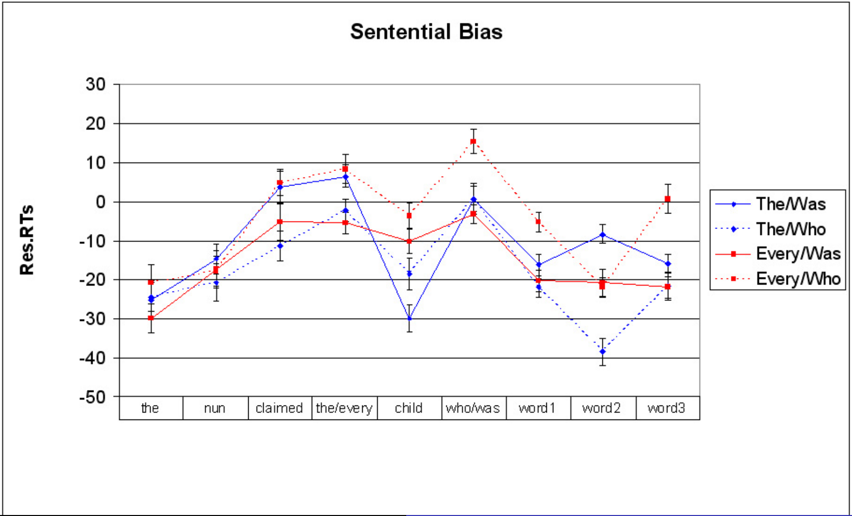
```
(1) The nun claimed the child ...
    a.  ...who was abused and malnourished.
    b.  ...was abused and malnourished.

(2) The nun claimed every child ...
    a.  ...who was abused and malnourished.
    b.  ...was abused and malnourished.
```

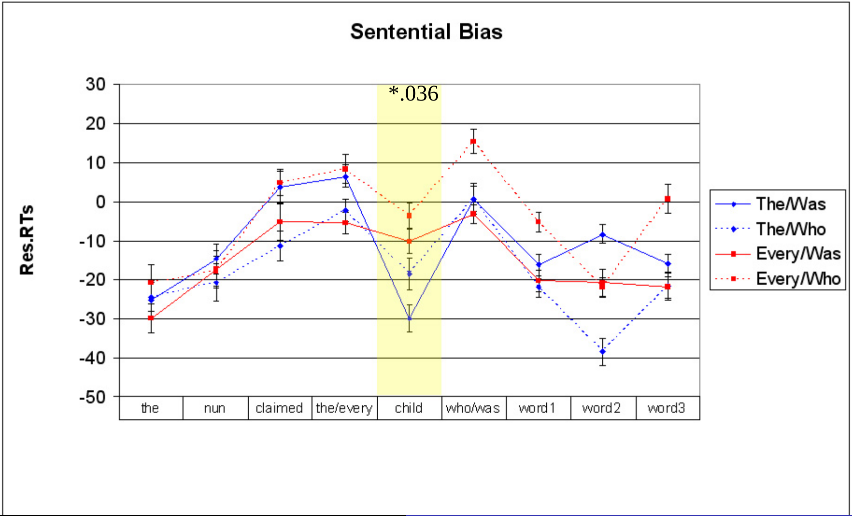
Analysis

- Residual reading times were calculated from sentences whose follow-up question was answered correctly.
- RRTs were trimmed by 3 stdv across subjects.
- Repeated Measures ANOVA on mean RRTs (word by word and across regions).

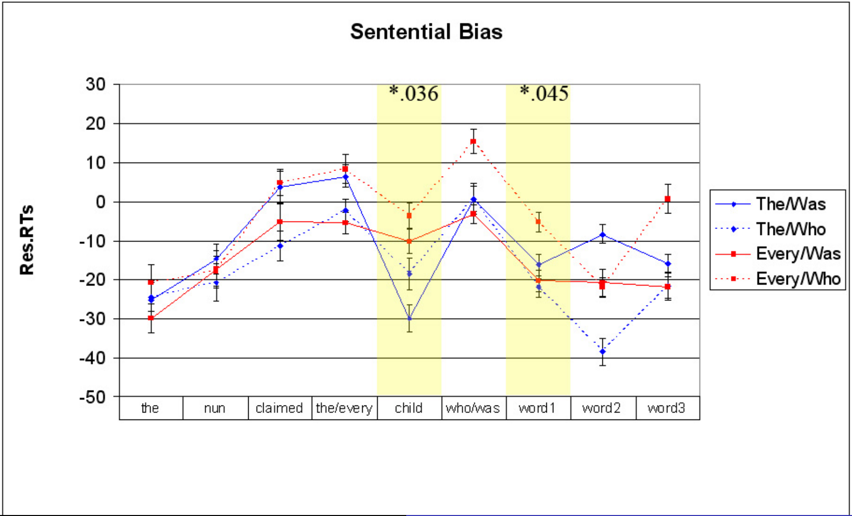
Residual Reading Times: S-Bias



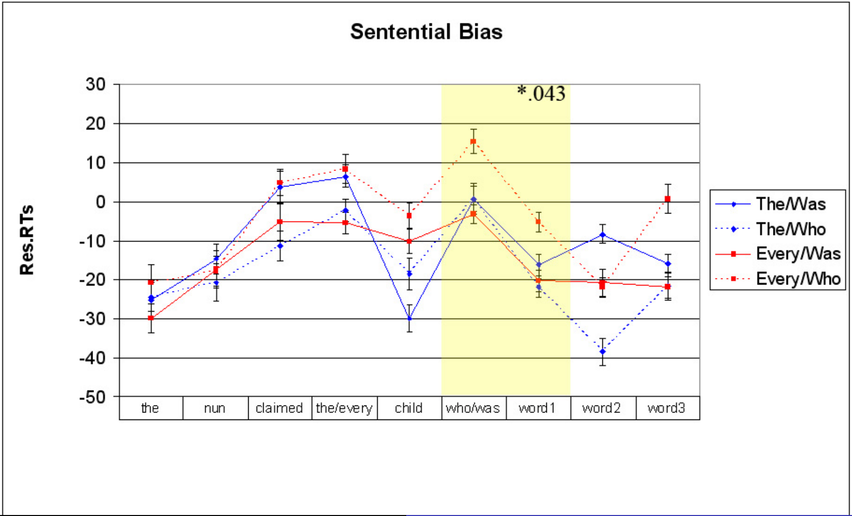
Residual Reading Times: S-Bias



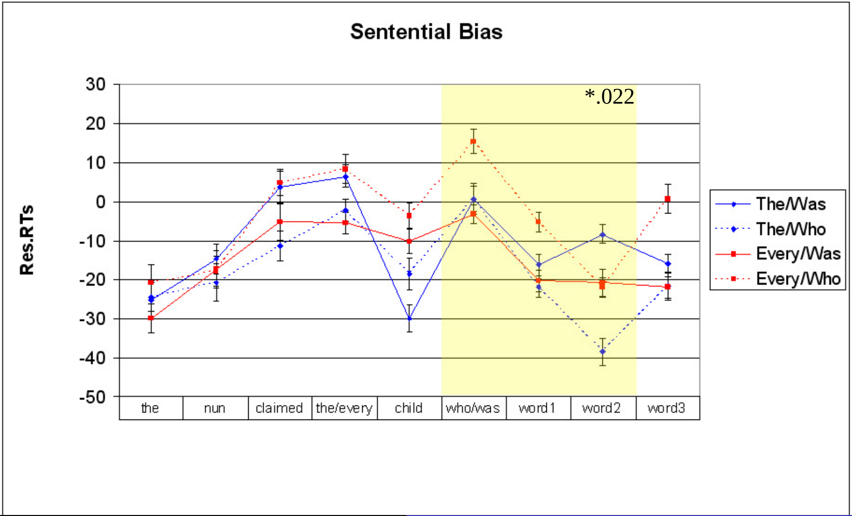
Residual Reading Times: S-Bias



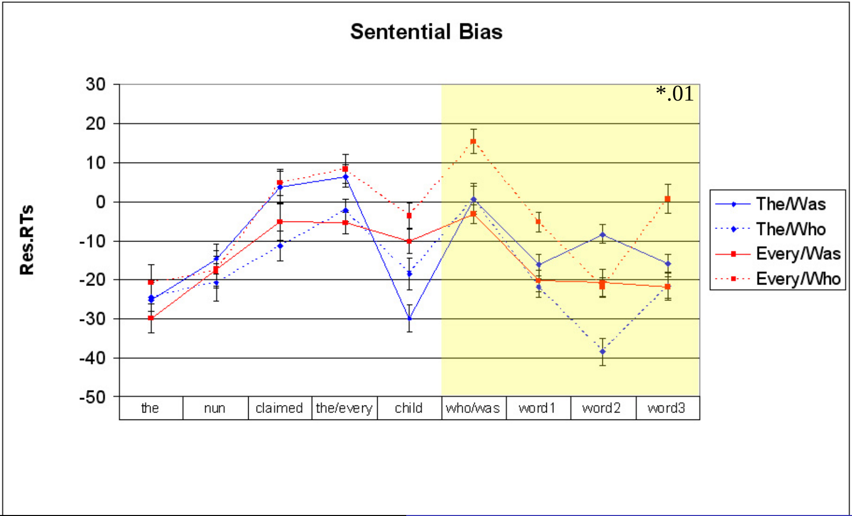
Residual Reading Times: S-Bias



Residual Reading Times: S-Bias



Residual Reading Times: S-Bias



Summary of Results: Experiment 1

Findings of Experiment 1

- Main effect of Determiner Type one word after the determiner.
- Interaction as early as one word after POD.
- Interaction stable over region from POD through three following words.

Summary of QOb processing studies

Conclusions from QOb experiments

- The parser distinguishes definite descriptions from quantifiers in object position.
- Quantifier-hood is a factor in local (first pass) ambiguity resolution.
- These observations are inconsistent with uniform analyses of DPs.

- What is the mechanism by which quantifiers in object position are integrated into the larger structure?

The Paradox of Antecedent Contained Ellipsis

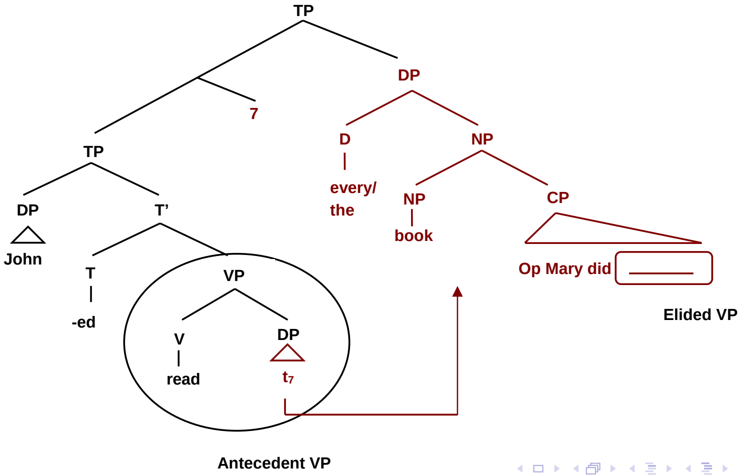
Antecedent Contained Ellipsis (ACE):

(1) John read every book Mary did [____].

(2) John [read every book Mary did [____]].

- An elided constituent can never be identical to its antecedent if the antecedent properly contains the elided constituent!

QR undoes Antecedent Containment



ACE as V-Ellipsis

ACE is a case of V-ellipsis (e.g. Jacobson'94)

(1) John read every book Mary did $\boxed{\_\_\_\_}$.

(2) John $\boxed{\text{read}}$ every book Mary did $\boxed{\_\_\_\_}$.

- There is no paradox since the ellided constituent is never a subconstituent of the antecedent!

Advantages of On-Line Data

Real time sentence processing is sensitive to linear order. The parser encounters the *QOb* trigger for QR before it encounters the **ACE** trigger for QR.

(3) `Mary talked to` **`every`** `student Sue` **`did.`**

- Jacobson: QOb und ACE are independent.
  $\Longrightarrow$ Complexity is additive!
- QR-based: QR to resolve QOb anticipates QR to resolve ACE.
  $\Longrightarrow$ Complexitity is not additive!

Experimental Design

2 Factors: Determiner by Gap Size

The secretary was trained to manage...

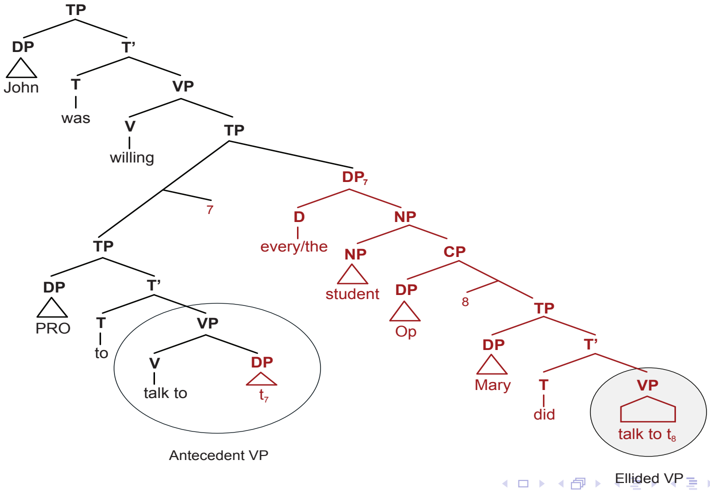
(A) the/every program that the intelligent young professional **designed**

(B) the/every program that the intelligent young professional **did**

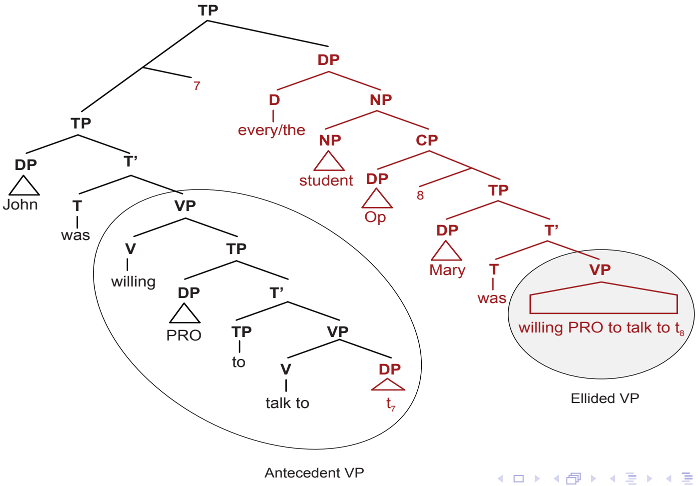
(C) the/every program that the intelligent young professional **was**

...during her four years at college.

Ellipsis size and Locality of QR



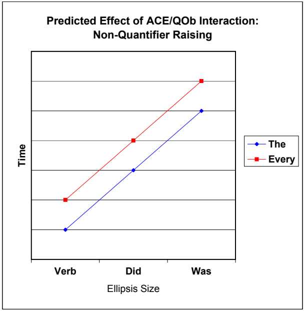
Ellipsis size and Locality of QR



Expected results (non-QR vs. QR)

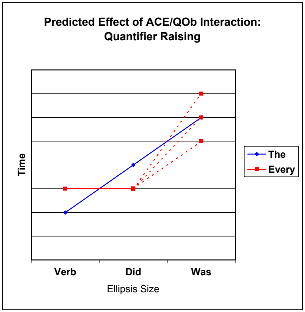
Semantic (NonQR) Analysis: If the mechanisms to resolve QOb and ACE are different, we would expect two main effects:

Ellipsis size - different gap sizes cause linear(?)increase



Expected results (non-QR vs. QR)

Syntactic (QR) Analysis: If QOb and ACE are dealt with in the same manner we predict an interaction between the two variables such that QR will only need to occur once in sentences that have both QOb and (low) ACE



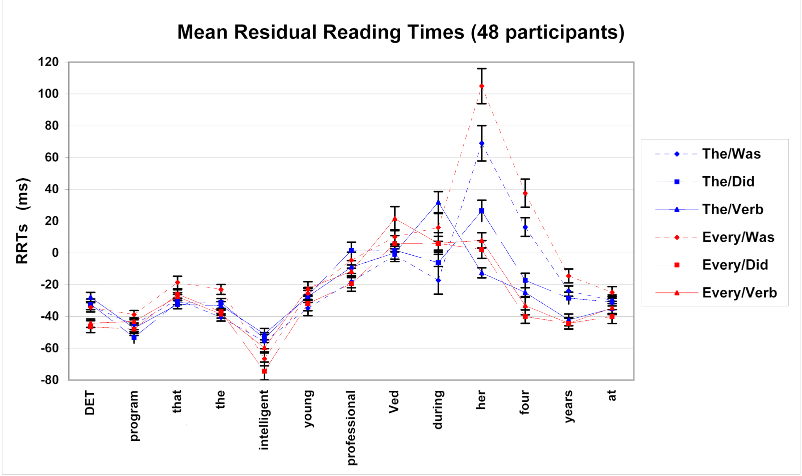
Methods and Materials

- 48 undergraduates from Claremont Colleges, native speakers of English.
- Single word, self-paced, moving window reading paradigm.
- 60 target items (10 in each cell), 120 filler items.
- Each sentence was followed by a comprehension question.

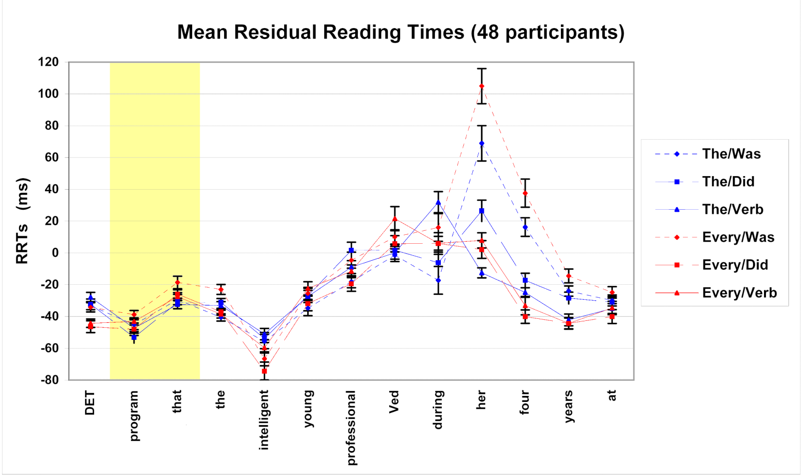
Analysis

- Residual reading times were calculated from sentences whose follow-up question was answered correctly.
- rRTs were trimmed by 2 standard deviations.
- Repeated Measures ANOVA on mean rRTs (word by word and across regions).

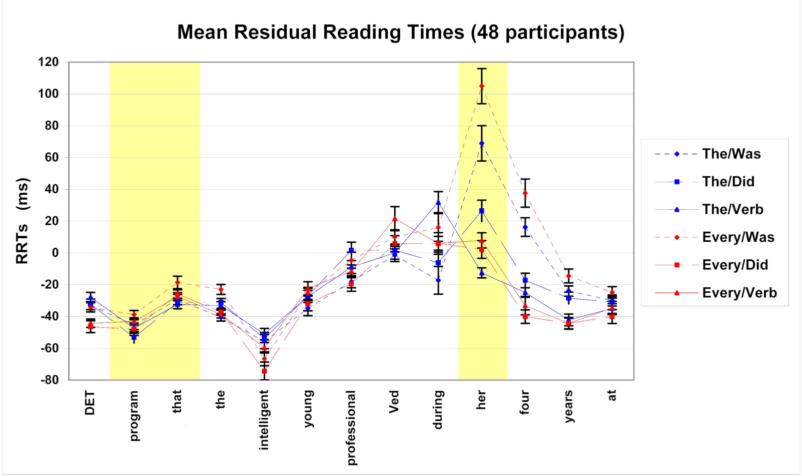
Residual Reading Times: ACE



Residual Reading Times: ACE



Residual Reading Times: ACE

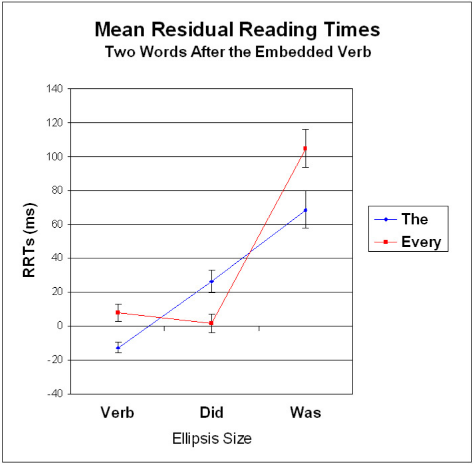


Results

Effects in the areas of interest:

- Main effect of Determiner on two words after determiner.
- Interaction Det. by GapSize on 2nd word after the gap.

Residual reading times two words after gap



Summary of ACE and QOb Experiments

Conclusions

- Uniform analyses cannot explain our processing evidence.
- QOb and ACE are resolved using the same mechanism, quantifier raising (QR).
- QR is local.

Are there “In situ Quantifiers”?

The results of Experiment 2 suggest that we can use the ease with which a down-stream ACE site is processed as indicator for in situ interpretations of DPs.

- If a DP hosting a ACE site stays in situ, we expected increased difficulty for processing the ellipsis site.
- If a DP hosting a ACE site is QR-ed, we expect no additional processing cost for ellipsis site.
  - Strong vs. weak QPs
  - Intensional transitive verbs
  - Wide-scope indefinites

Intensional Transitive Verbs

Intensional transitive verbs like look for give rise to opaque readings for some types of quantifiers.

(1) Mary found a cat.	$\exists x[C(x) \wedge F(x)(m)]$
(2) Mary was looking for a cat.	$\exists x[C(x) \wedge L(x)(m)]$
(3) Mary was looking for a dragon.	$\exists x[D(x) \wedge L(x)(m)]$
(4) Mary was looking for a unicorn.	$\exists x[U(x) \wedge L(x)(m)]$
(5) Mary was looking for every unic.	$\forall x[U(x) \rightarrow L(x)(m)]$
(6) Mary was looking for the unicorn.	$\exists! x[U(x) \wedge L(x)(m)]$

The Quine-Montague Analysis

The classical Quine-Montague analysis of look for exploits the fact that it can be faithfully paraphrased as try to find.

(1) Mary was looking for a screw driver.
(2) Mary was trying to find a screw driver.

(3) $[\![\text{seek}]\!]^{w,g} = \lambda Q \in D_{set,st}.\lambda x.$ x tries for$_{w'}$ Q$_{w'}$(λ w”. λ y. x finds y in w”)(w’)

Opaque and Transparent Readings via Scope

The Quine-Montague analysis explains the transparent/opaque ambiguity in terms of scope.

- If the object is in the scope of try we get the opaque reading.
- If the object scopes higher than try the transparent reading.

(4) $[\![$Mary is looking for a screw driver$]\!]^{w,g} = 1$ *iff*
m tries for$_{w'}$ in w that $\exists$ x [screw driver(x) in w' and m finds x in w']

(5) $[\![$Mary is looking for a screw driver$]\!]^{w,g} = 1$ *iff*
$\exists$ x [screw driver(x) in w and m tries for$_{w'}$ that m finds x in w']

Transparent Readings in situ?

If we assume that world evaluation parameters are realized in the object language as silent world pronouns that can stay unbound (e.g. Percus 2001), we can represent the transparent reading of an object quantifier in situ.

(6) $[\![$Mary is looking for D screw driver$]\!]^{w,g} = 1$ *iff*
m tries for$_{w'}$ in w that D(screw driver in w')(λ y. m finds y in w')

(7) $[\![$Mary is looking for D screw driver$]\!]^{w,g} = 1$ *iff*
m tries for$_{w'}$ in w that D(screw driver in w)(λ y. m finds y in w')

Looking for an Interaction

We can distinguish QR-based approaches to transparent readings under intensional transitive verbs from in situ approaches in terms of their predictions for down-stream ACE resolution.

(1) Mary was looking for a screw driver John was.

- A QR based account of opacity predicts an interaction between the opacity of the object DP and ACE.
- An in situ approach predicts a main effect of ellipsis.

Experimental Design

2 Factors: Determiner by Ellipsis

Mary: Who was looking for what? John: The producer was looking for...

a. an/the/every actress that the director **was**
b. an/the/every actress that the director **wanted**

...before finalizing the casting list.

Table 2

Intensional	every	a	the
Verb	3	1	3 / 1
ACD	3	5	3 / 5

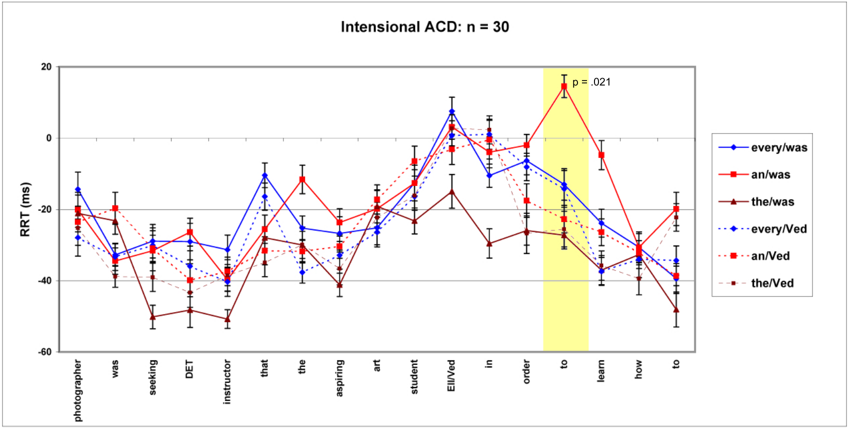
Methods and Materials

- 30 undergraduates from Claremont Colleges, native speakers of English.
- Single word, self-paced, moving window reading paradigm.
- 60 target items (10 in each cell), 120 filler items.
- Each sentence was followed by a comprehension question.

Analysis

- Residual reading times were calculated from sentences whose follow-up question was answered correctly.
- rRTs were trimmed by 2 standard deviations.
- Repeated Measures ANOVA on mean rRTs (word by word and across regions).

Residual Reading Times: Intensional Verbs



Results

Effects in the areas of interest:

- Interaction Determiner by Ellipsis on 2nd word after the gap, $F(2,28) = 4.526$; $p = .021$
- Interaction driven by det*ell for every/the and an/the // ($F(1,29) = 4.805$; $p = .037$, $F(1,29) = 9.224$; $p = .005$)

Summary of Intensional Verb Experiment

Conclusions

- 'Every' and 'the' seem to undergo QR in intensional contexts; 'a' does not
- Definite determiners can behave like quantifiers in certain enviroments
- Transparent readings for DPs and ACE are resolved using the same mechanism, quantifier raising (QR).

Conclusions from Experiments 1 - 3

- The parser's sensitivity to the semantic status of DPs is conditioned by the syntactic environment.
- Quantificational host DPs anticipate ACE resolution downstream.
- "Transparent DPs" (whether they are inherently quantificational or not) anticipate ACE resolution downstream.
- The grammer needs to provide a mechanism (such as QR), which tightly links ...
  - Qob and ACE
  - transparent interpretations of object DPs and ACE

End

Thank You!

Indefinites and Existential Closure

- Indefinites are existential quantifiers (type et,t) and create the same problem as other quantifiers do when they appear in internal argument positions.
  - $\Rightarrow$ Indefinites behave like *every NP*
  - $\Rightarrow$ Facilitation of ACE processing downstream.

- Indefintes are predicates and stay insitu. There is an independent Existential Closure operator contributes the quantificational meaning. (e.g Heim 1982)
  - $\Rightarrow$ Indefintes behave like definites;
  - $\Rightarrow$ No facilitation of ACE processing downstream.

Indefinites as Predicates in situ

(1) The producer was talking to...

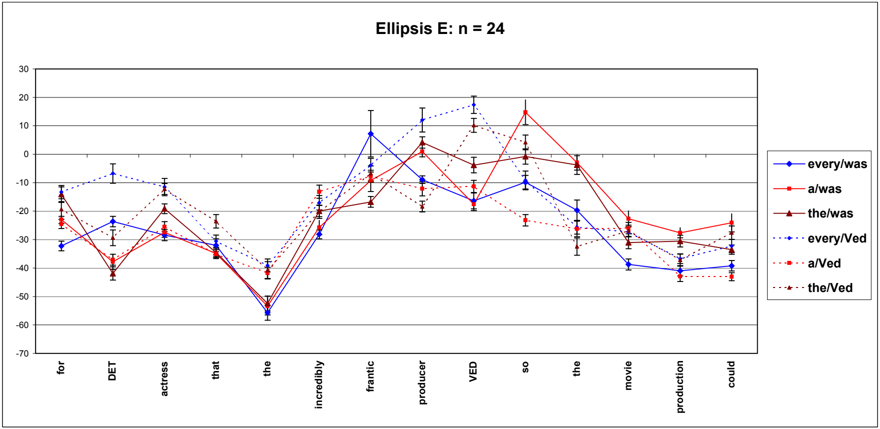
a. an/the/every actress that the photographer **was**
b. an/the/every actress that the p. was **looking for**

...after the scene was completed.

Table 1

Extensional	every	a	the
Verb	3	3 / 1	1
ACD	3	3 / 5	5

Pilot data: Extensional Verbs (n=24)



Follow-up Experiments to Experiment 1a

Additional experiments showing that the parser is sensitive to the semantic status of a DP

- Quantifiers in Object Postion: NP-biased verbs
- Quantifiers in Subject Position

Experiment 1b: NP-bias

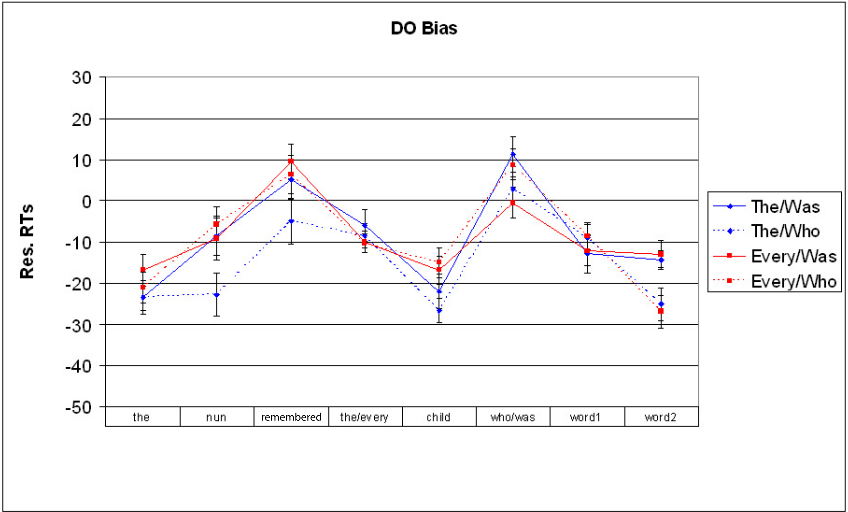
Materials

- Sentence frames as in Experiment 1a.
- NP-biased verbs were chosen from Trueswell et al.'93 (verb bias was checked against Brown and Wall Street Journal Corpus of Penn Tree Bank).

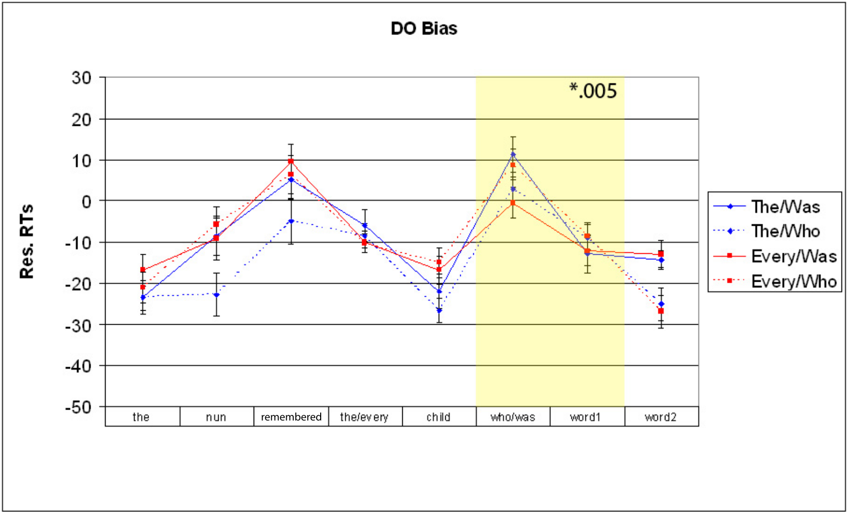
```
(1) The nun remembered the child ...
    a.  ...who was abused and malnourished.
    b.  ...was abused and malnourished.

(2) The nun remembered every child ...
    a.  ...who was abused and malnourished.
    b.  ...was abused and malnourished.
```

Residual Reading Times: NP-Bias



Residual Reading Times: NP-Bias



Summary of Results: Experiment 1b

Findings of Experiment 1b

- Difference on word after the determiner approaches significance.
- Significant Interaction in region including POD and the following word.

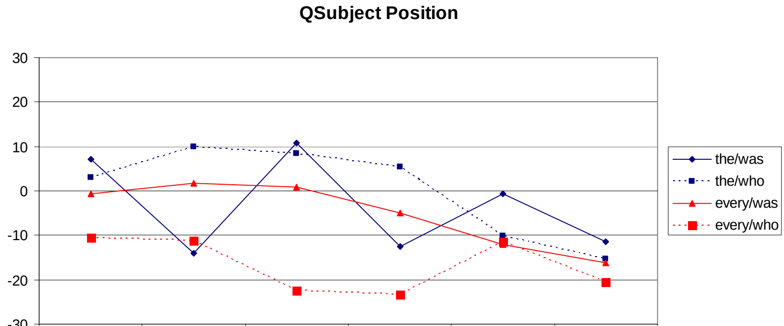
Experiment 1c: Quantifiers in Subject Position

- Sentence frames as in Experiment 1a.
- S-biased verbs were followed by *that* to ensure that he following DP is construed as subject of the embedded clause.

```
(1) The nun claimed that the child ...
    a.  ...who was abused and malnourished ...
    b.  ...was abused and malnourished ...

(2) The nun claimed that every child ...
    a.  ...who was abused and malnourished ...
    b.  ...was abused and malnourished...
```

Residual RTs: Quantifiers in Subject Position (n=20)



	w as	abused	and	malnourished	before	leaving
the/w as	7.188513424	-13.98520408	10.81661518	-12.45696037	-0.626319386	-11.47592475
the/w ho	3.074882471	9.950358662	8.343004989	5.378435139	-10.11338048	-15.38788695
every/w as	-0.642915148	1.650660359	0.827914121	-4.877519825	-12.17037997	-16.08488261
every/w ho	-10.51118896	-11.26208181	-22.36989831	-23.38204092	-11.47651039	-20.4514209

Summary of Results: Experiment 1c

Findings of Experiment 3

- No significant difference across all conditions
- Every/who is not, on its own, more complex, and so could not explain results of Experiment 1 and 2

References

Frazier, L., and Clifton, C. 2005. "The Syntax-Discourse Divide: Processing Ellipsis". *Syntax* 8:2,121 - 174.
Heim, I., and Kratzer, A. 1998. "Semantics in Generative Grammar". Oxford: Blackwell.
May, R. 1977. "The Grammar of Quantification". Doctoral Dissertation, MIT. Cambridge, MA.
Montague, R. 1973. "The Proper Treatment of Quantifiers in Ordinary English". Formal Philosophy ed. Richmond H. Thomason. Yale University Press.
Percus, O. 2001."Constraints on some other variables in syntax". *NALS* 8:173 - 229.
Sag, I. 1976. "Deletion and Logical Form". Doctoral Dissteratation, MIT, Cambridge, MA: MITWPL.
Varvoutis, J., Hackl, M. 2006. "Parsing Quantifiers in Object Position". In preparation.
Williams, E. 1974. "Rule Ordering in Syntax". Doctoral Dissteratation, MIT, Cambridge,MA: MITWPL.
Zimmermann, E. 1993. "On the proper treatment of opacity in certain verbs". *NALS* 1:149 - 179.