

# Prior beliefs and at-issueness independently modulate projection

Word count (excluding Abstract, Supplements, and References): 2,994 words

Word count (excluding Abstract and Supplements): 3,516 words

## Abstract

Interpreters' inferences about what an utterance means are modulated by their *prior beliefs* about contents expressed by the utterance and the extent to which such contents are *at-issue* with respect to the question under discussion. Contemporary research differs with respect to whether these factors are taken to independently modulate interpreters' inferences, or whether a content's at-issueness is constrained by interpreters' prior beliefs about the content. This paper reports the results of an experiment investigating projection inferences, that is, inferences about whether the speaker is committed to content contributed by an expression in an entailment-canceling environment. The relevant expressions under investigation are sentences containing clause-embedding predicates. We replicate the effects of prior beliefs and at-issueness on projection inferences, and do not find support for the assumption that a content's at-issueness is constrained by interpreters' prior beliefs about it. This result provides support for theoretical models of utterance interpretation that assume the two factors are independent.

**Keywords:** Projection inferences; prior beliefs; at-issueness; clause-embedding predicates; English

# 1 Introduction

Interpreters’ inferences about what an utterance means are modulated by a variety of factors. These include interpreters’ prior beliefs about contents expressed by the utterance (e.g., Winograd 1972; Chambers et al. 2004; Hagoort et al. 2004; Degen et al. 2015) and the extent to which such content is at-issue, that is, addresses the question under discussion addressed by the utterance (e.g., Zondervan 2010; Degen and Goodman 2014; Ronai and Xiang 2020). One such inference are projection inferences (e.g., Langendoen and Savin 1971; Potts 2005). These are inferences about the extent to which the speaker is committed to the truth of an utterance content even though that content is contributed by an expression in an entailment-canceling environment, such as polar questions. For instance, from Scott’s utterance of the polar question in (1), interpreters may infer that Scott is committed to the truth of the content of the complement of *discover*, that Julian dances salsa.

- (1) Scott: “Did Cole discover that Julian dances salsa?”

Projection inferences are modulated by the question under discussion (e.g., Cummins and Rohde 2015; Tonhauser et al. 2020), captured by the Gradient Projection Principle of Tonhauser et al. (2018): the extent to which content projects is positively correlated with the extent to which it is not at-issue. That is, the less Scott’s utterance in (1) is taken to address the question of whether Julian is dancing (i.e., the more that content is not at-issue), the more it projects. Projection inferences are also modulated by interpreters’ prior beliefs about the content (e.g., Mahler 2020). For instance, the greater an interpreter’s a priori belief that Julian dances salsa, the more they take Scott to be committed to that content, that is, the more that content projects (Degen and Tonhauser, 2021).

Models of utterance interpretation formulated in the Rational Speech Act (RSA) framework assume that prior beliefs about and at-issueness of content independently modulate a variety of inferences, including scalar implicatures (e.g., Degen and Goodman 2014). The two factors are independent in that an interpreter’s prior beliefs about content are modeled as affecting interpretation directly, whereas the at-issueness of content is modeled as affecting the speaker’s production model and therefore only entering interpretation indirectly, via consideration of the speaker model. And, indeed, extant RSA models of projection inferences implicitly assume that the two factors are independent, as they assume uniform priors but changing questions under discussion (Qing, Goodman, and Lassiter 2016; Stevens, de Marneffe, Speer, and Tonhauser 2017). In contrast, the two factors are not independent according to the Non-redundancy Principle for At-issue Content (Tonhauser, de Marneffe, and Degen, 2020): according to this principle, the more an interpreter takes a content to be a priori true (i.e., before observing an utterance), the less likely it is that they take the speaker to have intended for the content to be at-issue with respect to the implicit question under discussion.

This paper reports on the results of an experiment designed to investigate whether prior beliefs about and at-issueness of a content independently modulate its projection, as assumed in RSA models, or whether the two factors interact, as hypothesized in Tonhauser et al. 2020. The particular type of content whose projection is investigated is the content of the complement of English clause-embedding predicates, like *discover* in (1). Projection research has long recognized that predicate meaning modulates the projection of the content of the clausal complement, such that, for instance, content embedded under *discover* is less projective than content embedded under *know* (e.g., Kiparsky and Kiparsky 1970; Degen and Tonhauser in print). The experiment therefore includes the meaning of the clause-embedding predicate as a third factor that modulates projection. RSA models lead us to expect that prior beliefs modulate projection inferences independently of the predicate, whereas the at-issueness of content should interact with the predicate, as both affect the speaker’s production model.

## 2 Experiment

The experiment investigates the relation between interpreters’ prior beliefs about content and the content’s at-issueness in modulating its projection. Participants rated the prior probability, at-issueness, and projection of 20 contents.

### 2.1 Methods

**Participants** 600 participants with U.S. IP addresses and at least 99% of previous HITs approved were recruited on Amazon’s Mechanical Turk platform (ages: 18-73, median: 38.5). They were paid \$2.20.

**Materials and procedure** The prior probability, at-issueness, and projection of the contents of 20 clauses were measured in three separate blocks. Prior probability was manipulated by pairing each of the 20 clauses (e.g., *Julian dances salsa*) with two facts between participants: the content of each clause was expected to have a higher prior probability in the presence of one fact (e.g., *Julian is Cuban*) than of the other (e.g., *Julian is German*). See Supplement A for the full set of 20 clauses and facts, and Supplement C for evidence that the facts successfully manipulated the prior probability of the respective contents.

In the prior block, the 20 clauses were realized as the complements of *How likely is it that...?* questions (Degen and Tonhauser, 2021). As shown in Fig. 1a, each target item consisted of one of the two facts for that clause and the *How likely is it that...?* question. Participants read the fact and assessed the prior probability of the content, given the fact. They gave their responses on a slider marked ‘impossible’ at one end (coded as 0) and ‘definitely’ at the other (coded as 1).

In the at-issueness and projection blocks, target items consisted of a fact and a polar question that was uttered by a named speaker, as in Fig. 1c and Fig. 1d, respectively. The polar questions were formed by realizing the 20 clauses as the complements of the 20 clause-embedding predicates in Fig. 1b. Participants were told to imagine that they are at a party and that, on walking into the kitchen, they overhear somebody ask somebody else a question. At-issueness was measured using the ‘asking whether’ diagnostic (Tonhauser et al. 2018): participants were asked to rate whether the speaker was asking about the content of the complement (CC), taking into consideration the fact. They gave their responses on a slider marked ‘yes’ at one end (coded as 0) and ‘no’ at the other (coded as 1). Greater not-at-issueness of the CC with respect to the implicit question under discussion should result in higher slider ratings. Projection was measured using the ‘certain that’ diagnostic (Tonhauser et al. 2018; Mahler 2020): participants were asked to rate whether the speaker was certain of the CC, taking into consideration the fact. They gave their responses on a slider marked ‘no’ at one end (coded as 0) and ‘yes’ at the other (coded as 1). Greater projection of the CC should result in higher slider ratings.

The at-issueness and projection blocks also included 6 control trials each, which functioned as attention checks: the contents of these items were expected to be at-issue and not to project. The same 6 contents were also used to form 6 filler trials in the prior block. These filler items were not used to assess participants’ attention. For the full set of control and filler items see Supplement A.

Each participant’s set of items was semi-randomly generated: first, the 20 clauses were randomly paired with the 20 predicates. Then, one random half of the items was assigned the respective clause’s higher-probability fact, and the other half its lower-probability fact. Participants completed a total of 78 trials: 20 target trials in each block, 6 control trials in the projection and at-issueness blocks each, and 6 filler trials in the prior block. Each participant completed the same filler and control trials. The prior block was presented first to all participants; the projection and at-issueness blocks were then presented in random order. Within blocks, trial order was randomized.

After completing the experiment, participants filled out a short optional demographic survey. To encourage truthful responses, participants were told that they would be paid no matter what answers they gave

**Fact: Julian is German.**

How likely is it that Julian dances salsa?

**impossible**
**definitely**

(a) Target trial in prior block.

*acknowledge, admit, announce, be annoyed, be right, confess, confirm, demonstrate, discover, establish, hear, inform, know, pretend, prove, reveal, say, see, suggest, think*

(b) 20 clause-embedding predicates in not-at-issueness and projection blocks.

**Fact (which Scott knows):** Julian is German.

Scott asks: *"Did Cole suggest that Julian dances salsa?"*

Is Scott asking whether Julian dances salsa?

**no**
**yes**

(c) Target trial in not-at-issueness block.

**Fact (which Scott knows):** Julian is German.

Scott asks: *"Did Cole suggest that Julian dances salsa?"*

Is Scott certain that Julian dances salsa?

**no**
**yes**

(d) Target trial in projection block.

Figure 1: Sample target trials and clause-embedding predicates in the experiment.

in the survey.

**Data exclusion** Data was excluded based on self-declared non-native speaker status and other criteria shown in Supplement B, leaving 10,100 data points from 505 participants (ages 20-73; mean age: 39.5).

## 2.2 Results

Fig. 2a shows participants' certainty ratings (measuring projection) against prior probability ratings: the positive correlation suggests that the higher an interpreter's prior belief about content is, the more that con-

tent projects, as also observed in Degen and Tonhauser 2021. Fig. 2b shows participants’ certainty ratings (measuring projection) against asking-whether ratings (measuring not-at-issueness): the positive correlation suggests the more a content is not-at-issue, the more that content projects, as predicted by Tonhauser et al.’s 2018 Gradient Projection Principle. In contrast, Fig. 2c, which shows participants’ asking-whether ratings (measuring not-at-issueness) against prior probability ratings, suggests that a content’s not-at-issueness is independent of interpreters’ prior beliefs about the content, contrary to Tonhauser et al.’s 2020 Non-redundancy Principle for At-issue Content.

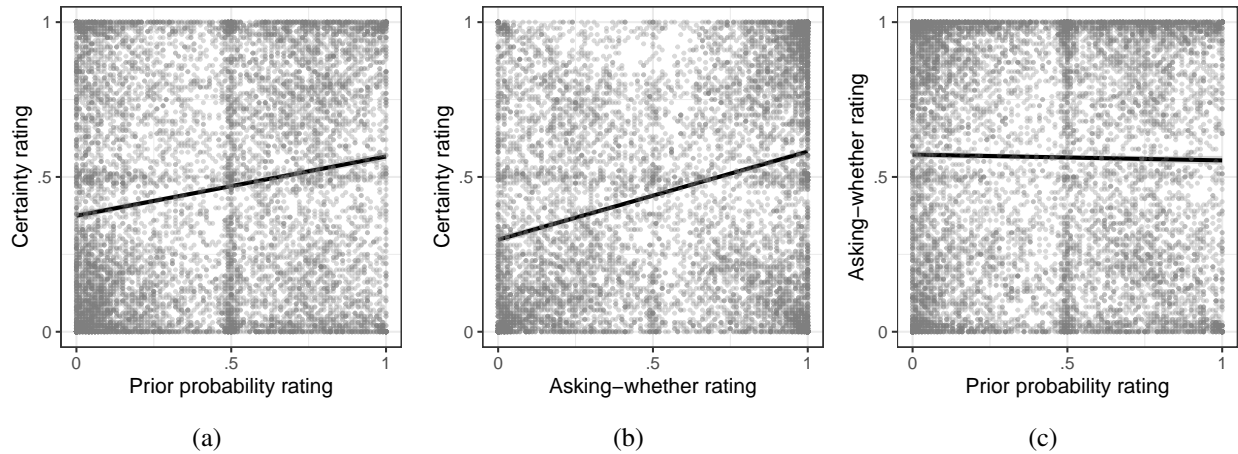


Figure 2: Participants’ (a) certainty ratings against prior probability ratings, (b) certainty ratings against asking-whether ratings, and (c) prior probability ratings against asking-whether ratings. Linear smoothers with 95% confidence intervals overlaid.

These observations were borne out statistically.<sup>1</sup> To assess whether at-issueness and prior beliefs modulate projection, we fit a mixed-effects linear regression predicting certainty ratings from a centered fixed effect of asking-whether rating, a centered fixed effect of prior probability rating, a centered fixed effect of block (with ‘at-issueness as 2nd block’ as the reference level before centering), and their interactions. The model included the maximal random effects structure justified by the data and the theoretical assumptions: random by-item and by-participant intercepts,<sup>2</sup> and random by-item and by-participant slopes for the prior probability and asking-whether fixed effects. There were significant main effects of asking-whether rating ( $\beta = .2$ ,  $SE = .01$ ,  $t=13.3$ ,  $p < .001$ ) and prior probability rating ( $\beta = .16$ ,  $SE = .01$ ,  $t=14.1$ ,  $p < .001$ ) on certainty ratings in the expected direction.<sup>3</sup> These results replicate Degen and Tonhauser’s 2021 result – that prior beliefs modulates projection – and they are consistent with Tonhauser et al.’s 2018 Gradient Projection Principle — that at-issueness modulates projection. Critically, the interaction between prior probability and asking-whether ratings was not significant ( $\beta = .03$ ,  $SE = .02$ ,  $t=1.3$ ,  $p = .2$ ). While null effects should be interpreted with caution, this preliminarily suggests that prior probability and at-issueness independently modulate projection.

To further investigate the relation between at-issueness and prior beliefs, we fit a mixed-effects linear

<sup>1</sup>All analyses were conducted in R (R Core Team 2016, version 4.1.2) using the `lme4` package (Bates et al. 2015). P-values were obtained via Satterthwaite approximations as implemented in the `lmerTest` package (Kuznetsova et al. 2017).

<sup>2</sup>An item is a combination of a predicate and an embedded clause.

<sup>3</sup>There was also a significant main effect of block ( $\beta = .04$ ,  $SE = .01$ ,  $t=2.9$ ,  $p < .01$ ), such that certainty ratings were higher when the projection block immediately followed the prior block, as well as a significant interaction of prior probability ratings and block ( $\beta = .09$ ,  $SE = .02$ ,  $t=3.9$ ,  $p < .001$ ), and of asking-whether and block ( $\beta = -.05$ ,  $SE = .02$ ,  $t=-2.1$ ,  $p < .05$ ). This suggests that the effect of prior beliefs and at-issueness on projection was stronger when the corresponding block immediately preceded the projection block. The three-way interaction was not significant.

regression predicting asking-whether ratings from a centered fixed effect of prior probability rating.<sup>4</sup> The model included random by-item and by-participant intercepts, and random by-item and by-participant slopes for prior probability. There was no main effect of prior probability rating ( $\beta = .004$ ,  $SE = .01$ ,  $t = .3$ ,  $p = .7$ ), further suggesting that the at-issueness of and prior beliefs about content are independent of each other. This result supports an assumption made by RSA models: that interpreters' prior beliefs about utterance content and the at-issueness of utterance content independently modulate projection inferences, contrary to the interaction hypothesized in Tonhauser et al. 2020.

We next examined the interaction between the two factors and predicate meaning. Fig. 3 shows participants' certainty ratings against prior probability ratings (panel a) and asking-whether ratings (panel b) by clause-embedding predicate; the predicates are ordered by the strength of the projection of the content of their complements (least projective: *pretend*; most projective: *be annoyed*).<sup>5</sup> The positive correlations in Fig. 3a suggest that the effect of prior probability on projection is independent of predicate meaning. By contrast, Fig. 3b suggests an interaction between at-issueness and predicate meaning: whereas there is a positive correlation for most predicates, some display none or a negative one.

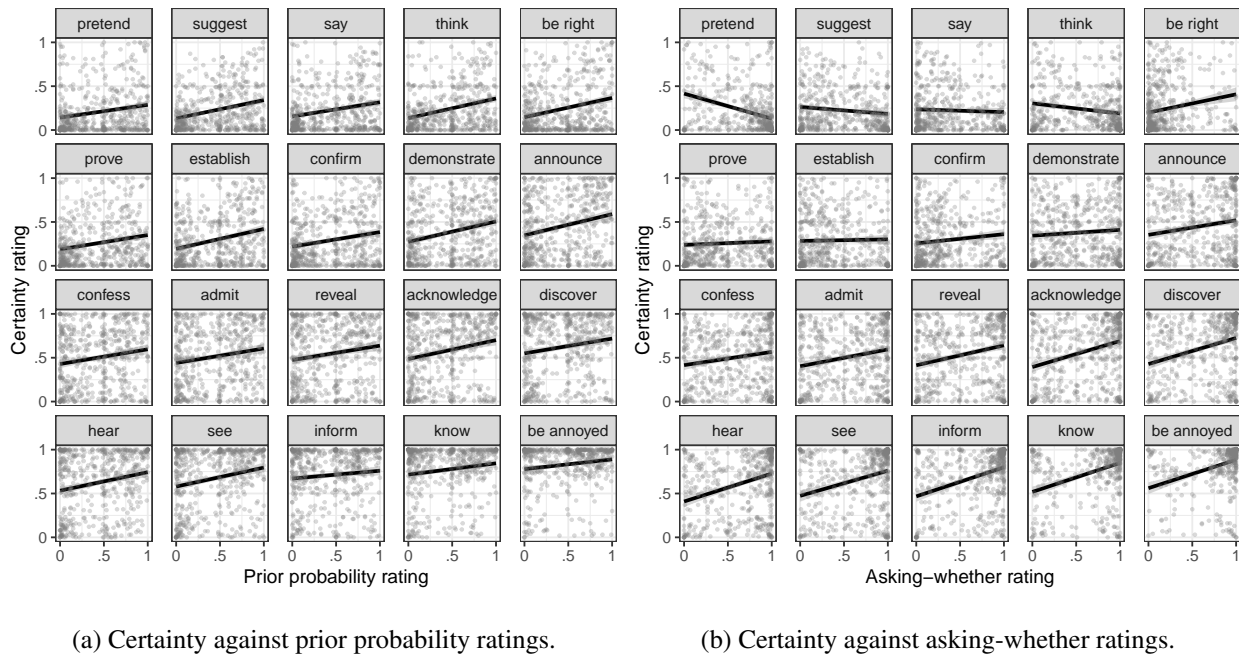


Figure 3: Certainty ratings against (a) prior probability ratings and (b) asking-whether ratings, by predicate. Linear smoothers with 95% confidence intervals overlaid.

These observations were confirmed by mixed-effects linear regression models predicting certainty ratings from a centered fixed effect of prior probability or asking-whether rating, predicate,<sup>6</sup> and their interaction. The models included the maximal random effects structure that was justified by the design and

<sup>4</sup>Fixed effects of block and its interaction with prior probability ratings did not reach significance and were therefore omitted from the model reported here.

<sup>5</sup>Our experiment replicates the result from Degen and Tonhauser's in print Exp. 1a and Degen and Tonhauser's 2021 Exp. 1 that predicate meaning modulates the projection of the content of the clausal complement (Spearman rank correlations: .982 and .985; for visualizations see Supplement E).

<sup>6</sup>To facilitate the interpretation of the interactions, the reference level was set to the predicate for which the slope of the fixed effect on certainty rating was closest to 0, namely *be annoyed* (fixed effect: prior probability) and *prove* (fixed effect: asking-whether).

that allowed them to converge: random by-clause and by-participant intercepts, and random by-clause and by-participant slopes for the prior probability or asking-whether fixed effects, respectively. The positive effect of prior probability on certainty ratings was observed for the contents of the complements of all predicates, suggesting that prior beliefs modulate projection across predicates. This result replicates Degen and Tonhauser 2021.

There was a significant effect of asking-whether on certainty ratings for most of the predicates, but not for *confirm*, *demonstrate*, *establish*, *prove* and *say*, and a negative effect for *pretend*, *suggest*, and *think*. (See Supplement D for model details.) This result suggests that projection inferences are not consistently modulated by the question under discussion.

### 3 General discussion and concluding remarks

Prior research suggests that projection inferences, that is, inferences about the extent to which the speaker is committed to the truth of non-entailed content, are modulated both by interpreters' prior beliefs about the content (Degen and Tonhauser 2021) and the content's at-issueness with respect to the question under discussion (Tonhauser et al. 2018). The main result of the experiment reported on in this paper suggests that these two factors independently modulate projection inferences, rather than at-issueness being constrained by, or even reducible to, interpreters' prior beliefs about the content (cf. Tonhauser et al. 2020).

This result provides empirical support for formal models of projection inferences that acknowledge the independent contribution of these two factors, such as the RSA models presented in Qing et al. 2016 and Stevens et al. 2017. Unfortunately, neither of these models naturally extend to the projection inferences investigated in this paper. Qing et al.'s 2016 analysis is limited to projection inferences that are triggered by change-of-state verbs like *stop*, whereas the inferences investigated here arise from a wide variety of clause-embedding predicates, albeit to varying degrees. Stevens et al.'s 2017 analysis is designed for projection inferences triggered by utterances' prosody. Even though the projection inferences investigated here are also modulated by prosody (see, e.g., Tonhauser 2016; Djärv and Bacovcin 2017), an empirically adequate analysis must also capture the variable contributions of the lexical meanings of the clause-embedding predicates to projection inferences. Developing such an analysis is a pressing task for future research.

Finally, our experiment revealed that a content's at-issueness with respect to the question under discussion does not invariably modulate projection of the content. Rather, our experiment revealed an interaction between the question under discussion and the meaning of the predicate that embeds the content. A predictive model of projection inferences must include a systematic account of this interaction. We hypothesize that (yet to be identified) components of lexical meaning constrain whether the projection of the content of the clausal complement is modulated by the question under discussion. For instance, an analysis according to which the lexical meaning of *pretend* entails that the speaker is committed to the falsity of the content of the complement predicts that this content does not project even when it is not at-issue. Which components of lexical meaning play a role in modulating projection inferences is an important question for future research.

### Data accessibility statement

The experiment, data, and R code for generating the figures and analyses reported on in this paper are available at [link redacted for review]. The experiment was preregistered at [link redacted for review].

## Ethics and consent

The experiment was declared exempt from review by the IRB of [university redacted for review]. Informed consent was obtained from the participants.

## References

- Bates, Douglas, Martin Mächler, Ben Bolker, and Steve Walker. 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67(1):1–48.
- Chambers, Craig G., Michael K. Tanenhaus, and James S. Magnuson. 2004. Actions and affordances in syntactic ambiguity resolution. *Journal of Experimental Psychology* 30:687–696.
- Cummins, Chris and Hannah Rohde. 2015. Evoking context with contrastive stress: Effects on pragmatic enrichment. *Frontiers in Psychology* 6:Article 1779.
- Degen, Judith and Noah D. Goodman. 2014. Lost your marbles? The puzzle of dependent measures in experimental pragmatics. In *Proceedings of the 36th Annual Conference of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.
- Degen, Judith, Michael Henry Tessler, and Noah D Goodman. 2015. Wonky worlds: Listeners revise world knowledge when utterances are odd. *Proceedings of the 37th Annual Conference of the Cognitive Science Society* (2):548–553.
- Degen, Judith and Judith Tonhauser. 2021. Prior beliefs modulate projection. *Open Mind* 5:59–70.
- Degen, Judith and Judith Tonhauser. in print. Are there factive predicates? An empirical investigation. *Language* 98.
- Djäv, Kajsa and Hezekiah Akiva Bacovcin. 2017. Prosodic effects on factive presupposition projection. *Semantics and Linguistic Theory* 27:116–133.
- Hagoort, Peter, Lea Hald, Marcel Mastiaansen, and Karl Magnus Petersson. 2004. Integration of word meaning and world knowledge in language comprehension. *Science* 304:438–441.
- Kiparsky, Paul and Carol Kiparsky. 1970. Fact. In M. Bierwisch and K. Heidolph, eds., *Progress in Linguistics*, pages 143–173. The Hague: Mouton.
- Kuznetsova, Alexandra, Per B. Brockhoff, and Rune H. B. Christensen. 2017. lmerTest package: Tests in linear mixed effects models. *Journal of Statistical Software* 82:1–26.
- Langendoen, Terry and Harris Savin. 1971. The projection problem for presuppositions. In C. Fillmore and T. Langendoen, eds., *Studies in Linguistic Semantics*, pages 54–60. New York: Holt, Rinehart and Winston.
- Mahler, Taylor. 2020. The social component of projection behavior of clausal complements. *Linguistic Society of America* 5:777–791.
- Potts, Christopher. 2005. *The Logic of Conventional Implicatures*. Oxford: Oxford University Press.
- Qing, Ciyang, Noah D. Goodman, and Daniel Lassiter. 2016. A rational speech-act model of projective content. *Cognitive Science* .



- R Core Team. 2016. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.
- Ronai, Eszter and Ming Xiang. 2020. Pragmatic inferences are qud-sensitive: an experimental study. *Journal of Linguistics* 57(4):841870.
- Stevens, Jon Scott, Marie-Catherine de Marneffe, Shari R. Speer, and Judith Tonhauser. 2017. Rational use of prosody predicts projectivity in manner adverb utterances. *Annual Meeting of the Cognitive Science Society* 39:1144–1149.
- Tonhauser, Judith. 2016. Prosodic cues to speaker commitment. *Semantics and Linguistic Theory* 26:934–960.
- Tonhauser, Judith, David Beaver, and Judith Degen. 2018. How projective is projective content? Gradience in projectivity and at-issueness. *Journal of Semantics* 35:495–542.
- Tonhauser, Judith, Marie-Catherine de Marneffe, and Judith Degen. 2020. Evaluative adjective sentences: A question-based analysis of projection. *Glossa* 51(87):1–33.
- Winograd, Terry. 1972. Understanding natural language. *Cognitive Psychology* 3(1):1–191.
- Zondervan, Albert Jan. 2010. *Scalar implicatures or focus: An experimental approach*. Ph.D. thesis, University of Utrecht.

## Supplements

### A Target and control items

**Target items** This list shows the 20 clauses of the target items alongside their lower and higher probability facts, respectively:

1. Mary is pregnant. Facts: Mary is a middle school student / Mary is taking a prenatal yoga class
2. Josie went on vacation to France. Facts: Josie doesn't have a passport / Josie loves France
3. Emma studied on Saturday morning. Facts: Emma is in first grade / Emma is in law school
4. Olivia sleeps until noon. Facts: Olivia has two small children / Olivia works the third shift
5. Sophia got a tattoo. Facts: Sophia is a high end fashion model / Sophia is a hipster
6. Mia drank 2 cocktails last night. Facts: Mia is a nun / Mia is a college student
7. Isabella ate a steak on Sunday. Facts: Isabella is a vegetarian / Isabella is from Argentina
8. Emily bought a car yesterday. Facts: Emily never has any money / Emily has been saving for a year
9. Grace visited her sister. Facts: Grace hates her sister / Grace loves her sister
10. Zoe calculated the tip. Facts: Zoe is 5 years old / Zoe is a math major
11. Danny ate the last cupcake. Facts: Danny is a diabetic / Danny loves cake
12. Frank got a cat. Facts: Frank is allergic to cats / Frank has always wanted a pet
13. Jackson ran 10 miles. Facts: Jackson is obese / Jackson is training for a marathon
14. Jayden rented a car. Facts: Jayden doesn't have a driver's license / Jayden's car is in the shop
15. Tony had a drink last night. Facts: Tony has been sober for 20 years / Tony really likes to party with his friends
16. Josh learned to ride a bike yesterday. Facts: Josh is a 75-year old man / Josh is a 5-year old boy
17. Owen shoveled snow last winter. Facts: Owen lives in New Orleans / Owen lives in Chicago
18. Julian dances salsa. Facts: Julian is German / Julian is Cuban
19. Jon walks to work. Facts: Jon lives 10 miles away from work / Jon lives 2 blocks away from work
20. Charley speaks Spanish. Facts: Charley lives in Korea / Charley lives in Mexico

In the target items of the projection and at-issueness blocks, eventive predicates, like *discover* and *hear*, were realized in the past tense and stative predicates, like *know* and *be annoyed*, were realized in the present tense. The direct object of *inform* was realized by the proper name *Sam*. Each clause-embedding predicate was paired with a unique subject proper name. The speaker of the target items was realized by a randomly sampled unique proper name.

**Control and filler items** The not-at-issueness and projection blocks included 6 control trials each; sample control trials are shown in Fig. A1b and Fig. A1c, respectively. The full set of control items is given in (2). The content of these items was expected to be at-issue and not to project: For example, in Fig. A1b, the speaker is asking about the main clause content, that is, whether Samantha has a new hat, and, in Fig. A1c, the speaker is not committed to the main clause content, that Samantha has a new hat. The same 6 main clauses were also used to form 6 filler trials in the prior block; a sample trial is given in Fig. A1a. These filler items were not used to assess participants' attention.

- (2) a. Do these muffins have blueberries in them? Fact: Muffins are sold at the bakery.
- b. Does this pizza have mushrooms on it? Fact: Pizza is sold at the pizzeria.

**Fact:** Hats are worn on the head.

How likely is it that Samantha has a new hat?

**impossible** **definitely**

Next

(a) Filler trial in prior block.

**Fact (which Gary knows):** Hats are worn on the head.

Gary asks: *"Does Samantha have a new hat?"*

Is Gary asking whether Samantha has a new hat?

**no** **yes**

Next

(b) Control trial in not-at-issueness block.

**Fact (which Gary knows):** Hats are worn on the head.

Gary asks: *"Does Samantha have a new hat?"*

Is Gary certain that Samantha has a new hat?

**no** **yes**

Next

(c) Control trial in projection block.

Figure A1: Sample control and filler trials in Exp. 1.

- c. Was Jack playing outside with the kids? Fact: Many children like ice cream.
- d. Does Ann dance ballet? Fact: Ballet is a type of dance.
- e. Were Carl's kids in the garage? Fact: Garages are used to store cars and other things.
- f. Does Samantha have a new hat? Fact: Hats are worn on the head.

## B Data exclusion

We excluded the data from 16 participants who did not self-identify as native speakers of American English. We also excluded the data from one participant who always clicked on the same point of the scale across the target trials, as well as the data from 78 participants whose response means on the 6 not-at-issueness and projection control items were more than 2 sd above the group means. Data from 505 participants (ages 20-73; mean age: 39.5) entered into the analysis (10,100 data points from target trials).

## C Manipulation of prior beliefs

Fig. A2 shows the prior probability ratings of the 20 contents by fact. As shown, contents presented with the higher probability fact received higher prior probability ratings than contents presented with the lower

probability fact. This result is confirmed by a mixed-effects linear regression model that predicts prior probability slider ratings from dummy-coded fact type (reference level: ‘lower probability’) and random by-item and by-participant intercepts and slopes for fact type. The content’s mean prior probability was rated as higher when it was presented with its higher probability fact than when it was presented with its lower probability fact ( $\beta = 0.51$ ,  $SE = 0.01$ ,  $t = 51.52$ ,  $p < .0001$ ). This result suggests that the manipulation of the prior probability of the 20 contents was successful. This result replicates the results of Exps.1 and 2a from Degen and Tonhauser 2021.

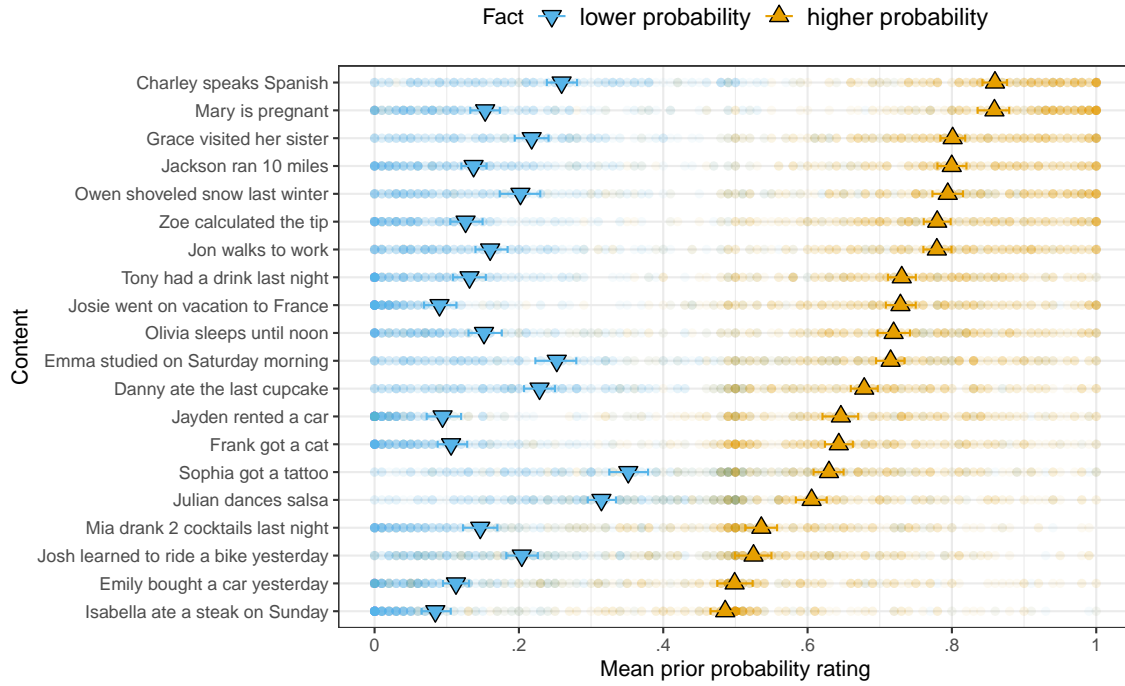


Figure A2: Mean prior probability rating by content and fact in Exp. 1. Error bars indicate 95% bootstrapped confidence intervals. Transparent dots indicate individual participant ratings.

## D Results of predicate interaction models

Table A1 provides the details of the model predicting certainty ratings from prior probability ratings, predicate (with *be annoyed* as the reference level), and their interaction. Table A2 provides the details of the model predicting certainty ratings from asking-whether ratings, predicate (with *be annoyed* as the reference level), and their interaction.

Fixed effect	$\beta$	SE	p-value
(Intercept)	.83	(.01)	***
prior prob.	.09	(.04)	*
inform	-.12	(.02)	***
acknowledge	-.25	(.02)	***
admit	-.31	(.02)	***
announce	-.37	(.02)	***
be right	-.59	(.02)	***
confess	-.32	(.02)	***
confirm	-.54	(.02)	***
demonstrate	-.45	(.02)	***
discover	-.20	(.02)	***
establish	-.54	(.02)	***
hear	-.20	(.02)	***
know	-.06	(.02)	***
pretend	-.62	(.02)	***
prove	-.56	(.02)	***
reveal	-.28	(.02)	***
say	-.60	(.02)	***
see	-.15	(.02)	***
suggest	-.60	(.02)	***
think	-.59	(.02)	***
prior prob. * inform	.01	(.05)	
prior prob. * acknowledge	.12	(.05)	*
prior prob. * admit	.06	(.05)	
prior prob. * announce	.14	(.05)	**
prior prob. * be right	.12	(.05)	*
prior prob. * confess	.09	(.05)	
prior prob. * confirm	.08	(.05)	
prior prob. * demonstrate	.13	(.05)	*
prior prob. * discover	.08	(.05)	
prior prob. * establish	.11	(.05)	*
prior prob. * hear	.11	(.05)	*
prior prob. * know	.03	(.05)	
prior prob. * pretend	.06	(.05)	
prior prob. * prove	.04	(.05)	
prior prob. * reveal	.05	(.05)	
prior prob. * say	.09	(.05)	
prior prob. * see	.10	(.05)	*
prior prob. * suggest	.09	(.05)	
prior prob. * think	.15	(.05)	**

\*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$

Table A1: Details for model predicting certainty ratings from prior probability ratings, predicate (with *be annoyed* as the reference level), and their interaction.

Fixed effect	$\beta$	$SE$	$p$ -value
(Intercept)	.27	(.01)	***
not-at-issue	.06	(.04)	
be annoyed	.43	(.02)	***
inform	.37	(.02)	***
acknowledge	.28	(.02)	***
admit	.24	(.02)	***
announce	.17	(.02)	***
be right	.06	(.02)	*
confess	.23	(.02)	***
confirm	.06	(.02)	**
demonstrate	.11	(.02)	***
discover	.32	(.02)	***
establish	.04	(.02)	*
hear	.30	(.02)	***
know	.41	(.02)	***
pretend	-.03	(.02)	
reveal	.26	(.02)	***
say	-.04	(.02)	*
see	.36	(.02)	***
suggest	-.05	(.02)	**
think	-.04	(.02)	*
not-at-issue * be annoyed	.38	(.06)	***
not-at-issue * inform	.31	(.05)	***
not-at-issue * acknowledge	.24	(.05)	***
not-at-issue * admit	.17	(.05)	***
not-at-issue * announce	.12	(.05)	**
not-at-issue * be right	.16	(.06)	**
not-at-issue * confess	.11	(.05)	*
not-at-issue * confirm	.06	(.05)	
not-at-issue * demonstrate	.03	(.05)	
not-at-issue * discover	.24	(.05)	***
not-at-issue * establish	-.00	(.05)	
not-at-issue * hear	.29	(.05)	***
not-at-issue * know	.31	(.05)	***
not-at-issue * pretend	-.27	(.05)	***
not-at-issue * reveal	.17	(.05)	***
not-at-issue * say	-.05	(.05)	
not-at-issue * see	.24	(.05)	***
not-at-issue * suggest	-.11	(.05)	*
not-at-issue * think	-.15	(.05)	***

\*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$

Table A2: Details for model predicting certainty ratings from asking-whether ratings, predicate (with *prove* as the reference level), and their interaction.

## E Replication of by-predicate projection variation

The mean certainty ratings of the predicates in the experiment reported in this paper are compared in Fig. A3a to those of Exp. 1 of Degen and Tonhauser in print (abbreviated ‘Exp 1 DT in print’) and, in Fig. A3b, to those of Exp. 1 of Degen and Tonhauser 2021 (abbreviated ‘Exp 1 DT 2021’).

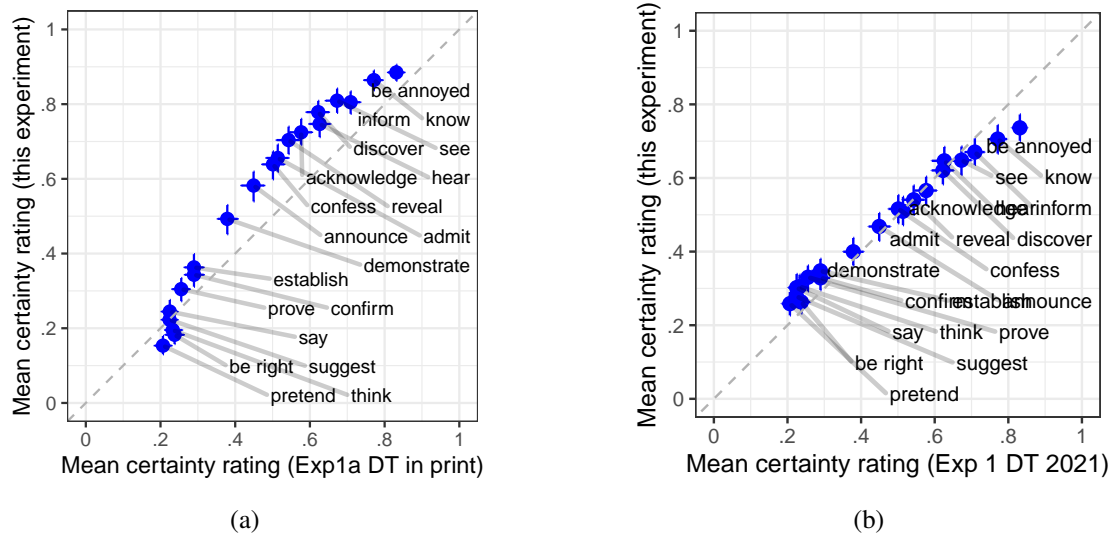


Figure A3: Comparisons of mean by-predicate certainty ratings from the experiment reported on in this paper and Exp. 1 from Degen and Tonhauser 2021 (abbreviated ‘Exp 1 DT 2021’). Error bars indicate 95% bootstrapped confidence intervals.