Interpretation of Conditionals

Britta Grusdt
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Conditionals

If you pour sugar in your coffee, it tastes great.
But if you pour sugar and gasoline in your coffee, it tastes awful.

Material implication

Interpretation of natural language conditionals match predictions by material implication?

$A \rightarrow C$	A/C dependent?	$\neg A \rightarrow \neg C$?
If you mow the lawn, I'll give you \$5.(Geis & Zwicky, 1971)	yes	yes
	Conditional Perfection	

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If you mow the lawn, I'll give you \$5.(Geis & Zwicky, 1971)	yes	yes
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If the train is on time, we'll join you at the bar.	yes	rather yes

$A \to C$	A/C dependent?	$\neg A \to \neg C$?
If you mow the lawn, I'll give you \$5.(Geis & Zwicky, 1971)	yes	yes
	Conditional Perfection	
If the train is on time, we'll join you at the bar.	yes	rather yes
If you scratch on the eight-ball, you will loose the game.(von Fintel, 2001)	yes	no

$A \rightarrow C$	A/C dependent?	$\neg A \rightarrow \neg C$?
If you mow the lawn, I'll give you $5.(Geis & Zwicky, 1971)	yes	yes
	Conditional Perfection	
If the train is on time, we'll join you at the bar.	yes	rather yes
If you scratch on the eight-ball, you will loose the game.(von Fintel, 2001)	yes	no
There are cookies on the sideboard, if you want some.(Austin, 1961)	**no**	no
	Biscuit Conditionals	

Simple Indicative Conditionals

If Mary comes to the party, **Joe will come as well.**

$$M \rightarrow J$$

Expectations

- Joe attending the party depends on whether Mary attends the party
- $P(J \mid M)$ is high
- Speaker doesn't know whether M holds, nor whether J holds

Uncertainty: "If A, C" describes different situations.

Situation 1

	$\boldsymbol{A}$	$\neg \boldsymbol{A}$
$\boldsymbol{C}$	**0.9**	0.025
$\neg \boldsymbol{C}$	0.05	0.025

$$P(C \mid A) \approx 0.947$$
$$P(C) = 0.925$$

Situation 2

	$\boldsymbol{A}$	$\neg \boldsymbol{A}$
$\boldsymbol{C}$	**0.65**	0.05
$\neg \boldsymbol{C}$	0.07	**0.23**

$$P(C \mid A) \approx 0.903$$
$$P(C) = 0.7$$

Conditionals

In which situations would a speaker choose to say "*If A, C*"?

$\rightarrow$ When she is not in the position to utter "*C*"

RSA-model

- takes alternative utterances into account
- reflects uncertainty by making predictions in terms of probability distributions
- gives the possibility to include prior knowledge about context of utterance

Rational-Speech-Act model

Vanilla RSA

$$\boldsymbol{P_{PL}}(s \mid u) \propto P_{speaker}(u \mid s) \cdot P_{bn}(s)$$ **Bayes' rule**

$$\boldsymbol{P_S}(u \mid s) \propto exp(\alpha \cdot U(u; s))$$ **Softmax**

$$U(u; s) = \log P_{LL}(s \mid u) - \mathrm{cost}(u)$$ **Utility function**

$$\boldsymbol{P_{LL}}(s \mid u) \propto \delta_{[\![u]\!](s)} \cdot P_{bn}(s)$$ **Literal interpretation**

$$P_{bn}(s = < cn, t >) = P(t \mid cn) \cdot P_{cn}(cn)$$ **Bayes net prior**

Model components

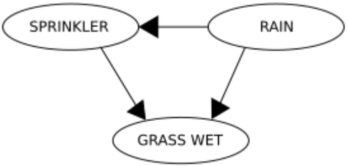
What do we need to specify?

1. Definition of world states
2. Prior over world states
3. Utterances
4. Utterance costs
5. Literal Meaning

World States

Causal Bayes nets (Pearl, 1988, 2009)

	SPRINKLER	
RAIN	T	F
F	0.4	0.6
T	0.01	0.99



RAIN	
T	F
0.2	0.8

		GRASS WET	
SPRINKLER	RAIN	T	F
F	F	0.0	1.0
F	T	0.8	0.2
T	F	0.9	0.1
T	T	0.99	0.01

(https://en.wikipedia.org/wiki/Bayesian_network)

Computational Model

World States

Set of **joint probability distributions** t

$$t \sim \mathrm{Dirichlet}(\alpha = [1, 1, 1, 1])$$

	A	$\neg A$
C	t_0	t_1
$\neg C$	t_2	t_3

$+$ **causal networks**

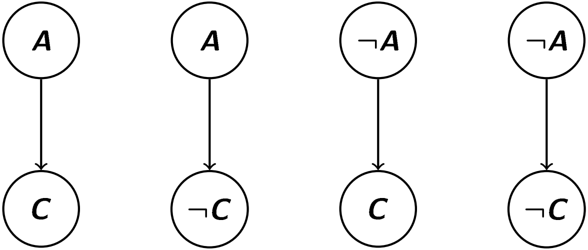
$\Rightarrow$ We get a set of **tuples**:

$$\left\{ \begin{array}{c} < t_0, cn_1 >, < t_0, cn_2 >, \ldots, < t_0, cn_9 > \\ < t_1, cn_1 >, < t_1, cn_2 >, \ldots, < t_1, cn_9 > \\ \ldots \end{array} \right\}$$

Computational Model

Causal networks

1. **Dependent networks**

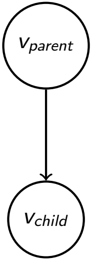


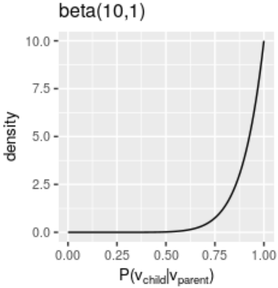
($\times 2$ for switched direction)

World States

Likelihood $<$ table,cn$_{dep}$ $>$

What is the likelihood for a given probability distribution to be associated with a particular **dependent** causal network?





$$P(t \mid cn_{dep}) \propto \mathrm{beta}(P(v_{child} \mid v_{parent}) \mid 10, 1) \cdot \\ \mathrm{beta}(P(v_{child} \mid v_{parent}) \mid 1, 1) \cdot \\ \mathrm{beta}(P(v_{child} \mid v_{parent}) \mid 1, 1) \cdot \tag{1}$$

World States

Likelihood $< \mathrm{table}, \mathrm{cn}_{A||C} >$

What is the likelihood for a given probability distribution to be associated with the **independent** causal network?

$$A||C \Rightarrow P(A, C) = P(A) \cdot P(C)$$

$$p_1 : |P(C \mid A) - P(C \mid \neg A)| \leqslant \epsilon$$
$$p_2 : |P(A \mid C) - P(A \mid \neg C)| \leqslant \epsilon$$

$$P(t \mid cn_{ind}) \propto \begin{cases} \mathrm{beta}(0.99 \mid 10, 1) & \text{if } p_1 \text{ and } p2 \text{ hold} \\ \mathrm{beta}(0.01 \mid 10, 1) & \text{else} \end{cases} \tag{2}$$

Computational Model

Literal Meaning

1. Set of states to which utterance is applicable

utterance	$[\![u]\!]$
If A, C	$\{< cn, t >\mid P(C \mid A) \geqslant \theta\}$
A and C	$\{< cn, t >\mid P(A, C) \geqslant \theta\}$
A	$\{< cn, t >\mid P(A) \geqslant \theta\}$
likely A	$\{< cn, t >\mid P(A) \geqslant \theta_{likely}\}$

$\theta = 0.9, \theta_{likely} = 0.5$

Computational Model

Costs

2. Utterance costs

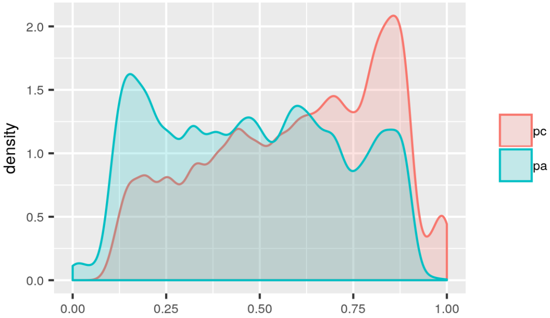
$$
\begin{aligned}
U &\rightarrow_0 \quad L \mid N \mid P \mid C \mid I \\
N &\rightarrow_{0.125} \quad \neg\mathrm{L} \\
T &\rightarrow_0 \quad L \mid N \\
P &\rightarrow_{0.1} \quad \text{likely } T \\
C &\rightarrow_{0.25} \quad T \text{ and } T \\
I &\rightarrow_{0.55} \quad \text{if } T, T \\
L &\rightarrow_0 \quad \text{``A''} \mid \text{``C''}
\end{aligned}
$$

Results

Speaker uncertainty

Utterance: Any simple indicative conditional "**If A, C**", e.g.
If the sun shines, I'll go climbing.

Pragmatic Listener

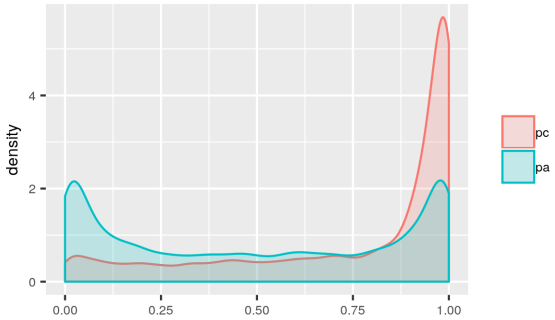


- $P(A)$ and $P(C)$ mainly in $(0.1, 0.9)$
- $P(C)$ increases roughly linearly in interval
- $P(A)$ roughly uniform in interval

Results

Speaker Uncertainty

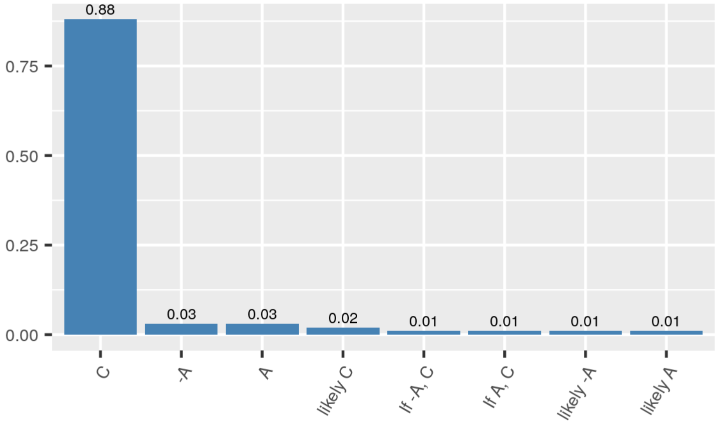
Literal Listener



- is not able to draw inference that C is uncertain

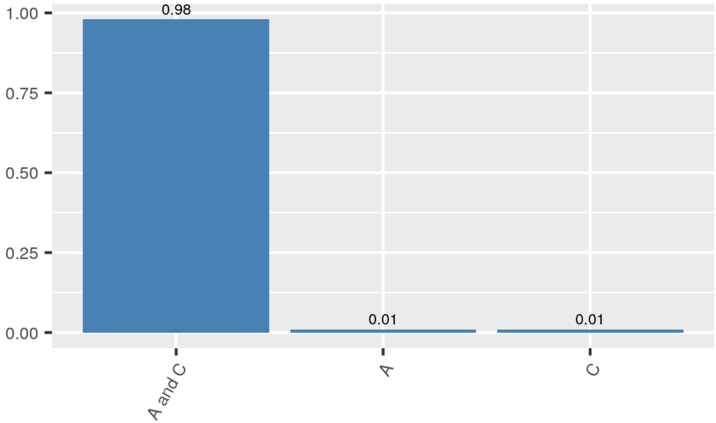
Results

Speaker: C is true (but not $C \wedge A$ nor $C \wedge \neg A$)



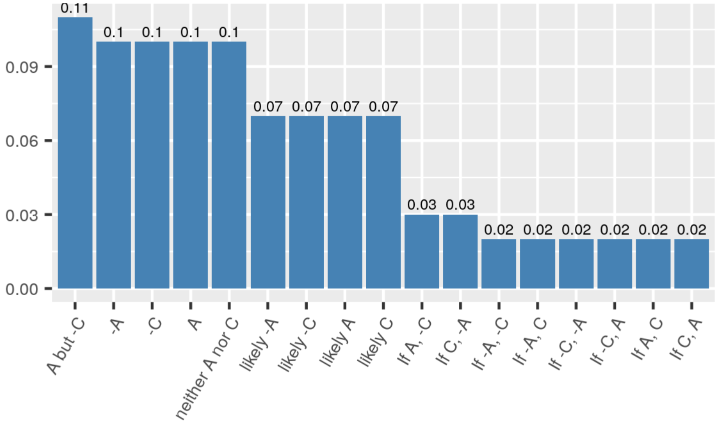
Results

Speaker: C and A are true



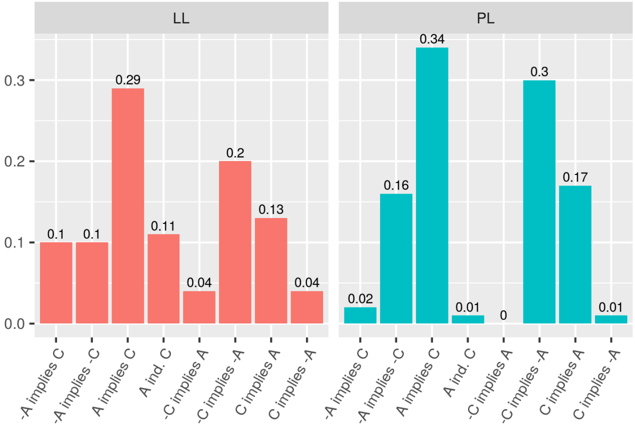
Results

Speaker: C is not true



Results

Causal Networks



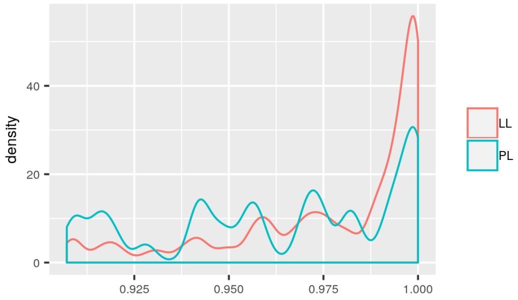
Results

Biscuit conditionals

Prior context

Knowledge about the world: A and C are independent for any Biscuit conditional. $P(cn = A||C) = 1$

$P(C)$

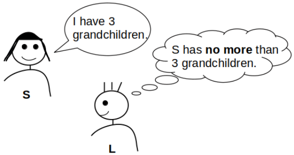


- Literal Listener is already able to make inference that C is likely true!
- Interpretation arises from world knowledge
- I-implicature

Theory of Implicatures

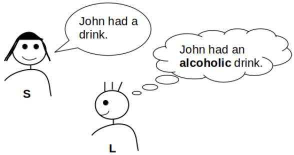
(Atlas & Levinson, 1981; Levinson, 1987; Horn, 1984)

Q-implicatures



- alternative utterances taken into account, i.e. S could have said "*I have 5, 6, . . . grandchildren.*"
- Grice's Maxim of Quantity: Say as much as necessary, but not more.

I-implicatures



- Interpretation arises "*from an inference to the best interpretation*"
- world knowledge taken into account
- L does not reason about what S could have said

Biscuit Conditionals

Remarks 1

The model does not consider syntactical differences, but they may influence the interpretation:

Simple Indicative Conditional

Wenn du mich brauchst, (dann) arbeite ich heute zu Hause.
(If you me need, (then) *work I* at home)

Biscuit Conditional

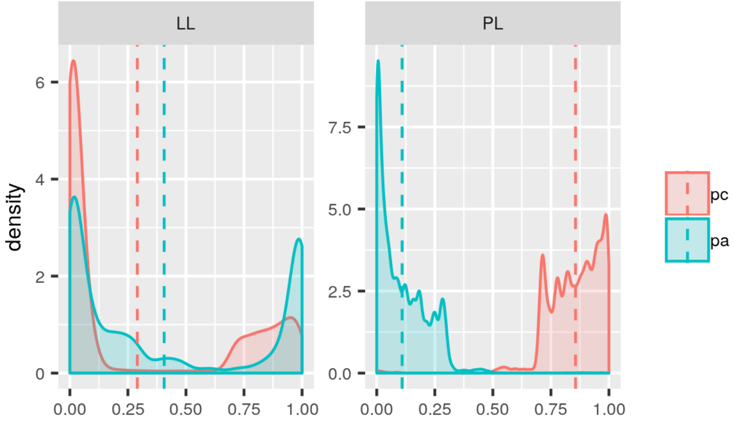
Wenn du mich brauchst, ich arbeite heute zu Hause.
(If you me need, *I work* today at home)

Results

Context

"*Sarah and Marian have arranged to go for sundowners at the Westcliff hotel tomorrow. Sarah feels there is some chance that it will rain, but thinks they can always enjoy the view from inside. To make sure, Marian consults the staff at the Westcliff hotel and finds out that in the event of rain, the inside area will be occupied by a wedding party.*" (Douven & Romeijn, 2011, p.7, lines 1-6)

"If it rains tomorrow, we cannot have sundowners at the Westcliff."



Utterance: "**If A, not C**"

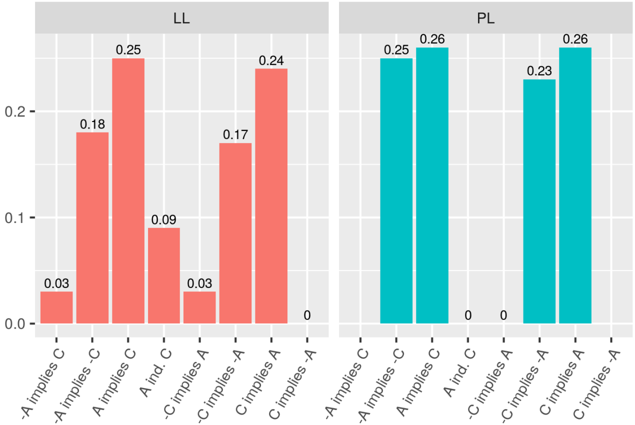
Prior: $P(C) > 0.7$ favored and probability for A and C being independent very high ($P(A||C) = 0.98$)

Results

Conditional Perfection

Utterance: **"If you mow the lawn, I'll give you $5."**

Prior: $P(\neg A, C)$ is small. (not mowing lawn and listener gets $5).



Conditional Perfection

Strength