

We present experimental evidence **(i)** that the projection of the content of attitude complements varies across four entailment-canceling operators (negation, question, modal, antecedent of conditional) and **(ii)** that 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). Instead, the observed by-operator variation groups predicates by lexical semantic/pragmatic properties that raise important questions for future research on projection.

(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.'

There has been, to date, one investigation of by-operator variation: Smith and Hall (2014), who investigated by-operator projection variation for negation and conditional embeddings, observed that there is by-operator variation for some contents (e.g., that of know, but not that of clefts) and that this by-operator variation differs across contents: The content of NRRCs and win was more projective under conditionals than negation, the opposite pattern was observed for know and epithets. However, the response task they used asked participants to rate how surprised they would be to learn the content under investigation after observing the utterance. Since factors other than speaker commitment modulate surprisal, it is not clear that they (only) measured projection.

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).

1

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 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 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 Fig.2: We tentatively hypothesize that negation (but not the other operators) interacts with the semantic or pragmatic antiveridicality contributed by these predicates. 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 panel (b), may suggest that the discourse effect of a conditional interacts with the change-of-state communication predicates. The inferential predicates prove, confirm, and establish exhibit a ‘**Negation low**’ pattern, shown in panel (c): Here, we tentatively hypothesize that the veridical meaning component interacts with negation (but not operators), to result in lower projection ratings under negation. Fi-

nally, the predicates inform, know, and be annoyed exhibit a ‘**Modal low**’ pattern, shown in panel (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.

In spite of a lack of categorical distinctions about the projection behavior of our verbs, we can find some interesting patterns. Fig.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 ($N > M, Q, C$). announce, 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 ($C > Q > M, N$). prove, confirm, and establish are more projective under modals and conditionals than under questions and negation ($M, C > Q, N$). Finally, inform and know are most projective under questions, and least projective under modals ($Q > N, Q > M$).

The picture that emerges is complex and requires a nuanced view of lexical effects on projection. It 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.

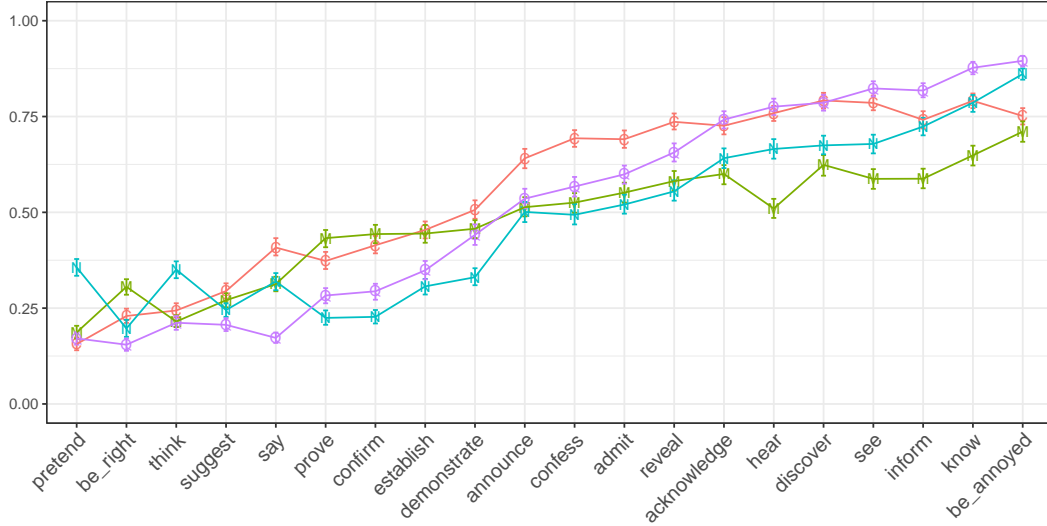


Figure1: Mean certainty ratings by predicate and operator with 95% bootstrapped confidence intervals. Embedding operator coded by letter and color: N (blue): negation, M (green): modals, C (red): conditional antecedents, Q (purple): polar questions.

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	***

Table1: 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.

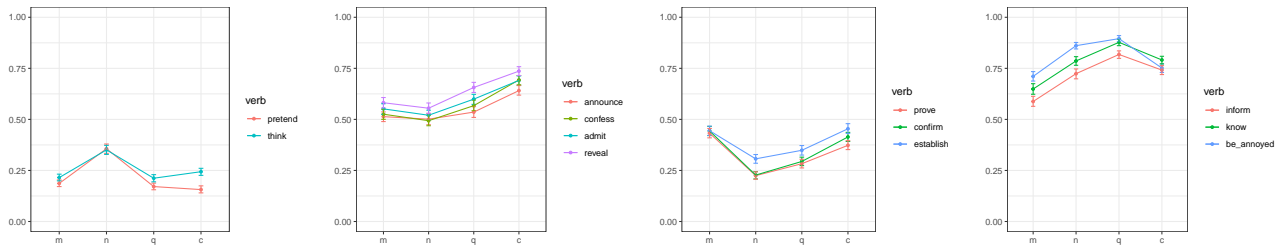


Figure2: Mean certainty-ratings by operator for four predicate patterns in our data.

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