Projection differs across embedding operators—but not like you think

We present experimental evidence that i) the projection of the content of the clausal complement of attitude predicates varies across entailment-canceling operators (negation, question, modal, conditional) and ii) this by-operator variation differs across attitude predicates. Our results do not align with the long-standing distinction between factive and semi-factive predicates (see, e.g., Karttunen, 1971; Hooper and Thompson, 1973; Djärv et al., 2018, though see Beaver, 2010). Instead, the observed by-operator variation groups predicates by lexical semantic/pragmatic properties that raise important questions for future research on projection.

Projection across entailment-cancelling operators. Interpreters may infer that a speaker who utters one of the attitude ascriptions 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 from under 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.

There has been, to date, one investigation of by-operator variation: Smith and Hall 2014, who investigated by-operator variation (negation, conditional) for the projective content of six expressions (*know, the, win*, epithets, clefs, non-restrictive relative clauses (NRRCs)), observed by-operator variation for some contents (e.g., that of *know*, but not that of clefs) and that this by-operator variation differs across contents (e.g., the content of NRRCs was more projective under conditionals than negation, the opposite pattern was observed for *win*). It is not clear, however, whether the response task used by Smith and Hall 2014 measured projection, as participants were asked to rate how surprised they would be to learn the content under investigation after observing the utterance.

There has not yet been an experimental investigation of by-operator variation between factive and semi-factive predicates. Djärv et al. 2018 and Tonhauser et al. 2018 did, however, observe by-predicate projection variation under polar questions. Djärv et al. 2018 observed a difference between *be happy* and *appreciate* (which they assumed are factive predicates) and *be aware* and *realize* (which they assumed are semi-factive predicates). However, the response task (acceptability of an affirmation of the CC while the main clause content was denied) did not measure projection of the CC. Tonhauser et al. 2018 measured projection of the CC of a broad range of attitude predicates from under polar questions: The by-predicate projection differences they observed did not align with what would be expected from Karttunen's classification (e.g., the CC of semi-factive *realize* was as projective as that of factive *be annoyed* and more projective than that of semi-factive *discover*).

Experiment. We present the results of an experiment designed to investigate 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 also, 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 and and 'yes' (coded as 1) on the other end. 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. We 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. Fig. 1 shows the 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 from under conditionals and modals, the CC of *know* projects less from under negation than under questions, but more from under negation than from under modals, and the CC of *discover* projects less from negation than from under conditionals and questions, and more from under negation than modals. These results (which are supported by linear mixed effects models, see Table 1) are not aligned with the distinction between factive and semi-factive predicates proposed in Karttunen 1971 or assumed in Djärv et al. 2018: 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. For *know*, we observe a third pattern – one that is not aligned with a classification as a factive nor as a semi-factive predicate.

Discussion and Conclusion. Our results clearly show that different entailment-cancelling operators affect projection in different ways, and that the effect of entailment-cancelling operator on projection differs for different verbs. The picture that emerges could not be characterized in terms of Karttunen's characterization of (semi)factives. Our results indicate a need for a more nuanced view of the family-of-sentences diagnostics of projection, as well as a better understanding of the effect of the interaction between lexical semantics and operators on projection.

Further, we were able to replicate the results of Degen and Tonhauser, 2022), observing that projection varies by predicate (e.g., the CC of *be annoyed* is more projective than that of *discover*, and finding no categorical distinction between factive and non-factive predicates either.

In spite of a lack of categorical distinctions about the projection behavior of our verbs, we can find some interesting patterns. **Figure 2** gives the mean certainty ratings for the four operators by verb, for some groups of our verbs that group together in the way that they show by-operator variation. We highlight four 'projection-profiles'here: the verbs *pretend, think* are the only verbs that are most projective under negation compared to all other operators ($\texttt{N} > \texttt{M, Q, C}$). *annouce, confess, admit,* and *reveal* are most projective under conditionals, while there is also a tendency that there is more projection from questions compared to modals and negation, a difference that may not be robust for *announce* ($\texttt{C} > \texttt{Q} >_? \texttt{M, N}$). *prove, confirm,* and *establish* are more projective under modals and conditionals than under questions and negation ($\texttt{M, C} > \texttt{Q, N}$). Finally, *inform* and *know* are most projective under questions, and least projective under modals ($\texttt{Q} > \texttt{N, Q} > \texttt{M}$).

The picture that emerges is complex and requires a nuanced view of lexical effects on projection. I raises the question of how lexical differences between verbs could explain why certain verbs project more from under certain operators and less from others. While much previous work on

this question has based their generalizations on impressionistic judgments, empirically establishing different projection-profiles associated with verbs therefore provides a basis for future research on lexical effects on projection.

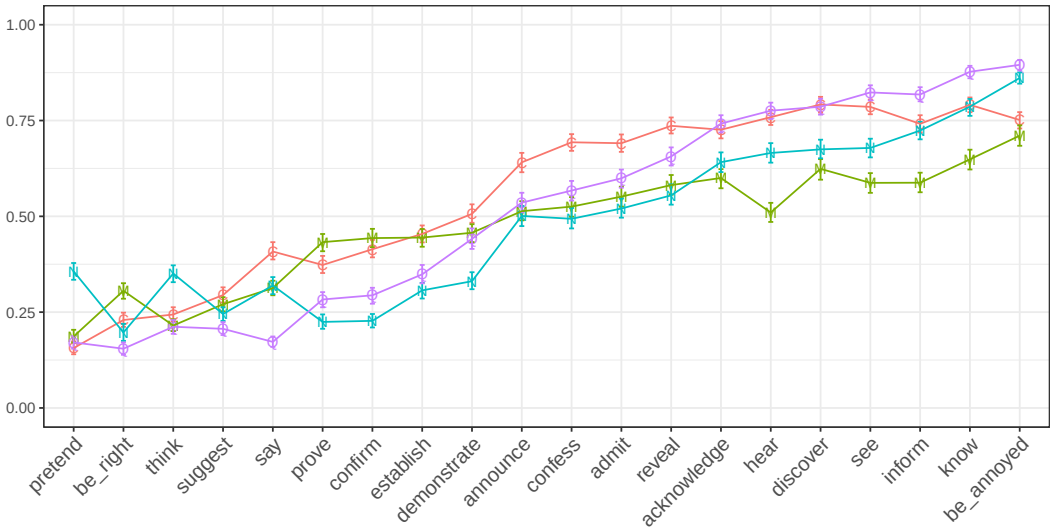

Figure 1: Mean certainty ratings by predicate and operator with 95% bootstrapped confidence intervals. Embedding operator coded by letter and color: `N` (blue): negation, `M` (green): modals, `C` (red): conditional antecedents, `Q` (purple): polar questions.

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`; Bates et al., 2015; Kuznetsova and Christensen, 2016; Team, 2014.

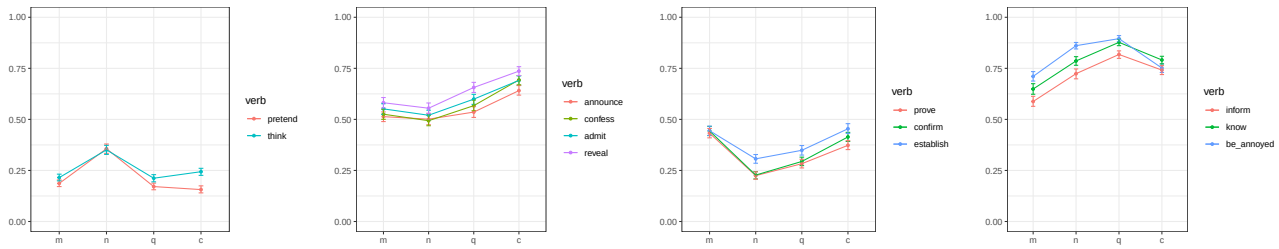

Figure 2: Mean certainty-ratings by operator for each verb, showing different 'verb-profiles'.

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