

Memory retrieval selectively targets different discourse units

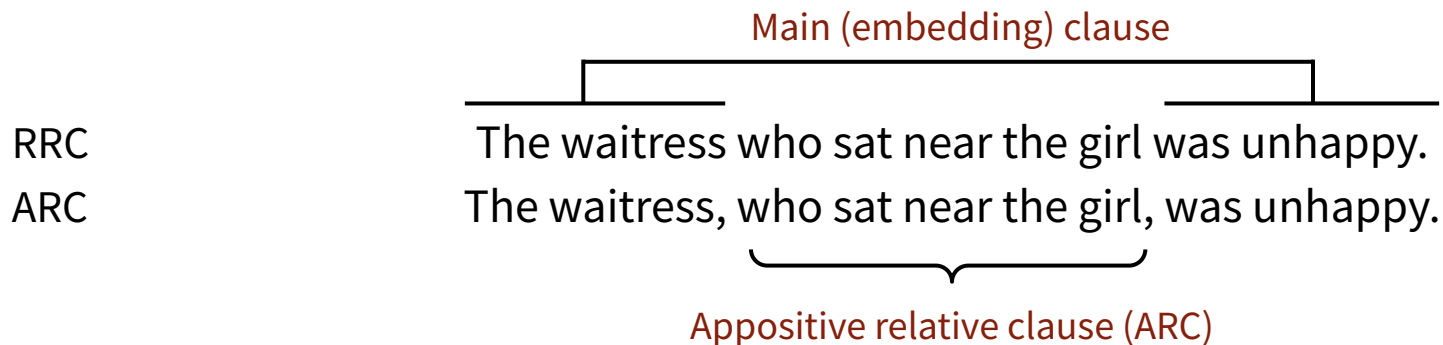
Sanghee J. Kim & Ming Xiang (The University of Chicago)

Annual Meeting of the Society for Human Sentence Processing (UC Santa Cruz, March 24-26, 2022)

Discourse information in working memory

- A large body of work investigated the interaction of working memory and sentence comprehension^[1-5]
- Relatively little work on how discourse information is organized in working memory^[6-8]
- Current study: Does working memory organize distinct discourse units in different ways?
- Case study: Working memory retrieval in processing appositive relative clauses (ARCs) vs. restrictive relative clauses (RRCs)

Characteristics of ARCs



- “Side comments”: not related to the main point of utterance^[e.g., 9]
- “Subordinate discourse unit”: does not push the discourse forward^[e.g., 10]
- Distinct from RRCs syntactically & semantically^[e.g., 11]

Separation between subordinate discourse information (ARC) and main discourse information (main clause) in real-time comprehension?

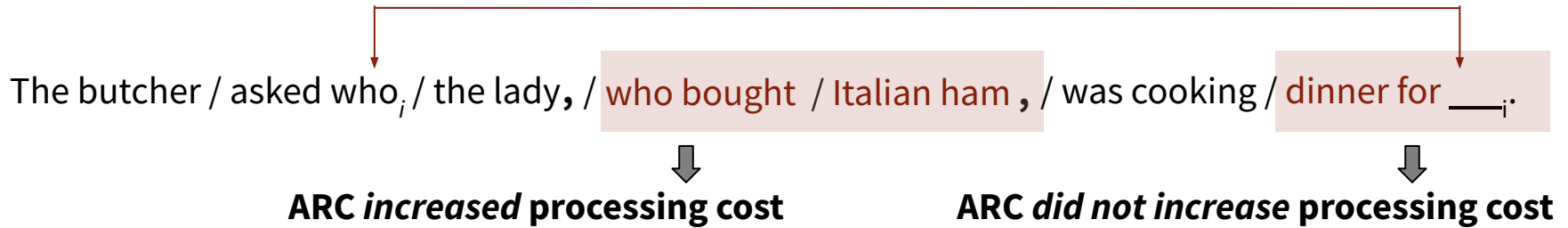
Observations on the interaction between appositives and main clause

➤ Appositives and main clauses do not interact

- Increased syntactic complexity leads to greater processing cost with RRCs; but not with appositives ^[12-13]
- No number agreement attraction effect found with appositives ^[14 (Expt. 1)]
 - (a) RRC
The former mayor *who* hired **the project managers** certainly **were* upset [..]
 - (b) Appositives
The former mayor, the one who hired **the project managers**, certainly **were* upset [..]
- Appositives do not interact with the main clause
- *But, results from the agreement attraction are mixed* ^[14 (Expts. 2-3); 15]

Observations on the interaction between appositives and main clause

➤ Appositives and main clauses are not completely separated^[16]



- Appositives interact with the main clause
- Interactivity is incremental
 - While ARC is being processed ('who bought'): Interaction is present
 - Once ARC has been processed ('dinner for'): No interaction

Current study

Question

- What underlies the variation in the different degrees of interaction between ARC and main clause?
- To what extent do ARCs interfere with the main clause in memory retrieval?

Empirical case study

- Number agreement attraction effect (extending [14])
- Comparison of the effect in RRCs vs. ARCs in English

Current study

Results: Presence of the number agreement attraction effect

- Experiment 1 RRC (yes) ARC (**no**)
 - Experiment 2 RRC (yes) ARC (**yes**)
 - Experiment 3 RRC (yes) ARC (**yes**)
- Appositives and main clauses are not completely separated

Current study

Proposal

- Memory retrieval targets “**active state of discourse question**”
- Framework on how memory retrieval targets distinct discourse units

Experimental Design (Experiments 1-3)

Experiments 1-3

- Self-paced reading tasks (with comprehension question tasks)
- English native speakers

Experiment 1: Subj n=120; Item n=48

Experiment 2: Subj n=96; Item n=48

Experiment 3: Subj n=96; Item n=48

Analysis

- Log reading times (RTs) analyzed with linear mixed-effects regression models

Experiment 1: Design & Material


- 2x2x2 design: Clause type x Distractor noun x Grammaticality
{RRC, ARC} x {Singular, Plural} x {Gramm., Ungram.}
- RRC adopted from Parker & An (2018): Presence of number agreement attraction effect

[RRC] **The waitress** / who / sat / near / the girl(s) / {**was** /***were**} / surprisingly / unhappy ...

Experiment 1: Design & Material

- 2x2x2 design: Clause type x Distractor noun x Grammaticality
{RRC, ARC} x {Singular, Plural} x {Gramm., Ungram.}
- RRC adopted from Parker & An (2018): Presence of number agreement attraction effect

[RRC] **The waitress** / who / sat / near / the girl(s) / {**was** /***were**} / surprisingly / unhappy ...

 **Distractor**

Experiment 1: Design & Material

- 2x2x2 design: Clause type x Distractor noun x Grammaticality
{RRC, ARC} x {Singular, Plural} x {Gramm., Ungram.}
- RRC adopted from Parker & An (2018): Presence of number agreement attraction effect

[RRC] **The waitress** / who / sat / near / the girl(s) / **{was /*were}** / surprisingly / unhappy ...

↑ Grammaticality

Experiment 1: Design & Material

- 2x2x2 design: Clause type x Distractor noun x Grammaticality
{RRC, ARC} x {Singular, Plural} x {Gramm., Ungram.}
- RRC adopted from Parker & An (2018): Presence of number agreement attraction effect

[RRC] **The waitress** / who / sat / near / the girl(s) / {**was** /***were**} / surprisingly / unhappy ...

[ARC] **The waitress** , / who / sat / near / the girl(s) , / {**was** /***were**} / surprisingly / unhappy ...





Clause type



Experiment 1: Design & Material

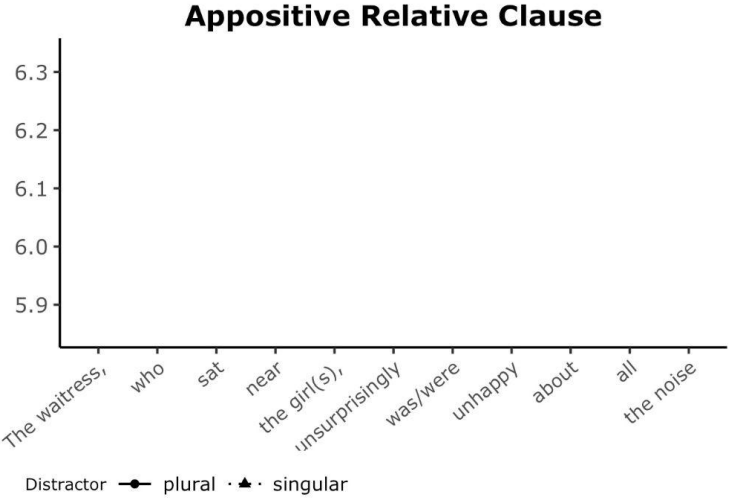
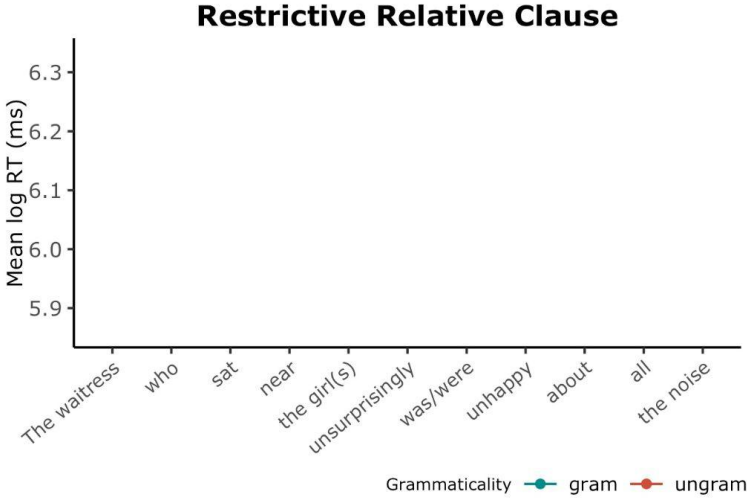
- 2x2x2 design: Clause type x Distractor noun x Grammaticality
{RRC, ARC} x {Singular, Plural} x {Gramm., Ungram.}
- RRC adopted from Parker & An (2018): Presence of number agreement attraction effect

[RRC] **The waitress** / who / sat / near / **the girl(s)** / {**was** /***were**} / surprisingly / unhappy ...
[ARC] **The waitress** , / who / sat / near / **the girl(s)** , / {**was** /***were**} / surprisingly / unhappy ...

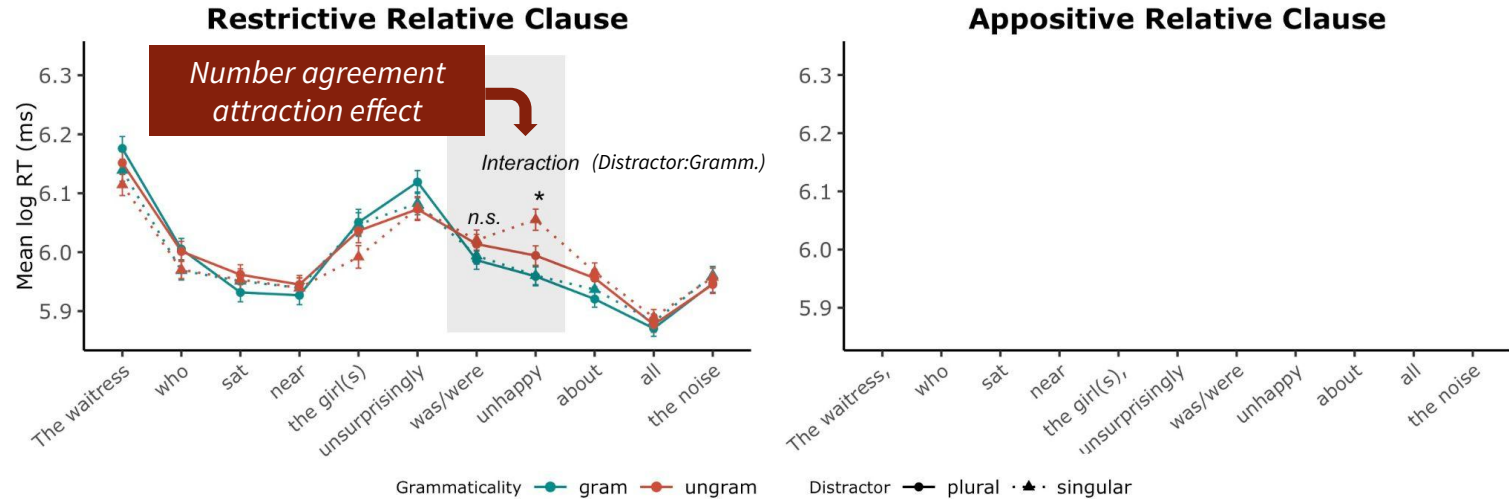
 **Target**  **Distractor**

Would the distractor in the ARC interfere with the target in the main clause?

Experiment 1: Results (split by Clause)



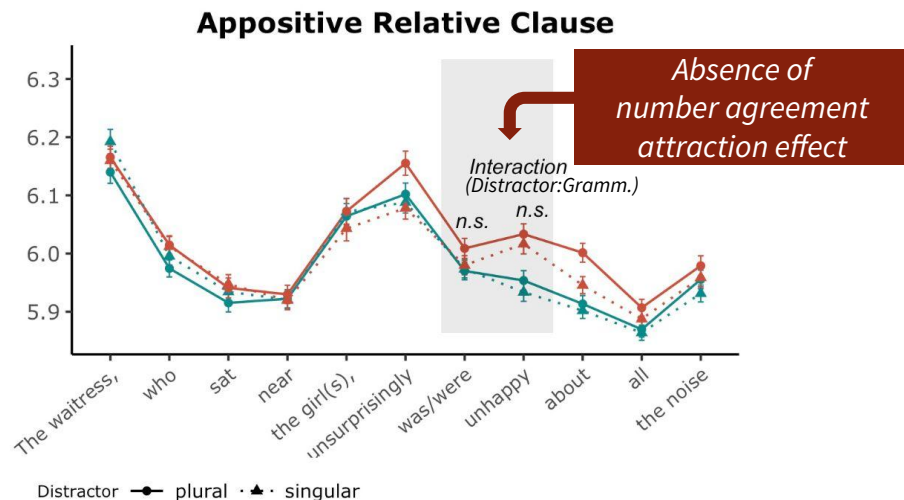
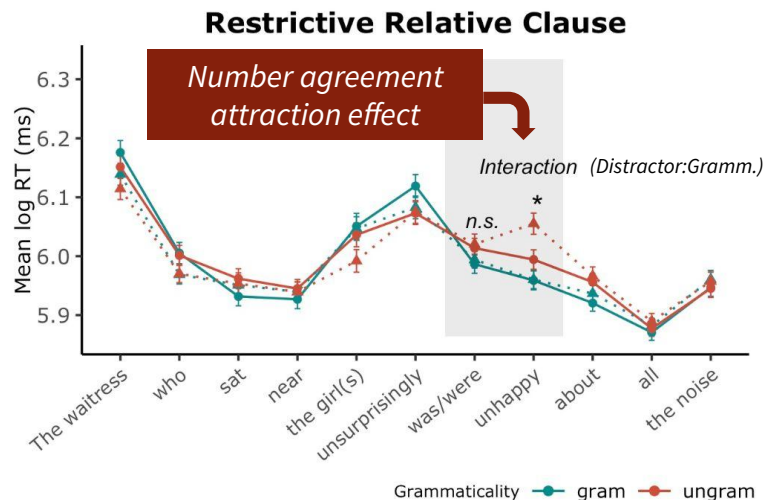
Experiment 1: Results (split by Clause)



Within RRC

- Distractor:Gramm. ($\beta=0.012$, $se=0.006$, $t=2.024$)
- Grammaticality ($\beta=-0.029$, $se=0.006$, $t=-4.537$)

Experiment 1: Results (split by Clause)



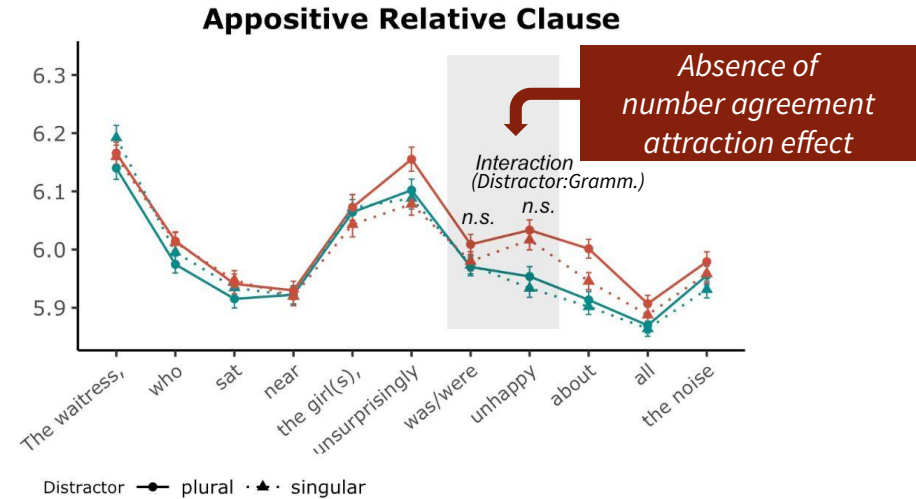
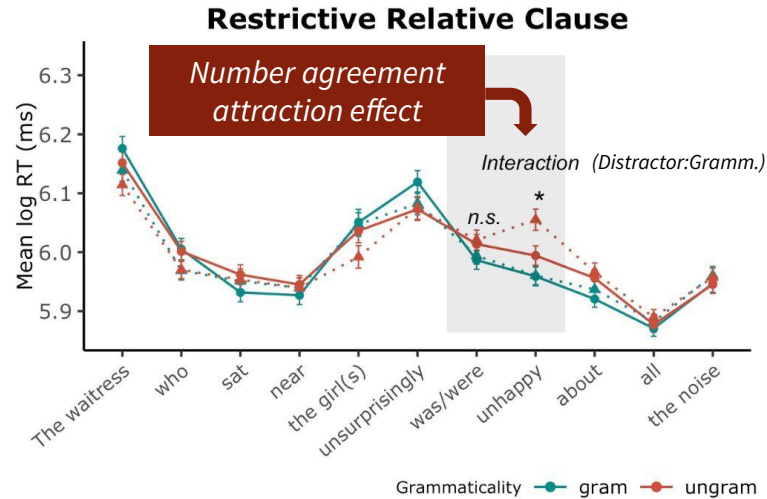
Within RRC

- Distractor:Gramm. ($\beta=0.012$, $se=0.006$, $t=2.024$)
- Grammaticality ($\beta=-0.029$, $se=0.006$, $t=-4.537$)

Within ARC

- Distractor:Gramm. ($\beta=0.003$, $se=0.006$, $t=0.534$)
- Grammaticality ($\beta=-0.036$, $se=0.006$, $t=-6.020$)

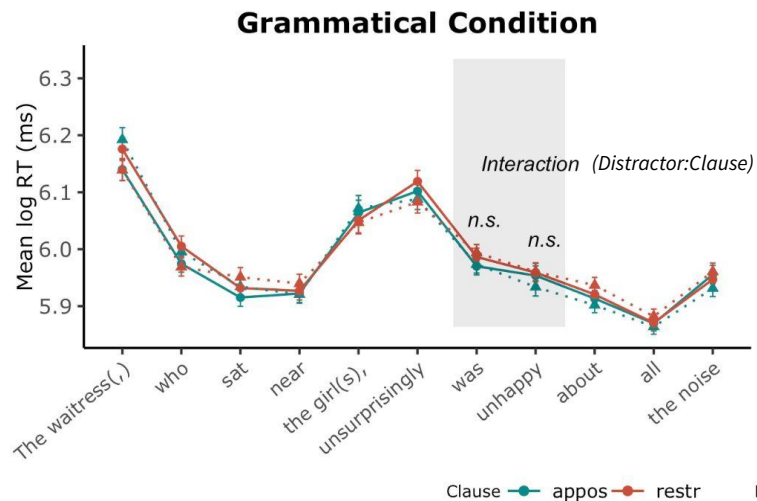
Experiment 1: Results (full model)



Full model

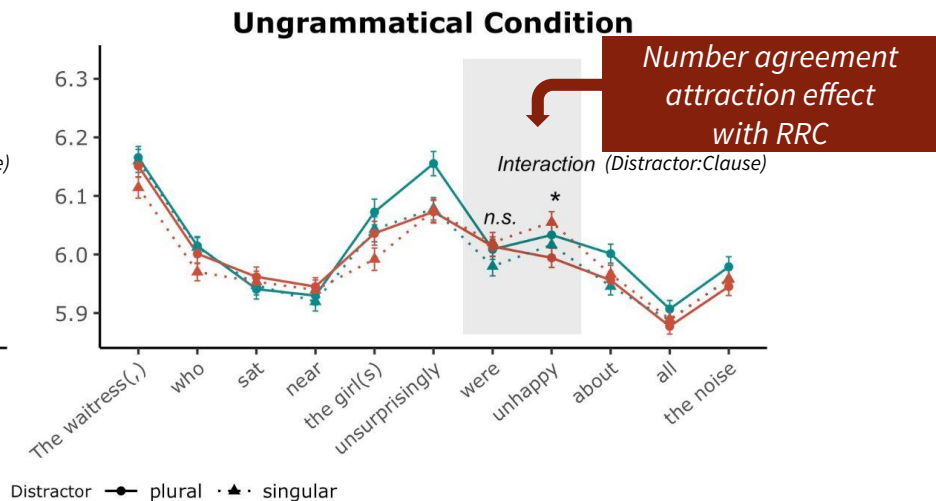
- Grammaticality ($\beta=-0.033$ $se=0.006$, $t=-5.768$)
- Clause:Distractor ($\beta=0.009$, $se=0.004$, $t=-2.083$)
- Clause:Distractor:Grammaticality $\beta=-0.004$, $se=0.004$, $t=-1.034$)

Experiment 1: Results (split by Grammaticality)



Within Grammatical condition

- Clause:Distractor ($\beta=0.005$, $se=0.006$, $t=0.871$)



Within Ungrammatical condition

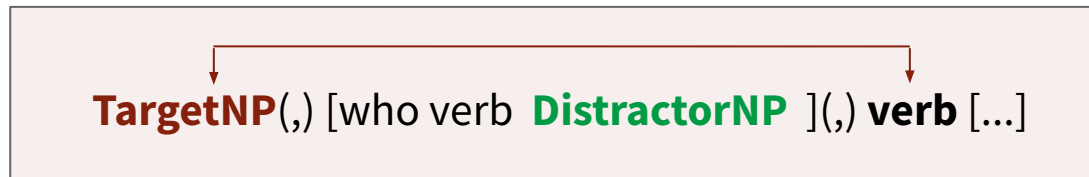
- Clause:Distractor ($\beta=0.013$, $se=0.006$, $t=2.149$)

Experiment 1: Summary

- Number agreement attraction effect **only in RRC** and **not in ARC** (replicating [14])

Complete separation between ARC and main clause?

- Current design:



- Direction of interference: ARC (Distractor) → Main clause (Target)

What if the direction of interference changes?

Experiment 1

TargetNP(,) [who verb **DistractorNP**](,) **verb** [...]



- RC unit (Distractor) → Main clause unit (Target)

Experiment 2

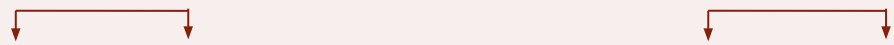
DistractorNP(,) [who **TargetNP verb**](,) verb [...].



- Main clause unit (Distractor) → RC unit (Target)
- Open dependency from the matrix clause

Experiment 3

Subject verb **DistractorNP**(,) [who **TargetNP verb** [...]].



- Main clause unit (Distractor) → RC unit (Target)
- No open dependency from the matrix clause

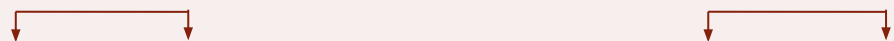
Would the distractor in the main clause interfere with the target in the ARC?

Experiment 2


DistractorNP(,) [who **TargetNP verb**](,) verb [...].

- Main clause unit (Distractor) → RC unit (Target)
- Open dependency from the matrix clause

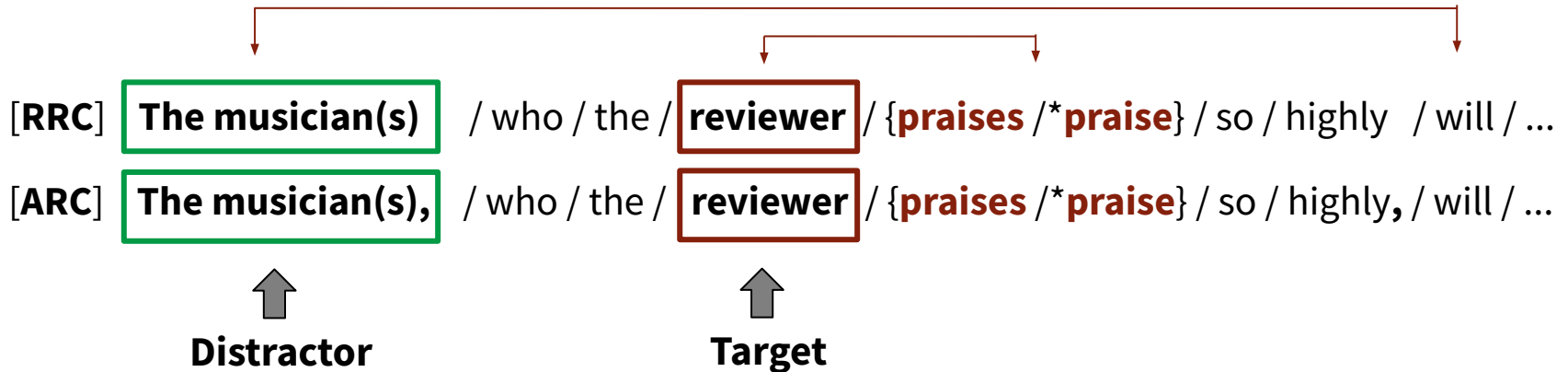
Experiment 3


Subject verb **DistractorNP**(,) [who **TargetNP verb** [...]].

- Main clause unit (Distractor) → RC unit (Target)
- No open dependency from the matrix clause

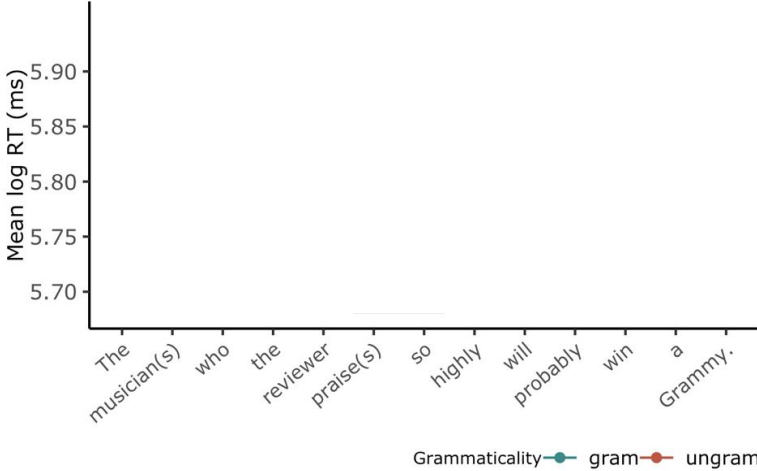
Experiment 2: Design & Material

- 2x2x2 design: Clause type x Distractor noun x Grammaticality
{RRC, ARC} x {Singular, Plural} x {Gramm., Ungram.}
- RRC adopted from Wagers et al. (2009): Presence of number agreement attraction effect

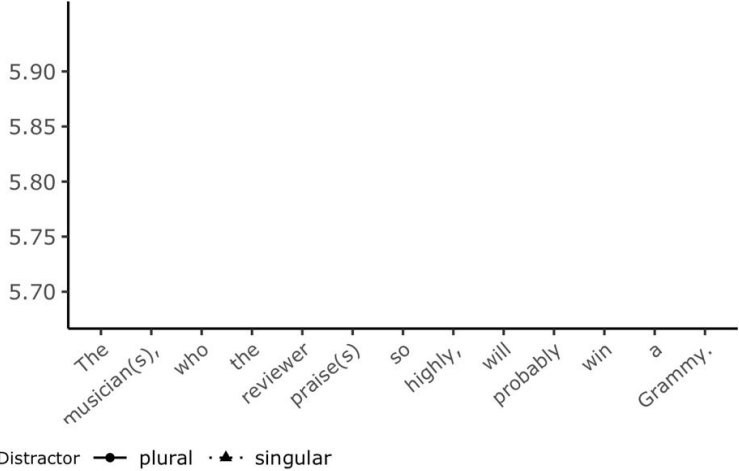


Experiment 2: Results

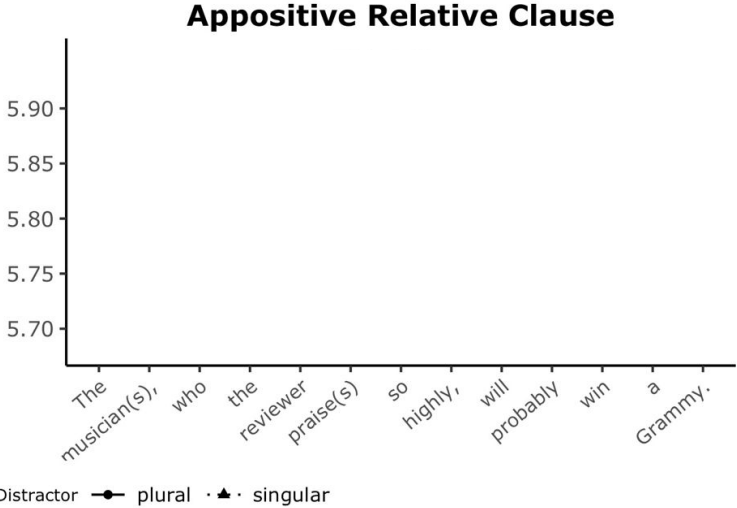
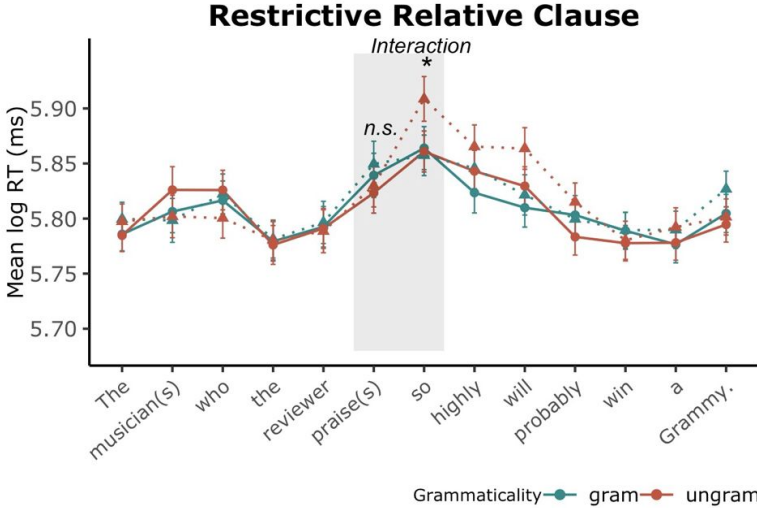
Restrictive Relative Clause



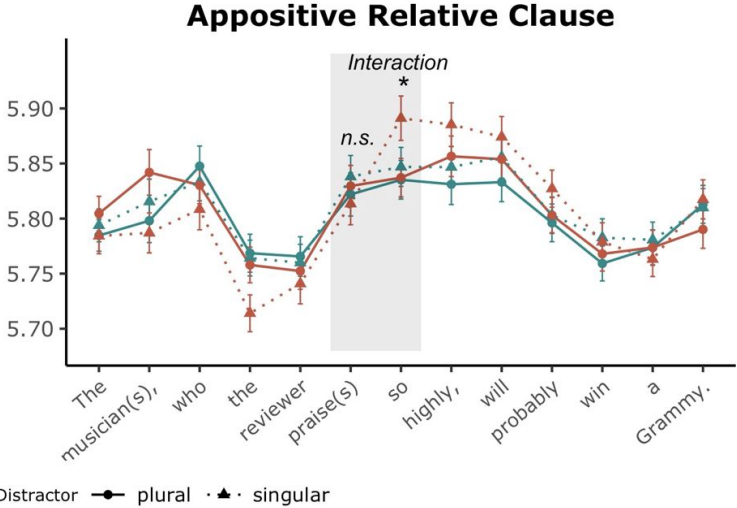
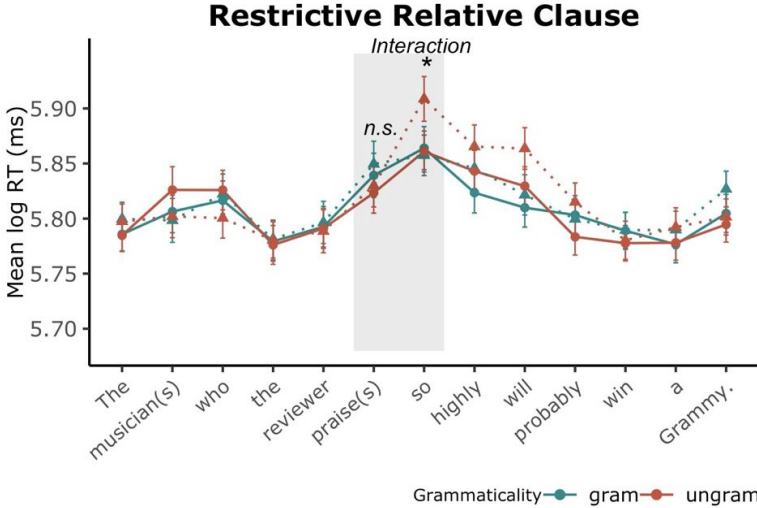
Appositive Relative Clause



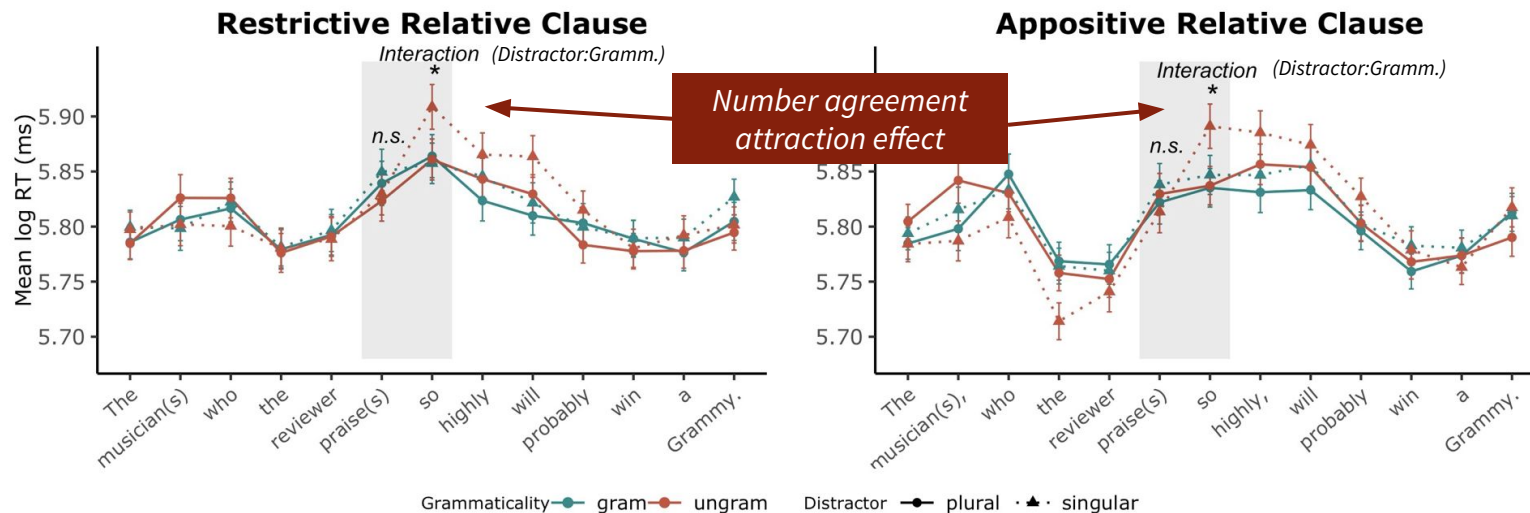
Experiment 2: Results



Experiment 2: Results



Experiment 2: Results



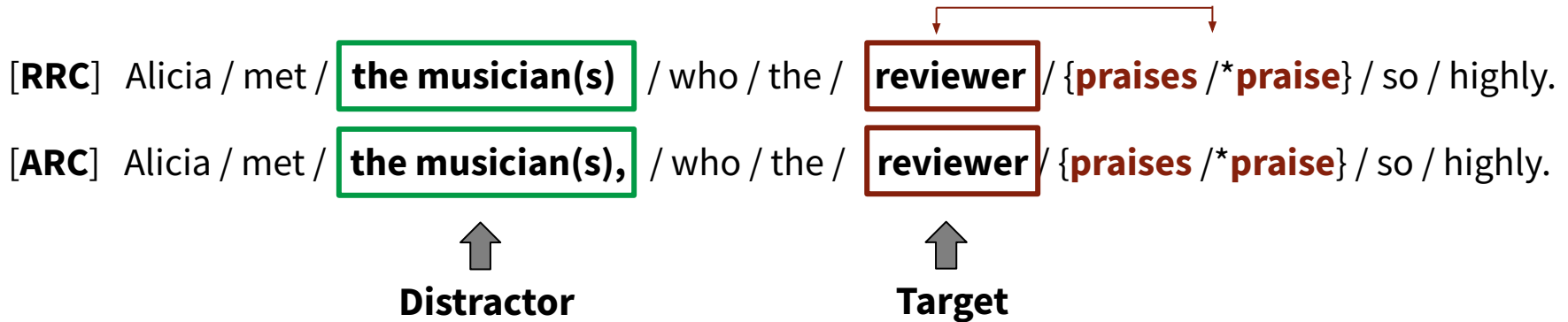
Full model

- Distractor:Gramm. ($\beta=0.014$, $se=0.005$, $t=2.981$)
- Clause:Distractor:Gramm. ($\beta=0.000$, $se=0.005$, $t=0.014$)
- Other interactions *n.s.*

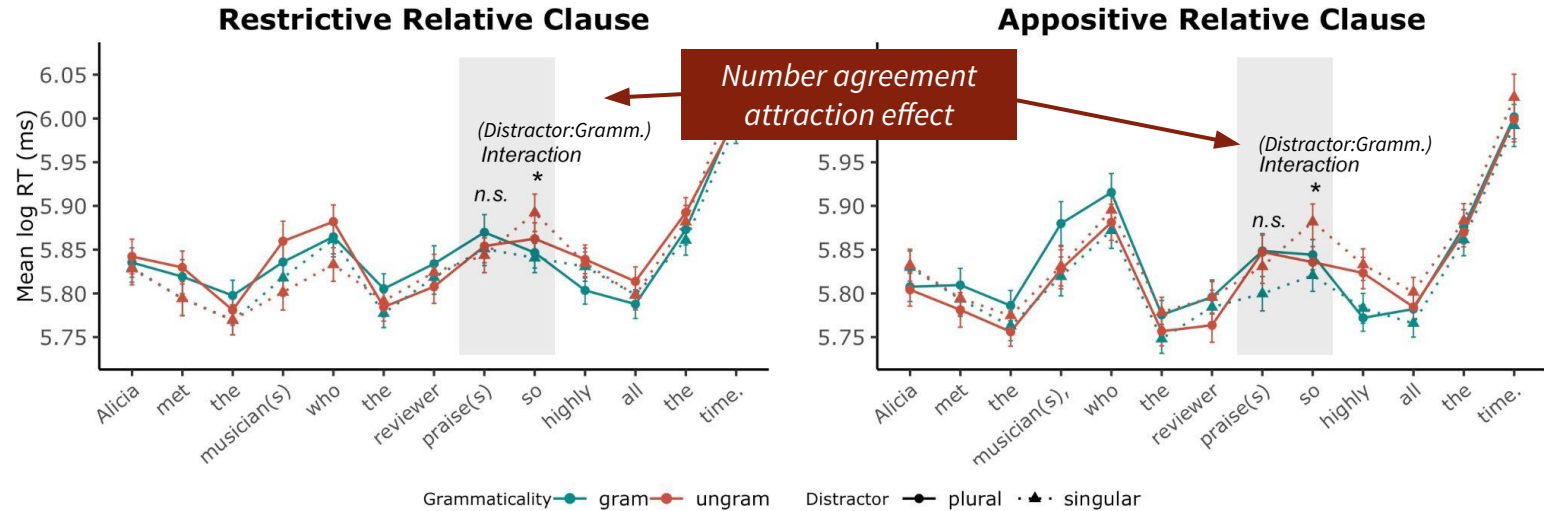
- Clause ($\beta=-0.012$, $se=0.005$, $t=-2.302$)
- Distractor ($\beta=-0.014$, $se=0.005$, $t=-2.776$)
- Gramm. ($\beta=-0.016$, $se=0.006$, $t=-2.699$)

Experiment 3: Design & Material

- 2x2x2 design: Clause type x Distractor noun x Grammaticality
{RRC, ARC} x {Singular, Plural} x {Gramm., Ungram.}
- RRC modified from Experiment 2, adopted from Wagers et al. (2009)



Experiment 3: Results



Full model

- Distractor:Gramm. ($\beta=0.012$, $se=0.004$, $t=2.639$)
- Clause:Distractor:Gramm. ($\beta=0.003$, $se=0.004$, $t=0.653$)
- Other interactions *n.s.*

- Gramm. ($\beta=-0.013$, $se=0.006$, $t=-2.290$)

Presence of number agreement attraction effect

Experiment 1

TargetNP(,) [who verb **DistractorNP**](,) **verb** [...]
➤ **RRC (yes)** ➤ **ARC (no)**

Experiment 2

DistractorNP(,) [who **TargetNP** **verb**](,) verb [...].
➤ **RRC (yes)** ➤ **ARC (yes)**

Experiment 3

Subj verb **DistractorNP**(,) [who **TargetNP** **verb** [...]].
➤ **RRC (yes)** ➤ **ARC (yes)**

Summary of findings

1. Direction of interference matters in the interactivity between ARC and main clause
 - **ARC:** Directionality of interference –
information in the main clause can intrude on the ARC; but not vice versa
 - **RRC:** Interference is not modulated by directionality
2. ARCs and main clauses are not completely separated

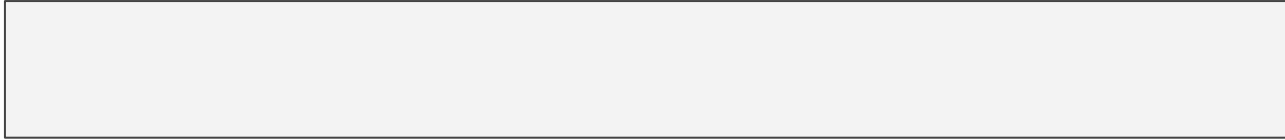
Proposal

- Directionality of interference is explained by the **incremental** construction of discourse structure
 - Similar insight in Dillon et al. (2017): At-issue vs. not-at-issue division
- Current proposal: Based on Question-based approach to discourse structure^[19-22]
- Memory retrieval is sensitive to the **active “discourse question”**

Incremental construction of discourse structure: Experiment 1 (RRC)

*The waitress who sat near the girl(s) {was/*were} surprisingly unhappy [...].*

Unit



Question



- Each discourse unit addresses an issue^[19-22], or “discourse question”

Incremental construction of discourse structure: Experiment 1 (RRC)

*The waitress who sat near the girl(s) {was/*were} surprisingly unhappy [...].*



Unit

The waitress

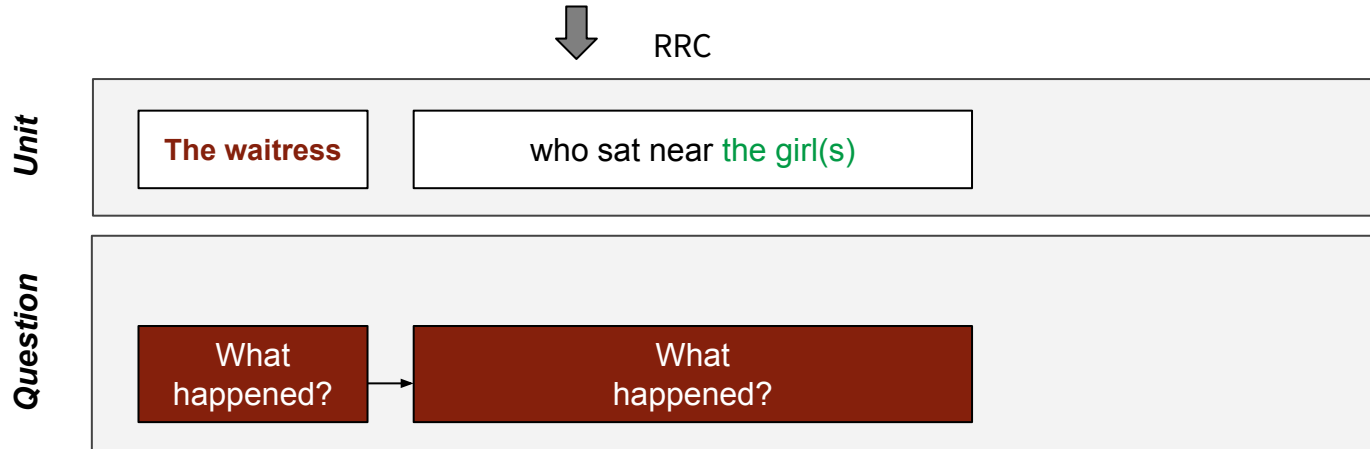
Question

What happened?

- Each discourse unit addresses an issue^[19-22], or “discourse question”

Incremental construction of discourse structure: Experiment 1 (RRC)

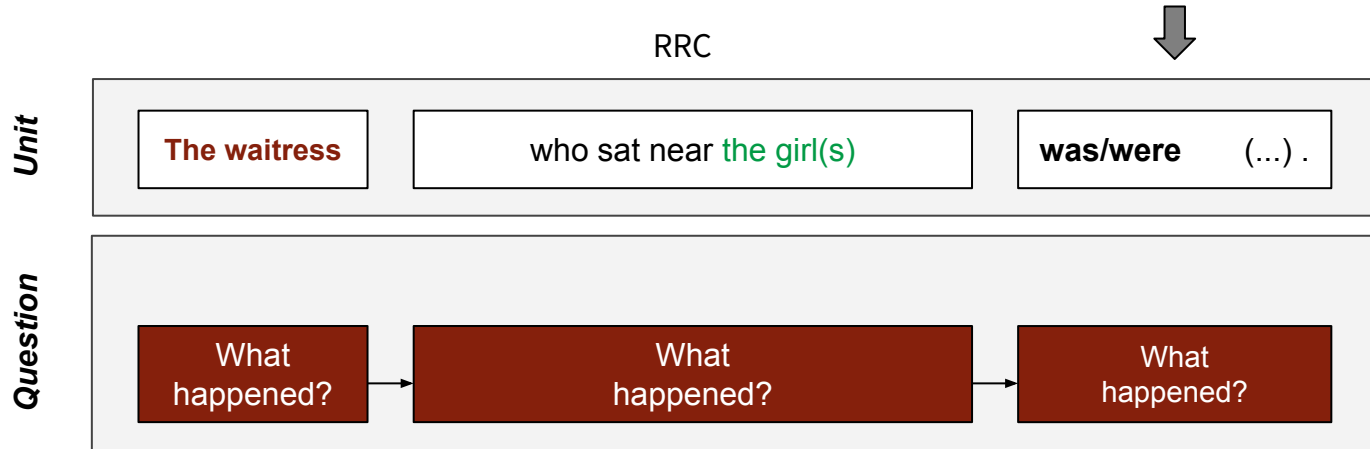
*The waitress who sat near the girl(s) {was/*were} surprisingly unhappy [...].*



- Each discourse unit addresses an issue^[19-22], or “discourse question”
 - RRC does not raise a new discourse question; continues the same question

Incremental construction of discourse structure: Experiment 1 (RRC)

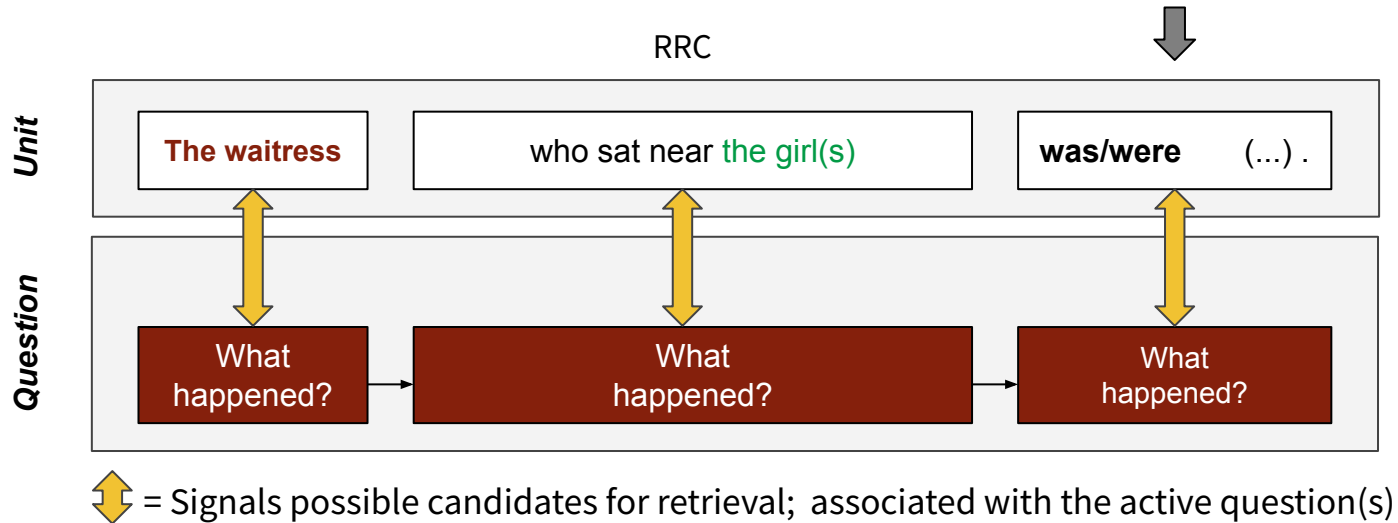
*The waitress who sat near the girl(s) {was/*were} surprisingly unhappy [...].*



- Each discourse unit addresses an issue^[19-22], or “discourse question”
 - RRC does not raise a new discourse question; continues the same question

Incremental construction of discourse structure: Experiment 1 (RRC)

*The waitress who sat near the girl(s) {was/*were} surprisingly unhappy [...].*



- Scope of retrieval is sensitive to the **active “discourse question”**
- Presence of the standard number agreement attraction effect

Incremental construction of discourse structure: Experiment 1 (ARC)

*The waitress, who sat near the girl(s), {was/*were} surprisingly unhappy [...].*

Unit

--

Question

--

Incremental construction of discourse structure: Experiment 1 (ARC)

*The waitress, who sat near the girl(s), {was/*were} surprisingly unhappy [...].*



Unit

The waitress,

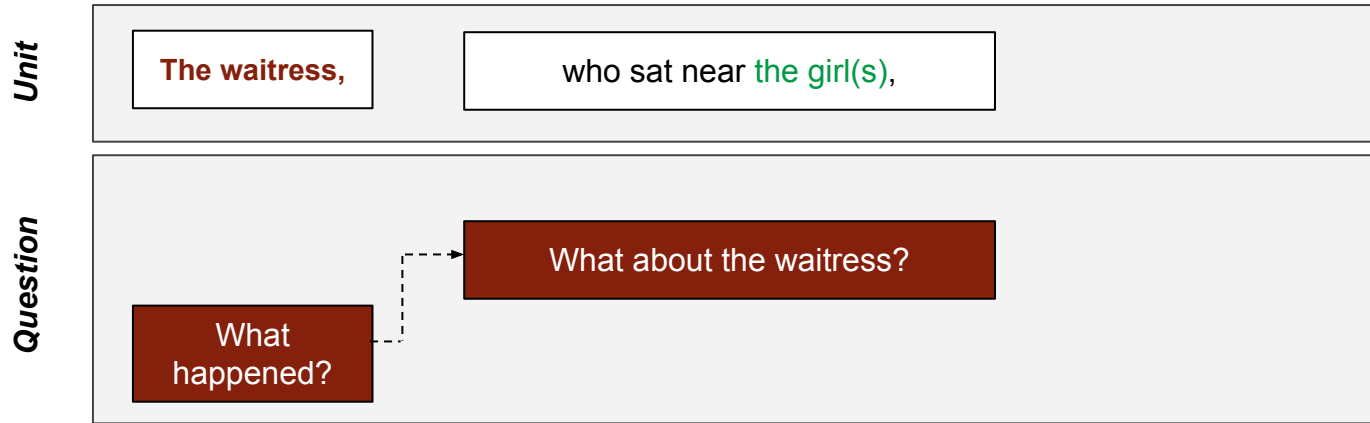
Question

**What
happened?**

- Each discourse unit addresses an issue^[19-22], or “discourse question”

Incremental construction of discourse structure: Experiment 1 (ARC)

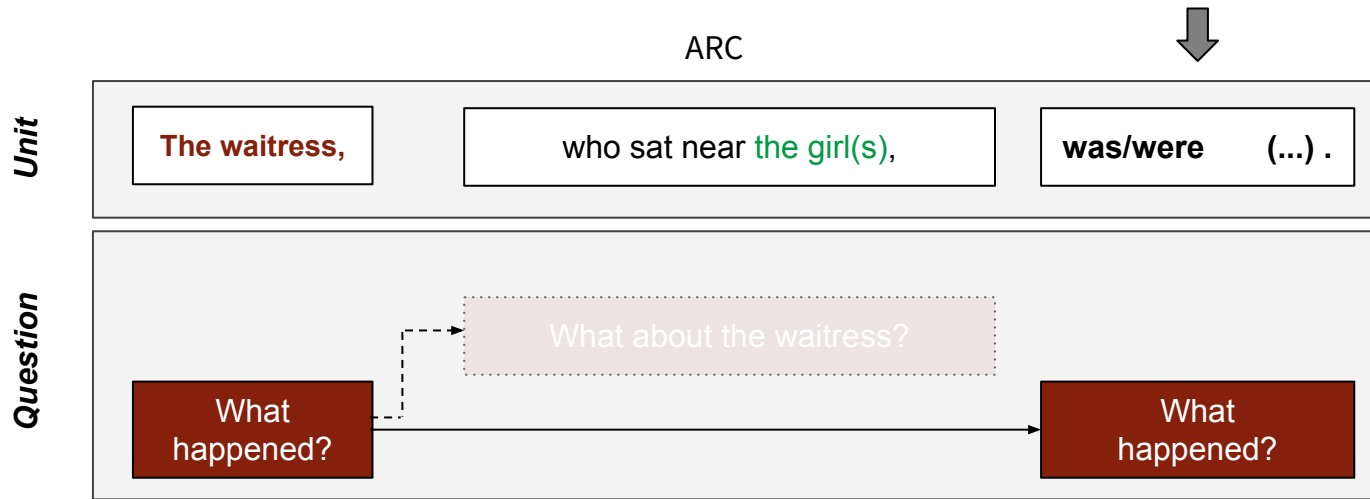
*The waitress, who sat near the girl(s), {was/*were} surprisingly unhappy [...].*



- Each discourse unit addresses an issue^[19-22], or “discourse question”
 - ARCs raise new questions^[20]
- While processing the **subordinate** unit, both the corresponding question and its **superordinate** question are both active^[19-20]

Incremental construction of discourse structure: Experiment 1 (ARC)

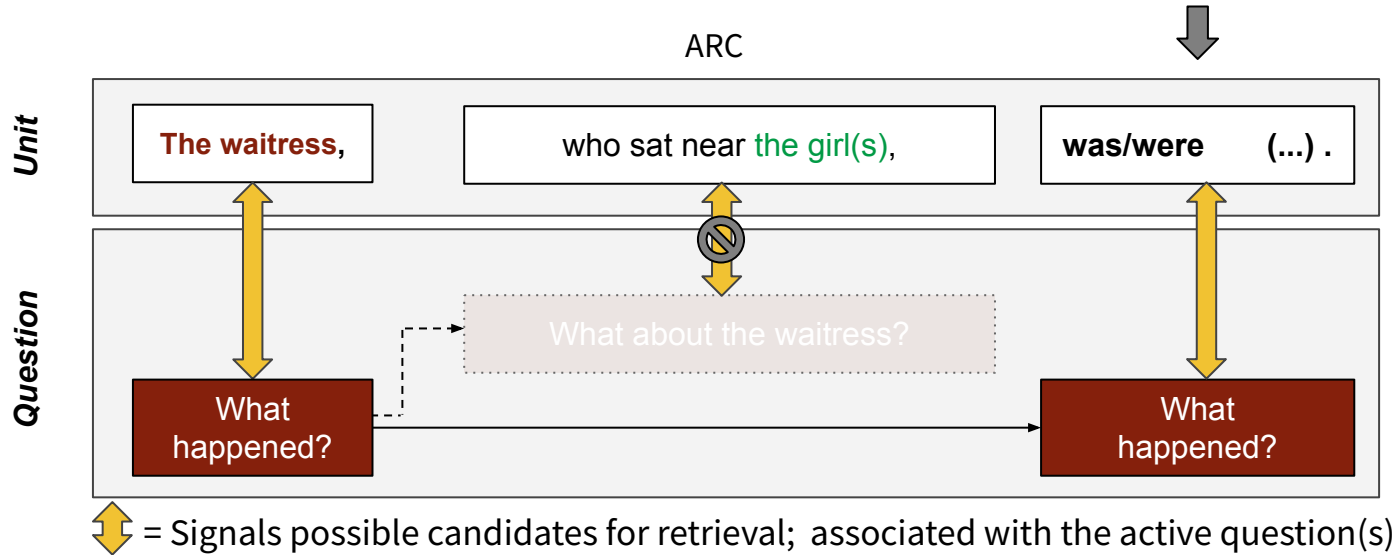
*The waitress, who sat near the girl(s), {was/*were} surprisingly unhappy [...].*



- After processing ARC, the question of the subordinate unit is no longer active; popped out^[19-20]
- Each discourse unit addresses an issue^[19-22], or “discourse question”

Incremental construction of discourse structure: Experiment 1 (ARC)

*The waitress, who sat near the girl(s), {was/*were} surprisingly unhappy [...].*



- Scope of retrieval is sensitive to the **active “discourse question”**
- Absence of the standard number agreement attraction effect

Incremental construction of discourse structure: Experiments 2-3 (ARC)

*The musician(s), who the reviewer {praises/*praise} so highly, will [...].*

Unit

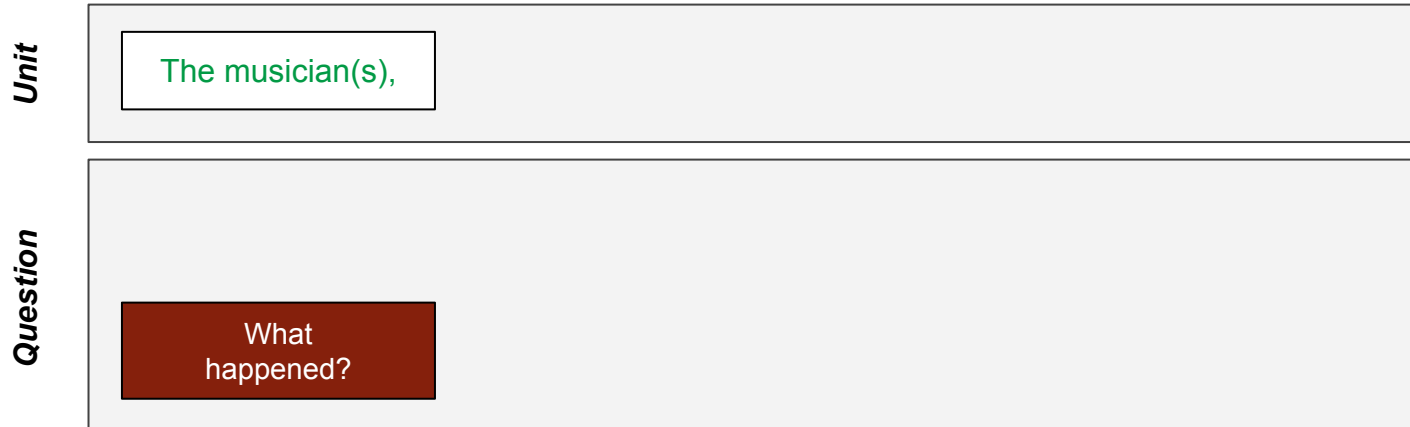
A large, empty rectangular box with a thin black border, intended for the user to input a unit of discourse structure.

Question

A large, empty rectangular box with a thin black border, intended for the user to input a question related to the discourse structure.

Incremental construction of discourse structure: Experiments 2-3 (ARC)

*The musician(s), who the reviewer {praises/*praise} so highly, will [...].*



- Each discourse unit addresses an issue^[19-22], or “discourse question”

Incremental construction of discourse structure: Experiments 2-3 (ARC)

*The musician(s), who the reviewer {praises/*praise} so highly, will [...].*



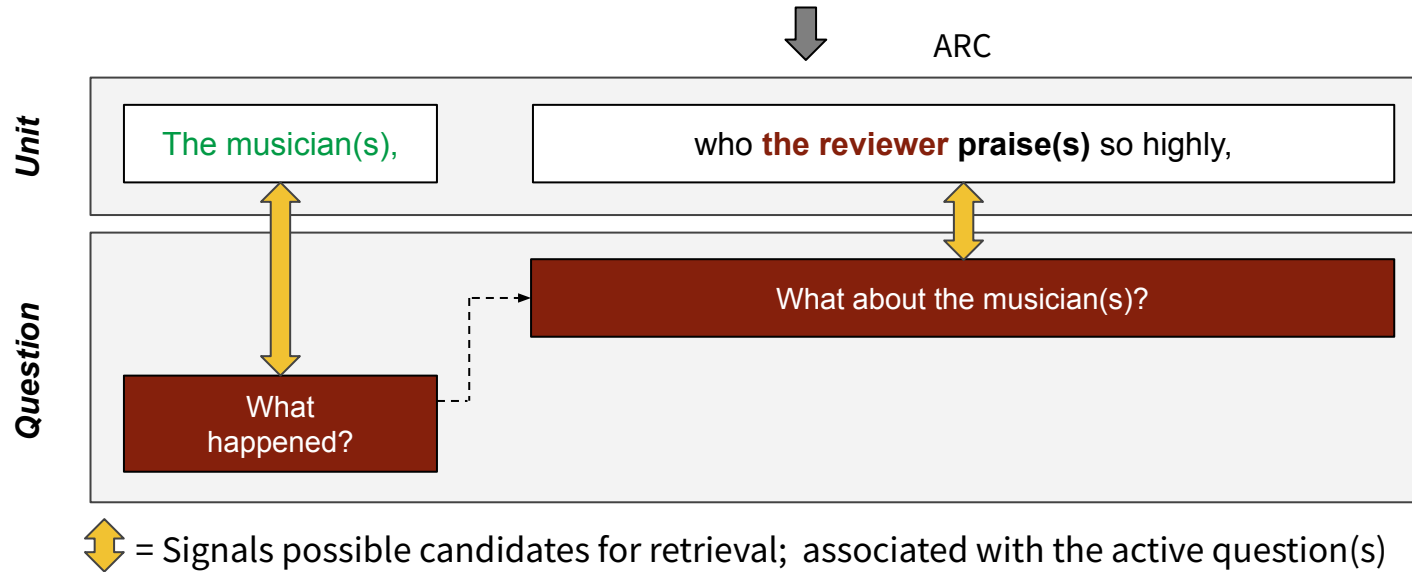
ARC



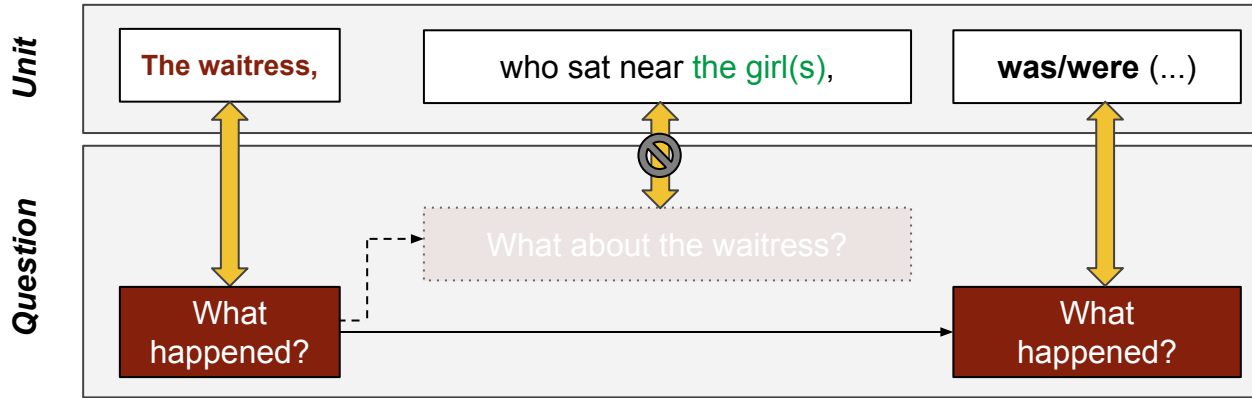
- Each discourse unit addresses an issue^[19-22], or “discourse question”
- While processing the **subordinate** unit, both the corresponding question and its **superordinate** question are both active^[19-20]

Incremental construction of discourse structure: Experiments 2-3 (ARC)

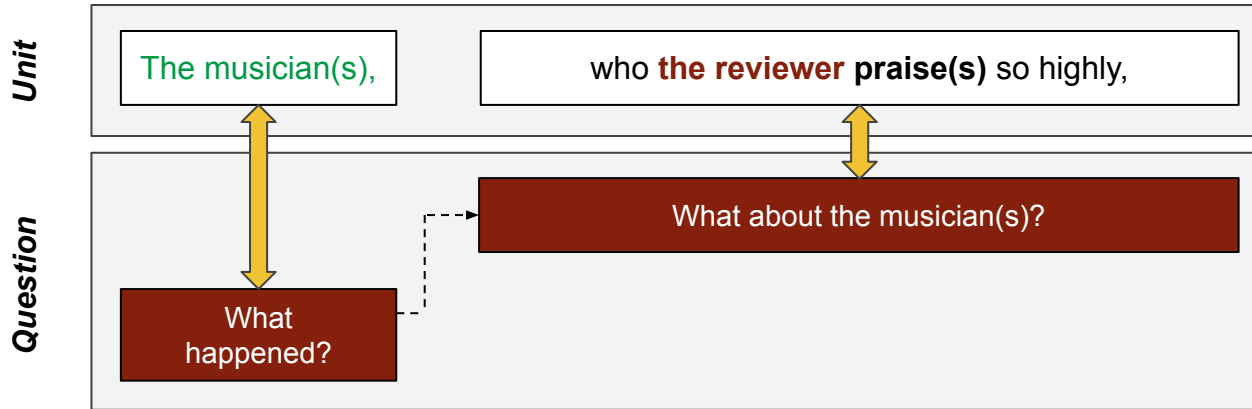
*The musician(s), who the reviewer {praises/*praise} so highly, will [...].*



- Scope of retrieval is sensitive to the **active “discourse question”**
- Presence of the standard number agreement attraction effect



Experiment 1 (ARC)
No number agreement
attraction effect



Experiments 2-3 (ARC)
Number agreement
attraction effect

Conclusion

- Empirical evidence for a **limited interactivity** between ARC and main clause (in line with [16])
- **Directionality of interference** with ARCs
- Scope of retrieval is sensitive to the **active state of “discourse questions”**
- Question-based approach to discourse structure introduces a framework for understanding the organization of discourse information in memory retrieval^[cf. 13]

Selected bibliography

- [1] Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, 99(1), 122.
- [2] MacDonald, M. C., Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive Psychology*, 24(1), 56-98.
- [3] Caplan, D., & Waters, G. S. (1999). Verbal working memory and sentence comprehension. *Behavioral and Brain Sciences*, 22(1), 77-94.
- [4] Gibson, E. (2000). The dependency locality theory: A distance-based theory of linguistic complexity. In A. P. Marantz, Y. Miyashita, & O. Wayne (Eds.), *Image, language, brain* (pp. 95–126). Cambridge, MA: MIT Press.
- [5] Lewis, R. L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science*, 29(3), 375-419.
- [6] Cutler, A., & Fodor, J. A. (1979). Semantic focus and sentence comprehension. *Cognition*, 7(1), 49-59.
- [7] Sturt, P., Sanford, A. J., Stewart, A., & Dawydiak, E. (2004). Linguistic focus and good-enough representations: An application of the change-detection paradigm. *Psychonomic Bulletin & Review*, 11(5), 882-888.
- [8] Foraker, S., & McElree, B. (2007). The role of prominence in pronoun resolution: Active versus passive representations. *Journal of Memory and Language*, 56(3), 357-383.
- [9] Dehé, N. & Kavalova, Y. (2007). Parentheticals: An introduction. In N. Dehé & Y. Kavalova (Eds.), *Parentheticals* (pp. 1-22). John Benjamins Publishing Company.
- [10] Asher, N. & Lascardes, A. (2003). *Logics of conversation*. Cambridge University Press.
- [11] Koev, T. (2013). *Apposition and the structure of discourse*. Rutgers University. Doctoral dissertation.
- [12] Dillon, B., Clifton, C. J., & Frazier, L. (2014). Pushed aside: Parentheticals, memory and processing. *Language, Cognition and Neuroscience*, 29(4), 483–498.

Selected bibliography

- [13] Kroll, M. & Wagers, M. (2019). Working memory resource allocation is not modulated by clausal discourse status. *Ms.* UC Santa Cruz.
- [14] McInnerney, A. & Atkinson, E. (2020). “Syntactically unintegrated parentheticals: Evidence from agreement attraction”. Talk presented at the *33rd CUNY Conference on Human Sentence Processing*, University of Massachusetts Amherst: Amherst, MA, March 19-March 21.
- [15] Ng, A. & Husband, M. (2017). “Interference effects across the at-issue/not-at-issue divide: Agreement and NPI licensing”. Poster presented at the *30th CUNY Conference on Human Sentence Processing*, MIT, Cambridge: MA, March 30-April 1 .
- [16] Dillon, B., Clifton, C. J., Sloggett, S., & Frazier, L. (2017). Appositives and their aftermath: Interference depends on at-issue vs. not-at-issue status. *Journal of Memory and Language*, 96, 93–109.
- [17] Wagers, M. W., Lau, E. F., & Phillips, C. (2009). Agreement attraction in comprehension: Representations and processes. *Journal of Memory and Language*, 61(2), 206–237.
- [18] Parker, D., & An, A. (2018). Not all phrases are equally attractive: Experimental evidence for selective agreement attraction effects. *Frontiers in Psychology*, 9, 1566.
- [19] Grosz, B. J., & Sidner, C. L. (1986). Attention, intentions, and the structure of discourse. *Computational Linguistics*, 12(3), 175-204.
- [20] Jasinskaja, K. (2016). Not at issue any more. *Ms.* University of Cologne.
- [21] Hunter, J., & Abrusán, M. (2015). Rhetorical structure and QUDs. In *JSAI International Symposium on Artificial Intelligence* (pp. 41-57). Springer, Cham.
- [22] Riester, A. (2019). Constructing QUD trees. In M. Zimmermann, K. von Heusinger, & E. Onea (Eds.), *Questions in discourse. Vol. 2: Pragmatics*, (pp. 163–192). Brill, Leiden.

Acknowledgment

We thank UChicago Graduate Research Aid Initiative in Linguistics and Council on Advanced Studies for their funding support.

This work has benefited from feedback from the UChicago Language Processing Lab members, the audience at the UChicago Linguistics QP Fest, and AMLaP 2021.

Thank you for listening!