Pragmatic Language Interpretation as Probabilistic Inference

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Understanding Language

"Trust me, this is a safe investment."

How should we interpret this sentence?

Understanding Language

"Trust me, this is a safe investment."

Context: During a consultation, a financial advisor with a strong track record in investment strategies says this to a client.

Interpretation: A reliable, informed recommendation based on the advisor's professional expertise.

Understanding Language

"Trust me, this is a safe investment."

Context: A friend known for his high-risk gambling habits and spontaneous financial decisions says the same sentence.

Interpretation: A personal opinion rather than a professional advice, not convincing due to the friend's unreliable financial history.

Understanding Language

Observation: The interpretation of language could depend on factors such as the identity of the speaker, the physical context of its use, and the previous discourse. This contextual flexibility is called pragmatics.

Question: How do we formalize pragmatics?

Grice's Theory

'...one of my avowed aims is to see talking as a special case or variety of purposive, indeed rational, behavior'

H. P. GRICE

Assumption: Speakers are truthful, relevant, informative and perspicuous; listeners derive implicatures - the speaker's intended communicative goal - based on a set of conversational maxims

difficult to formalize, only allows qualitative predictions while experimental data are typically graded and quantitative

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A 'Rational Speech Act' Model

Assumption: The speaker is rational such that she always maximizes the utility of language.

Expression 1: In the event that the customer decides to terminate the contract earlier than agreed, the company reserves the right to impose a penalty.

Expression 2: If the customer terminates the contract early, the company may impose a penalty.

A 'Rational Speech Act' Model

The listener infers the state of the world, w, using Bayes' rule, given the utterance, u, the speaker chose:

$$P_L(w|u) \propto P_S(u|w)P(w) \tag{1}$$

By assumption, the speaker chose u in proportion to the utility she expects to gain:

$$P_S(w|u) \propto exp(\alpha U(u; w)) \tag{2}$$

Here α is the extent to which the speaker maximizes her utility, which represents the social benefit of providing epistemic help to a listener.

A 'Rational Speech Act' Model

$U(u; w)$ represents how certain the literal listener becomes about the intended world after hearing the utterance:

$$U(u; w) = logP_{Lit}(w|u) \tag{3}$$

, where Lit denotes the literal listener, who believes in the conventional meaning of u.

$$P_{Lit}(w|u) \propto \delta_{[u]}(w)P(w) \tag{4}$$

Here, $\delta_{[u]}(w) = 1$ if the conventional meaning of u, $[u]$, applies to w. Otherwise, $\delta_{[u]}(w) = 0$.

A 'Rational Speech Act' Model

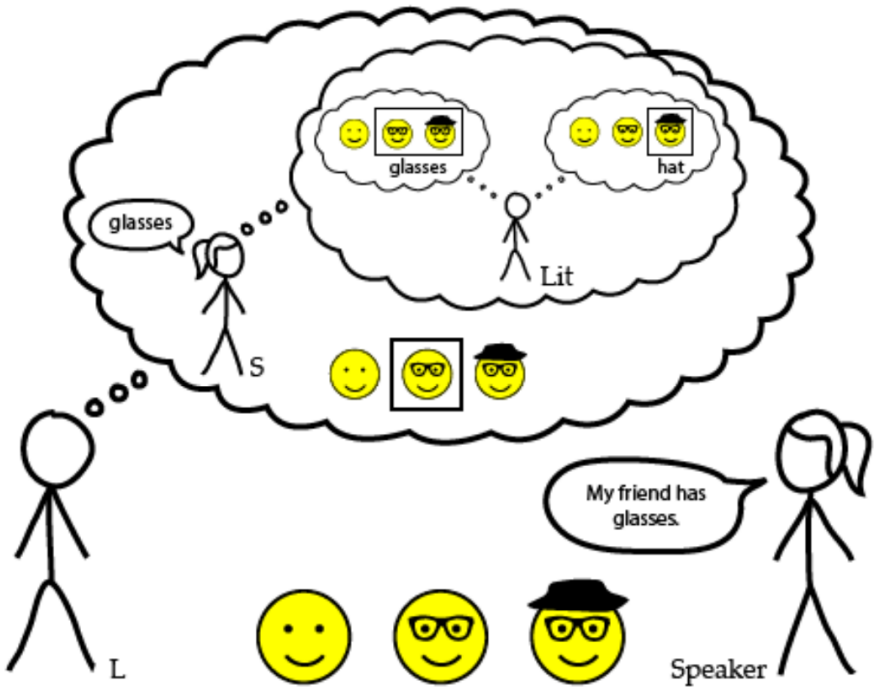

Figure: Application of Rational Speech Act-Style Reasoning to a Signaling Game.

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Example: Signaling Game

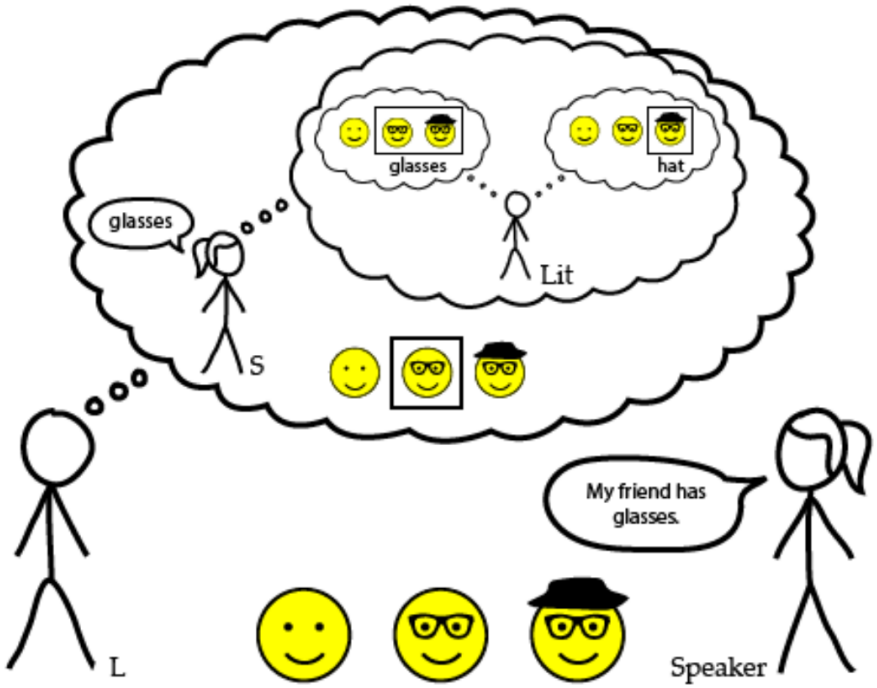

Figure: Listener (Speaker) refines pragmatic inference from speaker (listener)

Intuition 1: How rational are speakers?

1. RSA assumes rational expressions from speakers.
2. Most interesting pragmatic inferences come when speakers are not maximally informative.
3. Previous example: helpful speakers: "with glasses"

Intuition 2: Level of Social Recursion

1. Previous example: depth is 1
2. Deeper recursion is commonly seen in language comprehension

Intuition 3: Utility functions of RSA

Basic utility function:

$$U(u; w) = \log P_{\text{Lit}}(w|u) \tag{5}$$

Refinements

1. Capture speaker's tendency of being parsimonious

$$U(u; w) = \log P_{\text{Lit}}(w|u) + \text{cost}(u) \tag{6}$$

2. Choose utterance

$$U(u; w) = \mathbb{E}_{P(w|k)}[U(u, w)] \tag{7}$$

3. Topic relevance

$$U(u; w, t) = \log \sum_{w' \text{ s.t. } t(w')=t(w)} P_{\text{Lit}}(w'|u) \tag{8}$$

Refined RSA could reason linguistic implicatures.

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Uncertrain RSA (uRSA)

1. Question: Listener is not sure if speaker's behaviour is appropriate
2. Parameter s parameterizes different speaker types:

$$P_L(w, s|u) \propto P_S(u|w, s)P(s)P(w) \tag{9}$$

3. Advantages: It allows RSA to capture different linguistic phenomena. (Followed by three examples)

Example 1: Nonliteral language

Definition: Utterances are easily interpreted but not "actually true", such as hyperbole, sarcasm, and metaphor.

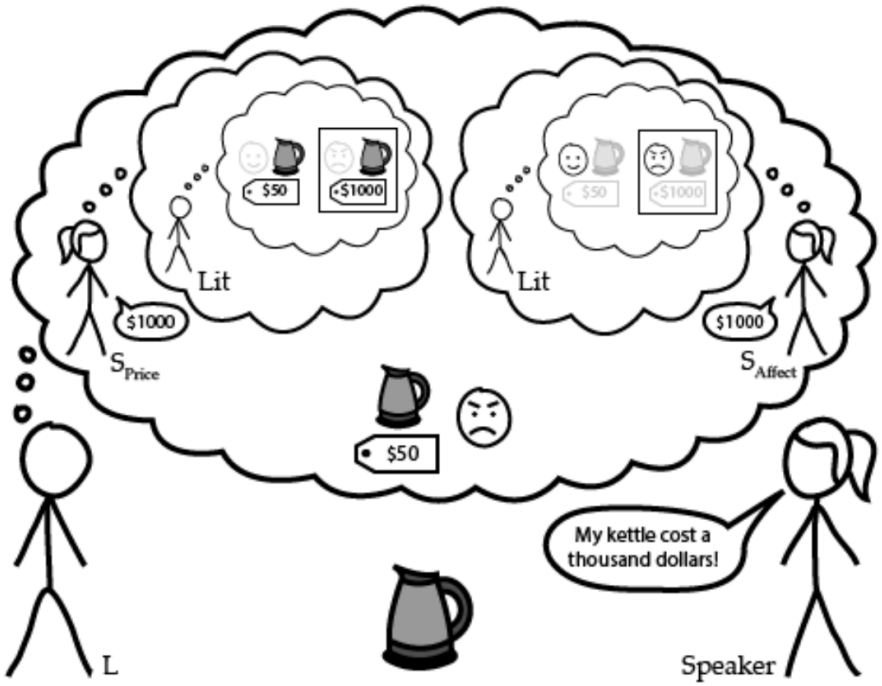

Figure: Hyperbole: "Kettle is worth $1000"

Example 2: Vagueness

- Example: "expansive" and "tall".
- Solution: Threshold
- Trade-off: Informativity and plasusibility
- uRSA accounts for three key phenomena of vague adjectives: the inferred meaning depends on the class, there are borderline cases, and the interpretations are subject to a sorites paradox

Example 3: Embedded implicatures

Cases: "Exactly one letters connected with some of its circles"

Interpretation often includes "some but not all," which standard Gricean theories fail to generate.

Basic RSA models could not capture the embedded implicatures found in experimental data.

uRSA, when implemented over fully-compositional semantic systems, showed a good fit to the experimental data.

Conclusion

1. New formal theories like the Rational Speech Act (RSA) model make quantitative predictions about complex linguistic phenomena.
2. The RSA model integrates with compositional semantics to clarify meanings in context, contributing to semantic theories.
3. RSA posits that pragmatic inferences are fundamental and immediate in language comprehension, aligning with modern psycholinguistic theories.

Future works

1. Future extensions of RSA will include more complex worlds, compositional pragmatic alternatives, sophisticated discourses, and improved utility structures for social interactions.

2. Implementing RSA models faces computational challenges as world states and utterances increase, necessitating further algorithm development.

3. RSA models and their extensions are valuable tools for explaining empirical data in language understanding, aiming to illuminate the flexibility and systematicity of human communication.