The best response: Speaker rationality in an interactive paradigm

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Section 1

Implicature in Complex Sentences
Scalar Implicature and Implicature of Complex Sentences

Example (Unembedded implicature trigger)
1. **Some** of the girls found marbles.
   \[ \Rightarrow \] Not all found marbles.

Example (Embedded implicature trigger)
1. **Every** girl found **some** of their marbles.
The Standard Theory
Levinson (1983)

Example (Unembedded implicature trigger)

Some of the girls found marbles. \(= A(\text{some})\)
\(\implies\) Not all girls found marbles.

Reasoning:
- \(A(\text{all})\) : would have been more informative
- Speaker didn’t say \(A(\text{all})\) but \(A(\text{some})\)
- Hence, he must believe \(\neg A(\text{some})\)
- Cooperativity + competence \(\Rightarrow \neg A(\text{some})\)

Horn scales: \(\{\text{all, some}\}, \{\text{and, or}\},...\)
Embedded Implicature

Example

1. Every girl found some of her marbles.
2. Some of the girls found some of their marbles.

Variously predicted readings:
(Chierchia 2004, Sauerland 2004, Chierchia et al 20012)

1. Every girl found some of her marbles.
   — literal: Every girl found some and possibly all of her marbles.
   — global: Not every girl found all of her marbles.
   — local: Every girl found some but not all of her marbles.

2. Some of the girls found some of their marbles.
   — glob/loc: Not all of the girls found some of their marbles.
   — glob: None of the girls found all of her marbles.
Interactional approaches:

- Bergen et al. (in print), Potts et al. (in print): Bayesian Models.

Problem:

- GT provides no technique for analysing linguistic structure.
- Seems to be confined to a globalist approach.
Aims of this Talk

- Present a specific model of implicature in complex sentences.
- Introduce new interactive experimental paradigm for testing the model.
- Evaluate experimental results/different speaker strategies.
Section 2

Error Models
Communication as stochastic process (Shannon 1948).

\[ P(\varphi) \xrightarrow{F} S_F(F|\varphi) \xrightarrow{H} H(\psi|F) \]
Error Models

Benz 2012

- Communication as stochastic process (Shannon 1948).

\[
\begin{align*}
\text{Intentions} & \rightarrow \text{Signal} & \rightarrow \text{Interpretation} \\
\mathcal{L} & \rightarrow \mathcal{F} & \rightarrow \mathcal{L}
\end{align*}
\]

- Implicature

- If hearer can uniquely recover intended message \(\Rightarrow\) Success.
- If not \(\Rightarrow\) Clarification request.
Error Models: Critical Example

The Role of Errors

Example (Bus Ticket)

An email was sent to all employees that bus tickets for a joint excursion have been bought and are ready to be picked up. By mistake, no contact person was named. Hence, $H$ asks one of the secretaries:

$H$: Where can I get the bus tickets for the excursion?

$S$: Ms. Müller is sitting in office 2.07. ($U_{M2.07}$)

$\Rightarrow$ Bus tickets are available from Ms. Müller.

Problem:

- Hearer finds list with all room numbers of all employees.
  \(\Rightarrow\) Goes to 2.07.

\(\Rightarrow\) Literal content not enough for inducing hearer to choose intended action.
A Game Tree

Problem: \( EU(go-2.07 | [U_{M2.07}]) = EU(search | [U_{M2.07}]) = \varepsilon. \)

Implies: Literal content is irrelevant.
How it should have been played

- Literal content is deciding optimal action.
- In Example speaker omitted part of message.
Omitting Part of Message

- Literal content is deciding optimal action.
- In Example speaker omitted part of message.
Consider for each state of affairs the optimal assertions.

Consider all utterances which can result from omitting a conjunct of message.

⇒ Noise ($\mathcal{N}_\varphi$)

Consider the reduced utterances from which the original message can be reconstructed. ($\mathcal{U}_\varphi$)

<table>
<thead>
<tr>
<th>$\varphi$</th>
<th>$\text{Lit}(\varphi)$</th>
<th>$\mathcal{N}_\varphi$</th>
<th>$\mathcal{U}_\varphi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varphi_{M \text{ has}/2.07}$</td>
<td>$U_{M \text{ has}/2.07}$</td>
<td>$U_{M \text{ has}/2.07}, F_{M \text{ has}}, U_{M/2.07}$</td>
<td>$U_{M/2.07}$</td>
</tr>
<tr>
<td>$\varphi_{M \text{ has}/3.11}$</td>
<td>$F_{M \text{ has}/3.11}$</td>
<td>$F_{M \text{ has}/3.11}, F_{M \text{ has}}, F_{M/3.11}$</td>
<td>$F_{M/3.11}$</td>
</tr>
<tr>
<td>$\varphi_{S \text{ has}/2.07}$</td>
<td>$F_{S \text{ has}/3.11}$</td>
<td>$F_{S \text{ has}/3.11}, F_{S \text{ has}}, F_{S/3.11}$</td>
<td>$F_{S/3.11}$</td>
</tr>
<tr>
<td>$\varphi_{S \text{ has}/3.11}$</td>
<td>$U_{S \text{ has}/3.11}$</td>
<td>$U_{S \text{ has}/3.11}, F_{S \text{ has}}, F_{S/3.11}$</td>
<td>$F_{S/3.11}$</td>
</tr>
</tbody>
</table>
Characteristics

- Uniform explanation of relevance and quantity implicature
- No gambling: short utterances communicate message with certainty
- No blocking: preference for short utterances does not lead to risky utterances
- No hidden semantic operators
Testing for Implicature by Decision Making

The basic best response paradigm
Nicole Gotzner & Anton Benz
Scenario

Background:
- 4 girls who each own a set of 4 special edition marbles (Degen & Goodman, 2014);
- marbles get lost during play and girls have to find them
- mother offers rewards to girls

Reward system:
- chocolate: girl finds all 4 of her marbles
- candy: girl finds fewer than 4 of her marbles
- gummy bears: girl finds none of her marbles (consolation prize)
Instructions

- Mother tells participants how many marbles each girl found
- Task: Participants are asked to buy sweets for the girls

Example

Sentence: **No girl found any of her marbles**

<table>
<thead>
<tr>
<th>Sweets</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocolate</td>
<td>X</td>
<td>Yes</td>
</tr>
<tr>
<td>Candy</td>
<td>X</td>
<td>Yes</td>
</tr>
<tr>
<td>Gummy bear</td>
<td>Yes</td>
<td>X</td>
</tr>
</tbody>
</table>
The Experiment as Signalling Game

Playing the game:
1. Mother = speaker knows actual world
2. Mother chooses an utterance
3. Subject chooses an action: buying sweets
4. Game ends

- Game structure common knowledge
- Game of pure coordination: preferences aligned

Preferences:
- Every girl should get her appropriate sweet
- No superfluous sweets should be bought
Seven possible worlds

- $\exists \nexists$: Some found none
- $\exists \exists^!$: Some found some but not all
- $\exists \forall$: Some found all

<table>
<thead>
<tr>
<th>$\exists$</th>
<th>$\nexists$</th>
<th>$\exists^!$</th>
<th>$\forall$</th>
<th>world</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>$v_1 = \text{[1]}$</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>$v_2 = \text{[2]}$</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>$v_3 = \text{[3]}$</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>$v_4 = \text{[4]}$</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>$v_5 = \text{[5]}$</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>$v_6 = \text{[6]}$</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>$v_7 = \text{[7]}$</td>
</tr>
</tbody>
</table>
Seven possible actions

Actions

- ▶️: Gummy bear
- ▶️: Candy
- ▶️: Chocolate

Best responses

<table>
<thead>
<tr>
<th>world</th>
<th>act</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_1$ = [ ]</td>
<td>◼ —</td>
</tr>
<tr>
<td>$v_2$ = [ ]</td>
<td>◼ —</td>
</tr>
<tr>
<td>$v_3$ = [ ]</td>
<td>◼ —</td>
</tr>
<tr>
<td>$v_4$ = [ ]</td>
<td>◼ —</td>
</tr>
<tr>
<td>$v_5$ = [ ]</td>
<td>◼ —</td>
</tr>
<tr>
<td>$v_6$ = [ ]</td>
<td>◼ —</td>
</tr>
<tr>
<td>$v_7$ = [ ]</td>
<td>◼ —</td>
</tr>
</tbody>
</table>
### Effect of Uncertainty

#### Best responses

<table>
<thead>
<tr>
<th>world</th>
<th>act</th>
<th>world</th>
<th>act</th>
<th>world</th>
<th>act</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ 1, □ 2</td>
<td></td>
<td>□ 2, □ 4</td>
<td></td>
<td>□ 1, □ 2</td>
<td></td>
</tr>
<tr>
<td>□ 1, □ 3</td>
<td></td>
<td>□ 2, □ 6</td>
<td></td>
<td>□ 2, □ 3</td>
<td></td>
</tr>
<tr>
<td>□ 2, □ 3</td>
<td></td>
<td>□ 3, □ 5</td>
<td></td>
<td>□ 3, □ 6</td>
<td></td>
</tr>
<tr>
<td>□ 1, □ 4</td>
<td></td>
<td>□ 3, □ 6</td>
<td></td>
<td>□ 3, □ 6</td>
<td></td>
</tr>
<tr>
<td>□ 1, □ 5</td>
<td></td>
<td>□ 3, □ 6</td>
<td></td>
<td>□ 3, □ 6</td>
<td></td>
</tr>
</tbody>
</table>

- In all other cases:
Error Models for Complex Sentences

Different alternatives:

▶ Alternative utterances constructed from worlds.

Literal descriptions of worlds:

<table>
<thead>
<tr>
<th>world</th>
<th>utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$U_{\forall \mid \exists}$</td>
</tr>
<tr>
<td></td>
<td>$U_{\exists \mid \forall}$</td>
</tr>
<tr>
<td>2</td>
<td>$U_{\forall \mid \exists !}$</td>
</tr>
<tr>
<td></td>
<td>$U_{\exists \mid \forall !}$</td>
</tr>
<tr>
<td>3</td>
<td>$U_{\forall \mid \exists}$</td>
</tr>
<tr>
<td></td>
<td>$U_{\exists \mid \forall}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>world</th>
<th>utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>$U_{\exists \mid \exists !} \land U_{\exists \mid \exists !} \land U_{\exists \mid \exists !}$</td>
</tr>
<tr>
<td>5</td>
<td>$U_{\exists \mid \exists !} \land U_{\exists \mid \exists !} \land U_{\exists \mid \exists !}$</td>
</tr>
<tr>
<td>6</td>
<td>$U_{\exists \mid \exists !} \land U_{\exists \mid \exists !} \land U_{\exists \mid \exists !} \land U_{\exists \mid \exists !}$</td>
</tr>
<tr>
<td>7</td>
<td>$U_{\exists \mid \exists !} \land U_{\exists \mid \exists !} \land U_{\exists \mid \exists !} \land U_{\exists \mid \exists !}$</td>
</tr>
</tbody>
</table>

▶ $U_{Q \mid Q'}$: $Q$ of the girls found $Q'$ of the marbles.

▶ $\exists^!$: some but not all, $\not\exists$: none
Error Models for Complex Sentences

- Shorter utterances constructed by elimination rules

Elimination rules:

1. $U(∃!)$ → $U(∃)$: reduction of ‘some but not all’ to ‘some’
2. $U_∩α ∧ U_β$ → $U_β$: elimination of conjuncts with empty subjects

Restrictions:

- Rule $U_x$ → $U_y$ only applicable if $[[U_x]] ⊆ [[U_y]]$
- Requirement: unique recoverability of meaning (long story)
### Application of Elimination rules

#### Literal descriptions of worlds:

<table>
<thead>
<tr>
<th>1</th>
<th>( \exists \neq \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>( \exists \neq \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} )</td>
</tr>
<tr>
<td>3</td>
<td>( \exists \neq \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} )</td>
</tr>
<tr>
<td>4</td>
<td>( \exists \neq \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} )</td>
</tr>
<tr>
<td>5</td>
<td>( \exists \neq \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} )</td>
</tr>
<tr>
<td>6</td>
<td>( \exists \neq \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} )</td>
</tr>
<tr>
<td>7</td>
<td>( \exists \neq \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} \land \exists \mathcal{r} )</td>
</tr>
</tbody>
</table>
Application of Elimination rules

Elimination of ‘none of the girls . . . :

<table>
<thead>
<tr>
<th>world</th>
<th>utterances</th>
<th>world</th>
<th>utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$U_{\exists \not \in}$</td>
<td>5</td>
<td>$U_{\exists i \in} \land U_{\exists i \not \in}$</td>
</tr>
<tr>
<td>2</td>
<td>$U_{\exists \in i}$</td>
<td>6</td>
<td>$U_{\exists i \in} \land U_{\exists i \not \in}$</td>
</tr>
<tr>
<td>3</td>
<td>$U_{\forall}$</td>
<td>7</td>
<td>$U_{\exists i \in} \land U_{\exists i \in} \land U_{\exists i \not \in}$</td>
</tr>
<tr>
<td>4</td>
<td>$U_{\exists i \not \in} \land U_{\exists i \not \in}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Application of Elimination rules

Elimination of some but not all:

<table>
<thead>
<tr>
<th>World</th>
<th>Utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ 1</td>
<td>$U_{\forall \neg \exists}$</td>
</tr>
<tr>
<td>□ 2</td>
<td>$U_{\forall \exists}$</td>
</tr>
<tr>
<td>□ 3</td>
<td>$U_{\forall \forall}$</td>
</tr>
<tr>
<td>□ 4</td>
<td>$U_{\exists \neg \exists} \land U_{\exists \forall}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>World</th>
<th>Utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ 5</td>
<td>$U_{\exists \neg \exists} \land U_{\exists \forall}$</td>
</tr>
<tr>
<td>□ 6</td>
<td>$U_{\exists \exists} \land U_{\exists \forall}$</td>
</tr>
<tr>
<td>□ 7</td>
<td>$U_{\exists \exists} \land U_{\exists \exists} \land U_{\exists \forall}$</td>
</tr>
</tbody>
</table>
Application of Elimination rules

Predicted maximal simplification:

<table>
<thead>
<tr>
<th></th>
<th>world</th>
<th>utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>$U_\exists \not\exists$</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>$U_\exists \exists$</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>$U_\forall \forall$</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>$U_\exists \not\exists \land U_\forall \exists$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>world</th>
<th>utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
<td>$U_\exists \not\exists \land U_\forall \exists$</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>$U_\exists \exists \land U_\forall \exists$</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>$U_\exists \not\exists \land U_\exists \exists \land U_\forall \exists$</td>
</tr>
</tbody>
</table>
Testable predictions:

- utterance length increases with complexity of world.
- critical strategy not less efficient than average human strategy.
- strategy is efficient:
  - increasing average utterance length does not increase communicative success.
  - decreasing average length should decrease communicative success (??)
    (claim in general probably not correct, however, we expected it in marble scenario)
Section 4

The interactive best response paradigm

Anton Benz & Nicole Gotzner
The interactive best response paradigm

- Participants play best response paradigm in groups, taking two different roles (speaker and hearer)
- **Speaker’s task**: Describe state of the world represented by picture
- **Response options**: all, some, none, some but not all, some and possibly all, any (up to 5 sentences)
Hearer’s task

- **Hearer’s Task**: Buy sweets based on speaker’s description

  ‘Some of the girls found all of their marbles and some of the girls found none of their marbles.’

  - chocolate  □ YES □ NO
  - candy      □ YES □ NO
  - gummy bear □ YES □ NO
Methods

Procedure:
- Participants are randomly assigned to each role (3 times)
- System pairs two participants, pairings change across blocks
- Participants learn reward system with pictures in practice phase

Items:
- 7 worlds are instantiated by six items
- In one block, a world is shown only once

Participants:
- 38 German participants (mean age: 29.3, 21 female, 17 male)
- 2 groups with 4 players (8), 5 groups with 2 players (10)
- 6 groups with 3 players plus experimenter (18); experimenter employs critical strategy (produces statements predicted by Benz’ model)
The interactive best response paradigm

Success rate of utterance

Calculation of success rate:

- Use average response/interpretation of participants
- Data of experimenter are eliminated
- $p_i(w|u)$: probability of participant $i$ interpreting utterance $u$ as $w$

$$\text{Succ}(u|w) = \sum_{i \in H(u)} p_i(w|u)/|H(u)|,$$

$H(u)$: set of participants who interpreted utterance $u$. 
Results: Success rate and length of utterance

Results (→: critical strategy):

<table>
<thead>
<tr>
<th>utterances</th>
<th>world</th>
<th>success %</th>
<th>length</th>
</tr>
</thead>
<tbody>
<tr>
<td>→ (None–any) (All–none)</td>
<td>1</td>
<td>98%</td>
<td>1.0</td>
</tr>
<tr>
<td>→ (All–some) (All–some but not all)</td>
<td>2</td>
<td>94%</td>
<td>1.58</td>
</tr>
<tr>
<td>→ (All–all)</td>
<td>3</td>
<td>99%</td>
<td>1.0</td>
</tr>
<tr>
<td>→ (Some–some, some–none) (Some–none, some–some, none–all) (Some–some)</td>
<td>4</td>
<td>95%</td>
<td>2.72</td>
</tr>
<tr>
<td>→ (Some–all, some–none)</td>
<td>5</td>
<td>96%</td>
<td>2.63</td>
</tr>
<tr>
<td>→ (Some–all, some–some)</td>
<td>6</td>
<td>98%</td>
<td>2.60</td>
</tr>
<tr>
<td>→ (Some–all, some–some, some–none)</td>
<td>7</td>
<td>100%</td>
<td>3.27</td>
</tr>
</tbody>
</table>
Results: Comparison with individual strategies

- Success rates of individual players with utterances occurring more than once in corpus
- Critical (Benz’ model): 0.971, average participant: 0.925
- Critical strategy is significantly better than average participant strategy (one-tailed t test: $p < .001$)
Results: Comparison with individual strategies

- y-axis: 1 — Success rates of individual players (utterances occurring more than once).
- x-axis: average length of utterances of strategy
- Critical: av.–length: 1.71429, failure rate: 0.029
Section 5

Comparison with other Theories
## Structural Accounts

### Sentence level accounts:

<table>
<thead>
<tr>
<th></th>
<th>Chierchia 2004</th>
<th>Sauerland 2004</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>some some</td>
<td>${4, 7}$</td>
<td>${4}$</td>
<td>${4}$ (25%), ${2}$ (75%)</td>
</tr>
<tr>
<td>some some &amp; some all</td>
<td>${7}$</td>
<td>${5, 7}$</td>
<td>${6}$ (98%)</td>
</tr>
<tr>
<td>some none &amp; some all</td>
<td>${7}$</td>
<td>${5, 7}$</td>
<td>${7}$ (100%)</td>
</tr>
<tr>
<td>some none &amp; some all</td>
<td>${5, 7}$</td>
<td>${5, 7}$</td>
<td>${5}$ (96%)</td>
</tr>
</tbody>
</table>
Predictions of Modern Localism

Example:
- Conjunction: Some some and some all
- Observed interpretation: 6 (98%)

Example (Modern Localism: Chierchia et al 2012)

possible readings

<table>
<thead>
<tr>
<th>some</th>
<th>some</th>
<th>and some all</th>
<th>readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>some</td>
<td>O</td>
<td>[some]</td>
<td>6,7</td>
</tr>
<tr>
<td>O [some]</td>
<td>some</td>
<td>...</td>
<td>5,7</td>
</tr>
<tr>
<td>O [some]</td>
<td>O [some]</td>
<td>...</td>
<td>6,7</td>
</tr>
<tr>
<td>O [some]</td>
<td>O [some]</td>
<td>...</td>
<td>⊥</td>
</tr>
<tr>
<td>O [some]</td>
<td>some</td>
<td>...</td>
<td>5,7</td>
</tr>
<tr>
<td>O [some]</td>
<td>some</td>
<td>...</td>
<td>5,7</td>
</tr>
</tbody>
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A Bayesian Model

Take into account:

- Aims at explanatory models (why vs. what)
- Uncertainty about contextual parameters
- Error prone communication
- Fit parametric models to data

What we tested:

- Pick one specific model: (Qing & Franke 2014)
- Fitted to experimental data
- Interested in qualitative behaviour
Reference Game Task

**Speaker:**
- chooses object: *e.g. green circle*
- signals: square, circle, green, blue

**Hearer:**
- receives signal, *e.g. green*
- chooses object, *e.g. green circle*

**goal:** speaker and hearer choose same object

An experimental token

- Green square
- Green circle
- Blue circle

Possible Parameters Influencing Production

- Probability with which hearer chooses worlds
- Preference for short utterances
Towards a model: Start with naive interpreter

Probability of choosing world $w$ given utterance $u$:

$$P_{\text{literal}}(w | u) = \begin{cases} 
\frac{1}{|u|} & \text{if } w \in u \\
0 & \text{else} 
\end{cases}$$

Expected utility of utterance $u$ given $w$ (disregarding preferences for signals):

$$EU(u | w) = P_{\text{literal}}(w | u).$$

Expected utility of utterance $u$ given $w$ (including preferences for signals):

$$EU(u | w) = P_{\text{literal}}(w | u) + \text{cost}(u). \quad \text{(if } w \in u)$$
Determining Speaker Production Probability

**Background:** Discrete rational choice theory.
- penalty *cost* for choosing colour: $0 \geq cost \geq -1$.
- degree of rationality $\lambda$

\[
P_{\text{prod}}(u \mid w, \lambda, cost) = \frac{\exp(\lambda \cdot EU(u \mid w, cost))}{\sum_{u'} \exp(\lambda \cdot EU(u' \mid w, cost))}
\]
\[
= \frac{\exp(\lambda \cdot (P_{\text{literal}}(w \mid u) + cost(u)))}{\sum_{u'} \exp(\lambda \cdot (P_{\text{literal}}(w \mid u') + cost(u')))}
\]

\[
P_{\text{inter}}(w \mid u; \lambda, cost) = \frac{P(w) P_{\text{prod}}(u \mid w, \lambda, cost)}{\sum_{w'} P(w') P_{\text{prod}}(u \mid w', \lambda, cost)}
\]
Comparison with other Theories

Two Models

Model 0:
- $\lambda = 4.96$, $cost = -0.27$ (Pearson’s $\rho$: 0.82)
- Fitted to average human production strategy
  (utterances occurring more than once)
- Literal interpretation strategy
- Fitted: Euclidean distance
- av. length: 1.83201, success rate: 0.78

Model 1:
- $\lambda = 4.45$, $cost = -0.94$ (Pearson’s $\rho$: 0.68)
- Fitted to average human interpretation strategy
  (utterances occurring more than once)
- $\lambda$ and $cost$ represent production strategy against literal interpretation strategy
- Fitted: Euclidean distance
- av. length: 1.10759, success rate: 0.52806
Comparison with individual strategies

- **y-axis**: 1 — Success rates of individual players (utterances occurring more than once).
- **X-axis**: average length of utterances of strategy
- **Critical**: av.-length: 1.71429, failure rate: 0.029
Comparison with individual strategies

- **y-axis**: Success rates of individual players (utterances occurring more than once).
- **X-axis**: Average length of utterances of strategy
- **Critical**: av.-length: 1.71429, failure rate: 0.029
Conclusion

Results:

▶ utterance length increases with complexity of world.
▶ critical strategy more efficient than average human strategy.
▶ strategies with higher average utterance lengths not more successful.
▶ strategies with lower average utterance lengths less successful.
▶ Results pose problems for structural accounts (localism and globalism)

Future direction:

▶ Extend paradigm to more sentence types
  (downward entailing, disjunction, non–monotonic, and more)
▶ Look at relation to RSA-models.
▶ Study scenarios with partial speaker knowledge.
Thank you for your attention!
References I


References II

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