Projection variability: Is the family of sentences really a family?[1]

Lisa HOFMANN — *University of Stuttgart*
Marie-Catherine DE MARNEFFE — *UCLouvain*
Judith TONHAUSER — *University of Stuttgart*

Abstract. We present experimental evidence that the projection of the content of clausal complements **(i)** varies across entailment-canceling operators, **(ii)** that the effect of operator varies between clause-embedding predicates, and **(iii)** we extend a result of Degen and Tonhauser 2022, that projection ratings in polar questions do not categorically distinguish factive from nonfactive predicates, to cases with negation, the epistemic possibility modal *perhaps*, and conditional antecedents. The observed variability is not captured by existing theoretical accounts of projection (e.g., Heim 1983, van der Sandt 1992, Abrusán 2011, Schlenker 2021). Our results suggest that an analysis must consider interactions between predicates and operators and raise important questions for future research on projection.

Keywords: Projection variability, entailment-canceling operators, (non)factive predicates.

1. Introduction

Textbooks typically present the family-of-sentences diagnostic for projection without addressing by-operator variation (e.g., Chierchia and McConnell-Ginet 1990). For instance, the clausal complement of *discover* is diagnosed as as projective content, if its content (here: that Julian dances salsa) follows not just from (1), but also from its variants in (2), where (1) has been embedded under an entailment-canceling operator, such as negation (2a), polar questions (2b), epistemic possibility modals (2c), or conditional antecedents (2d).

(1)   Cole discovered that Julian dances salsa.

(2)   a. **Negation:**   *Cole didn't discover that Julian dances salsa.*
        b. **Polar Question:**   *Did Cole discover that Julian dances salsa?*
        c. **Modal:**   *Perhaps Cole discovered that Julian dances salsa.*
        d. **Conditional:**   *If Cole discovered that Julian dances salsa, Logan will be joyful.*

However, prior research is suggestive of variation in the effect of different entailment-cancelling operators on projection. For instance, Karttunen (1971) proposed a distinction between English factive predicates (e.g., *regret*) and semi-factives (e.g., *discover*). Based on the examples in (3), he suggested that the CC of true factives projects across all four operators, but that of semi-factives does not always project from under polar questions, modals, or conditionals.[2]

(3)   Karttunen 1971: (22, 24–26)
        a. John didn't {regret/discover} that he had not told the truth.
        b. Did you {regret/discover} that you had not told the truth?

[2]See Beaver 2010 for naturally occurring examples in which the CCs of factive predicates do not project from under the four operators, thereby calling into question the distinction between factive and semi-factive predicates. For experimental research on the distinction see **?** and Djärv et al. 2018. We return to this literature in section 4.2.

     c.   If I {regret/discover} later that I have not told the truth, I will confess it to everyone.

     d.   It is possible that I {regret/discover} later that I have not told the truth.

There have been two experimental investigations of by-operator projection variation. First, the experiment reported in Smith and Hall (2014) investigated projection from under negation and antecents of conditionals for various types of English projective contents. They found that the expressive content of epithets (e.g., *idiot*) and the CC of *know* was more projective under negation than conditionals. In contrast, the content of appositive relative clauses and the preparatory content of *win* showed the opposite pattern, and the existential presupposition of clefts showed no difference.

Second, Sieker and Solstad (2022) compared the projection of German factives (*wissen* 'know', *bereuen* 'regret', *enthüllen* 'reveal') and semi-factives (*bemerken* 'notice', *entdecken* 'discover', *herausfinden* 'find out') between the four operators in (2). The results showed that the CCs of the predicates investigated projected more from under negation than the other three operators. contrary to what Karttunen 1971 suggested, a comparison of factive and semifactive predicates did not reveal that the CCs of factive predicates project more from under polar questions, modals, or antecedents of conditionals than the CCs of nonfactive predicates.

This paper reports on the results of a set of experiments that were designed to compare projection from under the four entailment-canceling operators in (2). Our experiments extend the empirical scope of prior research by investigating projection for a broader set of contents, namely the contents of the complements of the 20 English clause-embedding predicates in (4):

(4)   a.   (Semi)factive predicates: *be annoyed, know, reveal, discover, see*

       b.   Nonfactive predicates: *acknowledge, admit, announce, confess, confirm, establish, hear, inform, prove, be right, demonstrate, pretend, say, suggest, think*

As shown, the 20 predicates include both (semi)factive and nonfactive predicates. The inclusion of the latter set of predicates is motivated by the results of the empirical investigations in Degen and Tonhauser 2022, which suggested that the contents of complements of nonfactive predicates is also projective and that projection does not categorically distinguish factive and nonfactive predicates. As Degen and Tonhauser's 2022 result was established based on sentences where the predicates were embedded under polar questions, our experiments, which feature all four entailment-canceling operators, serve to replicate and extend this result of Degen and Tonhauser 2022.

2. Experiments

To assess the effect of entailment-cancelling operator and clause-embedding predicate on projection, we collected projection judgments for the CCs of the 20 clause-embedding predicates in four sets of experiments.[3] The predicates were embedded under negation in Exps. 1, under polar questions in Exps. 2, under the epistemic possibility modal *perhaps* in Exps. 3, and in conditional antecedents in Exps. 4. Each set of experiments consisted of three experiments

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[3]The data and analysis scripts can be found in the following GitHub repository: `https://github.com/judith-tonhauser/CommitmentBankPlus`. **LETS BE MORE SPECIFIC HERE ABOUT WHERE THINGS RELATED TO THIS PAPER ARE**

that differed in the at-issueness measure used in a separate block. In this paper, we limit our attention to the projection ratings collected in the 12 experiments.

Projection was measured in each experiment with the 'certain that' diagnostic, which has been used to measure projection with both polar interrogative and declarative sentences (see, e.g., Tonhauser 2016, Djärv and Bacovcin 2017, Stevens et al. 2017, Lorson 2018, Tonhauser et al. 2018, Mahler 2019, 2020, De Marneffe et al. 2019).[4] This diagnostic was also used in Sieker and Solstad 2022. Under this diagnostic, participants are presented with utterances like those in (5). They are asked to rate whether the (named) speaker is certain of the CC.

(5)   a.   Christopher: *'Cole didn't discover that Julian dances salsa.'*
        b.   Christopher: *'Did Cole discover that Julian dances salsa?'*
        c.   Christopher: *'Perhaps Cole discovered that Julian dances salsa.'*
        d.   Christopher: *'If Cole discovered that Julian dances salsa, Logan will be joyful.'*
        Projection question: Is Christopher certain that Julian dances salsa?

We assume, following Tonhauser et al. 2018 and Degen and Tonhauser 2022, that judgments of speaker certainty about some propositional content reflect speaker commitment to that content, that is, projection. If a participant interprets an utterance like (5a–d) in a way that the speaker (e.g., Christopher) is certain of the CC, it is assumed to project out of the entailment-canceling environment. If a participant does not take the speaker to be certain of the CC, this is taken to indicate that it does not project.

2.1. Methods

2.1.1. Participants

We recruited 250-300 participants for each of the 12 experiments. Participants for Exp. 1q were recruited on Amazon's Mechanical Turk platform; the participants were required to have U.S. IP addresses and at least 99% of previously approved HITs. Participants for the remaining experiments were recruited on Prolific; these participants were required to reside in the US, to be born in the US, to have English as their first language, and to have an approval rating of at least 99%. See Supplement D for further information about the participants.

2.1.2. Materials

The target sentences consisted of 400 combinations of the 20 clause-embedding predicates in (4) with 20 embedded clauses (provided in Supplement A). As mentioned above, the predicates were embedded under negation in Exps. 1, under polar questions in Exps. 2, under the epistemic possibility modal *perhaps* in Exps. 3, and in conditional antecedents in Exps. 4, for a total of 400 target stimuli in each of the four sets of experiments.

To assess whether participants were attending to the task, each experiment included six control stimuli. For details on the six control stimuli see Supplement C.
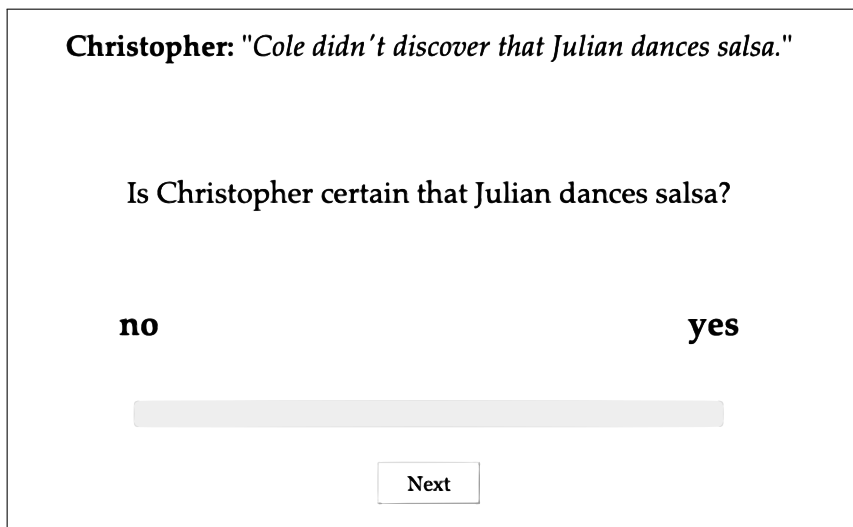
Each participant saw a random set of twenty-six stimuli: Each set contained one target stimulus for each of the 20 clause-embedding predicates (each with a unique complement clause) and

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[4]For other diagnostics of projection see, e.g. Smith and Hall 2011, Xue and Onea 2011, and Tonhauser et al. 2013; and discussion in Tonhauser et al. 2018.

the same six control stimuli.[5] Trial order was randomized.

2.1.3. Procedure

Participants were told to imagine that they are at a party and that, on walking into the kitchen, they overhear somebody say something to somebody else. On each trial, participants read an utterance and responded to the 'certain that' question. They gave their response on a slider marked 'no' (coded as 0) at one end and and 'yes' (coded as 1) on the other. A sample trial from Exps. 1 is illustrated in Figure 1. Following, e.g., Tonhauser et al. (2018), higher ratings of speaker certainty could reflect one of two things: On the one hand, higher ratings could reflect greater speaker commitment towards the CC, and therefore greater projection. This assumes that projection (and the relevant notion of speaker commitment) can itself be gradient. Conversely, higher ratings could also reflect the probability that a participant associates with a projective interpretation for the utterance. Under this interpretation, commitment may be interpreted categorically, and the gradience is a result of the uncertainty about possible interpretations (see also discussion in Grove and White 2023, which suggests the latter kind of interpretation).

<div style="border:1px solid">

Christopher: *"Cole didn't discover that Julian dances salsa."*

Is Christopher certain that Julian dances salsa?

no   **yes**

[slider]

Next

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Figure 1: A sample trial in Exps. 1. In the corresponding trials in Exps. 2-4, participants were presented with an utterance with a different entailment-cancelling operator.

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 in the survey.

2.1.4. Data exclusion

Data were excluded based on self-declared non-native speaker status and other criteria given in the Supplements D. The data from 2,682 participants entered into the analysis.

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[5]Each participant saw their set of 26 stimuli twice, once in the projection block and once in the at-issueness block. Block order was randomized. As mentioned above, we focus on the projection ratings here.

2.2. Results and discussion

We first address the question of whether there is by-operator variation (section 2.2.1) and then the question of whether there is by-predicate variation in the observed by-operator variation (section 2.2.2).

2.2.1. By-operator variation

Fig. 2 shows the mean certainty ratings by entailment-canceling operator, aggregating over the clause-embedding predicates. As shown, there is projection variability by operator: The CCs of the clause-embedding predicates were relatively more projective when embedded in the antecedent of a conditional than in a polar interrogative, where they were relative more projective than when they were embedded under negation or the epistemic modal *perhaps*.
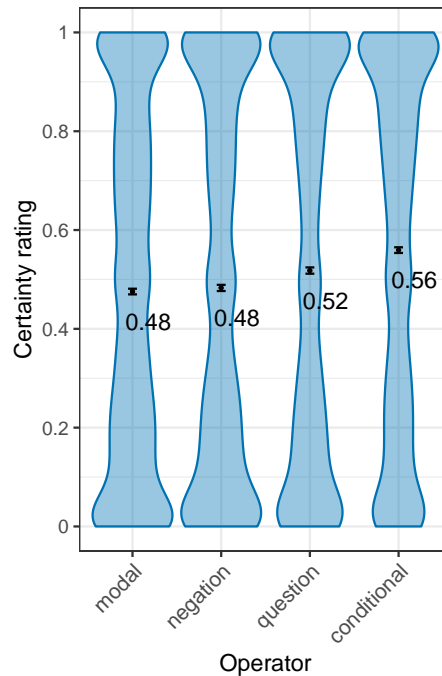

Figure 2: Mean certainty ratings by operator. Error bars indicate 95% bootstrapped confidence intervals. Violin plots indicate the kernel probability density of the individual participants' ratings.

These generalizations are supported by Model #1 reported in Table 1.

Model		Estimate	Std. Error	t-value	
#1	Intercept: *question*	0.51	0.01	44.78	***
	operator: conditional	0.05	0.01	5.30	***
	operator: modal	-0.04	0.01	-4.45	***
	operator: negation	-0.03	0.01	-4.67	***

Table 1: Excerpt from the model output of a linear mixed effects model with fixed effects of operator; random effects: participant and item intercepts, fitted with `lme4, lmertest` in R.

Like Sieker and Solstad (2022), we observe a small main effect of entailment-cancelling operator on projection. However, in contrast to their result that projection is strongest from under negation, our results suggest that projection is strongest from antecedents of conditionals. We note, however, that the differences in mean certainty ratings between the four entailment-canceling operators are very small. This suggests that, when abstracting away from individual projective contents, projection from under the four entailment-canceling operators is very similar. In other words, when abstracting away from individual projective contents, the family of sentences really are a family.

2.2.2. By-predicate variation in the effect of entailment-canceling operator

Fig. 3 shows mean certainty ratings by predicate and entailment-canceling operator (aggregating over the 20 CCs that each predicate was paired with). As shown, there is by-operator variation for the CCs of all 20 clause-embedding predicate, that is, there is not a single predicate for which there is no by-operator variation. The observed variation does not align with widely assumed predicate classes. For instance, the five (semi)factive predicates exhibit five different patterns: i) the CC of *be annoyed* projects more from under negation and questions than conditionals and modal *perhaps*; ii) the CC of *know* projects most from under questions, less from questions and negation, and least from under the modal *perhaps*; iii) the CC of *see* projects most from under questions and conditionals, less from under negation, and least from under the modal *perhaps*; iv) the CC of *discover* projects more from under conditionals and questions than negation and modal *perhaps*; and v) the CC of *reveal* projects most from conditionals, less from questions, and least from negation and modal *perhaps*. Thus, contrary to what Karttunen 1971 proposed, there is no predicate whose CC projects uniformly from under all four entailment-canceling operators (as he suggested for factive predicates) and the purported semi-factive predicates *discover* and *reveal* do not project more from under negation than the other three entailment-canceling operators. We also observe by-operator projection variation for nonfactive predicates. Some of this variation aligns with that observed for factive predicates: For instance, the CC of *inform* exhibits the same pattern as the CC of *know*, and the CC of *acknowledge* exhibit the same pattern as that of the CC of *discover*. Other nonfactive predicates exhibit other patterns: For instance, the CCs of *admit*, *confess* and *announce* project most from the antecedents of conditionals than the other three operators.

The observation that there is by-operator variation for the CC of each of the 20 clause-embedding predicates is confirmed by the statistical analysis. We fitted...

The CC of *know* projects less from under negation than questions, but more from under negation than modals, while the difference between negation and conditionals is not significant. These generalizations are supported by models # 2–4 in Table 2, which also each have at least 34 highly significant interaction terms (out of 57 possible interactions of operator and predicate).

Our results align with those of Smith and Hall 2014, who also observed by-expression by-operator variation. However, while they found that the CC of *know* projects more from under negation than the antecedent of a conditional, we did not find an effect here. We hypothesize that this difference is due to the difference in projection diagnostic used.

Our results differ from those of Sieker and Solstad 2022: While that work did not find differences in by-operator projection variation between factive and semi-factive predicates, our
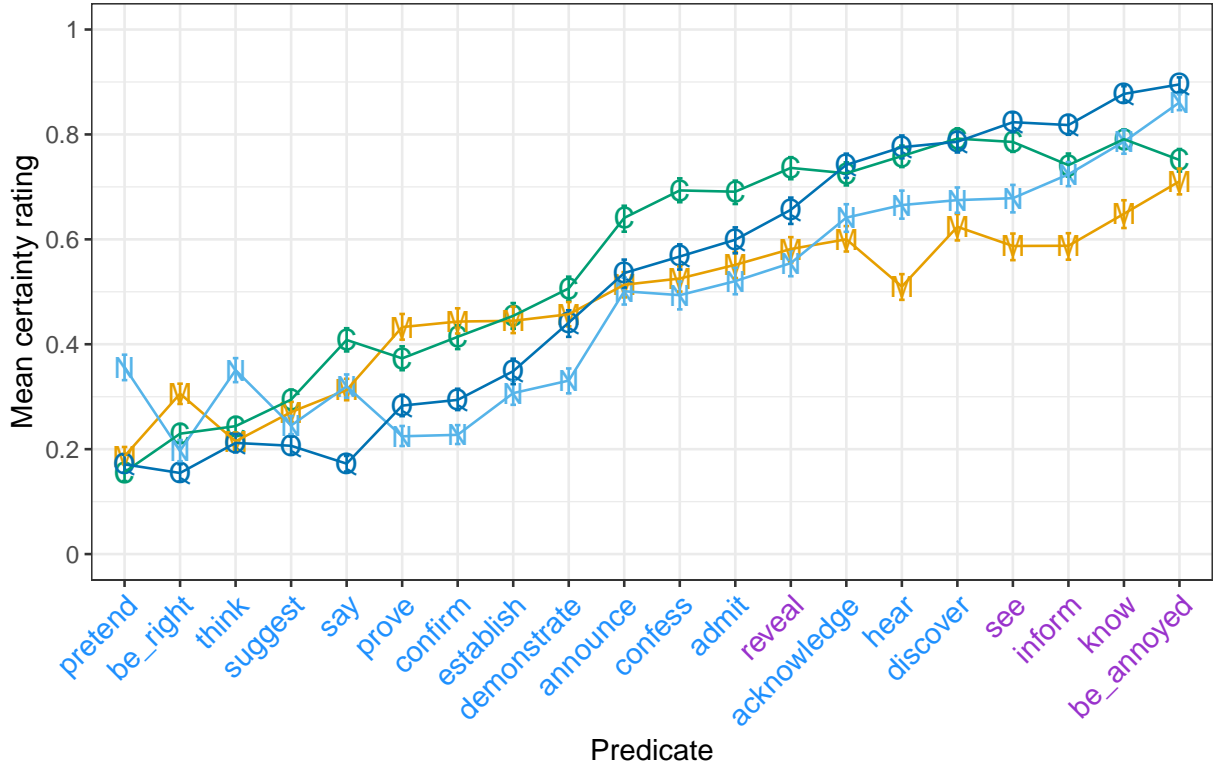
Figure 3: Mean certainty ratings by predicate and operator with 95% bootstrapped confidence intervals. Predicates are ordered by mean certainty rating pooled over the four operators. Embedding operator coded by letter and color: N (light blue): negation, M (orange): modals, C (green): conditional antecedents, Q (dark blue): polar questions.

results suggested five different patterns of by-operator variation for the five (semi)factive predicates. As Sieker and Solstad 2022 also used the 'certain that' diagnostic for projection, this difference in results is not likely due to the diagnostic. Other factors that varied between our experiments are the language under investigated (German vs. English), the clause-embedding predicates investigated, and the CCs that the predicates were paired with. Future research will need to establish which of these factors are implicated in the observed differences.

2.2.3. Factive vs. nonfactive predicates

Factive predicates are defined as predicates that presuppose the CC, while the CC of nonfactive predicates is not presupposed (e.g., Kiparsky and Kiparsky 1970, Karttunen 1971, Schlenker 2010, Abrusán 2011).[6] As presuppositions are assumed to project from under entailment-canceling operators, this definition leads one to expect that factive predicates are distinguished from nonfactive ones by the projection of their CCs: The CCs of factive predicates are expected to be categorically more projective than those of nonfactive ones. This expectation was investigated in Degen and Tonhauser 2022 based on the 20 clause-embedding predicates in (4), which were embedded in polar questions. Contrary to expectation, Degen and Tonhauser 2022 found variation among the CCs of the five factive predicates investigated and that the CCs of some

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[6]Some of these works additionally assume that the CC of factive predicates is entailed.

| Model		Estimate	Std. Error	t-value	
#2	Intercept: **be annoyed**/negation	0.87	0.01	79.86	***
	operator: conditional	-0.12	0.02	-7.36	***
	operator: modal	-0.16	0.02	-10.01	***
	operator: question	0.02	0.01	1.72	n.s.
#3	Intercept: **discover**/negation	0.68	0.01	62.70	***
	operator: conditional	0.11	0.02	7.11	***
	operator: modal	-0.06	0.02	-3.63	***
	operator: question	0.10	0.01	7.08	***
#4	Intercept: **know**/negation	0.79	0.01	72.97	***
	operator: conditional	0.00	0.02	-0.06	n.s.
	operator: modal	-0.14	0.02	-9.18	***
	operator: question	0.08	0.01	5.67	***

Table 2: Excerpt of the output from three linear mixed effects models, with fixed effects: operator, predicate, and their interaction; random effect: participant intercepts. Models were fit with `lme4`, `lmertest` in R. Models **#2–4** also had at least 34 highly significant interaction terms of `operator` and `predicate` with $p < 0.001$ (not shown here).

nonfactive predicates were as projective, or even more projective, than the CCs of some factive predicates. In short, projection of the CC from under polar questions did not categorically distinguish factive from nonfactive predicates.

The results of the set of experiments reported on in this paper replicate this result. As shown in Fig. 3, there is variation between the CCs of the five factive predicates in the polar question condition, and projection from under polar questions does not categorically distinguish factive from nonfactive predicates. Furthermore, the results of this set of experiments suggest that projection from under the three other entailment-canceling operators also does not categorically distinguish factive and nonfactive predicates. This result strengthens the conclusion of Degen and Tonhauser 2022 that there is, to date no empirical evidence for a coherent class of factive predicates.

IF THERE IS ROOM I WOULD LIKE TO INCLUDE 4 VERSIONS OF FIG 3 WHERE THE 20 PREDICATES ARE ORDERED BY OPERATOR, TO MAKE THE POINT OF THIS SECTION CLEARER. THAT WOULD ALSO BE GOOD FOR THE METHODOLOGICAL IMPLICATION SECTION BELOW.
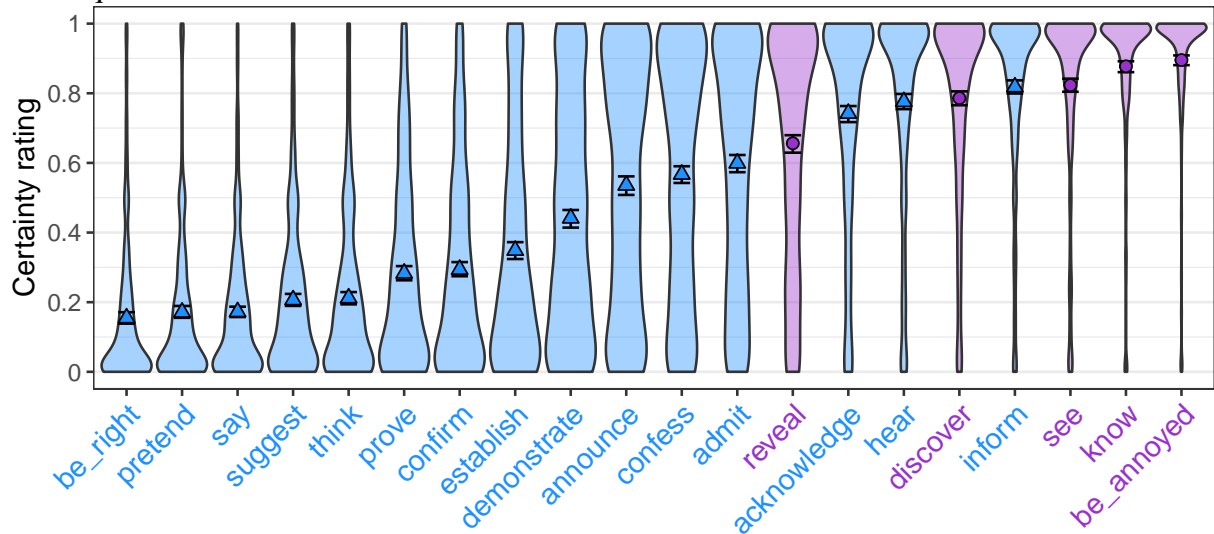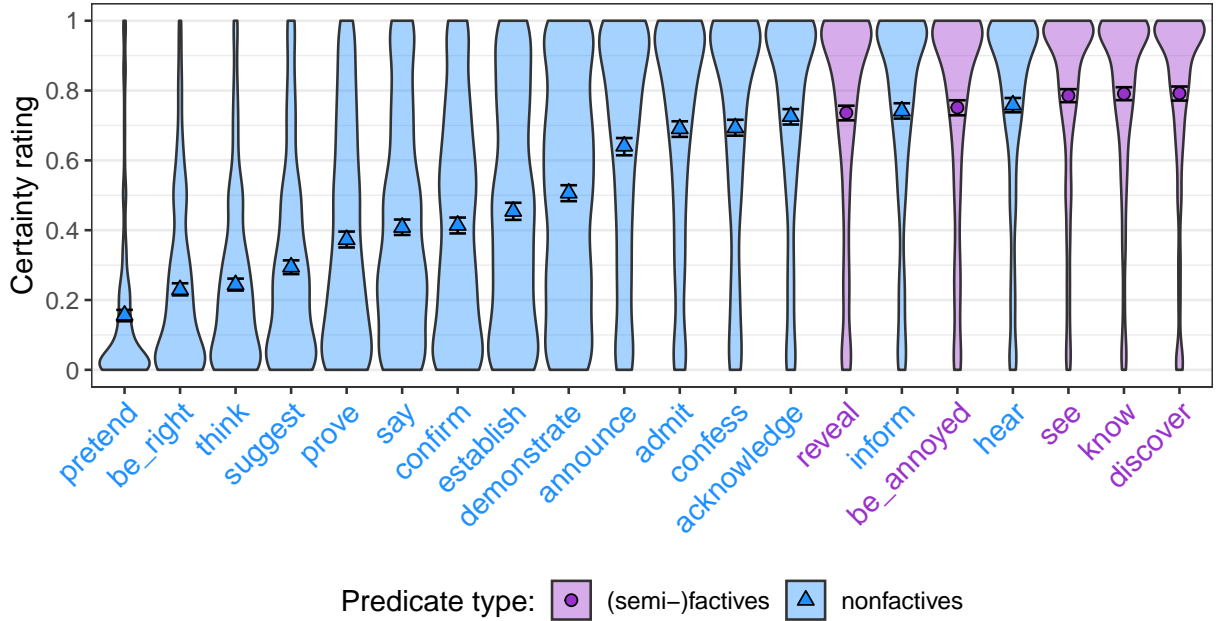
Modal:
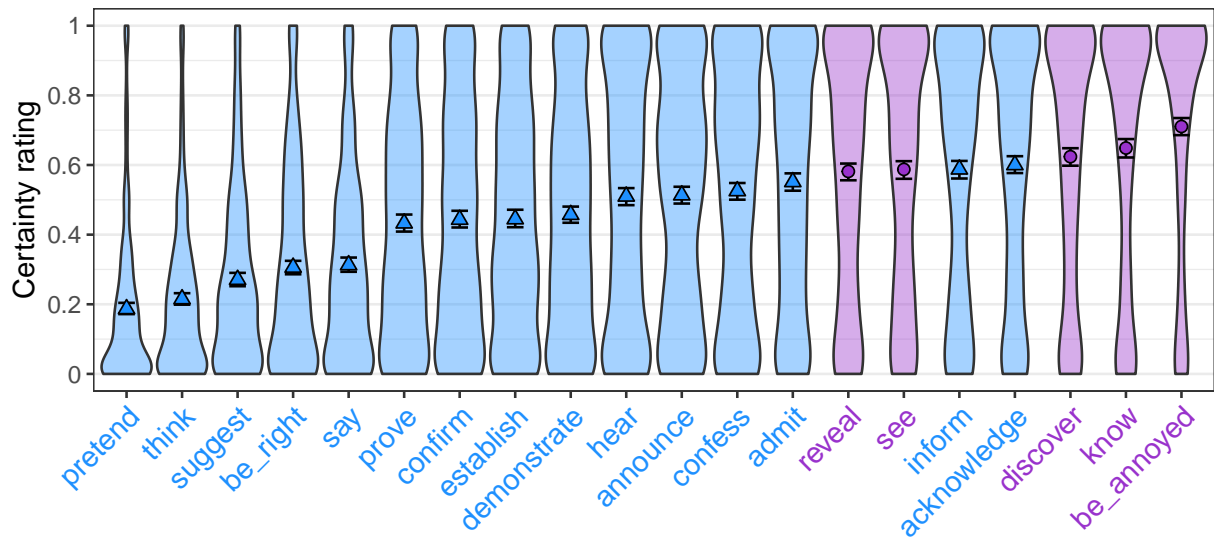
Negation:
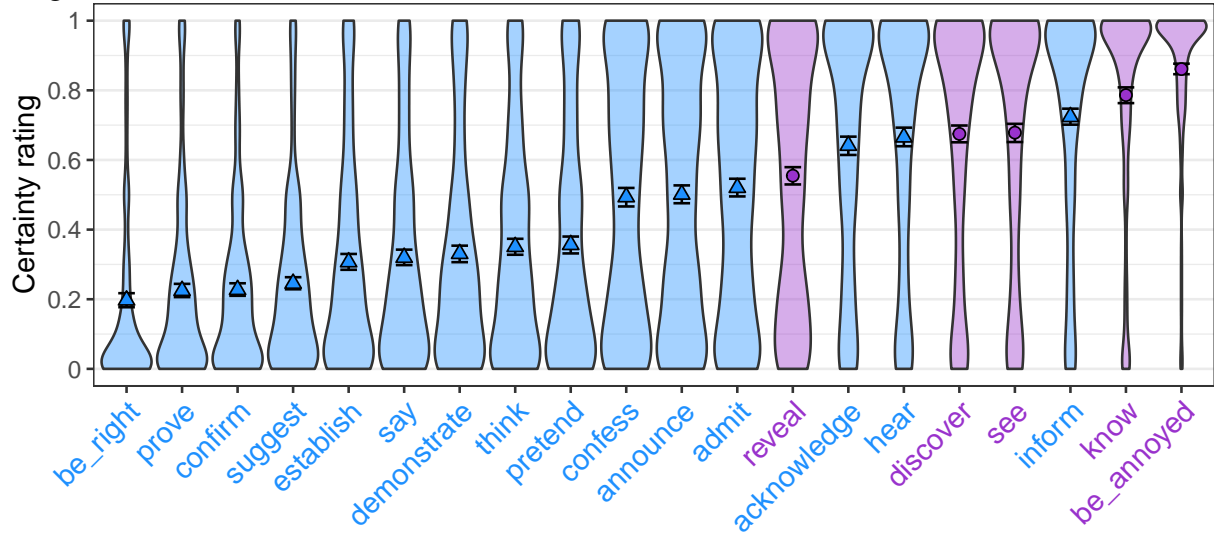
Polar questions:

Conditionals:

Predicate type: ⬤ (semi–)factives   △ nonfactives

2.2.4. Summary

The results of our experiments suggest that there is little by-operator variation when aggregating over clause-embedding predicates, but that the CCs of different clause embedding predicates exhibit by-operator projection variation. Crucially, the observed by-operator variation does not align with prior claims about differences between factive and semi-factive predicates in by-operator variation (e.g., Karttunen 1971). Finally, the results of our experiments provide further support for the results of Degen and Tonhauser 2022, who did not find empirical support for a class of factive predicates based on the projection of the CC from under polar questions. Our experiments suggest that projection of the CC from under negation, the antecedent of conditionals and epistemic modals also do not provide empirical support for a natural class of factive predicates.

Before discussing the methodological and theoretical implications of these results in section 4, we provide converging evidence from a different dataset in section 3.

3. Converging evidence for the by-operator variation

This section provides converging evidence for the by-operator variation based on the MegaVeridicality dataset (White and Rawlins 2018). This dataset contains projection ratings for the CCs of 517 English clause-embedding predicates. The stimuli that participants rated consisted of combinations of these predicates with what White and Rawlins (2018) referred to as 'low content arguments', as shown in (6) for *know*. The predicates were embedded under negation in stimuli like (6a), in the antecedent of a conditional and a polar question in stimuli like (6b), and under negation, in the antecedent of a conditional, and in a question in stimuli like (6c). To assess projection, participants were asked to respond to the question *Did that thing happen?* for stimuli like (6a) and to respond to the question posed by stimuli like (6b) and (6c). The response options were 'yes', 'maybe or maybe not', and 'no'.

(6)   a.   Somebody didn't know that a particular thing happened. Did that thing happen?

    b.   If somebody knows that a particular thing happened, did that thing happen?

    c.   If somebody didn't know that a particular thing happened, did that thing happen?

To investigate by-operator projection variability, we recoded 'yes' responses as 1, 'no' responses as -1, and 'maybe or maybe not' responses as 0. We then calculated the mean projection rating for 16 predicates under the three types of operator combinations shown in (6). The 16 predicates include ones also used in our experiment as purported factives (*be annoyed, know, reveal*) and semi-factives (*discover, see*), and eleven further predicates commonly characterized as factive or semi-factive (*amuse, find out, forget, learn, love, notice, realize, recognize, regret, remember, understand*).

The mean projection ratings by embedding context and predicate are presented in Figure 4, which shows that effect of embedding context on projection differs by predicate.
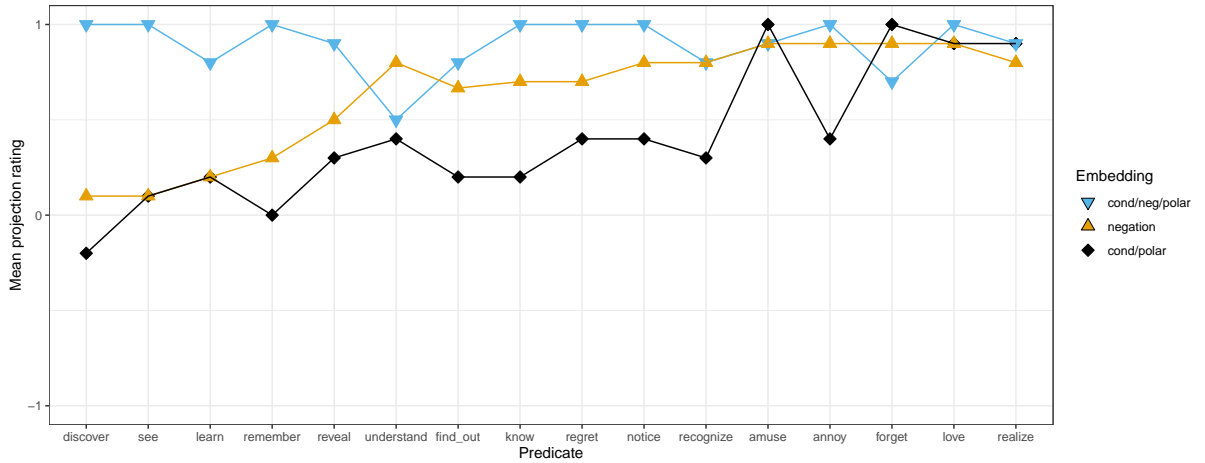
For instance,[7]

Figure 4: Mean projection ratings by embedding context and predicate.

It is worth noting that the task assesses global projection only in case of (6a), but not (6b+c), where the question *did it happen?* is embedded in the conditional consequent. It assesses whether the projective inference holds in the conditional local context. Nevertheless, the data provides supporting evidence for by-predicate variation in the effect of operators on projection. Crucially, the by-predicate variation in the effect of negation in the global context is different from the by-predicate variation in the effect of negation in the conditional context.

4. General discussion

In this section, we point out methodological implications of our results (section 4.1), discuss whether contemporary projection analyses can capture the observed variation (section 4.2), and speculate about lexical differences between the clause-embedding predicates that might predict the by-operator variation observed (section 4.3).

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[7]Give some examples of differences here, but first double check if lines are labeled correctly. Also angle labels on x-axis.

4.1. Methodological implications

A methodological implication of this latter result is that future research must relativize claims about projection variation to the entailment-canceling operator.

4.2. Theoretical implications

In this section, we consider whether contemporary analyses can capture the observed by-predicate projection variation and the interactions between predicate and entailment-canceling operator in projection ratings. We consider three types of analyses: (i) analyses that assume that the CCs of factive predicates are lexically specified as presupposed (Heim 1983, 1992, van der Sandt 1992), (ii) analyses on which backgrounded entailments are projective (Abrusán 2011, Simons et al. 2017), and (iii) an analysis on which contextual entailments are projective (Schlenker 2021).

4.2.1. Analyses on which presuppositions are lexically specified

On the analyses in Heim 1983, 1992 and van der Sandt 1992, the CCs of factive predicates are lexically specified as presupposed, in contrast to the CCs of nonfactive predicates. Presupposed CCs project to the global context, except when that would produce an inconsistency, in which case they are accommodated to the local context of the operator.

By-predicate variation.   Analyses on which some clause-embedding predicates are factive and others are nonfactive do not predict the observed by-predicate variation, for several reasons. One reason is that there is variation between the factive predicates: For instance, the CC of *be annoyed* is more projective than that of *discover*, which in turn is more projective than that of *reveal*. This variation is not predicted because the CCs of factive predicates are invariably specified as presupposed. The variation is also not predicted because, in our experiment, the stimuli were presented in minimal contexts that were not inconsistent with the CCs, thereby rendering local accommodation unlikely. A second reason is that the CCs of some nonfactive predicates (e.g., *inform, acknowledge*) are just as projective as those of some factive predicates, or even more projective. Analyses like those in Heim 1983, 1992 and van der Sandt 1992 fail to make predictions about the projection of the CCs of nonfactive predicates. Thus, as discussed in detail in Degen and Tonhauser 2022, the factive/nonfactive distinction is not sufficiently fine-grained to adequately predict the observed by-predicate projection variation.

By-operator variation.   The analyses in Heim 1983, 1992 and van der Sandt 1992 do not lead us to expect differential effects of entailment-cancelling operators on projection. This is because negation and conditional antecedents are given a semantics that derives their behavior as presuppositional 'holes' (in the sense of Karttunen 1971). For instance in Heim 1983, presupposition triggers under negation or in conditional antecedents are evaluated relative to the global context set. Therefore, presupposition triggers under these operators are predicted to behave like unembedded ones, with no expected differences. While the analyses does not explicitly address epistemic possibility modals or polar questions, we might expect that they would be treated as presuppositional holes along the same lines, therefore also not predicting the observed projection variation.

4.2.2. Analyses on which backgrounded entailments are projective

Abrusán 2011, 2016 and Simons et al. 2017 do not assume that presuppositions are lexically specified but rather that those entailments that are backgrounded with respect to the discourse context in which the utterance is made may project. In Abrusán 2011 and Abrusán 2016, an entailment is backgrounded if it is about a time that is not the event time of the matrix predication and it is not at-issue with respect to the Question Under Discussion (QUD, see Roberts 1996, 2012). In Simons et al. 2017, an entailment is backgrounded if it is not at-issueness relative to the QUD and not conventionally marked as at-issue.

By-predicate variation.   Like the analyses discussed in the previous section, the analyses in Abrusán 2011, 2016 and Simons et al. 2017 do not predict the observed by-predicate variation. First, if the CCs of factive predicates are entailed, they are invariably predicted to project, and so the observed differences are not predicted. Second, the analyses do not make predictions for nonentailed CCs, and hence they do not predict that the CCs of some nonfactive predicates project at least as much or even more than those of some factive predicates.

By-operator variation.   Neither of the analyses make predictions about by-operator variation.

4.2.3. Triggering based on contextual entailment

The triggering mechanism assumed in Schlenker 2021 operates on local contextual entailments of an expression, and determines which one of them projects based on probabilistic world knowledge about the truth of the invoked contents. For instance, the CC of the utterance with *discover* in (7a), that Julian dances salsa, has the potential to project if it is entailed by the sentence in the scope of negation (namely (7b)) together with information that is available in its local context. Negation is treated as a presuppositional hole, and the local context under negation is taken to be the global context (as in Heim 1983 and Schlenker 2009).

(7)   a.   Cole didn't discover that Julian dances salsa.
        b.   Cole discovered that Julian dances salsa.

The triggering mechanism states that an inference p of some propositional expression E projects if p is an epistemic precondition for the truth of E in its local context c'. So, the CC of (7a) projects if the CC is an epistemic precondition for the truth of (7b). p is an epistemic precondition of E in c' if, usually, when one acquires the belief in c' that E, one already knows that p. The CC of (7a) can be taken to be an epistemic precondition for (7b) based on the 'subjective conditional probability' that a generic epistemic agent would already believe that Julian dances salsa when learning that (7b) is true. Specifically, the CC is taken to be an epistemic precondition if that probability reaches a contextually given threshold.

By-predicate variation.   Schlenker 2021 predicts the potential of projection for CCs that are contextually entailed by the variants not embedded under an entailment-canceling operator. Thus, in contrast to the analyses reviewed above, this analysis can, in principle, predict the projection of non-entailed CCs, namely when the CCs are contextually entailed. While this

is a step in the right direction, it is not clear that the analysis can predict the projection of non-entailed CCs. Consider (8), the variant of (7a) with *inform*:

(8)   a.   Cole didn't inform Sam that Julian dances salsa.
       b.   Cole informed Sam that Julian dances salsa

On Schlenker's 2021 analysis, the CC projects in (8a) if, usually, when one acquires the belief that (8b), one already knows that Julian dances salsa. While it is certainly possible for Julian dancing salsa to be already known when one acquires the belief that (8b), it is not clear that this is "usually" the case. (Another question, of course, is what "usually" means.)

It is also not clear that this analysis can predict the observed by-predicate variation. To illustrate, consider the schemata in (9):

(9)   a.   Cole didn't PREDICATE that Julian dances salsa.
       b.   Cole PREDICATE that Julian dances salsa.

Given that the non-entailed CC of a given predicate projects in (9a) only if one "usually" already knows that the CC is true when one acquires the belief that (9b), Schlenker's 2021 analysis seems to predict that predicates fall into two groups: Those whose CCs one "usually" already knows to be true when one acquires the belief that (9b), and those for which this is not the case. If so, this analysis cannot predict the observed by-predicate projection variation.

By-operator variation.   Schlenker 2021 does not incorporate differential effects of entailment-cancelling operators on projection. Although subjective conditional probabilities are relativized to a local context, the local context under negation and in conditional antecedents is assumed to the global context (based on Heim 1983, Schlenker 2009). Therefore, no differential effect of operator is predicted, contrary to what is observed. For instance, the conditional probability for p given E vs. that of p given ($not\ E$) or that of p given ($if\ p, q$) should not differ.

4.2.4. Discussion: Contextual inferences and probabilistic triggering

Our data showed gradient projection variation, based on a main effect of predicate, and an operator-predicate interaction. We found these effects for the CCs of clause-embedding predicates under four entailment-cancelling operators in out-of-the-blue contexts. The fact that we see some amount of projection for all predicates (even non-veridical ones), can only be addressed by an account that assumes the potential of projection for contextual inferences, rather than only literal ones.

The main effect of predicate and the operator-predicate interaction are both gradient effects, and cannot be explained by a categorical distinction between presuppositional and non-presuppositional predicates. The effects could rather be addressed in a probabilistic account, where various embedding contexts (i.e., combinations of entailment-cancelling operator and predicate) are associated with different probabilities that the embedded content projects.

Under the assumption of information-structural triggering, this is the probability that the embedded content is not at issue in the (possibly imagined) discourse context. Under a world-knowledge-based triggering account, the projection probability can be associated with the probability that the embedded content is already known in the discourse context. These two notions

are, of course, related. If some proposition is already known, raising an issue about whether *p* is the case will be uninformative. Therefore, it is unclear whether these two approaches would make different predictions for our data. Both types of accounts would need to be extended to make concrete predictions for the contribution of the combinations of entailment-cancelling operators and predicates.

4.3. Lexical patterns

Can the observed interactions between predicate and entailment-canceling operator be predicted from lexical semantic/pragmatic properties of the predicates? This is a pressing question for future research, to which our data offer some tentative answers.

We can find some initial generalizations over lexical properties, indicated in Figure 5, which gives the mean certainty ratings for the four operators by predicate, identifying four groups of predicates that show similar by-operator variation.
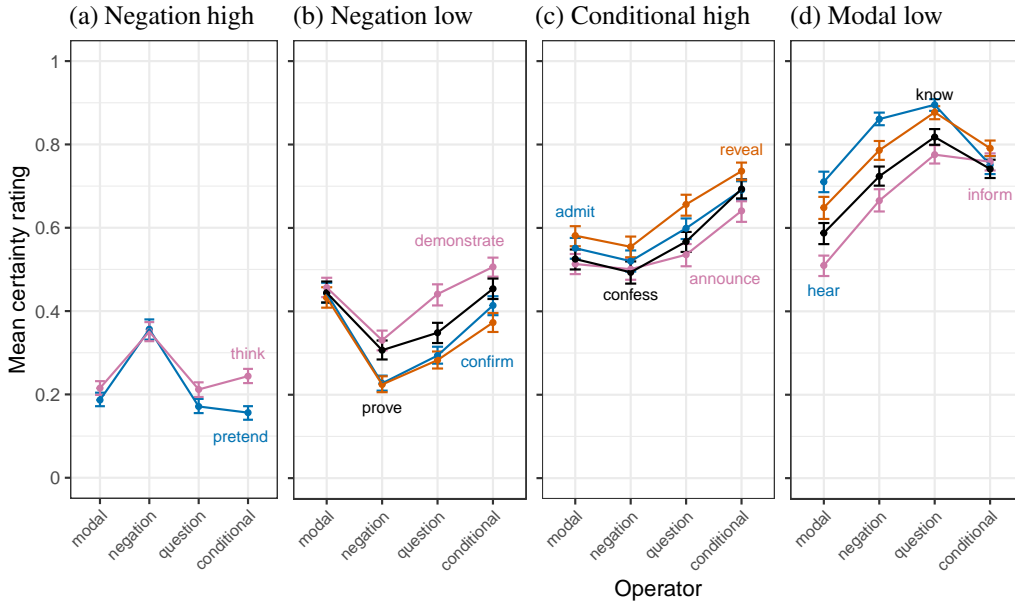

Figure 5: Mean certainty ratings by operator with 95% bootstrapped confidence intervals, for some groups of predicates ('predicate patterns').

The non-veridical predicates *pretend* and *think* exhibit the 'Negation high' pattern, shown in panel (a) of Figure 5. These are the only predicates that are most projective under negation compared to all other operators. This could be related to assumptions that non-veridical doxastics like *think* can often be interpreted in comparison to a stronger veridical alternative (e.g., Heim 1991, Chemla 2008). We tentatively hypothesize that this can lead to an inference that the CC is false in upward-monotone contexts, but not under negation. A similar alternative seems to be salient for *pretend*, but not the non-veridical communicative predicates *say* or *suggest*.

The inferential predicates *confirm, demonstrate*, and *prove* exhibit a 'Negation low' pattern, shown in panel (b). These are most projective under modals and conditionals and least projective under negation. Here, we may hypothesize that a negative statement involving these predicates is often only taken as relevant (in a Gricean sense) when it is antecedently known

that there was an attempt to confirm/demonstrate/prove the truth of the CC. This may result in an inference that this attempt failed and result in lower projection ratings under negation.

For *admit, announce, confess*, and *reveal*, the CC is most projective when embedded in conditional antecedents: This 'Conditional high' pattern (c) may suggest that the discourse effect of a conditional interacts with these change-of-state communication predicates.

Finally, the predicates *hear, inform,* and *know* exhibit a 'Modal low' pattern (d). The lexical meaning of these predicates, whose CCs are among the most projective, appears to interact with the modal adverb *perhaps*, yielding lower projection ratings.

5. Conclusion

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A. 20 clauses

The contents of the following 20 clauses, which realized the complements of the 20 clause-embedding predicates, were investigated in Exps. 1-4:

1. Mary is pregnant.

2. Josie went on vacation to France.

3. Emma studied on Saturday morning.

4. Olivia sleeps until noon.

5. Sophia got a tattoo.

6. Mia drank 2 cocktails last night.

7. Isabella ate a steak on Sunday.

8. Emily bought a car yesterday.

9. Grace visited her sister.

10. Zoe calculated the tip.

11. Danny ate the last cupcake.

12. Frank got a cat.

13. Jackson ran 10 miles.

14. Jayden rented a car.

15. Tony had a drink last night.

16. Josh learned to ride a bike yesterday.

17. Owen shoveled snow last winter.

18. Julian dances salsa.

19. Jon walks to work.

20. Charley speaks Spanish.

B. Consequents for conditional target stimuli in Exps. 4

We created 20 consequent clauses for the three experiments in which the 20 clauses were embedded in the antecedent of a conditional (Exps. 4). Each of the 20 clauses was paired with a unique consequent clause, as shown in the list below. To minimize the variability of the effect of the contents of these consequent clauses on the projection of the contents of the 20 complement clauses, the consequent clauses all consist of a uniquely named subject and an adjectival predication in the future tense (*will be*), and the adjectives all denote an emotion. We selected the 20 emotion-denoting adjectives based on the valence and arousal values reported in Warriner et al. 2013: 10 of the adjectives had a positive valence, and 10 had a negative valence; all 20 adjective had an arousal value between 4.7 and 6.5.

1. ...that Mary is pregnant, Esther will be mad.

2. ...that Josie went on vacation to France, Arnold will be frustrated.

3. ...that Emma studied on Saturday morning, Liam will be proud.

4. ...that Olivia sleeps until noon, Elijah will be embarrassed.

5. ...that Sophia got a tattoo, Ariel will be giddy.

6. ...that Mia drank 2 cocktails last night, Mariela will be worried.

7. ...that Isabella ate a steak on Sunday, Liz will be delighted.

8. ...that Emily bought a car yesterday, Kate will be excited.

9. ...that Grace visited her sister, Henry will be surprised.

10. ...that Zoe calculated the tip, Alex will be astonished.

11. ...that Danny ate the last cupcake, Harper will be disgusted.

12. ...that Frank got a cat, Lucas will be grouchy.

13. ...that Jackson ran 10 miles, Kayla will be cheerful.

14. ...that Jayden rented a car, Brittany will be furious.

15. ...that Tony had a drink last night, Victoria will be ashamed.

16. ...that Josh learned to ride a bike yesterday, Mason will be envious.

17. ...that Owen shoveled snow last winter, Bianca will be jealous.

18. ...that Julian dances salsa, Logan will be joyful.

19. ...that Jon walks to work, Caleb will be suspicious.

20. ...that Charley speaks Spanish, Jay will be happy.

C. Control stimuli in Exps. 1-3

The control stimuli in Exps. 1-3 were the contents of main clauses. In Exps. 1q, 2q and 3q, the control stimuli consisted of the polar questions in (1). The non-restrictive relative clauses (NRRCs), given in parentheses in (1), were included in Exps. 2q and 3q, where at-issueness was measured with an assent diagnostic. The control stimuli here consisted of two clauses (like the target stimuli), to allow the relevant speaker to assent with one of two clauses.

(1)   Sentences for control stimuli in in question embedding experiments (Exps. 1q, 2q and 3q)
     a.   Do these muffins (, which are really delicious,) have blueberries in them?
     b.   Does this pizza (, which I just made from scratch,) have mushrooms on it?
     c.   Was Jack (, who is my long-time neighbor,) playing outside with the kids?
     d.   Does Ann (, who is a local performer,) dance ballet?
     e.   Were John's kids (, who are very well-behaved,) in the garage?

      f.   Does Samantha (, who is really into fashion,) have a new hat?

We expected participants to give low responses on the 'certain that' diagnostic for the control stimuli in (1), indicating that the speaker is not certain of the main clause content, because main clause content is hypothesized to not project out of polar questions. These expectations were borne out, as shown in the third column of Table 3 for Exps. 1q, 2q, and 3q. We also expected participants to give low responses on the at-issueness diagnostics for the control stimuli in (1), indicating that the main clause content is at-issue. These expectations were borne out for Exps. 1q and 2q, as shown in the fourth column of Table 3, but the ratings were higher than expected for Exp. 3q. See below for discussion.

In the remaining experiments, the control stimuli consisted of the positive declarative variants of (1) given in (2). The NRRCs in parentheses were realized in Exps. 2 and 3 for the reason explained above, as well as in Exp. 1c, to make the control stimuli more similar to the target stimuli (which also consisted of two clauses, namely the antecedent and the consequent).

(2)   Sentences for control stimuli in negation, modal and conditional embeddings
      a.   These muffins (, which are really delicious,) have blueberries in them.
      b.   This pizza (, which I just made from scratch,) has mushrooms on it.
      c.   Jack (, who is my long-time neighbor,) was playing outside with the kids.
      d.   Ann (, who is a local performer,) dances ballet.
      e.   John's kids (, who are very well-behaved,) were in the garage.
      f.   Samantha (, who is really into fashion,) has a new hat.

We expected participants to give high responses on the 'certain that' diagnostic for the control stimuli in (2), indicating that the speaker is certain of the main clause content, because speakers are hypothesized to be committed to the asserted main clause content. These expectations were borne out, as shown in the third column of Table 3 for the 'n', 'm' and 'c' variants of Exps. 1, 2, and 3. We expected participants to give low responses on the at-issueness diagnostics for the control stimuli in (2), indicating that the main clause content is at-issue. These expectations were borne out for the 'n', 'm', and 'c' variants of Exps. 1, as shown in the fourth column of Table 3, but not for the 'n', 'm', and 'c' variants of Exps. 2 and 3. See below for discussion.

As mentioned above, the mean at-issueness ratings were higher than expected in the 'n', 'm', and 'c' variants of Exps. 2 and all four of the Exps. 3. We discuss these exceptions in more detail here because they allow us to further understand the various measures for at-issueness investigated in this paper. The example in (3a) illustrates the version of the assent diagnostic applied in Exps. 2n, 2m, and 2c: the assent particle *yes* is followed by the clause whose content is diagnosed, here, the content of the main clause. The related affirmation diagnostic applied in Exp. 2q (where the mean at-issueness rating was as low as expected) is illustrated in (3b).

(3)   a.   Sample control stimulus in Exps. 2n, 2m, and 2c
          A: These muffins, which are really delicious, have blueberries in them.
          B: Yes, that's true, they have blueberries in them.
          Question to participants: Does A's response to B sound good?
      b.   Sample control stimulus in Exp. 2q
          A: Do these muffins, which are really delicious, have blueberries in them?
          B: Yes, they have blueberries in them.

		Mean ratings		
Exp.	Control stimuli	Certainty	Not-at-issueness	At-issueness measure
1q	(1)	.14	.05	asking whether c
1n	(2)	.95	.04	sure that c
1m	(2)	.96	.03	sure that c
1c	(2) with NRRC	.94	.08	sure that c
2q	(1) with NRRC	.18	.07	*yes, c*
2n	(2) with NRRC	.96	.22	*yes, that's true, c*
2m	(2) with NRRC	.96	.25	*yes, that's true, c*
2c	(2) with NRRC	.96	.22	*yes, that's true, c*
3q	(1) with NRRC	.17	.28	*yes*, but $\neg c'$
3n	(2) with NRRC	.94	.44	*yes, that's true*, but $\neg c'$
3m	(2) with NRRC	.93	.50	*yes, that's true*, but $\neg c'$
3c	(2) with NRRC	.93	.53	*yes, that's true*, but $\neg c'$

Table 3: Mean certainty and at-issueness ratings for control stimuli, for self-declared American English participants

Question to participants: Does A's response to B sound good?

As shown in Table 3, the group mean on the control stimuli is numerically higher (at .22 or .25) than for Exp. 2q (.07). We hypothesize that a possible explanation for this difference is that participants take A to assert both the content of the main clause and of the NRRC in (3a) but is only asking about the main clause content in (3b). Whereas B's affirmation in (3b) specifies the one content that is affirmed, B's assent in (3a) specifies only one of the two contents that A asserted, seemingly leaving out a specification of the second content, that of the NRRC. Participants may judge B's response in (3b) to be less acceptable than in (3a) because of this missing content specification. This hypothesis is consistent with the results of Syrett and Koev's (2015) Exp. 3, which suggests that content of a sentence-medial NRRCs can be the target of a direct denial, though the main clause content is preferred as the target of such a denial. That the group means on the control stimuli in our Exps. 2n, 2m, and 2c are still relatively low may be due to the fact that the one content that was specified is the at-issue main clause content. One would expect lower acceptability ratings in a version of this diagnostic in which the one content that was specified is the NRRC.

The mean at-issueness ratings for the control stimuli were also higher than expected in Exps. 3. The examples in (4) illustrate the versions of the affirmation and assent diagnostics used in these experiments:

(4) a. Sample control stimulus in Exp. 3q
     A: Do these muffins, which are really delicious, have blueberries in them?
     B: Yes, but they aren't really delicious.
     Question to participants: Does A's response to B sound good?
   b. Sample control stimulus in Exps. 3n, 3m, and 3c
     A: These muffins, which are really delicious, have blueberries in them.
     B: Yes, that's true, they but they aren't really delicious.
     Question to participants: Does A's response to B sound good?

The mean at-issueness rating for the control stimuli in Exp. 3q was comparatively higher (at .28) than for Exp. 1q (.05) or Exp. 2q (.07). We hypothesize that that this difference (especially to Exp. 2q) is due the content of the NRRC being directly denied, even though it was presented as backgrounded content in A's question (as shown in (2), the content of none of the other NRRCs was a matter of personal taste).

The mean at-issueness ratings for the control stimuli in Exps. 3n, 3m, and 3c were numerically even higher than for Exp. 3q and, in fact, the highest across all 12 experiments (at .44, .50, and .53, respectively). There are two factors that could be implicated in the difference between Exp. 3q and Exps. 3n, 3m, and 3c: first, the NRRC is included in a polar question in the former but a declarative assertion in the latter; second, B utters an affirmation *yes* in the former but an assent *yes, that's true* in the latter. For instance, participants might judge B's direct denial of the content of the NRRC as less acceptable when A uttered a declarative assertion and B assented with that assertion using *yes, that's true* than when A uttered a polar question and B responded in the affirmative with *yes*. Both factors must be considered in future research on at-issueness measures.

D. Participant information and data exclusion criteria

This supplement provides information on the participants of the 12 experiments and the criteria by which participants' data were excluded. The first three columns of Table 4 show, for each of the 12 experiments how many participants were recruited, their age range and mean age, and their self-reported gender; no gender data was collected in Exp. 1q. The next three columns provide information on the number of participants whose data were excluded based on the following criteria:

- 'multiple': Due to an experimental glitch, some participants participated more than once in Exp. 1q. Since no information was available on which one was their first take, those participants' data was removed.

- 'language': Participants' data were excluded if they did not self-identify as native speakers of American English.

- 'controls': Participants' data were excluded if their mean rating on the 6 main clause control items in the projection block was more than 2 sd above the group mean (in Exps. 1q, 2q, and 3q) or more than 2 sd below the group mean (in the remaining experiments). Participants' data were also excluded if their mean rating on the 6 main clause control items in the at-issueness block was more than 2 sd above the group mean (across all experiments).

- 'variance': Participants' data were excluded if they always selected roughly the same point on the response scale for the target stimuli. To identify such participants, we first identified participants whose mean variance on the target stimuli was more than 2 sd below the group mean variance and then manually inspecting their response patterns. The data of participants who used the full scale was not excluded.

The remaining columns of Table 4 provide information on the remaining participants, that is, the participants' data that entered into the analysis. Participants took around 9-11 minutes to

complete the various experiments. Participants were paid more in Exps. 1c, 2c, and 3c than the remaining experiments because the target stimuli in those experiments were longer (as they consisted of conditionals). More women than men were recruited in many of the experiments because the experiments were run at a time when Prolific went viral on TikTok, resulting in a large number of young women registering for the service (around July 24, 2021; see `https://blog.prolific.co/we-recently-went-viral-on-tiktok-heres-what-we-learned/`, last accessed February 4, 2022).

Exp.	Recruited participants			Exclusion criteria				Remaining participants			
	total	ages (mean)	gender (f/m/o/u)	multiple	language	controls	variance	total	ages (mean)	gender (f/m/o/u)	payment
1q	300	19-74 (38.2)	—	5	7	35	0	242	21-74 (39.2)	—	$1.70
1n	300	18-74 (33.2)	150/145/5/0	0	8	17	1	274	18-74 (33.3)	141/128/5/0	$1.70
1m	300	18-74 (32.7)	150/141/7/2	0	0	19	0	281	18-74 (32.7)	144/129/7/1	$1.70
1c	300	18-58 (25.9)	249/45/6/0	0	6	26	2	266	18-58 (24.8)	235/25/6/0	$2.15
2q	250	18-58 (25.5)	201/43/6/0	0	4	24	1	220	18-58 (24.8)	187/28/5/0	$1.70
2n	250	18-69 (33.2)	127/114/6/1	1	4	29	0	215	18-69 (33.1)	113/95/6/1	$1.70
2m	251	18-74 (31.7)	132/113/6/0	0	4	27	0	220	18-70 (31.9)	116/98/6/0	$1.70
2c	250	18-56 (24.5)	212/30/8/0	0	0	26	0	224	18-56 (24.4)	195/24/5/0	$2.15
3q	250	18-66 (32.4)	140/102/7/1	0	4	20	0	225	18-66 (32.6)	125/93/7/0	$1.70
3n	250	18-70 (24.6)	214/31/5/0	0	5	13	4	228	18-70 (24.3)	198/25/5/0	$1.70
3m	250	18-63 (25.5)	205/40/5/0	0	3	14	0	233	18-63 (24.8)	197/31/5/0	$1.70
3c	250	18-59 (27.5)	182/64/4/0	0	3	17	0	230	18-59 (26.7)	177/49/4/0	$2.15

Table 4: Recruited participants, excluded data, and remaining participants in Exps. 1, 2 and 3. Gender distinctions were 'f' = female, 'm' = male, 'o' = other, and 'u' = undeclared.