Projection differs across embedding operators—but not like you think

We present experimental evidence **(i)** that the projection of the content of attitude complements differs between entailment-canceling operators, and **(ii)** that this by-operator variation differs between attitude predicates. Our results do not align with the long-standing distinction of factive vs. semi-factive predicates (see, e.g., Karttunen, 1971; Hooper and Thompson, 1973; Djärv et al., 2018). Instead, the observed by-operator variation reveals a more nuanced picture of lexical semantic/pragmatic properties which raises important questions for future research on projection.

Projection across entailment-cancelling operators. Interpreters may infer that a speaker who utters an attitude ascription, as in (1), is committed to the truth of the content of the complement (CC), even though it occurs under an entailment-canceling operator, such as negation (1a), a polar question (1b), a modal (1c), or a conditional (1d).

(1) 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.'*

Karttunen (1971) proposed that the CC of factive predicates (e.g. *regret, forget*) projects across all four operators, whereas that of semi-factive predicates (e.g. *discover, realize, see, notice*) always projects from under negation, but not always from under polar questions, modals, or conditionals. To date, systematic empirical investigations of Karttunen's intuition are scarce.

Smith and Hall (2014) investigated by-operator variation (negation, conditional) for various types of projective content, observing that the content of non-restrictive relative clauses and *win* was more projective under conditionals than negation, *know* and epithets exhibited the opposite pattern, whereas clefts showed no difference. However, their task asked participants how surprised they would be to learn the content under investigation after observing the utterance. Since factors other than speaker commitment modulate (un)expectedness (see e.g. Zimmermann, 2011; Tönnis, 2021), it is not clear that they (only) measured projection. So far, there has been no experimental investigation of by-operator variation comparing factive and semi-factive predicates. However, Djärv et al. (2018) and Tonhauser et al. (2018) observed by-predicate variation in polar questions. Djärv et al. (2018), assessing acceptability of affirming the main clause while denying the CC, found higher ratings for *be happy* and *appreciate* (assumed to be factive) and *be aware* than *realize* (assumed to be semi-factive). Here, it is also not obvious how exactly this task relates to projection. Tonhauser et al. (2018) measured projection of the CC of a broad range of attitude predicates more directly, by collecting ratings about speaker certainty about the CC. The observed by-predicate differences did not align the expectations from Karttunen's classification (e.g., the CC of semi-factive *realize* was as projective as that of factive *be annoyed* and more than that of semi-factive *discover*).

Experiment. We present the results of a study investigating by-operator projection variation for the CCs of 20 attitude predicates, including purported factive and semi-factive predicates (e.g., *be annoyed, discover*). Projection was measured for the same contents across all four operators in (1) using the 'certain that' diagnostic for projection (see e.g., Tonhauser et al., 2018; Djärv and Bacovcin, 2017; Mahler, 2020).

Methods and Expectations. Projection of the CC of the 20 attitude predicate was measured in four sets of experiments: The attitude predicates were embedded under polar questions in Exps. 1, under negation in Exps. 2, under *perhaps* in Exps. 3, and in the antecedent of a conditional in Exps. 4. (Each set of experiments consisted of three experiments that differed in the at-issueness measure used in a separate block. We focus on the projection ratings here.) In each experiment, participants were asked to read utterances like those in (1) and judge whether the speaker (who was named) was certain of the CC (e.g.: Is [the speaker] certain that Julian dances salsa?). Participants gave their response on a slider marked 'no' (coded as 0) at one end and and 'yes' (coded as 1) on the

other. Each participant rated the projection of the CC of all 20 attitude predicates (each paired with a unique content from a set of 20 contents) under one operator. We analyze the data from 2,682 self-reported native speakers of American English recruited on Prolific or Amazon's MT platform. Karttunen's generalization leads us to expect the CC of factive predicates to consistently receive relatively high projection ratings under all four operators, and the CC of semi-factive predicates to exhibit high projection ratings under negation and possibly lower ratings under the other operators.

Results. Figure 1 shows mean projection ratings for the 20 attitude predicates by embedding operator; the predicates are ordered by their mean projection across all operators (*be annoyed* has the highest overall projection mean). We observe by-operator variation in projection means as well as differences across the predicates in by-operator variation: For instance, whereas the CC of *be annoyed* projects more from under negation (and questions) than conditionals and modals, the CC of *know* projects less from under negation than questions, but more from under negation than modals, and the CC of *discover* projects less from negation than conditionals and questions, and more from under negation than modals. These results (which are supported by linear mixed effects models, see **Table 1**) are unexpected based on Karttunen's (1971) distinction between factive and semi-factive predicates: Contrary to assumption, the CC of the purportedly factive predicate *be annoyed* does not project invariably from all four operators, and the CC of the purportedly semi-factive predicate *discover* does not project more from under negation than the other three operators. The pattern observed for *know* is neither that of a factive nor that of a semi-factive predicate. Similar considerations apply to *see* and *reveal*, which are also considered (semi-)factive in the literature.

Discussion: Empirical and theoretical implications. Our results — that projection is modulated by entailment-canceling operators and that there is by-predicate variation in the effect of operator on projection — have several empirical and theoretical implications. First, the results for the predicates typically considered (semi-)factive, namely *be annoyed, know, see, discover* and *reveal*, call into question the assumed distinction between factive and semi-factive predicates (see also Beaver (2010)). Future research that appeals to these two categories must clarify their definition. Second, claims about projection variability must be relativized to the entailment-canceling operator. While our data replicate the result from Tonhauser et al. (2018) that, in a polar question, the CC of *discover* is less projective than that of *know*, this result does not carry over to conditionals. Finally, our results provide further support (from embedding under negation, modals, and conditionals) for the result of Degen and Tonhauser (2022), that projection does not categorically distinguish between (semi-)factive and non-factive predicates: The CCs of *inform* and *acknowledge*, for instance, are at least as projective as that of some (semi-)factive predicates.

Discussion: Novel research question. Can the observed interaction between predicate and operator in mean projection ratings be predicted from lexical semantic/pragmatic properties of the predicates, and, if so, how? This is a pressing question for future research, to which our data offer some tentative answers. We identify four major patterns. The predicates *pretend* and *think* exhibit the **'Negation high'** pattern, shown in panel (a) of **Figure 2**: We tentatively hypothesize that negation (but not the other operators) interacts with the semantic or pragmatic antiveridicality contributed by these predicates. The inferential predicates *prove, confirm*, and *establish* exhibit a **Negation low'** pattern, shown in panel (b): Here, we tentatively hypothesize that the veridical meaning component interacts with negation (but not the other operators), to result in lower projection ratings under negation. For *announce, confess, admit*, and *reveal*, the CC is most projective when embedded in the antecedent of a conditional: This **'Conditional high'** pattern, shown in (c), may suggest that the discourse effect of a conditional interacts with the change-of-state communication predicates. Finally, the predicates *inform, know*, and *be annoyed* exhibit a **'Modal low'** pattern, shown in (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.

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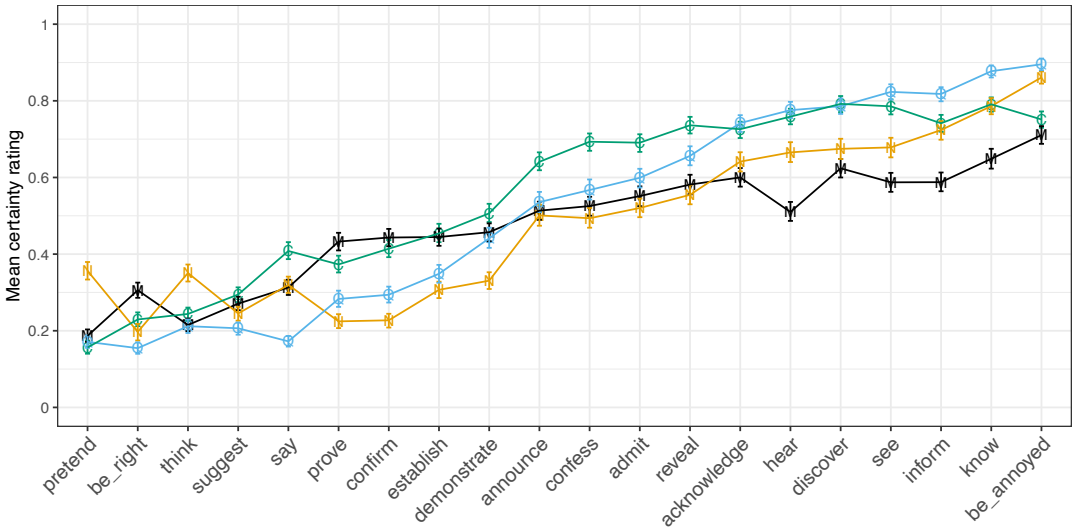

Figure 1: Mean certainty ratings by predicate and operator with 95% bootstrapped confidence intervals. Embedding operator coded by letter and color: `N` (orange): negation, `M` (black): modals, `C` (green): conditional antecedents, `Q` (blue): polar questions.

Model		Estimate	Std. Error	t-value	
#1	Intercept: **be annoyed**/negation	0.87	0.01	75.8	***
	operator: conditional	-0.12	0.02	-7.38	***
	operator: modal	-0.16	0.02	-10.04	***
	operator: question	0.02	0.01	1.74	n.s.
#2	Intercept: **know**/negation	0.79	0.01	69.24	***
	operator: conditional	-0.001	0.02	-0.08	n.s.
	operator: modal	-0.14	0.02	-9.2	***
	operator: question	0.08	0.01	5.72	***
#3	Intercept: **discover**/negation	0.68	0.01	59.48	***
	operator: conditional	0.11	0.02	7.11	***
	operator: modal	-0.06	0.02	-3.6	***
	operator: question	0.1	0.01	7.07	***

Table 1: Relevant parts of three linear mixed effects models that predict certainty ratings from a fixed effect of operator, predicate, and their interaction, with random effects for participant and CC. Models were fit with `lme4`, `lmertest` in `R`.

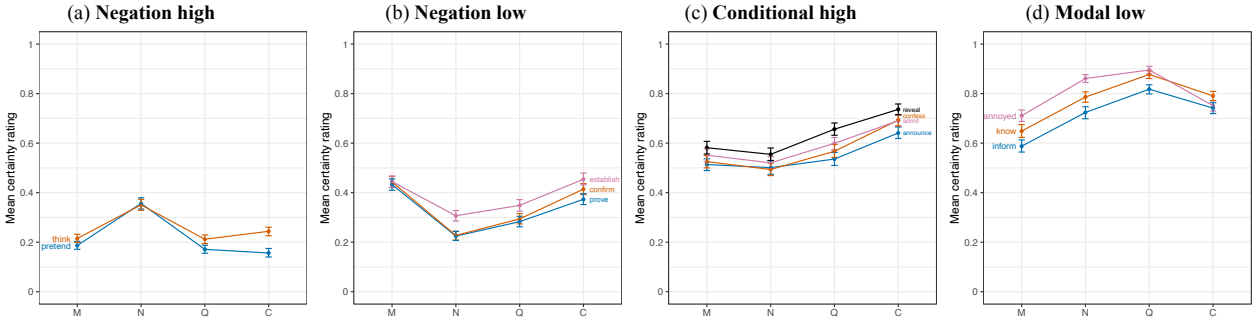

Figure 2: Mean certainty ratings by operator (`M`: Modal, `N`: Negation, `Q`: Polar Question, `C`: Conditional antecedent) with 95% bootstrapped confidence intervals, for some groups of predicates ('predicate patterns').