How do we communicate about beliefs, together with the evidence we use to form them? A case study: must

**Must** is strong, yet surprisingly weak

**Compare:** “It must be raining” vs. “It is raining”

Since Karttunen’s (1972) **must** is weak mantra, four decades of semanticists cannot agree on the meaning of must; but must communicates more than strength

Evidentials in language: Why would you say so?

**Consider:** (standing in rain) “It must be raining

**Must**?: (standing in rain) “It is raining. It must be raining

We examine speaker & listener behavior as they relate to evidence strength, then implement a formal model of both within the Rational Speech-Act framework

**Empirical results/model predictions**

**Exp. 1 (n=40): Evidence strength**

Rate probability of q (e.g., rain) given evidence (e.g., You see that it’s raining), for 20 pieces of evidence (Fig. 1)

Strength estimates used in subsequent analyses

**Exp. 2 (n=40): Utterance choice**

How likely are speakers to use the marked must p utterance as evidence strength decreases?

Given a piece of evidence for q, then asked to choose one of four utterances to tell friend about the situation

- **bare q, must q, probably q, might q** –

Participants were more likely to choose the more marked must q form over the bare form as the strength of evidence decreased

**Exp. 3a (n=120): Utterance interpretation**

How do listeners’ beliefs about q and the strength of speakers’ evidence for q depend on the utterance?

Given an utterance, then asked a) to rate the probability of q; and b) to select one out of five pieces of evidence that the speaker most likely had about q

Evidence strength lower after must q than after bare q (Fig. 3; β =-.08, SE=.01, t=-6.8, p<.0001)

Belief in q weaker after must q than after bare q (Fig. 4; β =-.21, SE=.02, t=-10.1, p<.0001)

**Exp. 3b (n=60): Inferring speaker belief**

How do listeners’ beliefs about speakers’ beliefs about q depend on the utterance?

Procedure as in Exp. 3a; asked to rate speakers’ belief in q (e.g. How likely is it that John thinks it’s raining?)

Listeners’ estimates of speakers’ beliefs stronger than their own (Fig. 4; β =.07, SE=.02, t=3.74, p<.001)

**Model**

**Model assumptions**

- p(q|bare) > Bb, p(q|must) > Bm, p(q|might) > 0
- cost(must) q = cost(might) q > cost(q) (fit to data)
- Prior probability of q = 0.5 (uniform)
- Probability of evidence e given q (fit to data)
- Probability of speaker belief b given evidence (Exp 1)

Listener infers that speaker has weaker belief given the costlier utterance must q. Given generative model of world state, evidence, and beliefs, listener then infers weaker evidence and lower probability of q, producing qualitatively similar results to those found in Exp 1 & 3

A new perspective on must

Weakened meaning derives straightforwardly from an M-implicature, which drives inference about evidence


Acknowledgements: This work was supported by a James S. McDonnell Foundation Scholar Award and a CNF grant N00014-13-1-0287 (DoD).