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How do people comprehend implausible sentences?

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The mother gave the candle the daughter.

Did the daughter receive something?

No: literal interpretation

Yes: nonliteral interpretation

Why do you interpret non-literally?

- *The mother gave the candle the daughter.*
- Why nonliteral interpretation?
- You might have misheard
 - Noisy environment
 - *The mother gave the candle ■ the daughter.*
- The speaker might have misspoken (speech error)
- In fact, you often do interpret implausible sentences non-literally (Gibson et al., 2013)

How do you interpret non-literally?

- **Non-literal syntactic analysis account**

- You construct a non-veridical syntactic analysis that leads to a plausible meaning.
- *The mother gave the candle the daughter.*
- → *The mother gave the candle **to** the daughter.*

- Consistent with traditional (modular or interactive) accounts of sentence comprehension (Ferreira & Clifton, 1986; Rayner, et al., 1983; MacDonald et al., 1994; Trueswell et al.,1994)

- Which meaning you get depends on how you analyse (parse) a sentence.
- *The spy saw the cop with a binocular.*
- Tough these accounts consider only literal interpretations (i.e., compatible with the input)

How do you interpret non-literally?

- **Non-literal semantic interpretation account**
 - You infer a plausible meaning based on the semantic relations among words/concepts
 - e.g., *the daughter* is a more likely *recipient* than *theme* of a giving event
 - No need for a non-veridical syntactic analysis
- Consistent with recent dual-route accounts of sentence comprehension (Kuperberg, 2007; Borkessel-Schlesewsky & Schlewsky, 2008; Ferreira, 2003; Townsend & Bever, 2001)
- *The mother gave the candle the daughter.*
- Semantic interpretation based on a syntactic analysis
 - DO analysis → GIVE (CANDLE_{Recipient}, DAUGHTER_{Theme})
- Semantic interpretation based on plausibility consideration
 - GIVE (CANDLE_{Theme}, DAUGHTER_{Recipient})

Interpretation of implausible sentences

- *The mouse was eaten by the cheese*
 - agent = mouse?
 - Answers indicated whether the sentence was interpreted literally (*no* to agent=mouse) or nonliterally (*yes* to agent=mouse).
- Participants often interpreted implausible passives according to plausibility (*mouse* as agent) rather than according to syntax (*cheese* as agent).
- These results may reflect post-interpretive decisions (Bader & Meng, 2018; Cutter et al., 2022).
 - Bader and Meng (2018) showed that participants were equally accurate at judging the plausibility of plausible and implausible sentences.

Interpretation of implausible sentences

- Participants read
 - *The mother gave the candle the daughter* (double-object dative, DO)
 - *The mother gave the daughter to the candle* (prepositional-object dative, PO)
- Then answered: *Did the daughter receive something?*
 - *No* → literal interpretation; *Yes* → nonliteral interpretation.
 - More nonliteral interpretations (*yes* to the question) of implausible DOs than of implausible POs.
- Noisy-channel account:
 - Communication tends to be noisy, leading to sentences being corrupted (e.g., misspeaking or mishearing).
 - People make inferences about whether a sentence is implausible as a result of misspeaking/mishearing.

Interpretation of implausible sentences

- A sentence can be implausible because a word is accidentally **omitted** due to misspeaking/mishearing.

Plausible PO

Implausible DO

- *The mother gave the candle **to** the daughter* → *The mother gave the candle the daughter.*

- A sentence can be implausible because a word is accidentally **inserted** due to misspeaking/mishearing.

Plausible DO

Implausible PO

- *The mother gave the daughter the candle.* → *The mother gave the daughter **to** the candle.*

- Omission is more likely to occur than insertion (Bayesian size principle; Tenenbaum, 1999; Xu & Tenenbaum, 2007).

- Likelihood of *to* being accidentally omitted due to mishearing/misspeaking = 1/8
- Likelihood of *to* being accidentally inserted due to mishearing/misspeaking = 1/6000?
- Hence more nonliteral interpretations of implausible DOs than of implausible POs.

Gibson, E., Bergen, L., & Piantadosi, S. T. (2013). Rational integration of noisy evidence and prior semantic expectations in sentence interpretation. *Proceedings of the National Academy of Sciences*, 110(20), 8051-8056.

Do people actually construct NL syntactic analyses?

- The noisy-channel account thus is consistent with the nonliteral syntactic analysis account
 - Participants revise the syntax of an implausible sentence to arrive at a nonliteral plausible interpretation.
- But this is an inference instead of direct evidence in Gibson et al. (2013).
- Cai, Zhao, and Pickering (2022) used *structural priming* to test if the structure of an implausible sentence is indeed revised.

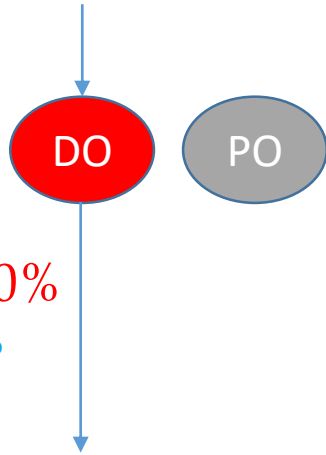
Structural priming

- People tend to repeat a syntactic structure that they have previously encountered (Bock, 1989).
 - If they have heard a DO sentence before, they tend to use a DO instead of a PO in picture description.
- Occurs across languages, methods, constructions – very robust effect; it mainly reflects the activation/learning of syntactic representations (Pickering & Ferreira, 2018)
- Often used to map out syntactic representations that people construct during sentence comprehension and production.
 - Syntactic representation of verb-phrase ellipsis (Cai et al., 2013)
 - Syntactic representation of missing arguments (Cai et al., 2015)
 - Syntactic representation in syntactic ambiguity resolution (Van Gompel et al., 2006)

Experiment 1: Logic

The mother gave the daughter the candle.

DO dative



DO = 70%
PO = 30%

The cop passed the artist a book.

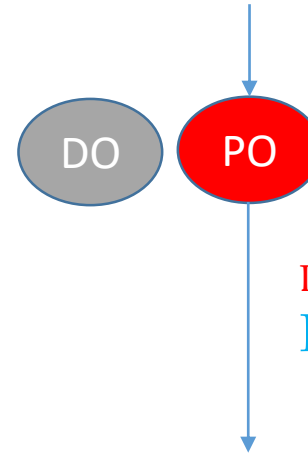
Double-object (DO) dative



PASS

The mother gave the candle to the daughter.

PO dative



DO = 30%
PO = 70%

The cop passed a book to the artist.

Prepositional-object (PO) dative

Following plausible sentences: priming effect = 70% - 30% = 40%

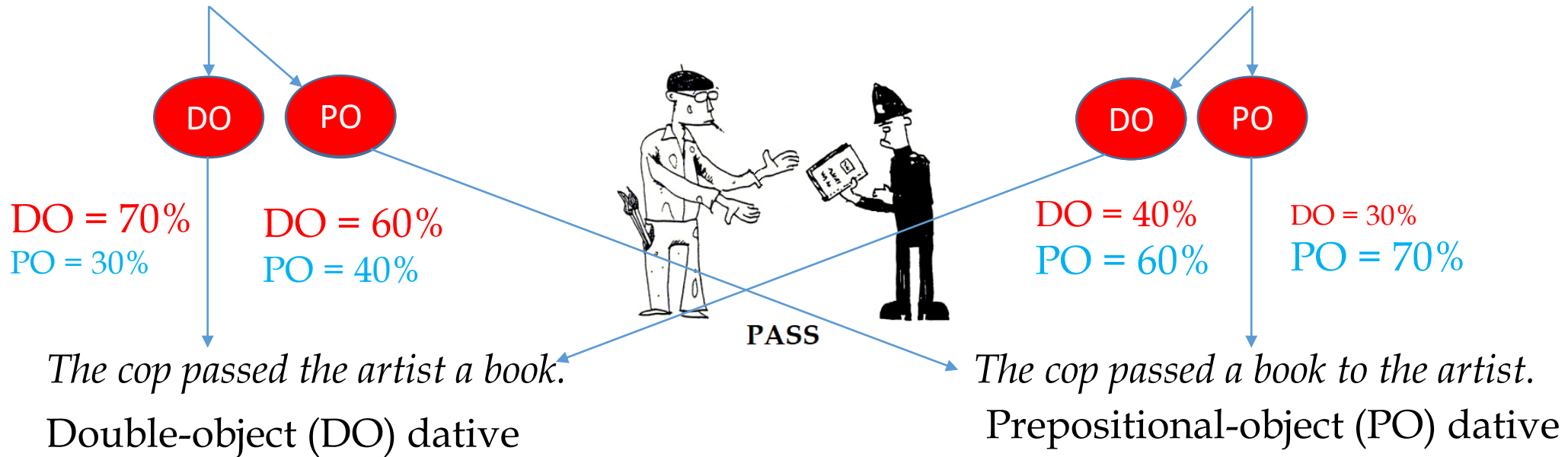
If the nonliteral syntactic analysis account is correct ...

The mother gave the candle the daughter.

Implausible DO dative

The mother gave the daughter to the candle.

Implausible PO dative



Following plausible sentences: priming effect = 70% - 30% = 40%

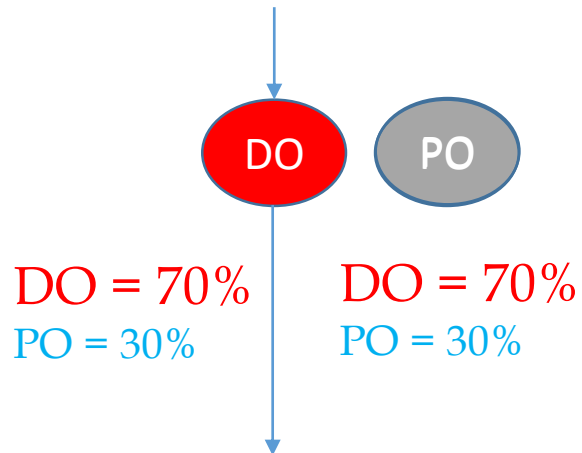
Following implausible sentences: priming effect = 60% - 40% = 20%

Reduced structural priming following implausible compared to following plausible primes.

If the nonliteral semantic interpretation account is correct ...

The mother gave the candle the daughter.

Implausible DO dative

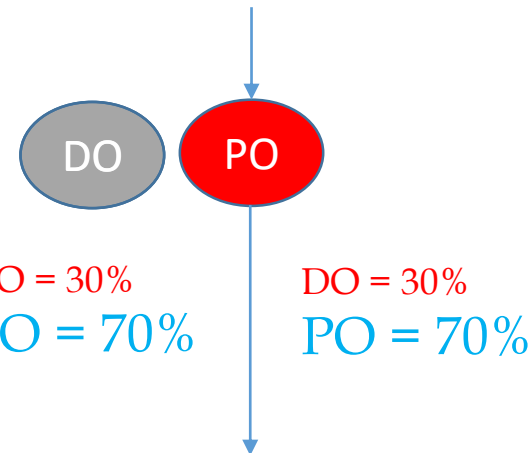


The cop passed the artist a book.

Double-object (DO) dative

The mother gave the daughter to the candle.

Implausible PO dative



The cop passed a book to the artist.

Prepositional-object (PO) dative

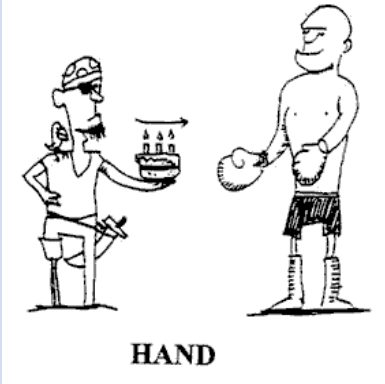
Following plausible sentences: priming effect = 70% - 30% = 40%

Following implausible sentences: priming effect = 70% - 30% = 40%

Similar structural priming following implausible compared to following plausible primes

Experiment 1: design

2 (plausibility: plausible vs. implausible) x 2 (structure: DO vs. PO)

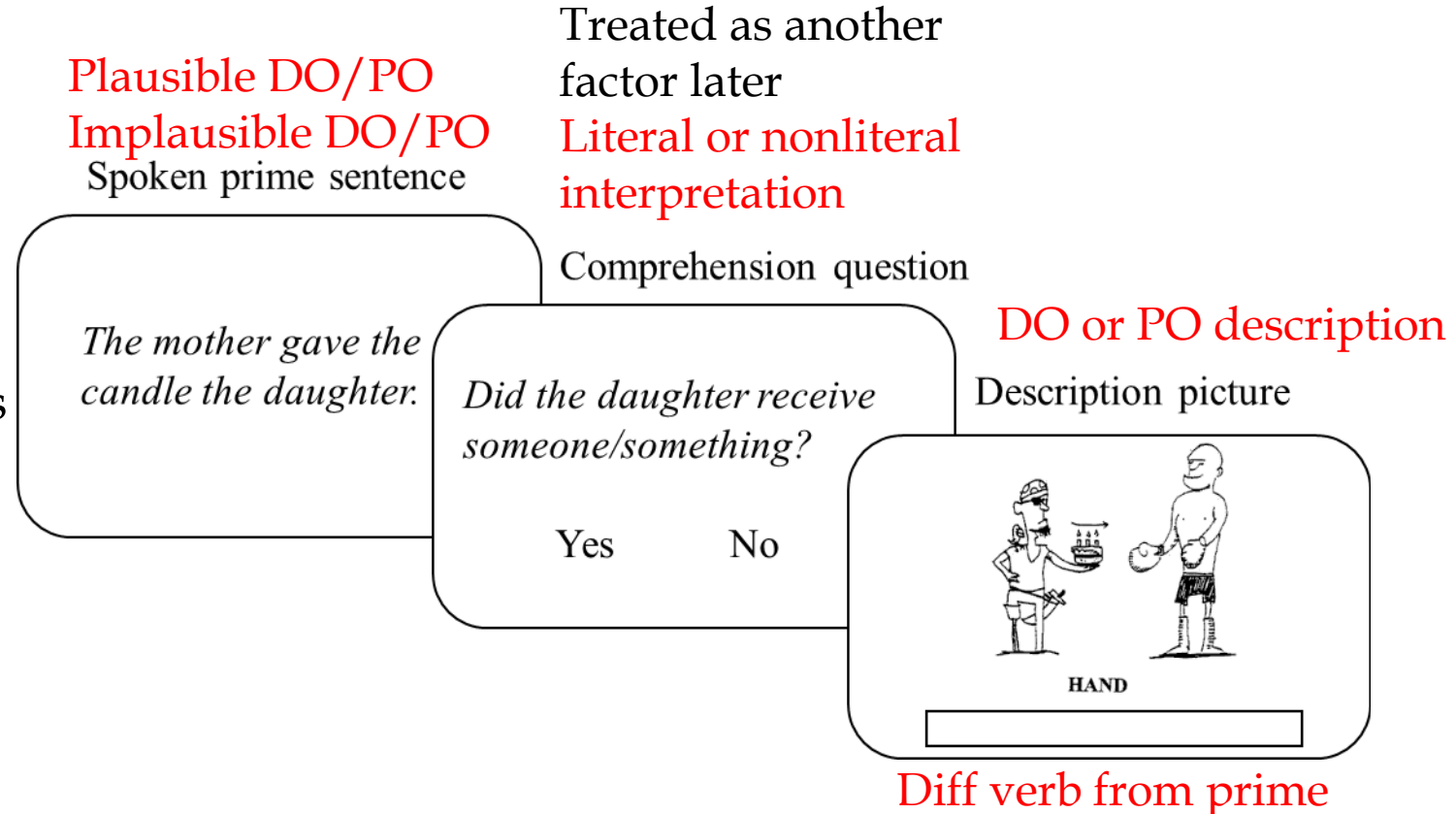
Prime	Prime sentence	Question: Did the daughter receive something/someone?	Target picture
Plausible DO	The mother gave the daughter the candle.	Yes → literal interpretation	
		No → nonliteral interpretation	
Plausible PO	The mother gave the candle to the daughter.	Yes → literal interpretation	
		No → nonliteral interpretation	
Implausible DO	The mother gave the candle the daughter.	Yes → nonliteral interpretation	
		No → literal interpretation	
Implausible PO	The mother gave the daughter to the candle.	Yes → nonliteral interpretation	

Experiment 1: methods

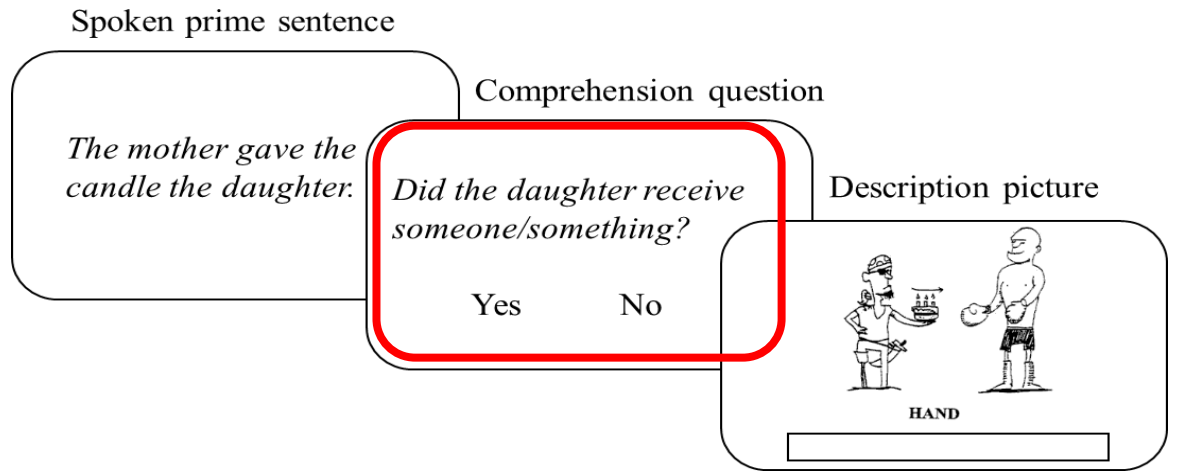
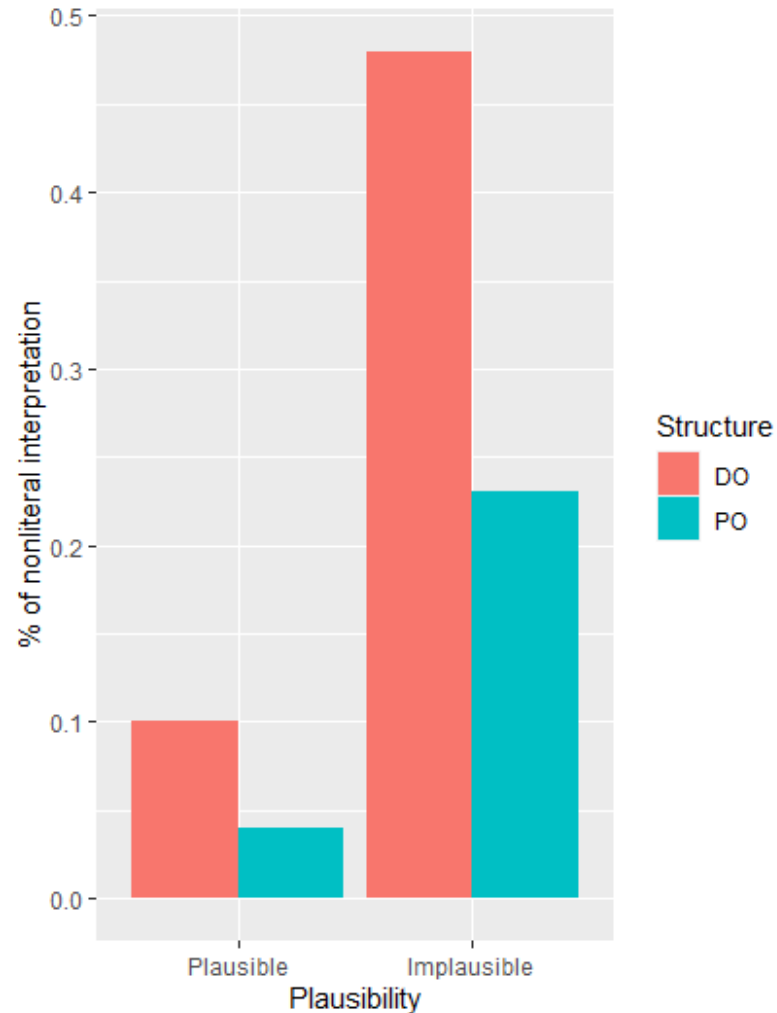
Online Qualtrics experiment

96 native speakers of English
(recruited via Prolific); 8 excluded for
not describing pictures as instructed.

20 experimental items (with 60 fillers
of various sentence types; sentences
from Gibson et al., 2017)



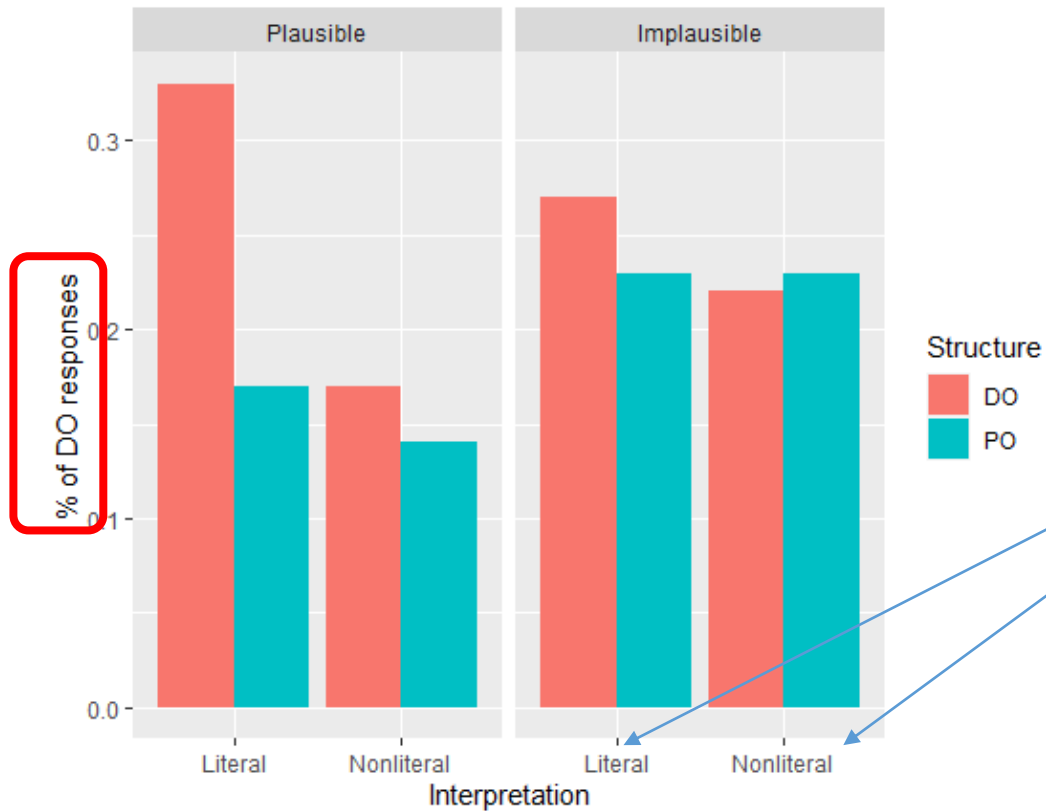
Prime sentence interpretation



NLs: Implausible > Plausible. Participants often interpret implausible sentences non-literally

NLs: DO > PO. Participants were more likely to nonliterally interpret DO sentences than PO sentences (Gibson et al., 2013, 2017)

Picture description



Spoken prime sentence

The mother gave the candle the daughter.

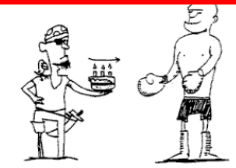
Comprehension question

Did the daughter receive someone/something?

Yes

No

Description picture

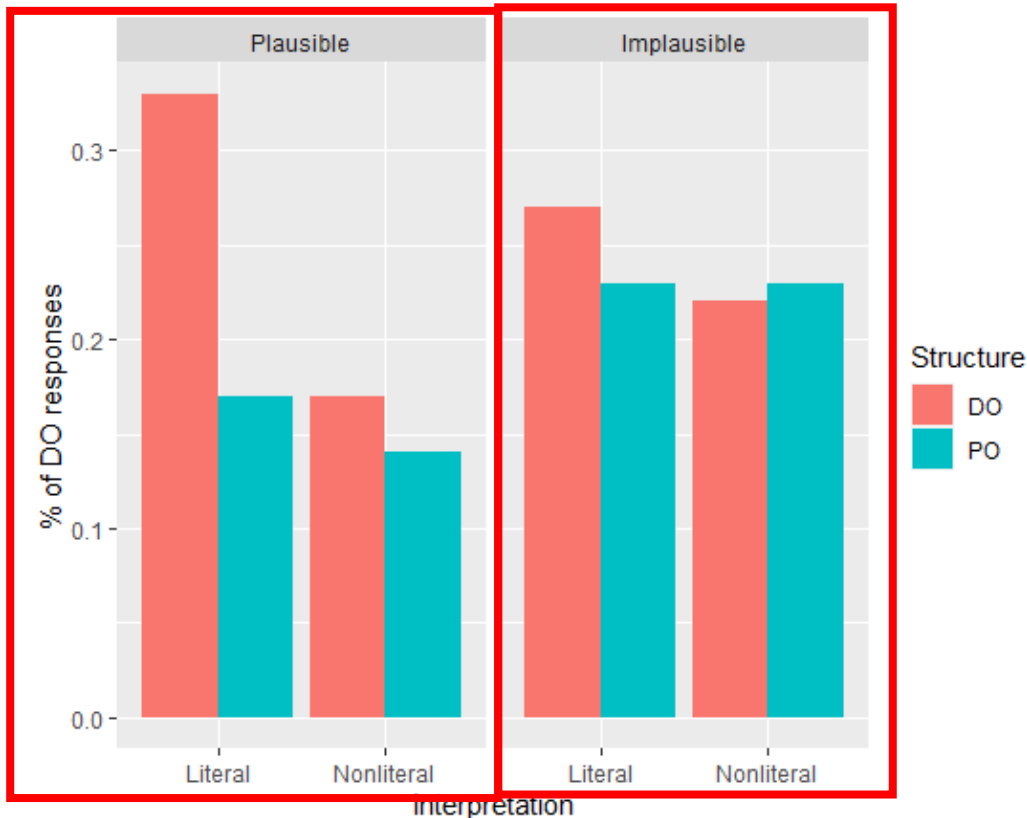


The pirate handed the boxer a cake. (DO)
The pirate handed a cake to the boxer. (PO)

Plausible vs implausible primes

The mother gave the daughter the candle.

The mother gave the candle the daughter.



More DO responses following a DO than a PO prime (28% vs. 20%, standard structural priming)

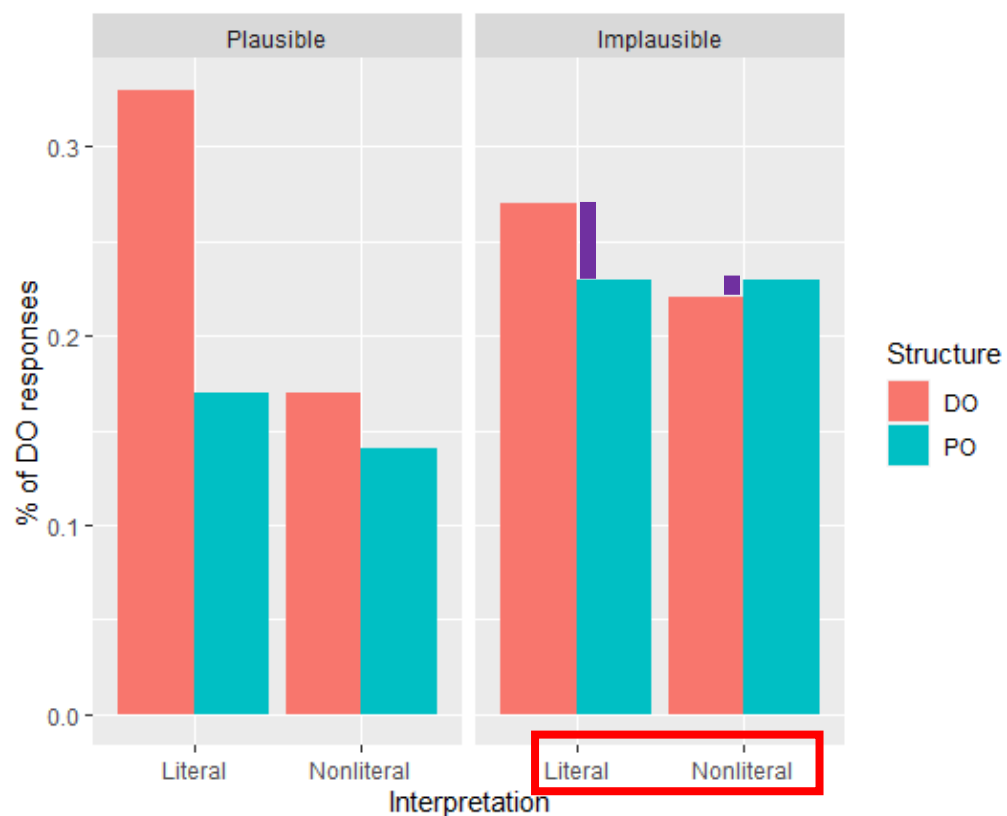
Less priming following implausible prime than plausible prime.

Nonliteral syntactic analysis account:

Implausible DOs → DO analysis + PO analysis

Implausible POs → PO analysis + DO analysis

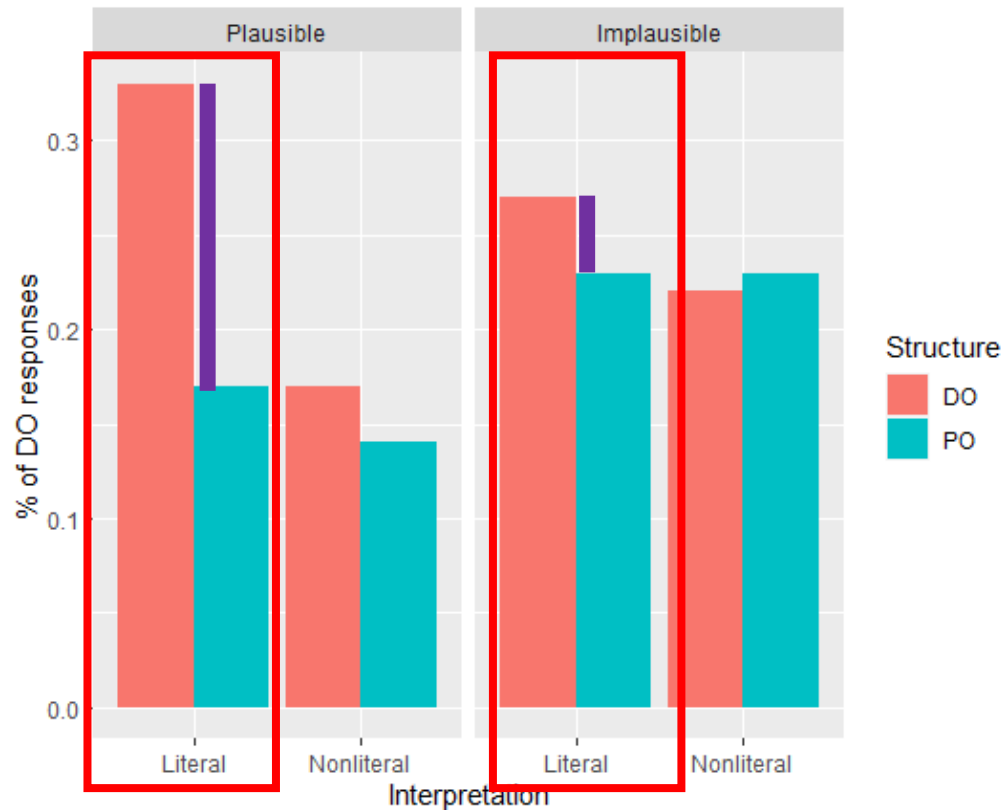
Implausible primes only: L- vs. NL-interpreted



Do people activate the nonliteral analysis to a greater extent when they interpret an implausible sentence nonliterally than when they do it literally?

Less priming when implausible primes were interpreted non-literally than literally (i.e., 0.03 vs. -0.01 – small but significant)

L-Interpreted plausible vs. implausible primes



Less priming following L-interpreted *implausible* primes than L-interpreted *plausible* primes.

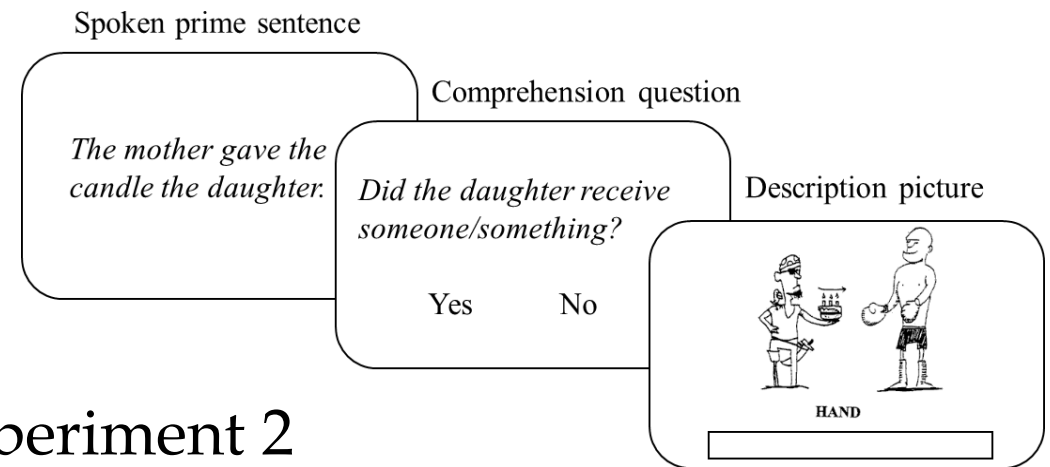
People still activate the nonliteral analysis of an implausible sentence even when it is literally interpreted.

Summary

- Participants were more likely to nonliterally interpret implausible than plausible sentences, and to nonliterally interpret DO sentences than PO sentences (Gibson et al., 2013, 2017).
- More importantly, structural priming was reduced ...
 - following implausible primes compared to plausible primes
 - following NL-interpreted implausible primes compared to L-interpreted implausible primes
 - following L-interpreted implausible primes compared to L-interpreted plausible primes
- All these findings are consistent with the NL syntactic analysis account but not with the NL semantic interpretation account.
 - Participants construct a nonliteral syntactic analysis for an implausible sentence.
 - For an implausible DO sentence, they construct both a DO analysis and a PO analysis.

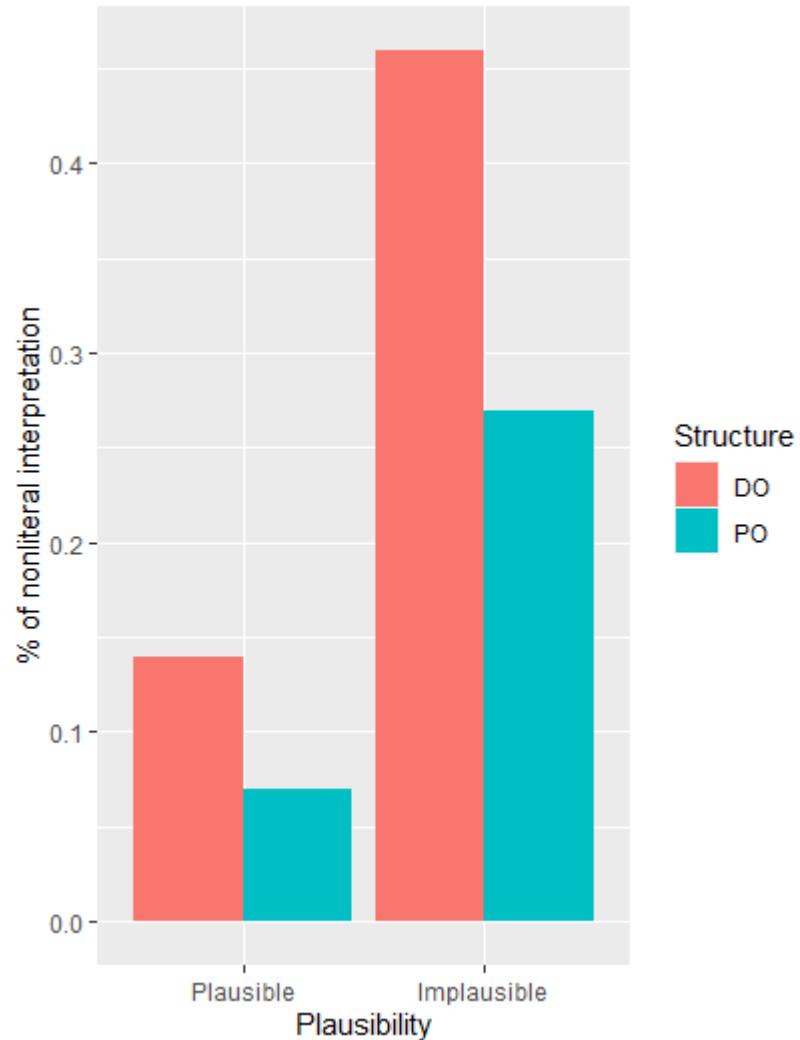
Experiment 2

- In Experiment 1, explicit interpretation (question-answering) occurred before picture description, and may have affected it



- Therefore we swapped their order in Experiment 2
- All other details were the same (13 out of 96 participants removed)

Prime sentence interpretation

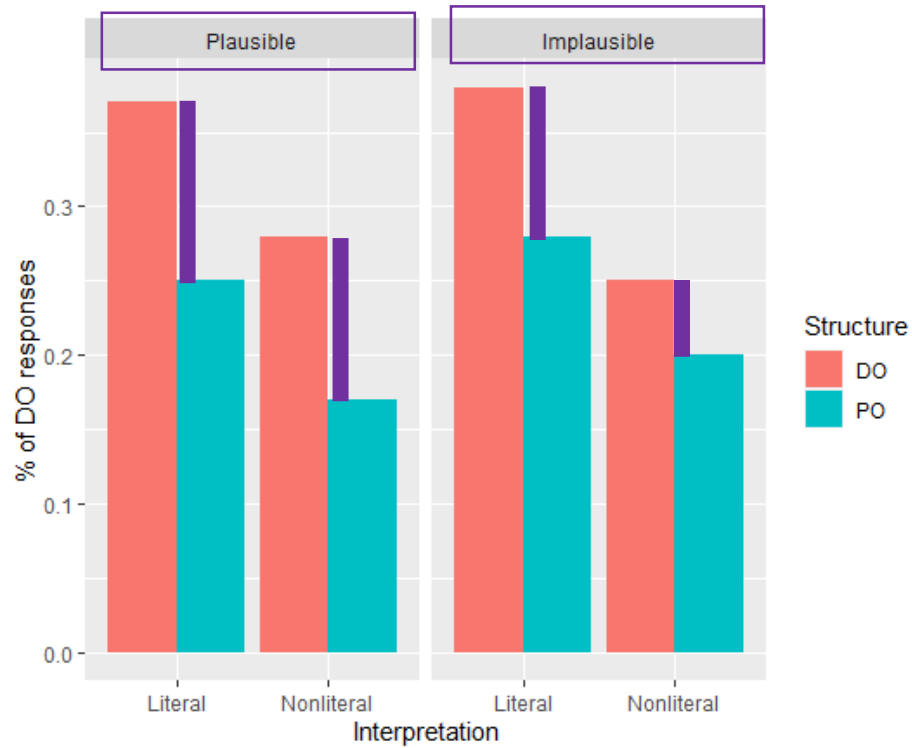


Same pattern as in Experiment 1.

NLs: Implausible > Plausible. Participants often interpret implausible sentences non-literally

NLs: DO > PO. Participants were more likely to nonliterally interpret DO sentences than PO sentences (Gibson et al., 2013, 2017)

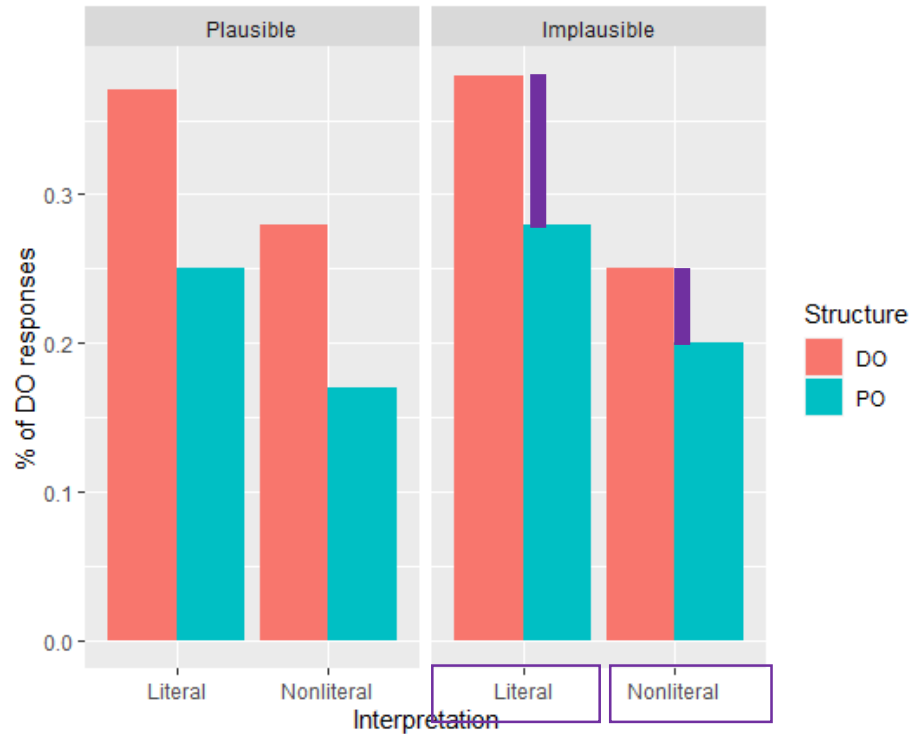
Plausible vs. implausible primes



Marginally less priming following implausible than plausible primes ($p = .054$), a weak replication of Experiment 1

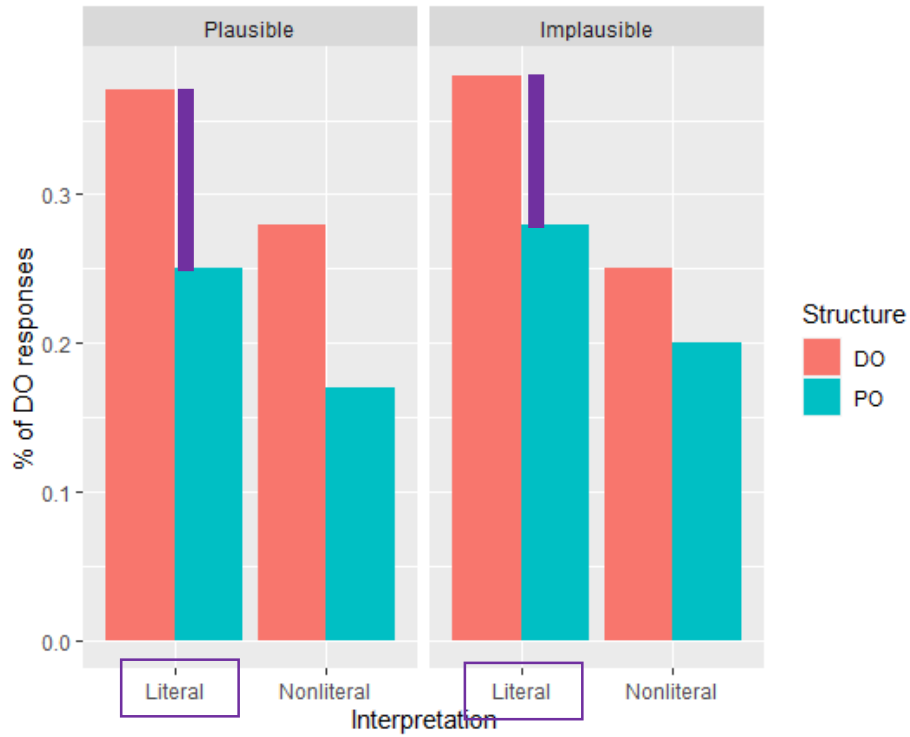
Implausible primes only: L- vs. NL-interpreted

Similar priming between L-interpreted and NL-interpreted implausible primes (contrary to E1)



L-Interpreted plausible vs. implausible primes

Similar priming between L-interpreted plausible and implausible primes (contrary to E1)



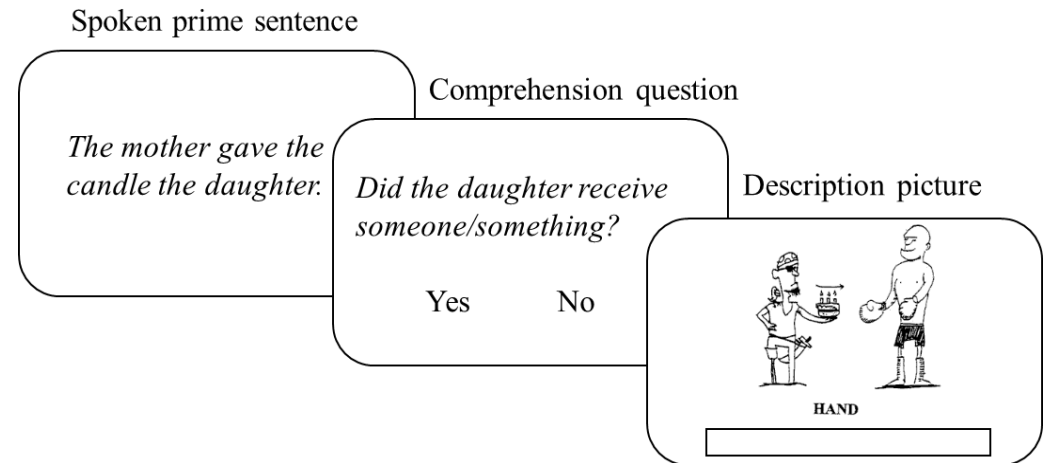
Discussion

- Between-experiments comparison found no important differences between the experiments
 - Even though some effects were weaker in Experiment 2 than Experiment 1
- It appears that the question-picture order is not critically important
- The small effects may occur because prime and target used different verbs
 - Same-verb priming is considerably stronger (Pickering & Branigan, 1998)

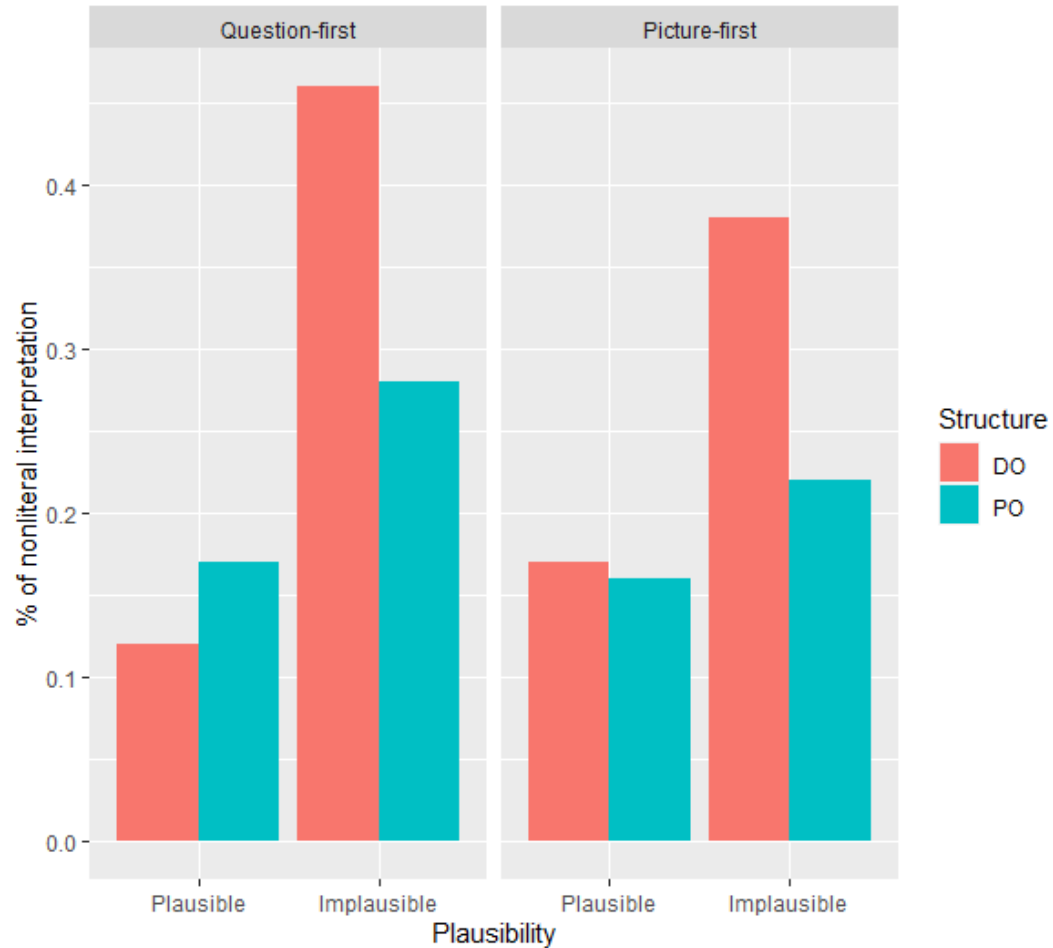
Experiment 3 (pre-registered)

- 2 (plausibility: plausible vs. implausible) × 2 (structure: DO vs. PO) × 2 (order: question-first vs. picture-first)
 - Verb repeated from prime to target

- 96 participants, 40 items (with 60 fillers)



Prime sentence interpretation

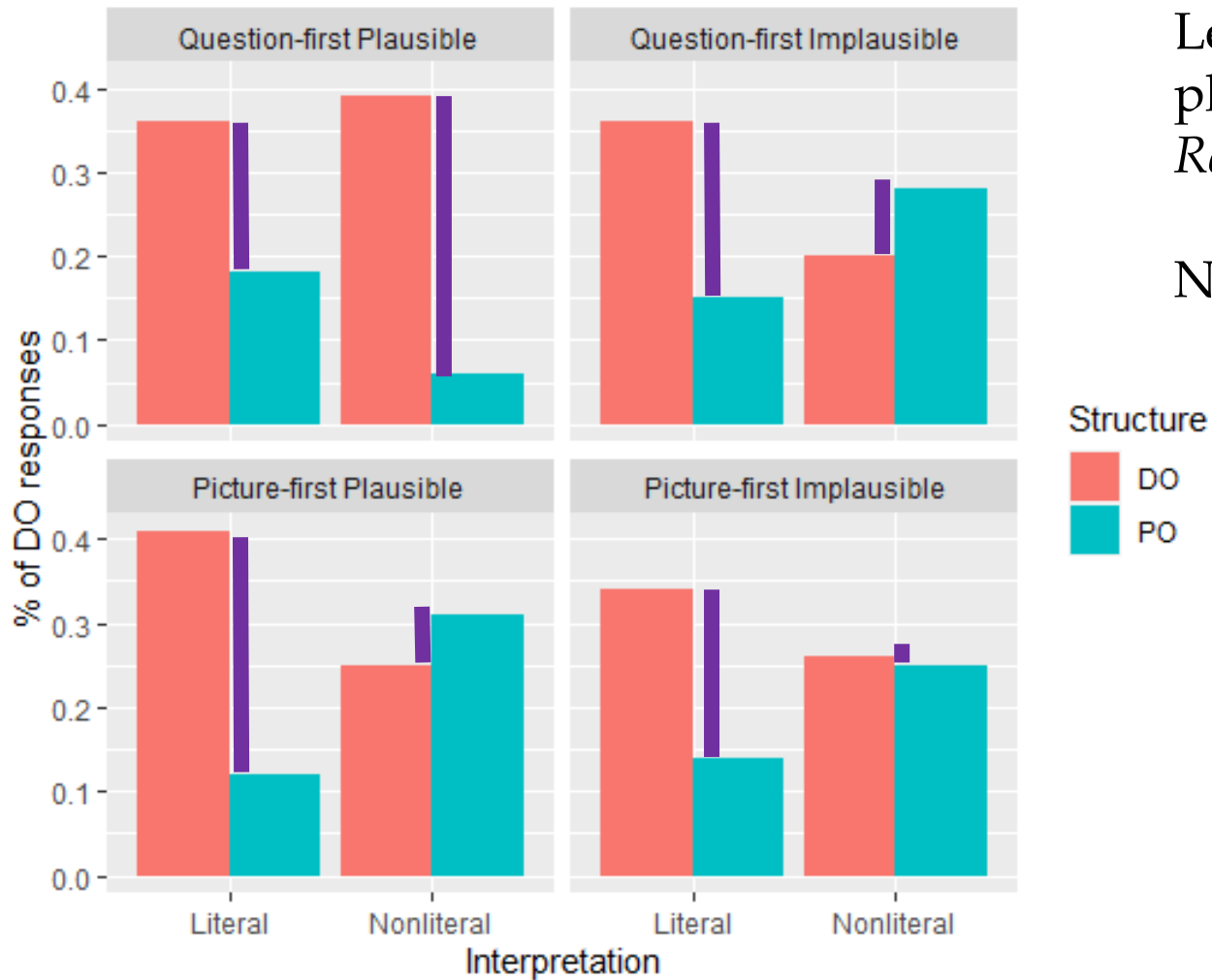


NLs: Implausible > Plausible. Participants often interpret implausible sentences non-literally

NLs: DO > PO. Participants were more likely to nonliterally interpret DO sentences than PO sentences (Gibson et al., 2013, 2017)

No sig. effect of order or sig. interaction involving order.

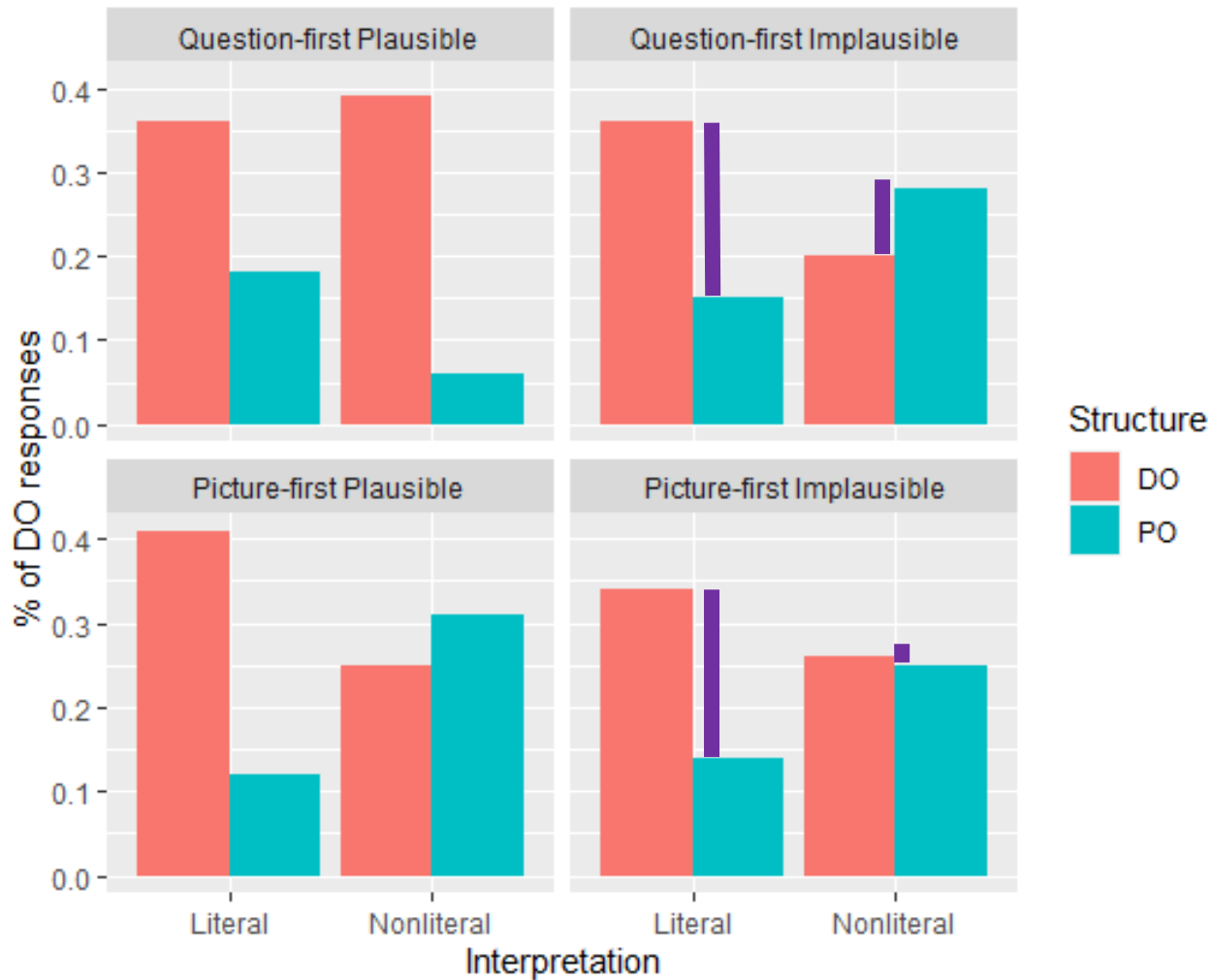
Plausible vs implausible primes



Less priming following implausible (12%) than plausible (22%) primes
Replicating E1 and E2

Not further modulated by order

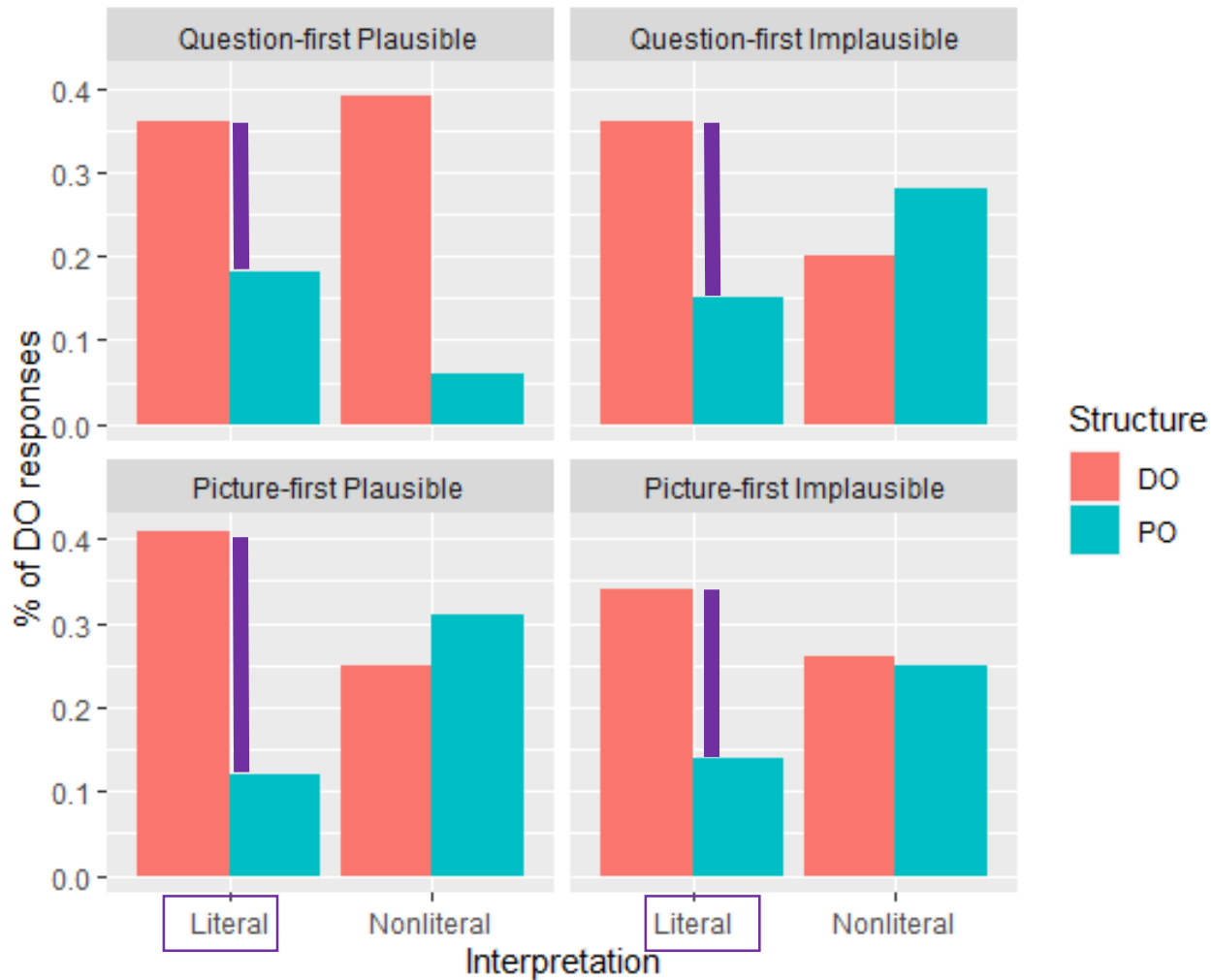
Implausible primes only: L- vs. NL-interpreted



Less priming when implausible primes were nonliterally (0%) than literally (20%) interpreted
Replicating E1

Again, no effects of task order

L-Interpreted plausible vs. implausible primes



Less priming following literally interpreted implausible primes (20%) than literally interpreted plausible primes (24%)
Replicating E1

Again, no effects of task order

Summary of key findings in three experiments

- In comprehending an implausible sentence, people construct a NL syntactic analysis that affords a plausible interpretation.
 - *The mother gave the candle the daughter.* (DO)
 - → *The mother gave the candle to the daughter.* (DO + PO)

 - *The mother gave the daughter to the candle.* (PO)
 - → *The mother gave the daughter the candle.* (PO + DO)

Summary of key findings in three experiments

- Less priming following

The mother gave the candle the daughter (implausible)

DO analysis + PO analysis

than following

The mother gave the daughter the candle (plausible)

DO analysis only

- Less priming following

The mother gave the candle the daughter (implausible, L-interpreted)

DO analysis + PO analysis

than following

The mother gave the daughter the candle (plausible, L-interpreted)

DO analysis only

- Less priming following

The mother gave the candle the daughter (implausible, NL-interpreted)

DO analysis + PO analysis

than following

The mother gave the candle the daughter (implausible, L-interpreted)

DO analysis + PO analysis

Why would people construct a NL analysis?

- A plausibility-driven prediction account.
- People often predict what they are going to hear, when it is predictable (e.g., Pickering & Gambi, 2018)
 - In particular, they predict syntax (e.g., Arai et al., 2007; Staub & Clifton, 2006)
- Abandoned analyses persist in “garden path” sentences (Cai et al., 2013; Christianson et al., 2001; Van Gompel et al., 2006)

Plausibility-driven syntactic prediction

- *The mother gave*
 - Activate both PO (next NP as the theme) and DO (next NP as recipient) (e.g., MacDonald et al., 1994)
- *The mother gave the candle*
 - *candle* is much more plausible as theme, so select/strongly favour PO
 - Predict an upcoming PP (i.e., containing the recipient).
- *The mother gave the candle the daughter* (implausible)
 - Construct/reactivate the DO analysis, but interpretation is implausible.
 - Also maintain the predicted PO analysis (by assuming *to* omitted due to noise), with a plausible interpretation.
 - Choose whichever analysis is more strongly activated and (typically) its associated interpretation
- For *the mother gave the candle to the daughter* (plausible), comprehenders predict PO at *candle*, which is confirmed by subsequent input.
 - No activation of the nonliteral DO analysis

Plausibility-driven syntactic prediction

- *The mother gave*
 - Activate both PO (next NP as the theme) and DO (next NP as recipient) (e.g., MacDonald et al., 1994)
- *The mother gave the daughter*
 - *daughter* is much more plausible as recipient, so select/strongly favour DO
 - Predict an upcoming NP (i.e., the theme).
- *The mother gave the daughter to the candle* (implausible)
 - Construct/reactivate the PO analysis, but interpretation is implausible.
 - Also maintain the predicted DO analysis (by assuming *to* was inserted due to noise), with a plausible interpretation.
 - Choose whichever analysis is more strongly activated and (typically) its associated interpretation
- For *the mother gave the daughter the candle* (plausible), comprehenders predict DO at *daughter*, which is confirmed by subsequent input.
 - No activation of the nonliteral PO analysis

Explaining our results

- For an implausible sentence, both L and NL analyses are activated.
 - Hence less priming following implausible than plausible primes
- More activated NL analysis leads to more likelihood of NL interpretation in question answering.
 - Hence less priming following NL-interpreted implausible primes than L-interpreted implausible primes.
- NL analyses are computed (predicted) even when people eventually choose to L-interpret an implausible sentence.
 - Hence less priming following L-interpreted implausible primes than L-interpreted plausible primes.

Conclusions

- Structural priming is reduced for implausible primes (versus plausible primes)
- It is further reduced when an implausible prime is interpreted non-literally (rather than literally)
- People compute a non-literal analysis that supports a non-literal but plausible interpretation
- We argue that non-literal analysis is achieved via prediction

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