

Projection variability of complement clauses across different operators

Short summary: We examine how the content of embedded complement clauses projects across different entailment-canceling operators for various clause-embedding predicates. We measured projection for 20 predicates across four operators: polar questions, negation, modals, and conditionals. Results reveal projection variation by operator and by-predicate variation in the effect of operator on projection. Existing theoretical accounts of projection (e.g., Heim 1983; van der Sandt 1992; Abrusán 2011; Schlenker 2021) do not capture the observed variability. Our findings highlight the importance of considering interactions between predicates and operators and generate important questions for future research on projection.

Projection across entailment-cancelling operators. Interpreters may infer that a speaker uttering a sentence with an embedded complement clause (1) is committed to the content of the complement (CC, here: *Julian dances salsa*,) even when embedded under an entailment-canceling operator (1a-d). Then we say the CC *projects*.

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| (1) | a. Polar Question: | <i>Did Cole discover that Julian dances salsa?</i> |
| | b. Negation: | <i>Cole didn't discover that Julian dances salsa.</i> |
| | c. Modal: | <i>Perhaps Cole discovered that Julian dances salsa.</i> |
| | d. Conditional: | <i>If Cole discovered that Julian dances salsa, Logan will be joyful.</i> |

Previous research has investigated differences in projection across these operators only rarely, and with conflicting findings. For English clause-embedding predicates, Karttunen (1971) proposed distinguishing factives (e.g., *be annoyed*, *regret*), where the CC projects across all four operators, and semi-factives (e.g., *discover*, *realize*, *see*, *notice*) where it projects across negation, but not always across the other operators. For German clause-embedding predicates, Sieker and Solstad (2022) found an overall pattern of more projection across negation than the other four operators, but no operator/predicate interactions. In contrast, Smith and Hall (2014) found different patterns for different English projective contents: That of epithets and the CC of *know* were more projective under negation than conditionals, whereas that of non-restrictive relative clauses and *win* showed the opposite pattern.

These diverging findings about whether there are operator/predicate interaction effects raise the question whether differences result from cross-linguistic variation, task differences, or different types of contents being tested. To address this, we conducted a series of experiments designed to assess projection across the four 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 factives (*be annoyed*, *know*, *reveal*) semi-factives (*discover*, *see*), and 15 non-factive predicates, given recent findings that their complements also project to varying degrees (Degen and Tonhauser 2022).

Method. Projection of the CC of 20 clause-embedding predicates was measured in four sets of experiments: Predicates were embedded in polar questions in Exps. 1, under negation (Exps. 2), under the modal '*perhaps*' (Exps. 3), and in conditional antecedents (Exps. 4). (Each set contained three experiments using different at-issueness measures in a separate block. Here, we focus on the projection-ratings.) Participants read utterances like in (1) and rated whether the speaker (who was named) was certain of the CC (e.g.: '*Is [the speaker] certain that Julian dances salsa?*'), on a slider marked '*no*' (coded as 0) at one end and '*yes*' (coded as 1) at another. Each participant saw all 20 clause-embedding predicates (each paired with a unique content) under one operator. We analyze data from 2,682 self-reported native speakers of American English.

Results and Analysis. Our analysis reveals two key results: (i) Projection varies by operator, with higher mean certainty-ratings for question-operators (Maximum likelihood estimate: 0.51) than negation (MLE: 0.48) and modals (0.47), but lower than for conditionals (0.56, see model #1 in Table 1). This differs from Sieker and Solstad's (2022) observation that the CC of German clause-embedding predicates projects more across negation than the other operators, suggesting potential cross-linguistic differences in projection of CCs across entailment-canceling operators.

(ii) There is by-predicate variation in the effect of operator on projection, illustrated in Figure 1, which shows mean projection-ratings for the 20 clause-embedding predicates by operator, with predicates ordered by their mean

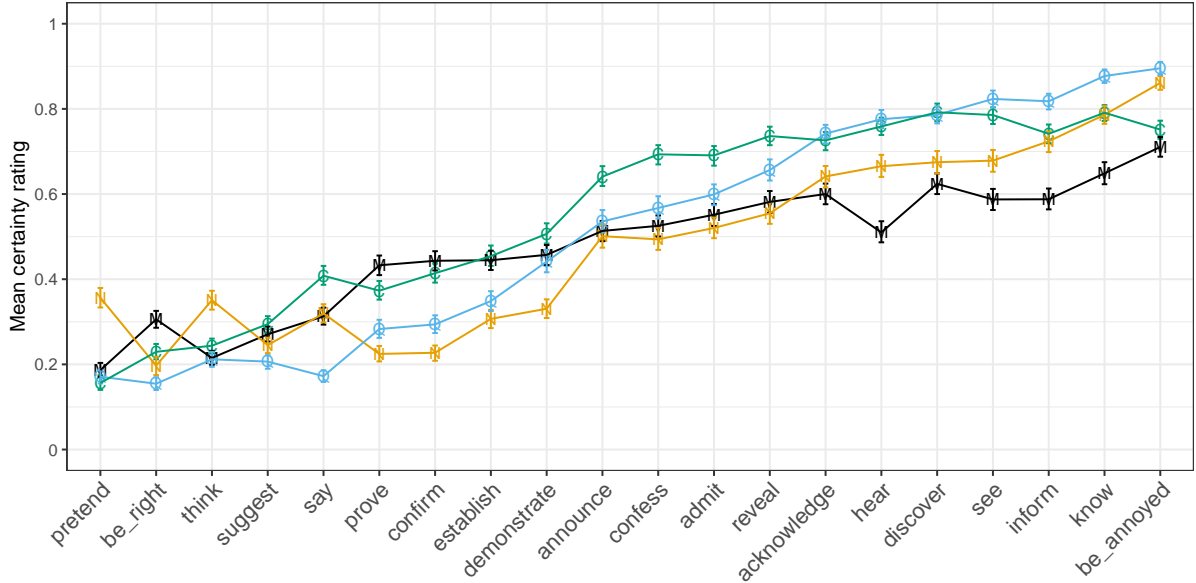


Figure 1: Mean certainty ratings by predicate and operator with 95% bootstrapped confidence intervals. Entailment-cancelling operator coded by letter and color: N: negation, M: modals, C: conditional antecedents, Q: polar questions.

rating across operators (*be annoyed* has the highest overall mean). For instance, the CC of *be annoyed* projects more across negation and questions than conditionals and modals, and the CC of *discover* projects less across negation than conditionals and questions, but more across negation than modals. The CC of *know* projects less across negation than questions, but more across 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).

Our finding of operator/predicate-interactions concurs with Smith and Hall (2011), but we did not replicate their result that the CC of *know* projects more from negation than conditionals. Our results also differ from Sieker and Solstad (2022), who found no interaction between predicates and operators. Given that our task and materials were very similar to theirs, this may suggest cross-linguistic variation in projection variability (cf. Tonhauser 2020). Additionally, our results contradict Karttunen’s (1971) distinction between factive and semi-factive predicates: The CC of (factive) *be annoyed* does not project invariably across four operators, and the CC of *discover*, 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 various entailment-canceling operators affect projection differently and there is by-predicate variation in the effect of operator on projection—are not captured by contemporary projection analyses, for several reasons. First, current theories do not predict variation along 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 be inconsistent, and the CC is accommodated locally. While it is conceivable that operator meanings systematically affect the possibility of local accommodation, this has not been spelled out. Second, many analyses only focus on (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). This limits their predictive power for other predicates. Schlenker (2021) may be an exception, predicting the potential of projection for contextually entailed CCs. In the full paper, we discuss how Schlenker’s analysis may be extended to capture the observed gradient patterns. Finally, no analysis makes sufficiently fine-grained distinctions between clause-embedding predicates (only distinguishing whether the CC is presupposed/entailed or not), precluding predictions about the by-predicate variation in operator effects.

Our results further question the effect of categorical lexical distinctions on projection: They challenge Karttunen’s (1971) factive/semi-factive distinction (see also Beaver 2010; Sieker and Solstad 2022), and provide support (from

negation, modals, and conditionals) for Degen and Tonhauser's (2022) result, 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 those of some (semi-)factive predicates. In the full version, we discuss how more fine-grained lexical distinctions may affect projection: For example, the CCs of (often used anti-veridically) '*think*' and '*pretend*' project more across negation than other operators. The CCs of '*reveal*, *confess*, *admit*' and '*announce*' (communicative achievement predicates) project most from conditionals.

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: 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 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. Significance code '***' indicates that $p < 0.001$. Models **#2-4** also had at least 34 highly significant interaction terms of operator and predicate with $p < 0.001$ (not shown here).

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