Projection variability of attitude complements across different operators

We present experimental data that the projection of the content of attitude complements **(i)** varies between entailment-canceling operators, and **(ii)** that this by-operator variation differs between attitude predicates. 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, which cannot be fully determined by lexical classes, instead revealing a more nuanced picture of lexical semantic and pragmatic properties. This raises important questions for future research on projection.

Projection across entailment-cancelling operators. Language users may infer that a speaker who utters an attitude ascription, as in (1), is committed to the content of the complement (CC, here: *Julian dances salsa,*) even when it occurs under an entailment-canceling operator, like negation (1a), polar questions (1b), modals (1c), or conditionals (1d), in which case we say that it *projects*.

(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.'*

Current research rarely examines projection variability across these operators, with conflicting findings. Karttunen (1971) proposed a distinction between English factive predicates (e.g., *be annoyed, regret*), where the CC projects across all four operators, and semi-factives (e.g., *discover, realize, see, notice*) where it always projects across negation, but not always for the other operators. Comparing different types of contents, Smith and Hall (2014) found that the projective content of epithets and the CC of *know* was more projective under negation than conditionals, whereas that of non-restrictive relative clauses and *win* showed the opposite pattern. Sieker and Solstad's (2022) study on German attitude predicates replicated Smith and Hall's (2014) result for German *wissen* ('know'), but as part of an overall pattern of higher projectivity across negation than other operators. They found no interaction with predicate type, or evidence for the (semi-)factive distinction.

These studies yield divergent results regarding whether they find interactions between operators and various projective contents, therefore raising the question if this is due to cross-linguistic variation, task differences, or different contents being tested. To address this, we conducted a series of experiments designed to assess projection across the four entailment-canceling operators in (1). We used the same projection measure as Sieker and Solstad (2022) (the 'certain that' diagnostic; see e.g., Tonhauser et al., 2018; Djärv and Bacovcin, 2017; Mahler, 2020) and applied it to the CC of 20 English clause-embedding predicates, including purported factive (*be annoyed, know, reveal*) and semi-factive predicates (*discover, see*), and 15 non-factive predicates, given recent findings that their complements are also projective, albeit to varying degrees (Degen and Tonhauser 2022).

Method. Projection of the CC of the 20 attitude predicates was measured in four sets of experiments: The predicates were embedded in polar questions in Exps. 1, under negation (Exps. 2), under *perhaps* (Exps. 3), and in conditional antecedents (Exps. 4). (Each set contained three experiments using different at-issueness measure in a separate block. Here, we focus on the projection ratings.) In each experiment, participants read utterances like those in (1) and judged 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 saw all 20 attitude predicates (each paired with a unique content from a set of 20 contents) under one operator. We analyze data from 2,682 self-reported native speakers of American English recruited on Prolific or Amazon's MT platform.

Results and Analysis. Our first key finding is that there is projection variability by operator: Across predicates, projection ratings were higher under question-embeddings than under negation and modals, but lower than in conditional antecedents. These differences, though small, are sig-

nificant and supported by linear mixed effects model **# 1** in **Table 1**. Second, there is by-predicate variation in the effect of operator on projection. This is illustrated in **Figure 1**, which shows mean projection ratings for the 20 attitude predicates by operator; predicates are ordered by their mean rating across all operators (*be annoyed* has the highest overall mean). 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. This finding is further supported by models **# 2–4** in **Table 1** each having at least 34 significant interaction terms (out of 57 possible interactions of `operator` and `predicate`). Contrary to what would be expected based on Karttunen's (1971) distinction between factive and semi-factive predicates, the CC of (factive) *be annoyed* does not project invariably from all four operators, and the CC *discover,* which is considered semi-factive, does not project more from under negation than the other three operators. The pattern we observed for *know* does not fit into either category. Our findings, that by-operator projection variability differs by content, are in line with Smith and Hall (2014), but contrary to their findings that the CC of *know* projects more from negation than conditionals, we found no significant difference here (Model **# 4** in **Table 1**).

LH: Alternatively, we might only talk about the missed predictions for the semi-factives here?

Instead, we found that it projects less from under negation than questions, but more from under negation than modals, while the difference between negation and conditionals is not significant here.

Like in Sieker and Solstad's (2022) study of German attitude predicates, we find a presence of a main effect of by-operator projection variation, but the particular effect we find is different: While Sieker and Solstad found highest projection ratings with negation compared to the other operators, we find overall highest projectivity across conditionals, then questions, then modals and negation. With many interaction effects of `operator` and `predicate` throughout, our results also differ from , who did not find such interactions for the German attitudes they investigated. Since our study used the same projection diagnostic, and a similar set of contents as Sieker and Solstad (2022), the different results indicate potential cross-linguistic variation in projection variability. This suggests extending the questions addressed in cross-linguistic investigations of projective variability (Tonhauser 2020; Xue and Onea 2011; Tonhauser et al. 2018) to interactions with various entailment-cancelling operators.

Discussion. Our results—that projection is modulated by entailment-canceling operators and that there is by-predicate variation in the effect of operator on projection—are not captured by contemporary projection analyses, for several reasons. The first reason is that contemporary analyses do not lead us to expect interactions with different types of entailment-cancelling operators. In Heim 1983, for instance, the CC of (semi-)factive predicates projects to the global context, except when that would produce an inconsistency, in which case the CC is accommodated to the local context of the operator. While it is conceivable for the meaning of the operator to systematically interact with the possibility of local accommodation, no such interaction has been spelled out. The second reason is that many contemporary analyses do not make predictions for the projection of the CC of many of the 20 predicates, as they are limited to (semi-)factive predicates (e.g., Heim 1983; van der Sandt 1992, whose CCs are analyzed as presuppositions) and or entailed CCs that project unless at-issue with respect to the Question Under Discussion (e.g., Abrusán 2011; Simons et al. 2017). A possible exception is the analysis of Schlenker 2021, which predicts the potential

for projection for CCs that are contextually entailed. In the full talk, we discuss how this analysis might be able to capture the gradient projection observed in our experiment. The third reason is that contemporary projection analyses do not make sufficiently fine-grained distinctions between different clause-embedding predicates (but only between whether the CC is a presupposition or entailed). Consequently, they do not make predictions about the by-predicate variation in the effect of operator on projection.

Our results further question the proposed difference between factive and semi-factive predicates (see also Beaver, 2010). Future research appealing to these categories must clarify their definition. Additionally, claims about projection variability must be relativized to the entailment-canceling operator. Finally, our results provide further support (from negation, modals, and conditionals) for the result of Degen and Tonhauser (2022), that projection does not categorically differentiate 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. In spite of a lack of categorical distinctions about the projection behavior of our verbs, we can find some interesting initial generalizations over lexical properties, indicated in **Figure 2**.

(Selected) References: Beaver (2010). Have you noticed that your belly button lint colour is related to the colour of your clothing? *Presuppositions and Discourse: Essays offered to Hans Kamp.* • **Degen & Tonhauser (2022).** Are there factive predicates? An empirical investigation. *Language.* • **Djärv & Bacovcin (2017).** Prosodic effects on factive presupposition projection. *Semantics and Linguistic Theory.* • **Djärv, Zehr & Schwarz (2018).** Cognitive vs. emotive factives: An experimental differentiation. *Proceedings of Sinn und Bedeutung.* • **Karttunen (1971).** Some observations on factivity. *Research on Language & Social Interaction.* • **Mahler (2020).** The social component of projection behavior of clausal complements. *Linguistic Society of America.* • **Smith and Hall (2014).** The relationship between projection and embedding environment. *Proceedings of the 48th Meeting of the Chicago Linguistics Society.* • **Tonhauser, Beaver, & Degen (2018).** How projective is projective content? Gradience in projectivity and at-issueness. *Journal of Semantics.* •

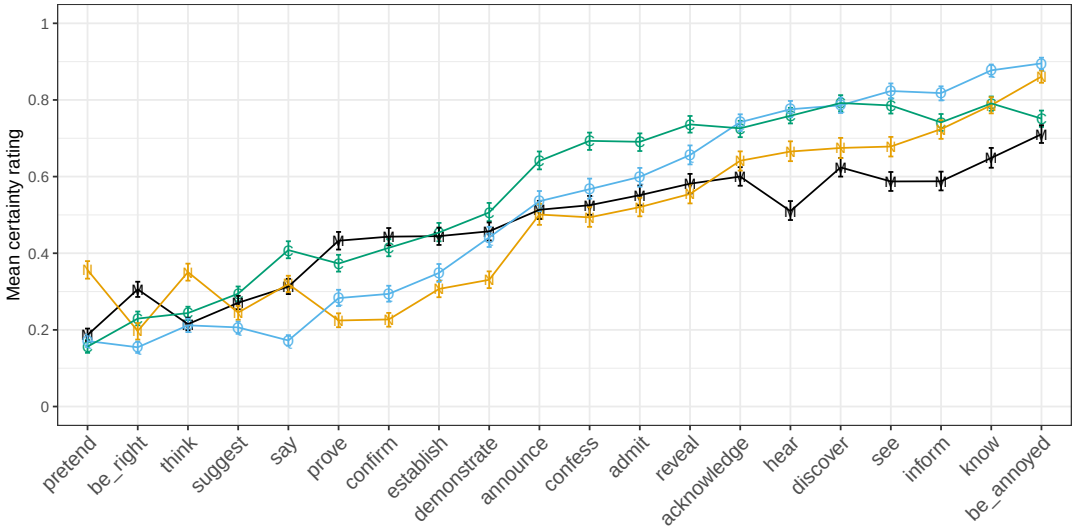

Figure 1: Mean certainty ratings by predicate and operator with 95% bootstrapped confidence intervals. Embedding operator coded by letter and color: `N` (orange): negation, `M` (black): modals, `C` (green): conditional antecedents, `Q` (blue): polar questions.

Model		Estimate	Std. Error	t-value	
#1	Intercept: *question*	0.52	0.01	87.31	***
	operator: conditional	0.04	0.01	5.07	***
	operator: modal	-0.04	0.01	-4.55	***
	operator: negation	-0.03	0.01	-4.30	***
#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 1: Excerpt of the output from three linear mixed effects models; **#1** has fixed effects of operator; random effect: participant intercepts, **#2-4** have fixed effect: operator, predicate, and their interaction; random effect: participant intercepts. Models were fit with `lme4`, `lmertest` in `R`. All three models also had at least 34 highly significant interaction terms of `operator` and `predicate` with $p < 0.001$ (Not shown here).

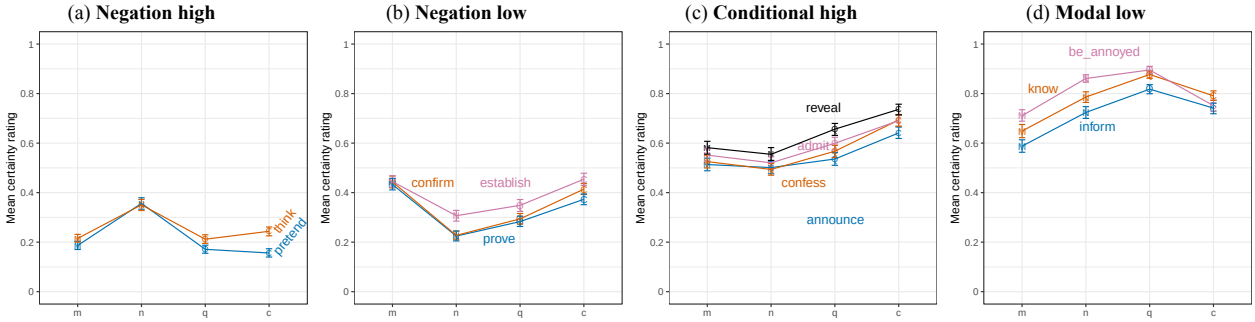

Figure 2: Mean certainty ratings by operator (`M`: Modal, `N`: Negation, `Q`: Polar Question, `C`: Conditional antecedent) with 95% bootstrapped confidence intervals, for some groups of predicates ('predicate patterns').

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