# Neglect-Zero Effects in the Interpretation of Quantifiers and Disjunction

O. Bott, F. Schlotterbeck, T. Klochowicz, S. Ramotowska, M. Aloni

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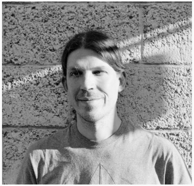
# The team

Oliver Bott



Fabian Schlotterbeck

Sonia Ramotowska

Maria Aloni

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# Some inferences in natural language

# Problematic models

(1) Some (of the) squares are black.

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|---|---|---|---|
| $\checkmark$ | $\times$ | $\#$ | $\#$ |

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(1) Some (of the) squares are black.

(2) Less than three squares are white.

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# Problematic models

(1) Some (of the) squares are black.

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Is there one theoretical tool we can use to explain all the $\#$?

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(7) Less than three squares are white
$\rightsquigarrow$ There are some squares. (Non-empty restrictor)

# Theories

- Negating alternatives (implicature based) e.g., Crnič et al. (2015)

| | NE-restrictor | NE-scope | Upper bound | Distributivity |
|---|---|---|---|---|
| Implicature | (✓) | ✓ | ✓ | ✓ |

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- Neglect Zero, Aloni (2022); Aloni and van Ormondt (2023)

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# Existing empirical data

Effect size of the inferences:

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- Non-empty scope inference:
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- Distributivity inference:
  **22%** (Crnič et al., 2015); **60-80%** under modalities and less robust ($\approx 40\%$) or absent under negation (Marty et al., 2024b).

# Existing empirical data: Reaction times

Reaction times to the inferences:

- Upper bound inferences derived from declaratives with '*some*':
  **Delay** of ≈ **500**ms (Bott and Noveck, 2004); ≈ **500**ms. (Huang and Snedeker, 2009), ≈ **250**ms for positive scales (Van Tiel and Pankratz, 2021).

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- Non-empty restrictor (existential import) inference: ???

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Aloni (2022) and Bott et al. (2019) argued that considering zero-models is cognitively demanding. Previous experiments showed **longer RT if the Neglect Zero principle is violated** (Bott et al., 2019; Ramotowska et al., 2022).

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Theories make orthogonal predictions. Scalar inferences are predicted to be costly and neglecting-zero to be cost-free while computing literal meaning comes with cost since it involves considering zero-models.

# This project

**Direct cross-experimental comparison of the Empty restrictor, Empty scope, Upper bound construal and Distributivity inferences.**

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**First test for their robustness in (polar) question environments.**

# Pragmatic effects in questions

1. Questions allow to distinguish presupposition from entailment through projection. (We introduce the *odd question* answer option.)
2. Questions allow to test positive and negative contexts at the same time without issues with the scope of negation (Marty et al., 2024b).

# Experimental Study

# The Experiments

72 German native speakers recruited from Prolific participated in three (sub-)experiments:

**Exp. 1 (ESQ)** ES-restrictor and ES-scope in downward entailing (ESQ) vs. upward-entailing (non-ESQ) quantifiers. (80 items)

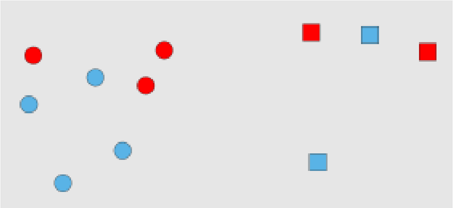
**Exp. 2 (DIST)** DIST effects in disjunctions embedded under universal quantifiers. (40 items)

**Exp. 3 (UB)** Scalar *some*. (20 items)

# Example trial

Are less than 3 squares blue?

# Example trial

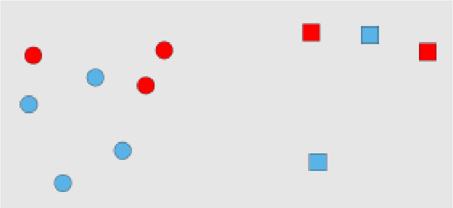


YES

ODD QUESTION

NO

# Example trial

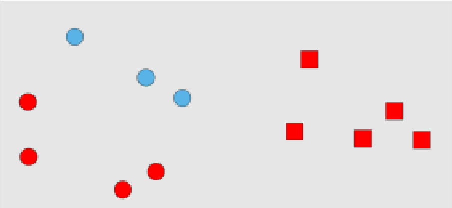


YES | ODD QUESTION | NO

To respond, participants used arrow keys (counterbalanced for order).

# Experiment 1 – Empty-Set Quantifiers

**Are less than 3 squares blue?**

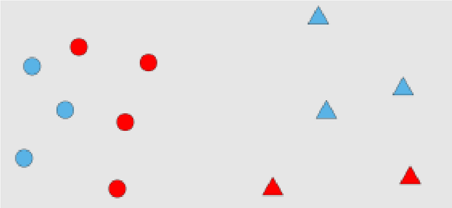


**Empty Scope**

(Target 1)

Lit: True; NE-scope: False

**Are less than 3 squares blue?**



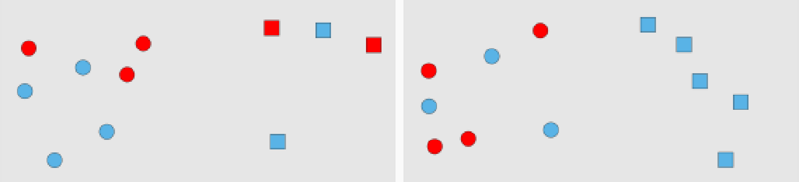
**Empty Restrictor**

(Target 2)

Lit: True; NE-restrictor: False

# Experiment 1 – Empty-Set Quantifiers

**Are less than 3 squares blue?**



**True and false controls**

Lit: True | False;

NE-scope: True; NE-restrictor: True

# Experiment 1 - Design

Downward vs. upward monotone and Aristotelian vs. comparative
(2 MONOTONICITY $\times$ 2 Q-TYPE within design for quantifiers):

1. Are less than 3 squares blue?
2. Are more than 3 squares blue?
3. Is no square blue?
4. Is every square blue?

With **4** MODELS for each quantifier ($\triangleright$ $2 \times 2 \times 4$ within design):
Empty scope, Empty restrictor, False, True (except '*no*').

# Experiment 2 – Distributivity

**Is each square red or blue?**

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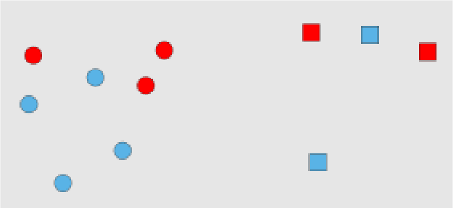
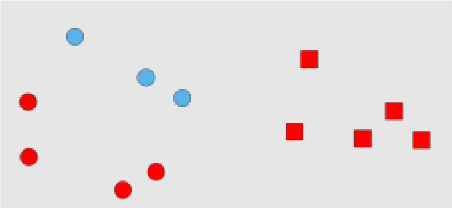


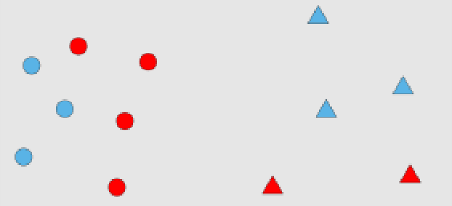
**Distributivity satisfaction**
(True Control)

**Is each square red or blue?**
**Is each square blue or red?**



**Distributivity violation**
(Target 3)

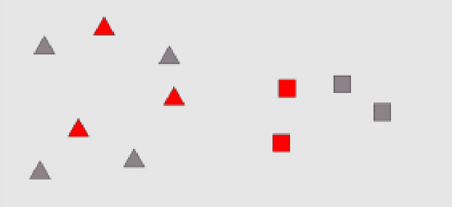
**Is each square red or blue?**
**Is each square blue or red?**



**Empty restrictor**
(Target 4)

# Experiment 2 – Distributivity

**Is each square red or blue?**
**Is each square blue or red?**



**False control**

2 (DISJUNCTION ORDER) $\times$ 4 (MODEL) within design

# Experiment 3 – Upper Bounded Readings

**Are some of the squares blue?**

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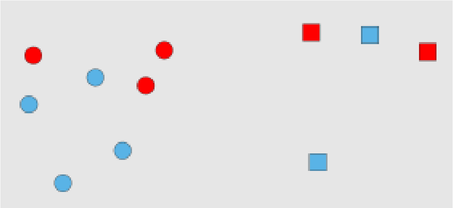

**Upper bound satisfaction**

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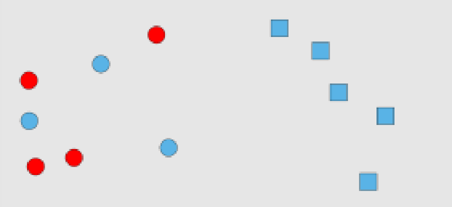
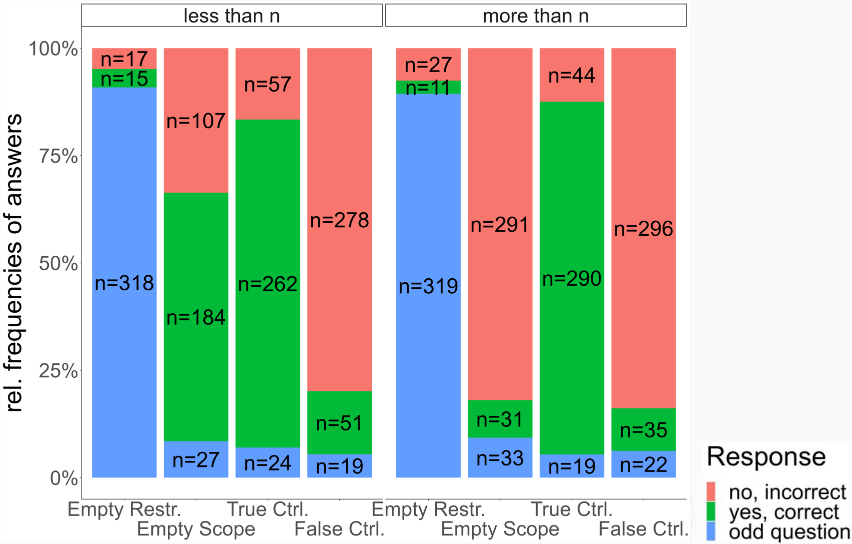


**Upper bound violation**

(Target 5)

# Results

# Response Distributions - Experiment 1



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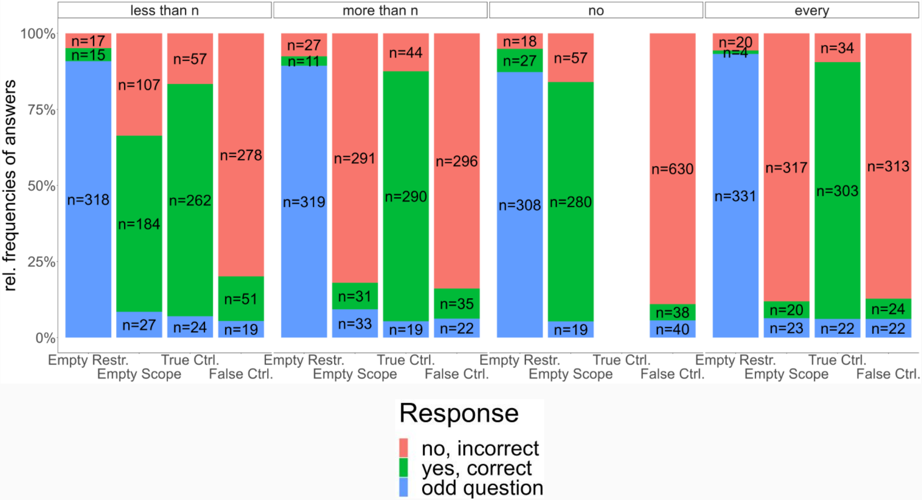

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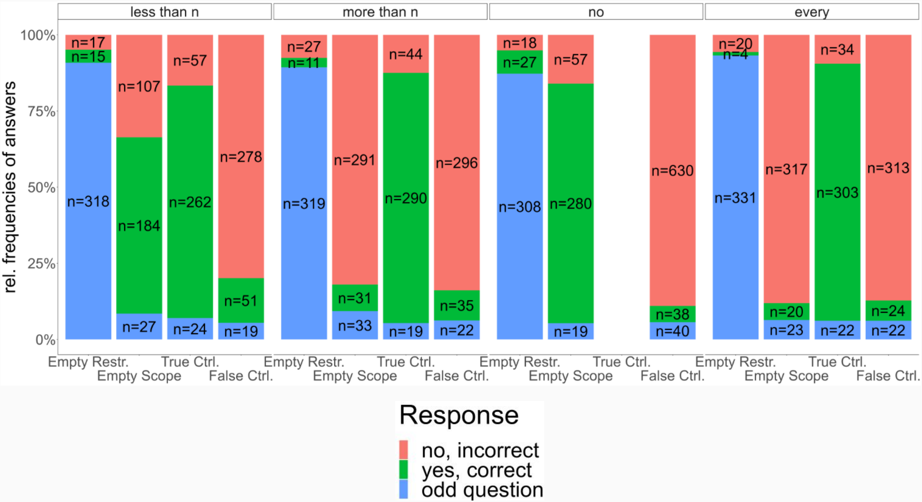
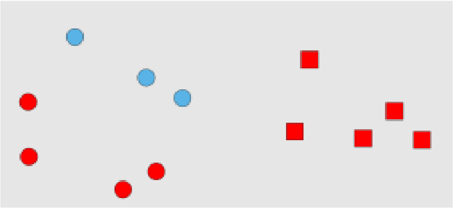



Empty-restrictor inferences project, i.e. behave like a presupposition.

(Geurts, 2007)

# Experiment 1: crucial interaction

**Empty Scope**



| | *Are less than 3 squares blue?* | *Are more than 3 squares blue?* |
|---|---|---|
| Target | **33%** *No* | 9% *Yes* |

(GLMER analysis of MONOTONICITY × MODEL interaction: $\hat{\beta} = 0.75$; $SE = .12$; $z = 6.02$; $p < .01$)

# Experiment 1: crucial interaction

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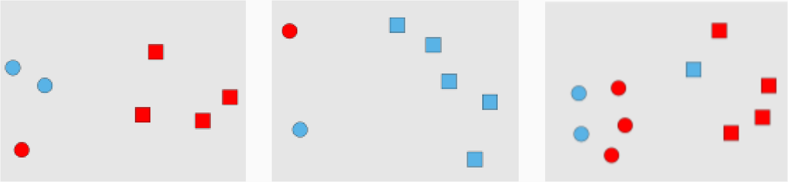


(a) (b) (c)

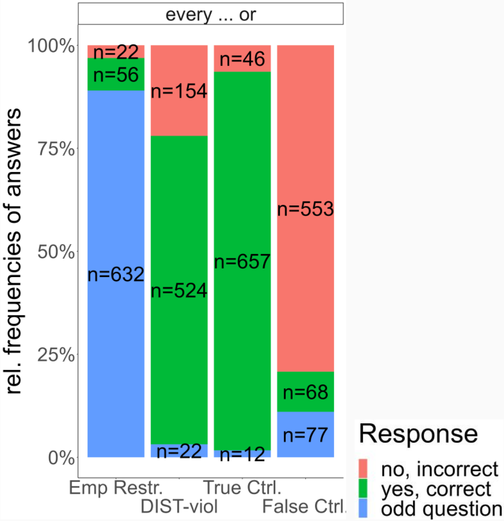
| | *Are less than 3 squares blue?* | *Are more than 3 squares blue?* |
|---|---|---|
| Target | **33%** *No* | 9% *Yes* |
| False | 15% *Yes* | 10 % *Yes* |
| True | 16% *No* | 12 % *No* |

(GLMER analysis of MONOTONICITY × MODEL interaction: $\hat{\beta} = 0.75$; $SE = .12$; $z = 6.02$; $p < .01$)

We observe an empty-set effect in questions only for empty-set (downward entailing) quantifiers.

(Bott et al., 2019; Aloni and van Ormondt, 2023)

# Acceptance rates - Experiment 2

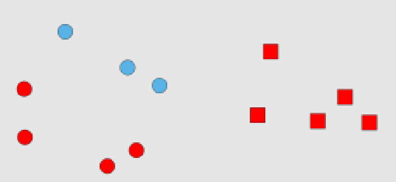


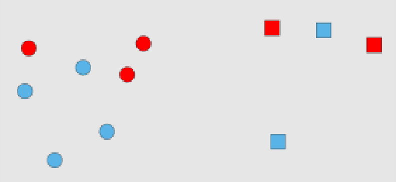

Models violating distributivity are less accepted than the true control.

(Crnič et al., 2015; Aloni and van Ormondt, 2023)

# Experiment 2: main difference

**Distributivity**





**Is each square red or blue?**

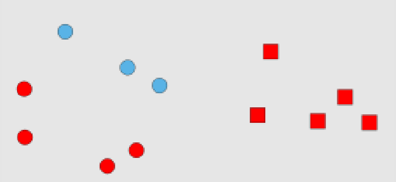
22% *No*

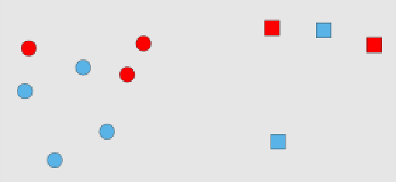
6% *No*

(GLMER fixed effect of MODEL (Target 3 vs. Control): $\hat{\beta} = -5.12$; $SE = .52$; $z = -9.84$; $p < .01$)

# Experiment 2: main difference

**Distributivity**





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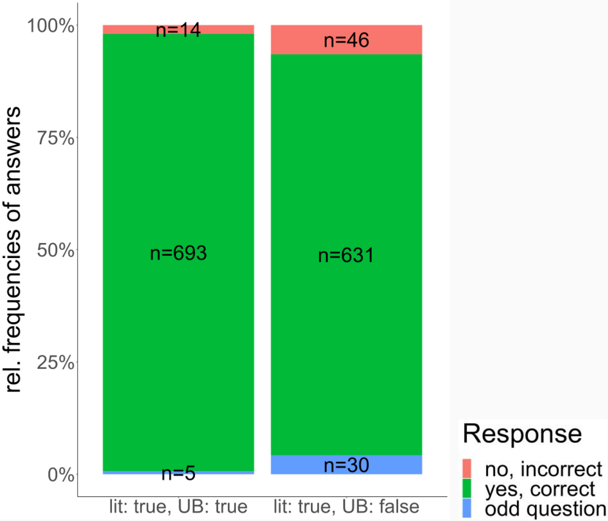
We observe the distributivity (empty-set) effect in questions.

(Crnič et al., 2015; Aloni and van Ormondt, 2023)

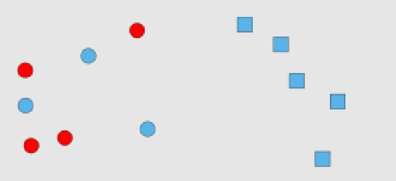
# Acceptance rates - Experiment 3

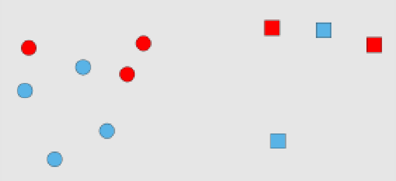



Overwhelmingly 'literal' responses.

As expected upper bound construal inferences barely project.

# Experiment 3: main difference





**Are some squares blue?**

7% *No* — 2% *No*

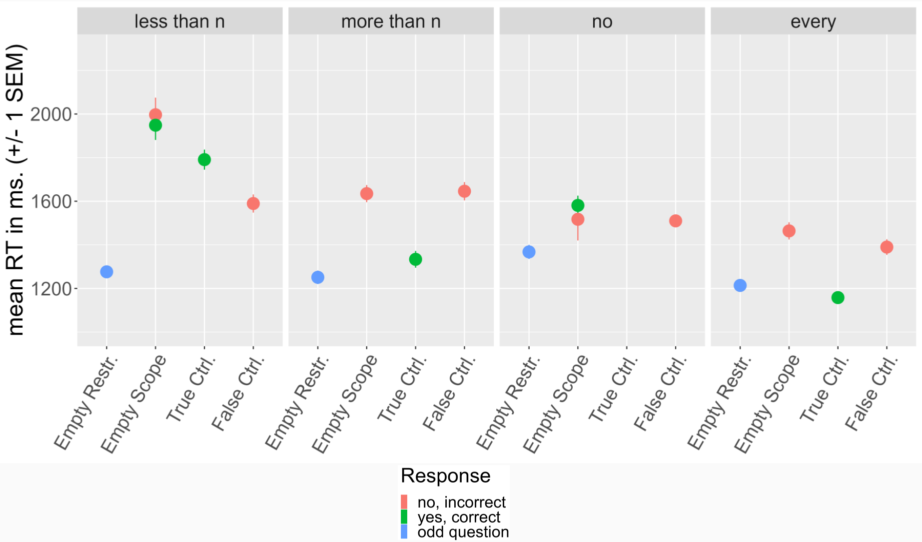
(GLMER fixed effect of MODEL (Target 5 vs. UB SAT.): $\hat{\beta} = -1.53$; $SE = .34$; $z = -4.51$; $p < .01$)

# Summary: acceptance rates

- Empty restrictor results in presupposition failure.
- Empty scope and distributivity effects occur in questions in a similar frequency to declaratives.
- Upper bound construal inferences barely occur in questions.

| | Response | Rate |
|---|---|---|
| Empty restrictor | Odd Q | $> 90\%$ |
| Empty scope DE | No | 33% |
| Empty scope UE | Yes | 9% |
| Distributivity | No | 22% |
| Upper Bound | No | 7% |

# Reaction times - Experiment 1




Processing empty restrictors is fast. (LMER: main effect of MODEL: $t = -3.68$; $p < .01$)

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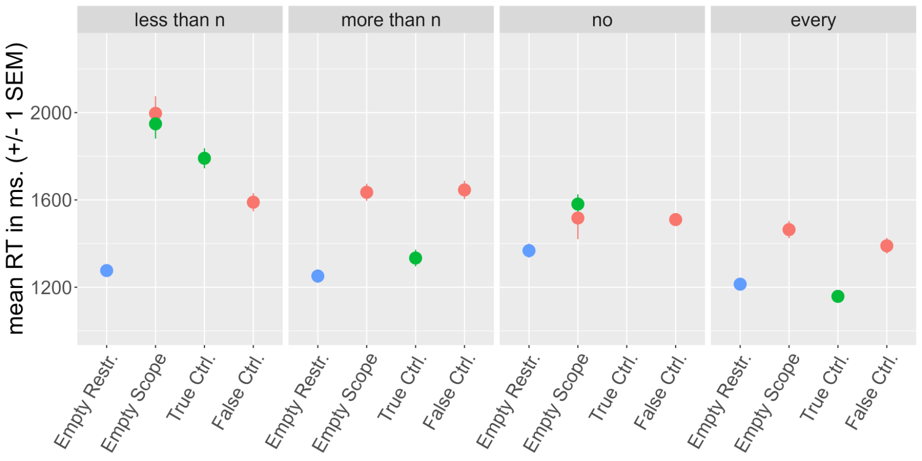


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Processing empty scope leads to processing cost for *less than* relative to other quantifiers. (LMER: MONOTONICITY × Q-TYPE × MODEL interaction: $t = -2.23$; $p < .05$)

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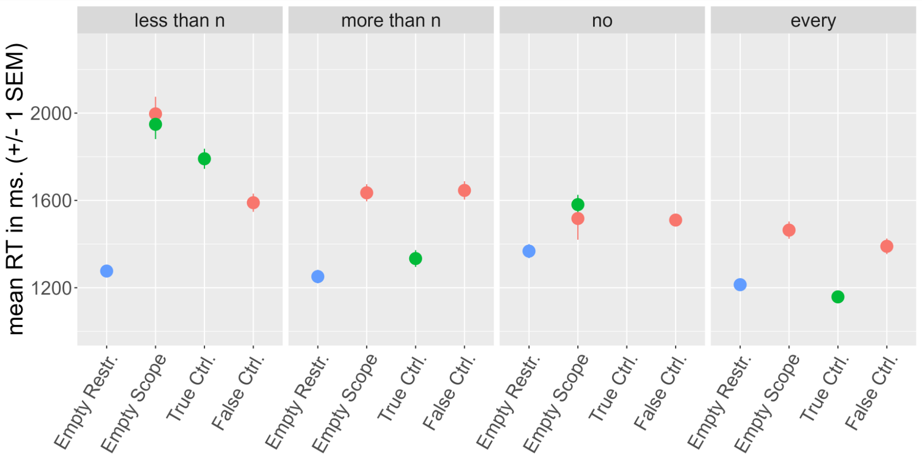
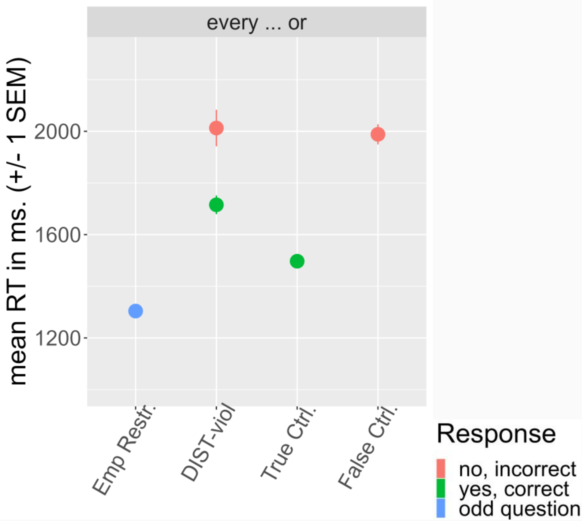



For DE-quantifier the answer-polarity effect is reversed.

(LMER: MONOTONICITY × POLARITY interaction : $t = 4.11$; $p < .01$)

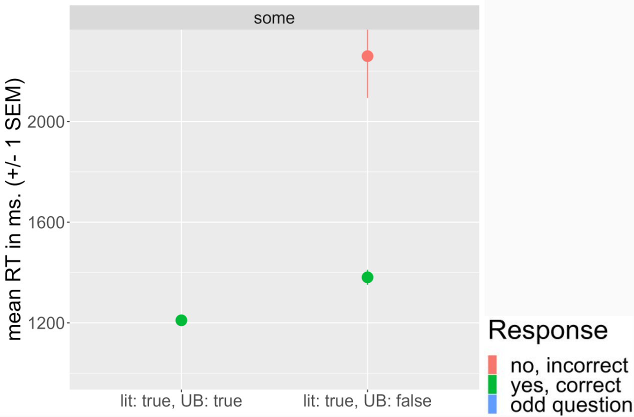
# Reaction times - Experiment 2




Violation of distributivity is costly, relative to TRUE control.

(LMER: contrast DIST vs. TRUE: $t = -2.06$; $p < .05$)

# Reaction times - Experiment 3




Computing UB-inferences takes longer.

(LMER: POLARITY effect in target models: $t = -2.86$; $p < .01$)

# Summary: reaction times

| | Critical Resp. | | RTs | |
|---|---|---|---|---|
| | Response | Prop. | Pragm./ES-Scope | Literal |
| Empty restrictor | Odd Q | $> 90\%$ | fast | - |
| Empty scope DE | No | 33% | slow | slow |
| Distributivity | No | 22% | fast | slow |
| Upper Bound | No | 7% | slow | fast |

- Detecting presupposition failure of empty restrictor is fast.

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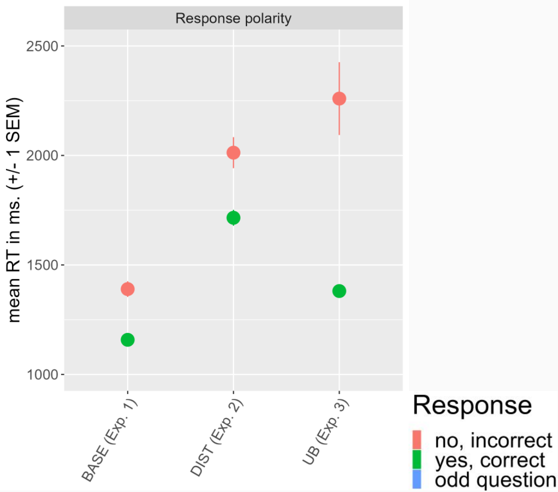
- Empty scope increases processing time for both literal and non-empty-scope interpretations of DE quantifiers.
- Computing the literal meaning in cases of distributivity violation is slow, but the pragmatic interpretation is fast.
- Computing the literal meaning for upper bound construals is fast, but computing the implicature is slow.

# RTs - Answer polarity effects across every & some




Computing UB inferences causes cost on top of general RESPONSE POLARITY effects. (LMER: EXPERIMENT × POLARITY interaction: $t = 3.34$; $p < .01$)

# Conclusions

# Different phenomena

| | Critical resp. | | RT | | Resp. polarity |
|---|---|---|---|---|---|
| | Response | Rate | Pragm./ES | Literal | effect |
| Empty restrictor | Odd Q | $> 90\%$ | fast | - | - |
| Empty scope DE | No | 33% | slow | slow | reversed |
| Distributivity | No | 22% | fast | slow | equal |
| Upper Bound | No | 7% | slow | fast | bigger |

# Available theories

| | NE-restrictor | NE-scope | Upper bound | Distributivity |
|---|---|---|---|---|
| Presupposition | ✓ | NA | NA | NA |
| Implicature | (✓) | ✓ | ✓ | ✓ |
| W-quantifier | NA | ✓ | NA | × |
| Neglect Zero | ✓ | ✓ | NA | ✓ |

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Presupposition check precedes generation of an answer (question) or a truth value judgment (declaratives), thus very fast inference.

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| Neglect Zero | ✓ | ✓ | NA | ✓ |

Presupposition check precedes generation of an answer (question) or a truth value judgment (declaratives), thus very fast inference.

Computing scalar implicatures is cognitively costly, because of additional pragmatic process. They do not project.

# Empty scope and Distributivity

Processing zero models is difficult in both declaratives and questions causing people to use **fast processing strategies** (e.g. to neglect zero-models) leading to longer reaction times and simplified responses.

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| | NE-restrictor | NE-scope | Upper bound | Distributivity |
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| Implicature | ($\checkmark$) | $\checkmark$ | $\checkmark$ | $\checkmark$ |
| Presupposition | $\checkmark$ | NA | NA | NA |
| W-quantifier | NA | $\checkmark$ | NA | $\times$ |
| Neglect Zero | $\checkmark$ | $\checkmark$ | NA | $\checkmark$ |

# Different tools

**Potential solutions:**

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3. **Different tools:** There are diverse phenomena at play in the data, which require multiple theoretical tools to be explained.
4. **Uniform theory...**

# Different tools

| | NE-restrictor | NE-scope | Upper bound | Distributivity |
|---|---|---|---|---|
| Implicature | ($\checkmark$) | $\checkmark$ | $\checkmark$ | $\checkmark$ |
| Presupposition | $\checkmark$ | NA | NA | NA |
| W-quantifier | NA | $\checkmark$ | NA | $\times$ |
| Neglect Zero | $\checkmark$ | $\checkmark$ | NA | $\checkmark$ |

# Ongoing research

**Structural priming** between Upper bound construals, Distributivity and Empty scope (see e.g. Marty et al., 2024a).

**EEG**: Are zero models more difficult to process?

**Acquisition**: Conjunctive interpretations of disjunction.

Thank you!

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# Original examples

(2) a. Sind **weniger als drei** Quadrate blau?
b. Sind **mehr als drei** Quadrate blau?
c. Ist **jedes** Quadrat blau?
d. Ist **kein** Quadrat blau?

(3) Ist **jedes** Quadrat entweder rot **oder** blau?

(4) Sind **einige** der Quadrate blau?

| **ja, stimmt** | **komische Frage** | **nein, stimmt nicht** |
|---|---|---|

# Individual participants analysis: Empty scope (less than).

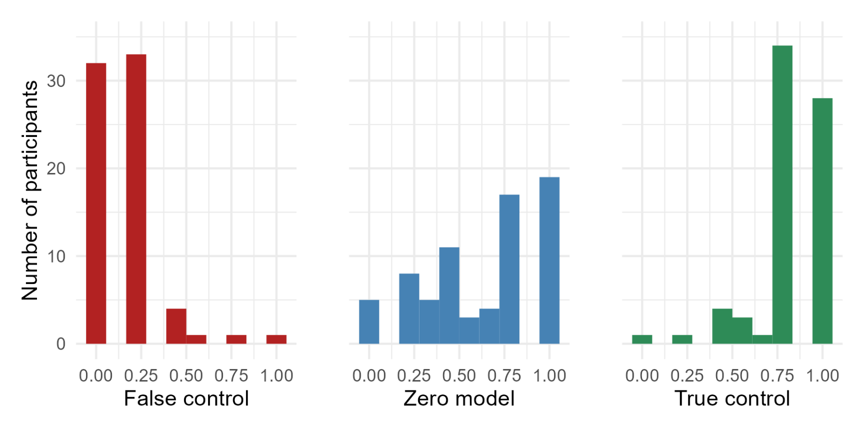


**Figure 1:** Participants' individual acceptance rate (without *odd question* responses.)

# Individual participants analysis: Distributivity

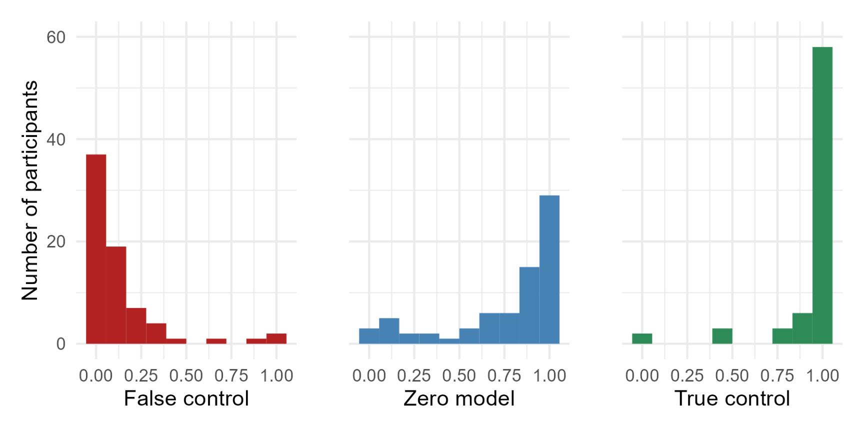


**Figure 2:** Participants' individual acceptance rate (without *odd question* responses.)

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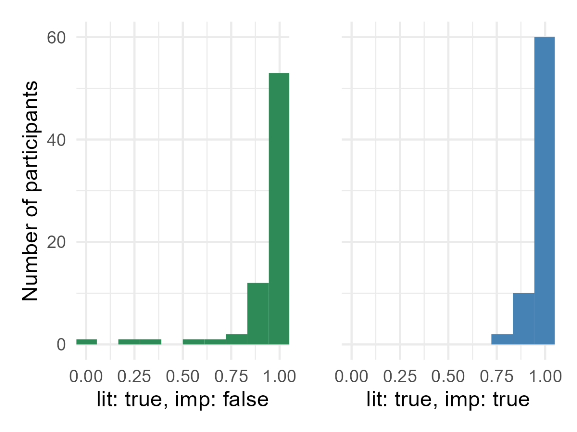


**Figure 3:** Participants' individual acceptance rate (without *odd question* responses.)