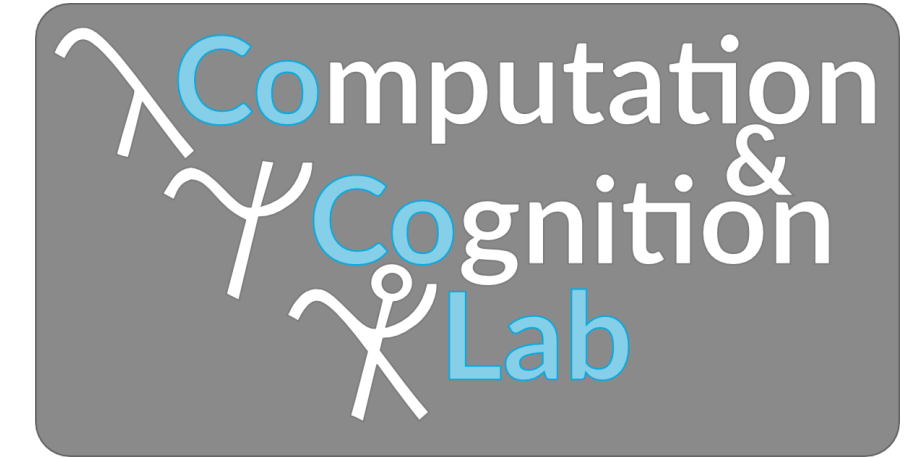




A cost- and information-based account of epistemic *must*

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Introduction

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 *q* requires/signals **weak evidence** for *q* (von Fintel & Gillies; Lassiter; Matthewson, 2014)

Our account: M(arkedness)-implicature

The bare form conveys *q*, so listeners take marked *must* *q* to convey a marked meaning: the speaker arrived at *q* via an evidentially less certain route

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

Experiment 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

Experiment 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 (Fig. 2; $\beta=5.4$, $SE=2.4$, $p<.05$)

Empirical results/model predictions

Fig. 1: Experiment 1

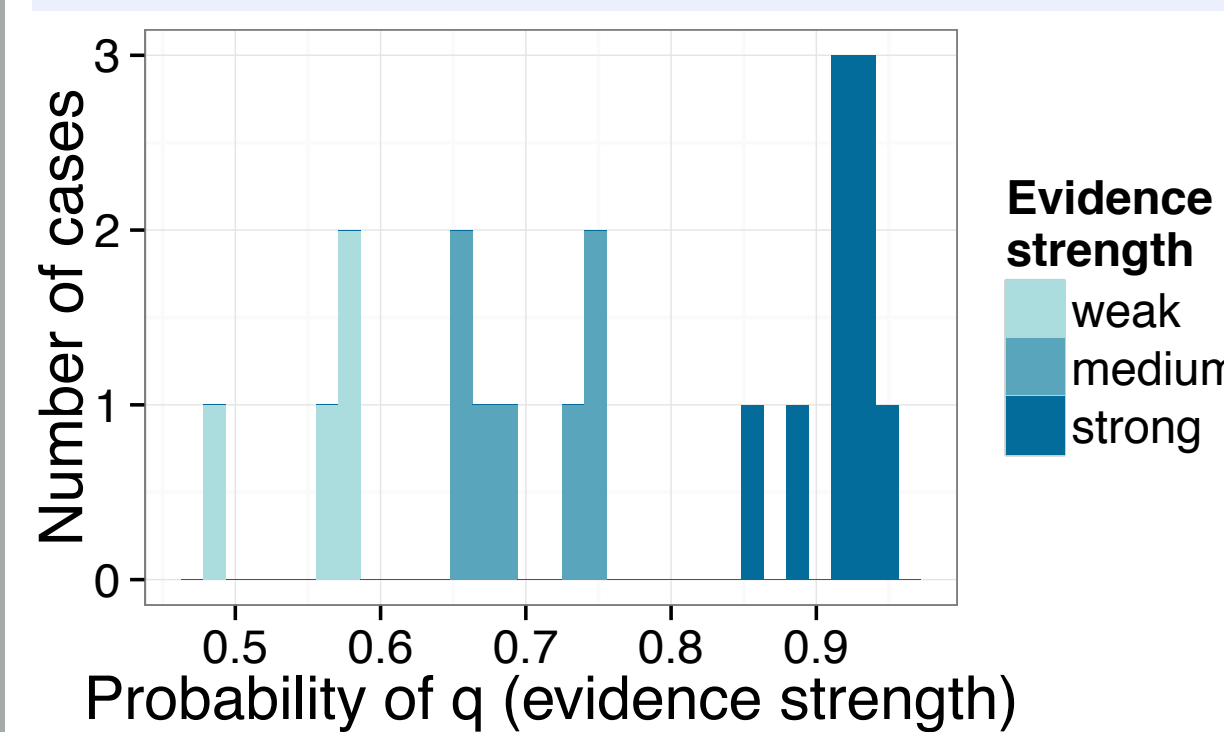


Fig. 2: Experiment 2

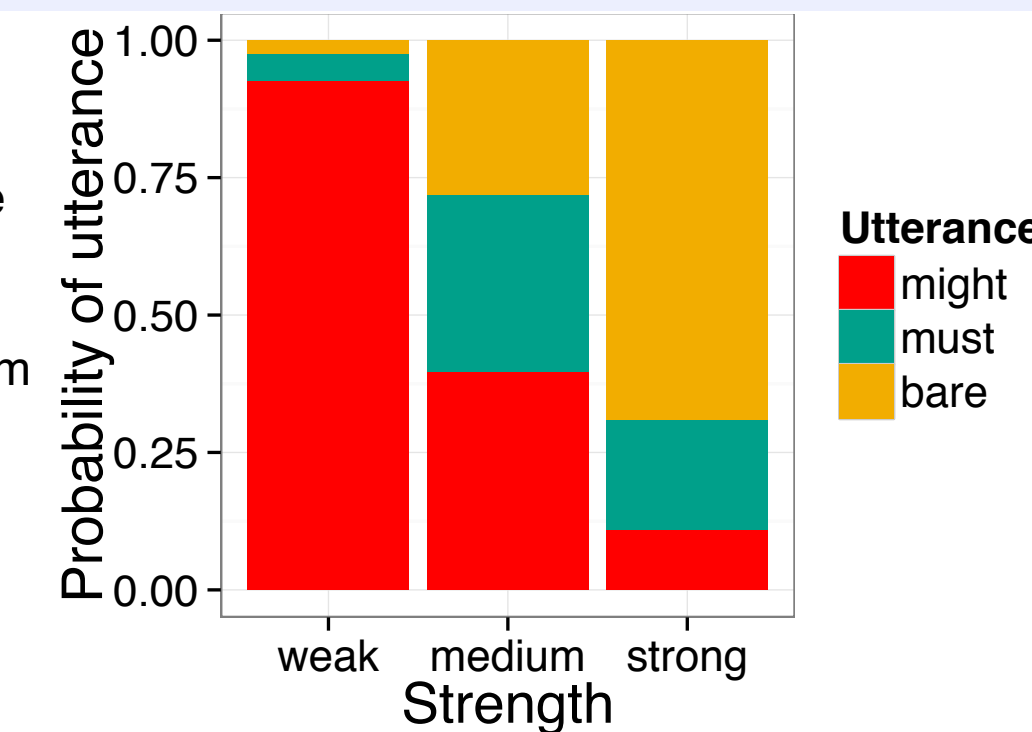


Fig. 3: Experiments 3a & 3b (inferred evidence strength)

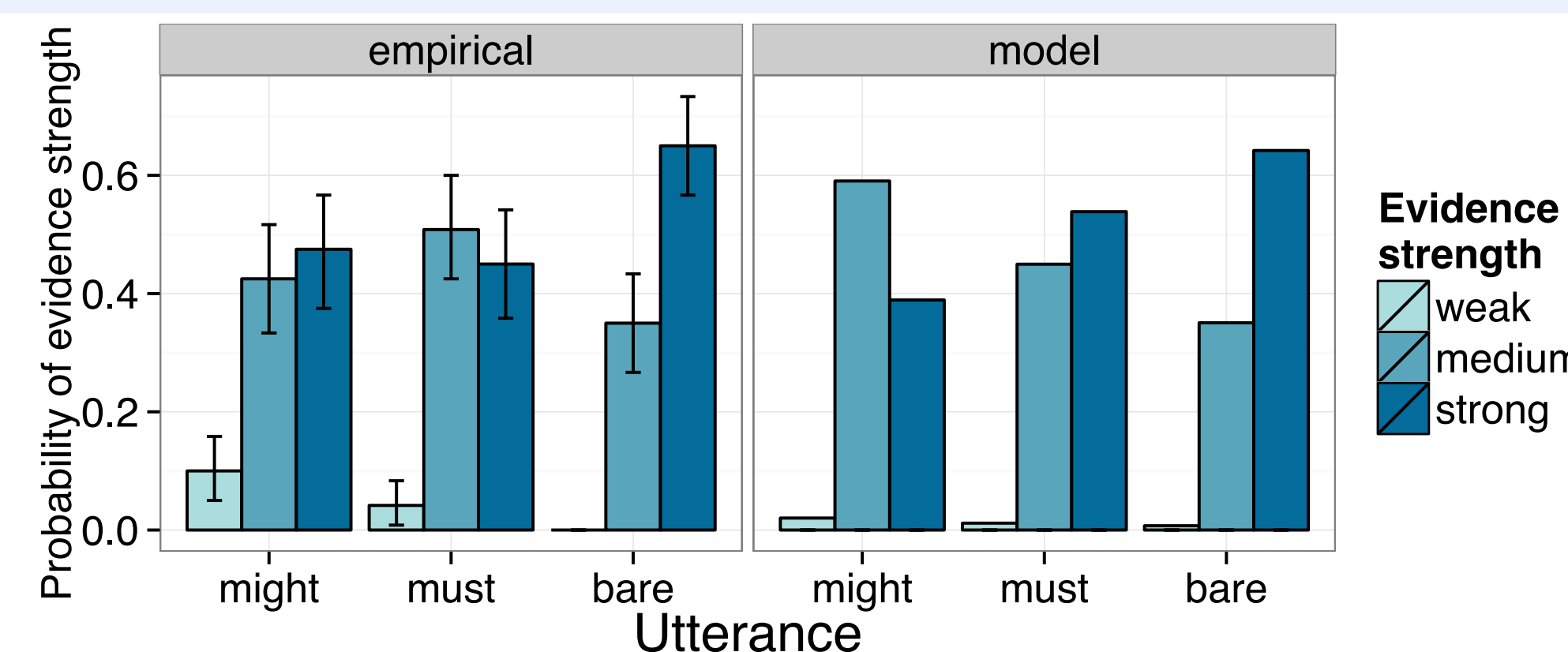
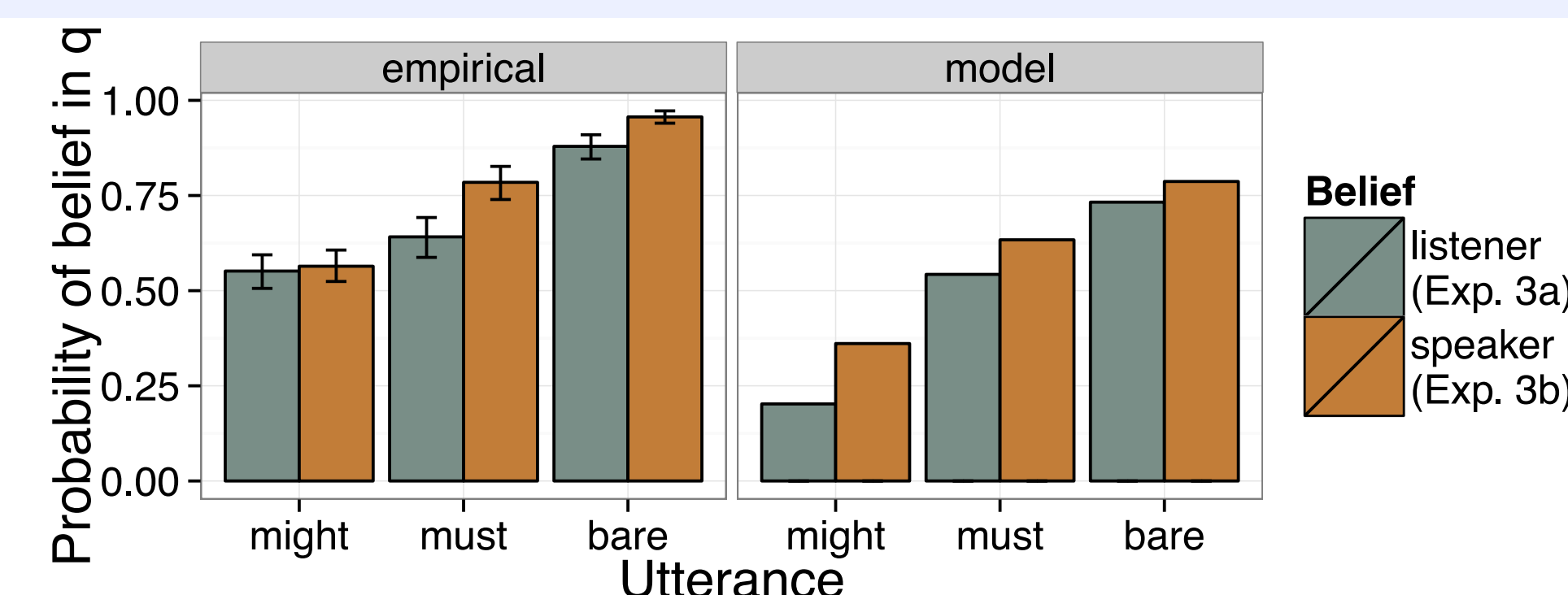


Fig. 4: Exps 3a & 3b (inferred degree of belief in *q*)



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; $\beta=-.08$, $SE=.01$, $t=-6.8$, $p<.0001$)

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

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; $\beta=.07$, $SE=.02$, $t=3.74$, $p<.001$)

Model

We present a model extension within the **Bayesian Rational Speech-Act** framework (Frank and Goodman, 2012) using **lexical uncertainty** and **threshold semantics** (Lassiter and Goodman, 2013)

Model assumptions

- $p(q|bare) > \theta_b$, $p(q|must) > \theta_m$, $p(q|might) > 0$
- $cost(must\ q) = cost(might\ q) > cost(q)$ (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)

$$L_1(q, b, \theta, e | u) \propto S_1(u | q, b, \theta, e) P(b | e) P(e | q) P(q)$$

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 Exps 1 & 3

A new perspective on *must*

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

References: von Fintel & Gillies (2010). *Must ... stay ... strong!* *Natural Language Semantics*, 18. Karttunen (1972). *Possible and must*. In *Syntax and Semantics*. Frank & Goodman (2012). Predicting pragmatic reasoning in language games. *Science*, 336. Lassiter (2014) The weakness of *must*. In *Proceedings of SALT 24*. Lassiter & Goodman (2013). Context, scale structure, and statistics in the interpretation of positive-form adjectives. In *Proceedings of SALT 23*. Matthewson (in press). Evidential restrictions on epistemic indefinites. In *Epistemic Indefinites*.

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