

# Projection variability of attitude complements across different operators

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We present experimental evidence 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 and raise 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. This result was replicated for German *wissen* ‘know’ in Sieker and Solstad’s (2022) study on German attitude predicates, but as part of an overall pattern of higher projection ratings with negation than other operators. They found no interaction with predicate type, or evidence for the distinction of factives vs. semi-factives.

These studies raise the question if the divergent results are 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 factive (*be annoyed*, *know*, *reveal*) and semi-factive predicates (*discover*, *see*), and 15 non-factive predicates, given recent findings that their complements may also project, 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 ‘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 analysis reveals two key results: (i) There is projection variability by operator. Mean projection ratings were higher under question-embeddings (Maximum likelihood estimate: 0.51) than under negation (MLE: 0.48) and modals (0.47), but lower than in conditional antecedents (0.56, see model #1 in Table 1). This result differs from that of Sieker and Solstad (2022), who observed that the CC of German attitude predicates projects more from under negation

than the other operators. (ii) 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, the CC of *be annoyed* projects more from under negation and questions than conditionals and modals, and the CC of *discover* projects less from negation than conditionals and questions, and more from under negation than modals. 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 1, which also each have at least 34 highly significant interaction terms (out of 57 possible interactions of operator and predicate). This result that by-operator projection variability interacts with predicate concurs with Smith and Hall (2014), while we did not reproduce their result that the CC of *know* projects more from negation than conditionals. This differs from the result of Sieker and Solstad (2022), who found no interaction between predicates and operators. Given that the methods and the set of projective contents of our experiment were very similar to theirs, this difference may suggest cross-linguistic variation in projection variability (cf. Tonhauser 2020). On the other hand, in line with Sieker and Solstad (2022), our results are 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 of *discover*, which is considered semi-factive, does not project more from under negation than the other three operators. The pattern observed for *know* does not fit into either category.

**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 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, whose CCs are analyzed as presuppositions (e.g., Heim 1983; van der Sandt 1992), 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 a full talk, we would like to discuss how this analysis might be extended 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 Karttunen’s (1971) 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: Abrusán (2011). Predicting the presuppositions of soft triggers. *Linguistics and philosophy*. • Degen & Tonhauser (2022). Are there factive predicates? An empirical investigation. *Language*. • Djärv & Bacovcin (2017). Prosodic effects on factive presupposition projection. *Semantics and Linguistic Theory*. • Heim (1983). On the Projection Problem for Presuppositions. *Proceedings of the Second West Coast Conference on Formal Linguistics*. • Karttunen (1971). Some observations on factivity. *Research on Language & Social Interaction*. • Schlenker (2021). Triggering presuppositions. *Glossa: A Journal of General Linguistics*. • Sieker & Solstad (2022). Projective variability of (semi) factive verbs in family of sentence contexts: A rating study. *Proceedings of the 23rd Amsterdam Colloquium*. • Smith and Hall (2014). The relationship between projection and embedding environment. *Proceedings of the 48th Meeting of the Chicago Linguistics Society*. • Tonhauser (2020). Projection variability in Paraguayan Guaraní. *Natural Language & Linguistic Theory*. • Tonhauser, Beaver, & Degen (2018). How projective is projective content? Gradience in projectivity and at-issueness. *Journal of Semantics*.

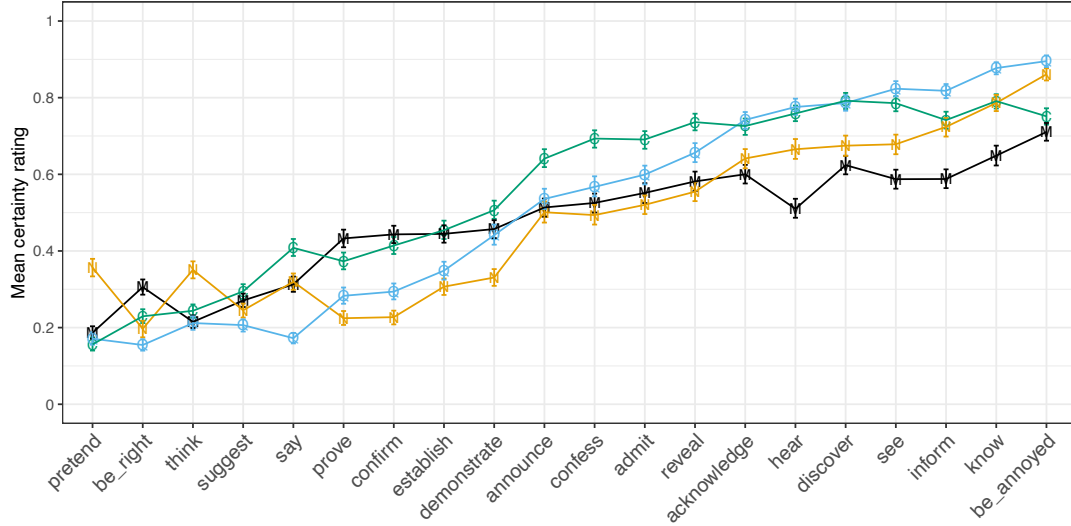


Figure 1: Mean certainty ratings by predicate and operator with 95% bootstrapped confidence intervals. Embedding operator coded by letter and color: N (orange): negation, M (black): modals, C (green): conditional antecedents, Q (blue): polar questions.

Model		Estimate	Std. Error	t-value	
#1	Intercept: <i>question</i>	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	***
#2	Intercept: <i>be annoyed/negation</i>	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: <i>discover/negation</i>	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: <i>know/negation</i>	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 effects: participant and item intercepts, #2-4 have fixed effect: 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).

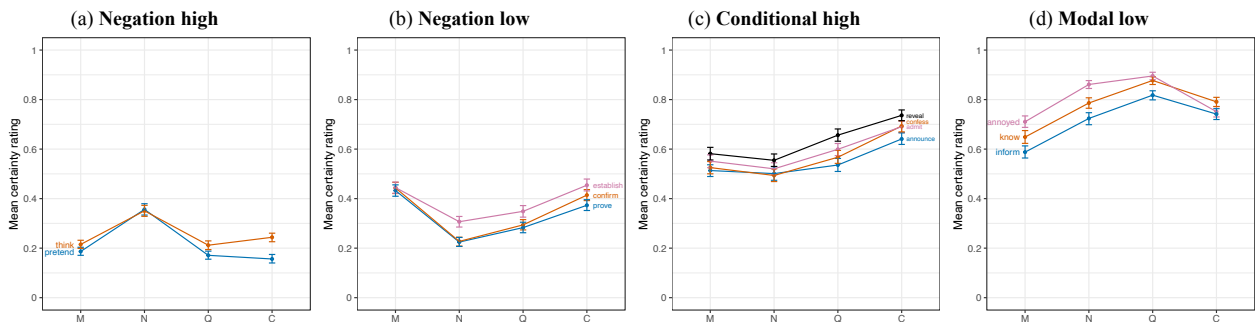


Figure 2: Mean certainty ratings by operator (M: Modal, N: Negation, Q: Polar Question, C: Conditional antecedent) with 95% bootstrapped confidence intervals, for some groups of predicates ('predicate patterns').