Modelling and experimenting with zero-models

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Slides: https://www.marialoni.org/resources/Paris25B.pdf

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Two views

- People draw conclusions beyond what is literally said
- The standard view: enriched interpretations (aka implicatures) result from an alternative-based mechanism (slow, deliberative, costly)
  - (i) computation of literal meaning; (ii) recognition of an alternative phrase which could have been used; (iii) negation of this alternative; ...
- The Nihil hypothesis: enrichments sometimes result from biases due to our cognitive limitations, notably: (fast, not deliberative, effortless)
  - a tendency to avoid emptiness (**neglect-zero**)
  - a negative bias towards the parallel processing of alternatives (**no-split**)

Today

1. Modelling neglect-zero in a team semantics: BSML, $\mathrm{BSML}^{\rightarrow}$, $\mathrm{qBSML}^{\rightarrow}$
2. Experimenting with zero-models: 3 recent studies testing the predictions of these two views

Focus on three inferences

(1) a. Some of the squares are red ⇒ not all of the squares are red [scalar **UB**]
b. Each square is white or red ⇒ there are white squares and red squares [**DIST**]
c. Less than 3 squares are white ⇒ there are some white squares [**ESQ**]

	UB	**DIST**	**ESQ**
Standard implicature view	alt-based	alt-based[1]	alt-based [?]
NIHIL	—	neglect-zero	neglect-zero

[1] Crnič, Chemla, & Fox (2015); Bar-Lev & Fox (2023).

The Nihil hypothesis

NEGLECT-ZERO
When interpreting a sentence speakers construct models depicting reality and in this process tend to neglect models that verify the sentence by virtue of an empty configuration (*zero-models*)

Illustrations

(2) Less than three squares are black. **[ESQ]**
a. Verifier: [■, □, ■] $\rightsquigarrow_{nz}$ there are black squares
b. Falsifier: [■, ■, ■]
c. Zero-models: [□, □, □]; [■, ■, ■]; ...

Zero-models in (2-c) verify the sentence by virtue of an empty set of black squares

(3) Every square is red or white. **[DIST]**
a. Verifier: [■, □, ■] $\rightsquigarrow_{nz}$ there are white squares & red squares
b. Falsifier: [■, □, ■]
c. Zero-models: [■, ■, ■]; [□, □, □]

Zero-models in (3-c) verify the sentence by virtue of an empty set of white sqrs or of red sqrs

NZ hypothesis: neglect-zero at the origin of many common departures from classical reasoning

- Free choice and ignorance [MA 2022]
- Existential Import: every A is B ⇒ some A is B
- Aristotle's Thesis: if not A then A ⇒ ⊥
- Boethius' Thesis: if A then B & if A then not B ⇒ ⊥

Neglect-zero in team semantic: BSML

- Team semantics: formulas interpreted wrt a set of points of evaluation (a team) rather than single ones [Väänänen 2007; Yang & Väänänen 2017]

Classical vs team-based modal logic

$[M = \langle W, R, V\rangle]$

- Classical modal logic: (truth in worlds)

$$M, w \models \phi, \text{ where } w \in W$$

- Team-based modal logic:

$$M, t \models \phi, \text{ where } t \subseteq W$$

Bilateral state-based modal logic (BSML)

- Teams $\mapsto$ information states [Dekker93; Groenendijk[+]96; Ciardelli[+]19]
- Assertion & rejection conditions modeled rather than truth

$$M, s \models \phi, \text{ “}\phi \text{ is assertable in } s\text{”}, \quad \text{with } s \subseteq W$$

$$M, s \mathrel{=\!\!|} \phi, \text{ “}\phi \text{ is rejectable in } s\text{”}, \quad \text{with } s \subseteq W$$

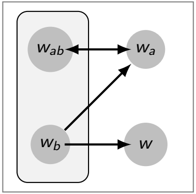
Modelling neglect-zero

- Crucial feature: **empty team** among possible teams/states: $\emptyset \subseteq W$
- Neglect-zero modelled via non-emptiness atom NE which disallows empty teams as possible verifiers: $M, s \models \text{NE} \text{ iff } s \neq \emptyset$
- **Bilateralism** crucial to derive cancellation of neglect-zero effects under negation

BSML: Classical Modal Logic + NE

Language

$$\phi := p \mid \neg\phi \mid \phi \vee \phi \mid \phi \wedge \phi \mid \Diamond\phi \mid \mathrm{NE}$$



Bilateral team semantics

Given Kripke model $M = \langle W, R, V \rangle$ & teams/states $s, t, t' \subseteq W$

$$
\begin{array}{rcl}
M, s \models p & \text{iff} & \text{for all } w \in s : V(w, p) = 1 \\
M, s \,=\!\!|\, p & \text{iff} & \text{for all } w \in s : V(w, p) = 0 \\
M, s \models \neg\phi & \text{iff} & M, s \,=\!\!|\, \phi \\
M, s \,=\!\!|\, \neg\phi & \text{iff} & M, s \models \phi \\
M, s \models \phi \vee \psi & \text{iff} & \text{there are } t, t' : t \cup t' = s \;\&\; M, t \models \phi \;\&\; M, t' \models \psi \qquad \Leftarrow \\
M, s \,=\!\!|\, \phi \vee \psi & \text{iff} & M, s \,=\!\!|\, \phi \;\&\; M, s \,=\!\!|\, \psi \\
M, s \models \phi \wedge \psi & \text{iff} & M, s \models \phi \;\&\; M, s \models \psi \\
M, s \,=\!\!|\, \phi \wedge \psi & \text{iff} & \text{there are } t, t' : t \cup t' = s \;\&\; M, t \,=\!\!|\, \phi \;\&\; M, t' \,=\!\!|\, \psi \\
M, s \models \Diamond\phi & \text{iff} & \text{for all } w \in s : \exists t \subseteq R[w] : t \neq \emptyset \;\&\; M, t \models \phi \\
M, s \,=\!\!|\, \Diamond\phi & \text{iff} & \text{for all } w \in s : M, R[w] \,=\!\!|\, \phi \qquad [\text{where } R[w] = \{v \in W \mid wRv\}] \\
M, s \models \mathrm{NE} & \text{iff} & s \neq \emptyset \\
M, s \,=\!\!|\, \mathrm{NE} & \text{iff} & s = \emptyset
\end{array}
$$

Entailment: $\phi_1, \ldots, \phi_n \models \psi$ iff for all M, s: $M, s \models \phi_1, \ldots, M, s \models \phi_n \Rightarrow M, s \models \psi$

Proof Theory: MA, Anttila & Yang (2024); Expressive completeness: Anttila & Knudstorp (2025); Comparisons via translation into Modal Information Logic: Knudstorp *et al* (2025)

Modelling zero-models: the logic team

Aleksi Anttila

Søren Knudstorp

Fan Yang

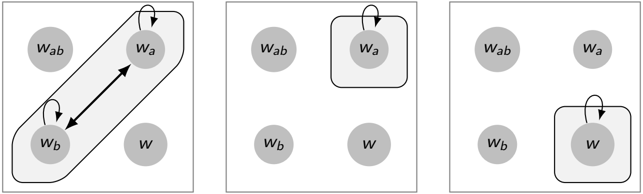
Nick Bezhanishvili

Fact (**Empty team property**). Every $\textsc{ne}$-free formula α in BSML is supported & anti-supported by the empty team: $M, \emptyset \models \alpha$ & $M, \emptyset \mathrel{=\!\!|} \alpha$

Neglect-zero effects in BSML: split disjunction

- A state s supports a **disjunction** iff s is the union of two substates, each supporting one of the disjuncts

$$M, s \models \phi \vee \psi \text{ iff } \exists t, t' : t \cup t' = s \;\&\; M, t \models \phi \;\&\; M, t' \models \psi$$



$\models a \vee b$ $\quad$ $\models a \vee b$ $\quad$ $\not\models a \vee b$

- State $\{w_a\}$ verifies $a \vee b$ by virtue of an empty witness for the second disjunct, $\{w_a\} = \{w_a\} \cup \emptyset \;\&\; M, \emptyset \models b$ $\quad\mapsto$ **zero-model**
- Main idea: define neglect-zero enrichment function $[\ ]^+$, whose core effect is to rule out such zero-models
- Implementation: $[\ ]^+$ defined using non-emptiness atom NE, which models neglect-zero in the logic

Neglect-zero effects in BSML: neglect-zero enrichment

Non-emptiness

NE is supported in a state if and only if the state is not empty

$$\begin{array}{lll} M, s \models \mathrm{NE} & \text{iff} & s \neq \emptyset \\ M, s \dashv \mathrm{NE} & \text{iff} & s = \emptyset \end{array}$$

Neglect-zero enrichment

For NE-free α, $[\alpha]^+$ defined as follows:

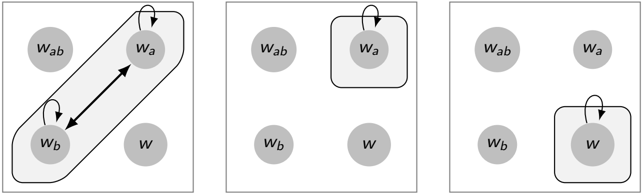
$$\begin{array}{rcl} [p]^+ & = & p \wedge \mathrm{NE} \\ [\neg\alpha]^+ & = & \neg[\alpha]^+ \wedge \mathrm{NE} \\ [\alpha \vee \beta]^+ & = & ([\alpha]^+ \vee [\beta]^+) \wedge \mathrm{NE} \\ [\alpha \wedge \beta]^+ & = & ([\alpha]^+ \wedge [\beta]^+) \wedge \mathrm{NE} \\ [\Diamond\alpha]^+ & = & \Diamond[\alpha]^+ \wedge \mathrm{NE} \end{array}$$

$[\ ]^+$ enriches formulas with the requirement to satisfy NE distributed along each of their subformulas

Neglect-zero effects in BSML: enriched disjunction

- *s* supports an **enriched disjunction** $[\alpha \vee \beta]^+$ iff *s* is the union of two non-empty substates, each supporting one of the disjuncts

$$[\alpha \vee \beta]^+ = (\alpha \wedge \mathrm{NE}) \vee (\beta \wedge \mathrm{NE}) \wedge \mathrm{NE}$$



No-zero verifier: $\models a \vee b$; $\models [a \vee b]^+$

Zero-model: $\models a \vee b$; $\not\models [a \vee b]^+$

Falsifier: $\dashv a \vee b$; $\dashv [a \vee b]^+$

- An enriched disjunction requires both disjuncts to be live possibilities [Zimmermann 2000]

(4) M ate an apple or a banana $\rightsquigarrow_{nz}$ It might be apple & it might be banana
$[\alpha \vee \beta]^+ \models \Diamond_e \alpha \wedge \Diamond_e \beta$ (where R is state-based)

- Main result: in BSML $[\ ]^+$-enrichment has non-trivial effect only when applied to *positive* disjunctions [MA 2022]
  - $\mapsto$ we derive ignorance, FC and related effects (for enriched formulas);
  - $\mapsto$ $[\ ]^+$-enrichment vacuous under single negation.

Neglect-zero effects in BSML: main results

After enrichment

- We derive ignorance, FC and related inferences:
  - Possibility: $[\alpha \vee \beta]^+ \models \Diamond_e\alpha \wedge \Diamond_e\beta$ (if R is state-based)
  - Narrow scope FC: $[\Diamond(\alpha \vee \beta)]^+ \models \Diamond\alpha \wedge \Diamond\beta$
  - Double negation FC: $[\neg\neg\Diamond(\alpha \vee \beta)]^+ \models \Diamond\alpha \wedge \Diamond\beta$
  - Wide scope FC: $[\Diamond\alpha \vee \Diamond\beta]^+ \models \Diamond\alpha \wedge \Diamond\beta$ (if R is indisputable)
- while no undesirable side effects obtain with other configurations:
  - Double prohibition: $[\neg\Diamond(\alpha \vee \beta)]^+ \models \neg\Diamond\alpha \wedge \neg\Diamond\beta$

Before enrichment

- The NE-free fragment of BSML is equivalent to classical modal logic:

$$\alpha \models_{BSML} \beta \text{ iff } \alpha \models_{ML} \beta \qquad [\text{if } \alpha, \beta \text{ are NE-free}]$$

Team-based constraints on accessibility relation

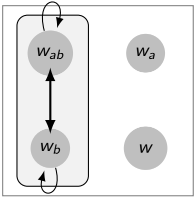
- R state-based in (M, s) iff all and only worlds in s are accessible within s [$\mapsto$ **epistemics** (always)]
- R indisputable in (M, s) iff all worlds in s access exactly the same set of worlds [$\mapsto$ **deontics** (sometimes)]

BSML$^{\rightarrow}$: adding implication

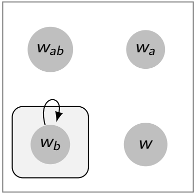
- A state s supports an implication $\phi \rightarrow \psi$ iff
  (i) every subset of s that supports ϕ also supports ψ;
  (ii) there is a subset of s which supports ϕ.

$M, s \models \phi \rightarrow \psi$ iff (i) for all $t \subseteq s:\ M, t \models \phi \ \Rightarrow\ M, t \models \psi$ & (ii) $\exists t \subseteq s:\ M, t \models \phi$

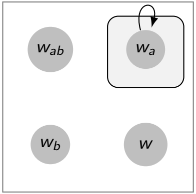
Because of empty team property condition (ii) trivial for classical $\alpha \rightarrow \beta$, but crucially non-trivial for enriched $[\alpha \rightarrow \beta]^+ = ([\alpha]^+ \rightarrow [\beta]^+) \wedge \mathrm{NE}$



No-zero verifier
$\models a \rightarrow b$; $\models [a \rightarrow b]^+$



Zero-model
$\models a \rightarrow b$; $\not\models [a \rightarrow b]^+$



Falsifier
$=\!\mid a \rightarrow b$; $=\!\mid [a \rightarrow b]^+$

- An enriched implication requires the antecedent to be a live possibility:

(5) If it is raining, M will go home $\rightsquigarrow_{nz}$ it might be raining
$[\alpha \rightarrow \beta]^+ \models \Diamond_e \alpha$ (where R is state-based)

Neglect-zero effects in BSML$^{\rightarrow}$: main results

After enrichment

- We derive possibility of antecedent and related Aristotelian principles:
  - Aristotle's theses: from something we cannot derive its negation
    $$[\alpha \rightarrow \neg\alpha]^{+} \models \bot \;\&\; [\neg\alpha \rightarrow \alpha]^{+} \models \bot$$
  - Abelard/Boethius: from something we cannot derive contradictory conclusions
    $$[(\alpha \rightarrow \beta) \wedge (\alpha \rightarrow \neg\beta)]^{+} \models \bot$$
  - Existential import: from *every A is B* to *some A is B* [in qBSML$^{\rightarrow}$]
    $$[\forall x(Ax \rightarrow Bx)]^{+} \models \exists x(Ax \wedge Bx) \qquad \text{(assuming max info)}$$

Before enrichment

- The NE-free fragment of BSML$^{\rightarrow}$ is equivalent to classical modal logic:
  $$\alpha \models_{BSML^{\rightarrow}} \beta \text{ iff } \alpha \models_{ML} \beta \qquad [\text{if } \alpha, \beta \text{ are NE-free}]$$

Emerging picture

- Admit zero $\mapsto$ classical logic (literal meanings);
- Disallow zero $\mapsto$ traditional logic (enriched meanings).

The point about zero is that we do not need to use it in the operations of daily life. No one goes out to buy zero fish. It is in a way the most civilized of all the cardinals, and its use is only forced on us by the needs of cultivated modes of thought. (AN Whitehead, quoted by Nieder 2016)

qBSML$^{\rightarrow}$: adding quantifiers (MA & vOrtmondt 2023)[2]

- A quantified modal language interpreted in models $\mathcal{M} = \langle W, D, R, I \rangle$
- **Teams** defined as sets of world-assignment pairs
- A state s supports $\forall x \phi$ iff $s[x]$, the universal x-extension of s, supports ϕ:

$$\mathcal{M}, s \models \forall x \varphi \text{ iff } \mathcal{M}, s[x] \models \varphi$$

- The universal x-extension of $s \mapsto s$ updated with all possible values for x

$$s = \boxed{\langle w, \lambda \rangle} \mapsto s[x] = \begin{array}{|c|} \hline \langle w, x \rightarrow a \rangle \\ \hline \langle w, x \rightarrow b \rangle \\ \hline \langle w, x \rightarrow c \rangle \\ \hline \langle w, x \rightarrow d \rangle \\ \hline \dots \\ \hline \end{array}$$

Figure: An initial max info state and its universal x-extension

- The NE-free fragment of qBSML$^{\rightarrow}$ is equivalent to classical quantified modal logic:

$$\alpha \models_{qBSML^{\rightarrow}} \beta \text{ iff } \alpha \models_{QML} \beta \qquad [\text{if } \alpha, \beta \text{ are NE-free}]$$

[2] MA & vOrtmondt, Modified numerals and split disjunction. *J of Log Lang and Inf* (2023)

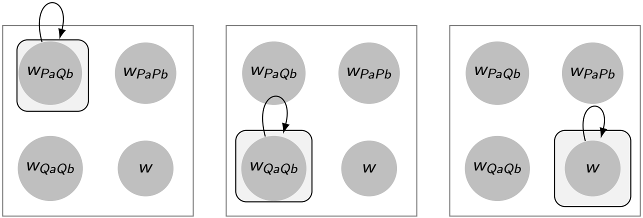
qBSML$^{\rightarrow}$: adding quantifiers

Interaction disjunction and quantifiers: distributive inference

$$D = \{a, b\}$$

$$s = \boxed{\langle w_{PaQb}, \lambda \rangle} \models [\forall x(Px \vee Qx)]^{+} \text{ since } s[x] = \boxed{\begin{array}{c} \langle w_{PaQb}, x \rightarrow a \rangle \\ \hline \langle w_{PaQb}, x \rightarrow b \rangle \end{array}} \models [Px \vee Qx]^{+}$$

$$s = \boxed{\langle w_{QaQb}, \lambda \rangle} \not\models [\forall x(Px \vee Qx)]^{+} \text{ since } s[x] = \boxed{\begin{array}{c} \langle w_{QaQb}, x \rightarrow a \rangle \\ \hline \langle w_{QaQb}, x \rightarrow b \rangle \end{array}} \not\models [Px \vee Qx]^{+}$$



No-zero verifier	**Zero-model**	Falsifier
$\models \forall x(Px \vee Qx)$	$\models \forall x(Px \vee Qx)$	$\dashv \forall x(Px \vee Qx)$
$\models [\forall x(Px \vee Qx)]^{+}$	$\not\models [\forall x(Px \vee Qx)]^{+}$	$\dashv [\forall x(Px \vee Qx)]^{+}$

Figure: Models for $\forall x(Px \vee Qx)$

(6) Everything is black or white $\rightsquigarrow_{nz}$ there are black things and white things
$[\forall x(Px \vee Qx)]^{+} \models \exists x Px \wedge \exists x Qx$ (with max info)

Neglect-zero effects on quantifiers

Predictions of qBSML$^{\rightarrow}$ (with max info)

(7) Less than three squares are black $\mapsto \forall xyz((Sx \wedge Bx \wedge \ldots) \rightarrow (x = y \vee \ldots))$

- a. Verifier: [■, □, ■]
- b. Falsifier: [■, ■, ■]
- c. Zero-models: [□, □, □]; [▲, ▲, ▲]; . . . $\rightsquigarrow_{nz}$ there are black squares

(8) Every square is black. $\mapsto \forall x(Sx \rightarrow Bx)$

- a. Verifier: [■, ■, ■]
- b. Falsifier: [■, □, ■]
- c. Zero-models: [△, △, △]; [▲, ▲, ▲]; . . . $\rightsquigarrow_{nz}$ there are squares

(9) No squares are black. $\mapsto$ (i) $\forall x(Sx \rightarrow \neg Bx)$; (ii) $\neg\exists x(Sx \wedge Bx)$

- a. Verifier: [□, □, □]
- b. Falsifier: [■, □, □]
- c. Zero-models for (i): [△, △, △]; [▲, ▲, ▲]; . . . $\rightsquigarrow_{nz}$ there are squares
- d. Zero-models for (ii): none — no neglect-zero effect

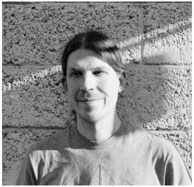
(10) Every square is red or white. $\mapsto \forall x(Sx \rightarrow (Rx \vee Wx))$

- a. Verifier: [■, □, ■]
- b. Falsifier: [■, □, ■]
- c. Zero-models: [■, ■, ■]; [□, □, □] $\rightsquigarrow_{nz}$ there are white sqrs & red sqrs

These predictions tested in 3 recent experiments

Experimenting with zero-models: the team

Oliver Bott



Fabian Schlotterbeck

Sonia Ramotowska

Tomasz Klochowicz

Experimenting with zero-models

Three inferences

(11) a. Some of the squares are red ⇒ not all of the squares are red [UB]
b. Fewer than 3 squares are white ⇒ there are some white squares [ESQ]
c. Each square is white or red ⇒ there are white squares and red squares [DIST]

Two competing accounts

	UB	ESQ	DIST
Standard implicature view	alt-based	alt-based [?]	alt-based
NIHIL	—	neglect-zero	neglect-zero

How to test these different hypotheses?

Strategy A

- Much is known about UB scalar implicatures:
  - Delay effect: $RT_{enriched} > RT_{literal}$ [L. Bott & Noveck, 2004]
  - Lower implicature-rate under cognitive load [De Neys & Schaeken, 2007]
  - Acquired late [Noveck, 2001]
  - Lower rate in questions
  - ...
- Do these features generalise to other inferences in (11)?
  - Standard view: in principle YES (all derive from single alt-based mechanism)
  - NIHIL: NO (some result from a preference to minimize cognitive effort)
- Strategy A: valuable and instructive but not resolutive on whether one and the same mechanism derives all inferences in (11)

Experimenting with zero-models

Three inferences

(12) a. Some of the squares are red ⇒ not all of the squares are red [UB]
b. Fewer than 3 squares are white ⇒ there are some white squares [ESQ]
c. Each square is white or red ⇒ there are white squares and red squares [DIST]

Two competing accounts

	UB	ESQ	DIST
Standard implicature view	alt-based	alt-based [?]	alt-based
NIHIL	—	neglect-zero	neglect-zero

How to test these different hypotheses?

Strategy B

- **Priming:** two assumptions (L. Bott and Chemla 2016)
  - Pragmatic inference-rate can systematically be affected by manipulations in a priming phase
  - If one single cognitive mechanism is responsible for deriving two different inferences, drawing/suspending one on a prime trial should increase/decrease the rate of the other in the subsequent trial
- Will inference-rate change after participants are primed to suspend other inferences in (12)?
  - Standard view: YES overall
  - NIHIL: only between ESQ & DIST

Experimenting with zero-models

Three inferences

(13)
a. Some of the squares are red ⇒ not all of the squares are red [UB]
b. Fewer than 3 squares are white ⇒ there are some white squares [ESQ]
c. Each square is white or red ⇒ there are white squares and red squares [DIST]

Two competing accounts

	UB	ESQ	DIST
Standard implicature view	alt-based	alt-based [?]	alt-based
NIHIL	—	neglect-zero	neglect-zero

Three experiments

- Exp 1: Answering questions about the empty set (O. Bott *et al*, SuB24) [StrA]
- Exp 2: Priming with zero-models (Klochowicz *et al*, CogSci 2025, SuB25) [StrB]
- Exp 3: Inferences under cognitive load (Ramotowska & MA, XPRAG25) [StrA]

Three main conclusions

1. Evidence that DIST differs from UB (Exp 1, Exp 2, Exp 3)
2. Mixed results concerning ESQ (Exp 3)
3. Evidence that DIST & ESQ (but not UB) involve the same cognitive process (Exp 2)

While 1 in principle explainable by both views (via lexical access) and 2 by neither view, 3 is a serious challenge for the standard implicature approach

Experimenting with zero-models

Three inferences

(14) a. Some of the squares are red ⇒ not all of the squares are red [UB]
b. Fewer than 3 squares are white ⇒ there are some white squares [ESQ]
c. Each square is white or red ⇒ there are white squares and red squares [DIST]

Two competing accounts

	UB	ESQ	DIST
Standard implicature view	alt-based	alt-based [?]	alt-based
NIHIL	—	neglect-zero	neglect-zero

Task

All experiments involved a picture verification task and compared:

- Target: literal reading ↦ **true** & enriched reading ↦ **false**

  [■, ■, ■, ■, ■]

- True-control: literal reading ↦ **true** & enriched reading ↦ **true**

  [■, ■, ■, □, □]

- False-control: literal reading ↦ **false** & enriched reading ↦ **false**

  [■, ■, □, □, □]

Exp1: Answering questions about the empty set (Bott et al, SuB 2024)

Four inferences

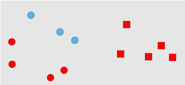
(15)
a. Some of the squares are black ⇒ not all of the squares are black [UB]
b. Each square is red or white ⇒ there are white squares and red squares [DIST]
c. Less than 3 squares are black ⇒ there are some black squares [ESQ-**scope**]
d. Less than 3/every/no squares are black ⇒ there are some squares [ESQ-**restrictor**]

Three competing accounts

	UB	DIST	ESQ-scope	ESQ-restrictor
Standard implicature view	alt-based	alt-based	alt-based [?]	—
O. Bott *et al* 2019	—	—	neglect-zero	presupposition
NIHIL	—	neglect-zero	neglect-zero	neglect-zero

- Question-answer task (German)

(16) Ist jedes Dreieck entweder rot oder blau? Ja/Nein/Komische Frage
(Is every triangle either red or blue?) Yes/No/Odd question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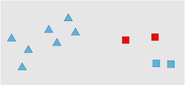
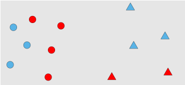
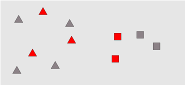

DIST target (zero-model)


control '*yes*'


control '*no*'

- Main results:
  1. Evidence that ESQ-restrictor is a presupposition: questions in empty restrictor models uniformly (more than 90%) perceived as odd

Exp1: Answering questions about the empty set (Bott et al, SuB 2024)

Four inferences

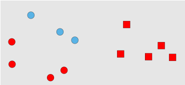
(17)
a. Some of the squares are black ⇒ not all of the squares are black [UB]
b. Each square is red or white ⇒ there are white squares and red squares [DIST]
c. Less than 3 squares are black ⇒ there are some black squares [ESQ-**scope**]
d. Less than 3/every/no squares are black ⇒ there are some squares [ESQ-**restrictor**]

Three competing accounts

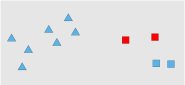
	UB	DIST	ESQ-scope	ESQ-restrictor
Standard implicature view	alt-based	alt-based	alt-based [?]	—
O. Bott *et al* 2019	—	—	neglect-zero	presupposition
NIHIL	—	neglect-zero	neglect-zero	neglect-zero

- **Question-answer task**:

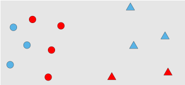
(18) Ist jedes Dreieck entweder rot oder blau? Ja/Nein/Komische Frage
(Is every triangle either red or blue?) Yes/No/Odd question



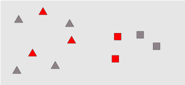
empty restr



DIST target (zero-model)



control '*yes*'



control '*no*'

- **Main results**:

2. Using results from previous studies: ESQ-scope (37%) & DIST (23%) unaffected by question environment; UB much less available (10%, while 40% when unembedded)
3. Inconclusive evidence on whether ESQ-scope & DIST have the same source

Exp2: Priming with zero-models (Klochowicz *et al*, CogSci 2025, SuB25)

Four inferences

(19)
a. Some of the squares are black ⇒ not all of the squares are black [UB]
b. Each square is red or white ⇒ there are white and red squares [DIST]
c. At most 2 squares are black ⇒ there are some black squares [**ESQ**-s]
d. Fewer than 3 squares are black ⇒ there are some black squares [ESQ]

Two competing accounts

	UB	DIST	ESQ(-s)
Standard implicature view	alt-based	alt-based	alt-based [?]
Nihil	—	neglect-zero	neglect-zero

The priming study

- 3 sub-experiments tested whether frequency of ESQ changed after participants were primed to suspend other enrichments in (19-a)-(19-c)
- Predictions/expectations:

	Implicature view	Nihil
DIST ⇒ ESQ	yes [?]	yes
UB ⇒ ESQ	yes [?]	no
ESQ-s ⇒ ESQ	yes [?]	yes

Exp2: Better-picture paradigm (adapted from L. Bott & Chemla 2016)

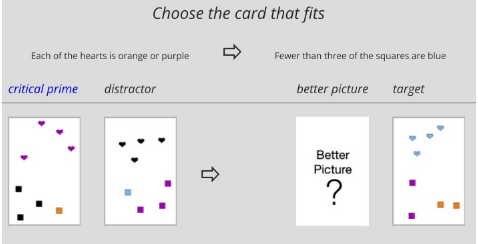


Figure: DIST ⇒ ESQ

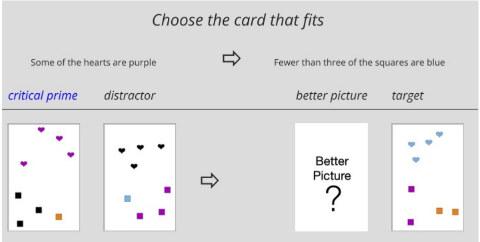
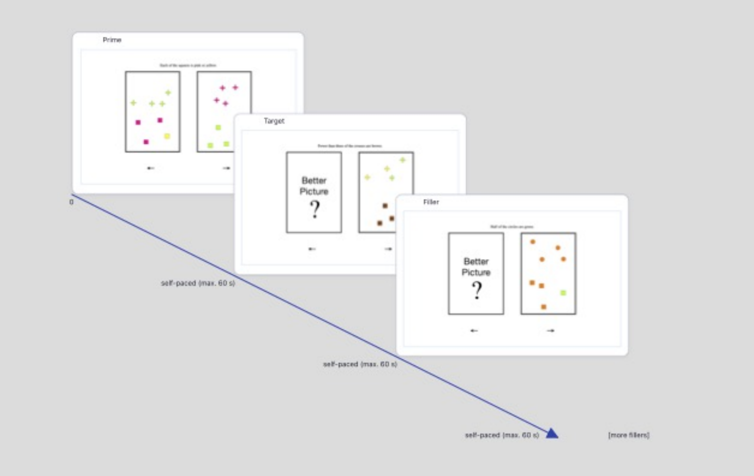


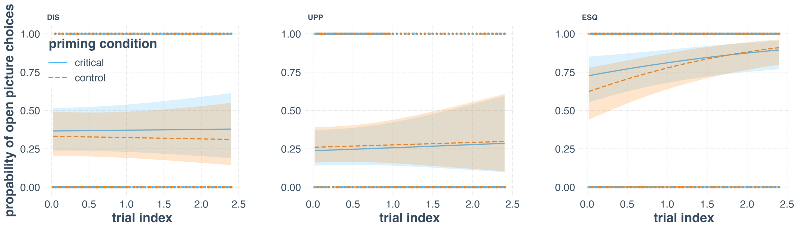
Figure: UB ⇒ ESQ

Exp2: Procedure



Succession of trials with prime-target pairs and fillers

Exp2: Summary of main findings



Results

1. DIST ⇒ ESQ: trial to trial priming
2. UB ⇒ ESQ: no priming and overall lower rate of zero-model choices
3. ESQ-s ⇒ ESQ: no trial-to-trial priming but global adaptation (spill-over) at ceiling towards end of experiment

Discussion

- Evidence of a common mechanism in use for deriving DIST & ESQ inferences (sub-exp 1), but not UB scalar implicatures (sub-exp 2)
  ↦ a challenge for standard view
- But results in sub-exp 3 puzzling (follow-ups planned)

Exp3: Inferences under cognitive load (Ramotowska & MA, XPRAG25)

Four inferences

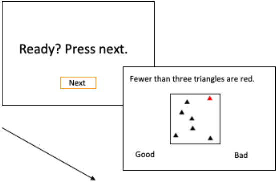
(20)
- a. Some of the squares are black ⇒ not all of the squares are black [UB]
- b. Fewer than 3 squares are black ⇒ there are some black squares [ESQ]
- c. Each square is white or red ⇒ there are white squares and red squares [DIST]
- d. White squares are scarce ⇒ white squares are not absent [**LB**]

Two competing accounts

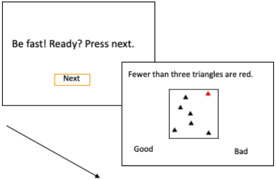
	UB	ESQ	DIST	LB
Standard implicature view	alt-based	alt-based [?]	alt-based	alt-based
NIHIL	—	neglect-zero	neglect-zero	neglect-zero [?]

- Background: different signatures of processing cost of implicatures:
  - Reaction Time (RT): delay (D) vs reverse delay (R) effect
  - Change in inference-rate under cognitive load (speed-pressure/dual task)
- The study: we tested RT & inference-rate in 3 sub-exps with same verification task, but different manipulations:
  - (i) baseline (BAS); (ii) speed-pressure (SP); (iii) dual task (WM).
- Predictions/expectations:
  - Alt-based implicatures: more costly than literal responses
    RT: delay effect & increase (↑) of literal responses under load
  - Neglect-zero effects: less costly than literal responses
    RT: reverse delay effect & decrease (↓) of literal responses under load

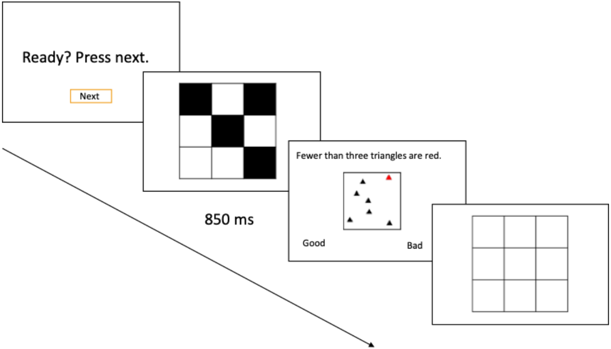
Exp3: Same verification task, different manipulations



(a) Baseline (no load)



(b) Speed-stressing instruct. (SP)



(c) Dual-task (WM)

Results exp3: target acceptance under cognitive load

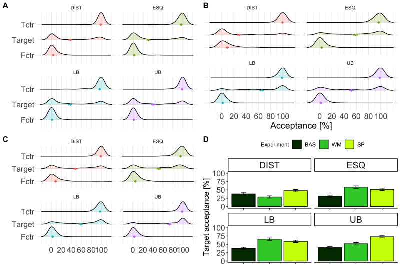


Figure: Acceptance rate in **A** BASELINE, **B** WM, **C** SP by conditions: Tctr (*true* control), Target, Fctr (*false* control). **D** target acceptance (literal responses) in each sub-exp

More literal responses under cognitive load for all cases except **DIST**:

- Fewer **UB** under cognitive load (replication)
- Similar results for **LB** ($\neq$ vTiel et al 2019) & **ESQ** (new)
- Different patterns for **DIST**: inference-rate unaffected by manipulation

$\mapsto$ a challenge for NIHIL

Results exp3: Reaction Time

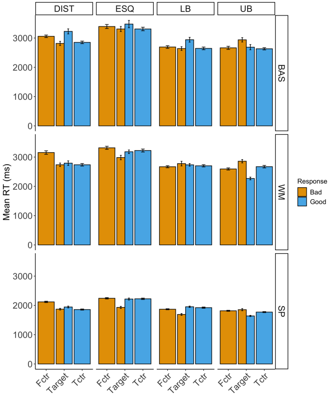


Figure: Mean reaction times in all sub-experiments.

- Replicated classical delay effect for **UB**:
  - target false > target true — enriched slower than literal
  - target false > false control
- Different patterns for **LB**, **ESQ** & **DIST**: reverse delay effect
  - target true > target false — literal slower than enriched
  - target true > true control

Exp3: Summary of main findings

	UB	ESQ	LB	DIST
BAS	N*	R	R	R
SP	$\uparrow$ D	$\uparrow$ R	$\uparrow$ N	$=$ R
WM	$\uparrow$ D	$\uparrow$ R	$\uparrow$ R	$=$ N

Table: Abbreviations: Reaction times: D - delay effect; R - Reverse delay effect; N - neither; * - marginal effect. Effects of manipulation: $\uparrow$ - higher rate of literal response; $\downarrow$ - lower rate of literal response; $=$ no effect.

Results

- Reaction Time:
  UB: delay effect; **ESQ, LB & DIST**: reverse delay effect
- Cognitive load:
  UB, ESQ & LB: more literal responses ($\uparrow$); **DIST**: no effect ($=$)

Discussion

- Different results for different signatures of cognitive cost:
  - RT results in agreement with Nihil hypothesis: UB | ESQ LB DIST
  - Manipulation results closer to implicature view: UB ESQ LB | DIST
- Challenges for both approaches:
  - Nihil: cognitive load results
  - Standard view: reverse delay effects; alt-based generation of ESQ

Experimenting with zero-models: general discussion

Inferences and competing hypothesis

(21) a. Some of the squares are black ⇒ not all of the squares are black [UB]
b. Fewer than 3 squares are black ⇒ there are some black squares [ESQ]
c. Each square is white or red ⇒ there are white squares and red squares [DIST]

	UB	ESQ	DIST
Standard implicature view	alt-based	alt-based [?]	alt-based
NIHIL	—	neglect-zero	neglect-zero

Contrasting results from different experiments

1. Inference-rate in questions (exp1) UB | ESQ DIST
2. Priming (exp2) UB | ESQ DIST
3. RT results (exp3) UB | ESQ DIST
4. Cognitive load (exp3) UB ESQ | DIST

Challenges for both views

- Standard implicature view: explains 4 (assuming lexical access), but leaves the rest unexplained & alt-based derivation of ESQ is unclear
- NIHIL: explains 1-3, but leaves the cognitive load data unexplained

Main challenge for Nihil: explain increase of literal ($0 < 3$) responses for ESQ under SP/dual-task

Cognitive load (dual-task) vs reaction time

RT results do not align with cognitive load findings

- RT results: $\mapsto$ explainable by neglect-zero
  - UB: delay effect (slower than literal interpretation)
  - LB, ESQ, DIST: reverse delay effect (faster than literal interpretation)
- Cognitive load results: $\mapsto$ challenging for neglect-zero
  - UB, LB, ESQ: higher rate of literal interpretations under load
  - DIST: equal rate of literal interpretations under load

- Marty & Chemla 2013, Marty *et al*, 2020; Marty *et al*, 2024:
  Dual-task and response time results need not pattern together and, consequently, the two measures may reflect distinct cognitive effects
  - Response times may reveal which interpretations are derived faster than others
  - Dual-task studies may reveal what resources are involved in the derivation of interpretations, independent of when these interpretations are derived and accessed

On the cost of zero-models: a speculation

Neglect-zero interpretations accessed first, but literal (zero-model) responses do not necessarily come with additional demands on (WM) resources

processing stage	**scalar implicatures**	**neglect-zero effects**
stage 1	literal	enriched
stage 2	enriched (+WM cost)	literal

RT findings: reverse delay explained by neglect-zero

(22) a. Some of the squares are red ⇒ not all [UB]
b. Fewer than 3 squares are white ⇒ some [ESQ]
c. Each square is white or red ⇒ some [DIST]
d. White squares are scarce ⇒ some [LB]

(23) **Target**: [■, ■, ■, ■, ■] [target false ↦ **enriched** & target true ↦ **literal**]

- UB: delay effect **[enriched > literal]**
  1. target false > target true
  2. target false > control false

  Standard explanation: extra cost of implicature calculation, *contra* defaultism
- LB, ESQ, DIST: reverse delay effect **[literal > enriched]**
  1. target true > target false
  2. target true > control true
- Neglect-zero explanation of reverse delay effects:
  - In target, ESQ, DIST & LB sentences judged true by virtue of an empty set ↦ require engaging and integration of a zero-model
- Nihil predictions:
  1. target true (zero-model used) > target false (zero-model not used)
  2. target true (zero-model used) > control true (no-zero verifier)
- Standard implicature view: reverse delay effects more challenging
  - Scalarity hypothesis (van Tiel *et al* 2019): SIs are cognitively demanding insofar as they introduce **negative** information ↦ only UB
- Possible explanation of reverse delay using generalisation of scalarity:
  1. target true > target false (positive SI) ???
  2. target true > control true ???

  ⇑ **extra cost literal reading unexplained without invoking defaultism!**

Cognitive load findings: some more speculations

- Ambiguity hypothesis (Marty & Chemla, 2013):
  executive cognitive resources are needed to entertain and decide among competing readings and when these resources are impaired, speakers default to the more readily accessible interpretation
- Our findings show that more readily accessible $\neq$ faster
  1. for scalar sentences (UB): their logical interpretation (faster) [$\uparrow$]
  2. for number sentences (ESQ): their math interpretation (slower) [$\uparrow$]
  3. for DIST: unclear, although enriched reading faster [$=$]
- Why ESQ[$\uparrow$] while DIST[$=$], if both are neglect-zero effects?
  - ESQ: math reading readily accessible because: (i) results from easy strategy relying on well-known math fact ($0 < 3$); (ii) zero-models more easily accessible once connected to number 0 (familiar, less abstract)
    [$\mapsto$ default n-z suspension due to basic math knowledge]
  - DIST: no reading prevails because (i) two competing readings hard to identify so no easy disambiguation strategy available; (ii) n-z reading involves splitting which further impairs WM resources. Thus although faster, n-z reading not necessarily more readily available under WM load
    [$\mapsto$ balance between literal (zero&no-split) & nz response (no-zero&split)]
- Ready accessibility of basic math fact ($0 < 3$) could also maybe explain global adaptation in ESQ-s $\Rightarrow$ ESQ priming sub-experiment (follow up with more complex non-numerical ESQ)

Conclusion

- Three inferences & two views

	UB	DIST	ESQ
Standard implicature view	alt-based	alt-based	alt-based[?]
NIHIL	—	neglect-zero	neglect-zero

- Modelling zero-models in team semantics: BSML, BSML$^{\rightarrow}$, qBSML$^{\rightarrow}$

  Literal meanings (classical) + neglect-zero (NE) $\Rightarrow$ ESQ, DIST, FC, possibility, Aristotelian principles, LB, . . . , but not UB

- Experimenting with zero-models: 3 experimental studies
  - Questions, priming & RT findings: in agreement with NIHIL hypothesis
  - Cognitive load findings: challenging for both views, but mostly for NIHIL

- New testable predictions arising from speculative discussion. E.g. under cognitive load we predict:
  - less increase of literal interpretations for more complex non-numerical ESQs;
  - more homogeneous interpretations (no-zero & no-split).

THANK YOU![3]

[3]This work is supported by NWO OC project *Nothing is Logical* (grant no 406.21.CTW.023).