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), that Julian dances salsa, even though the complement 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; **?**).

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 plots 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 questions and negation than from under conditionals and modals, the CC of *know* projects more from under questions than from under conditionals and negation, and the CC of *discover* projects more from under questions and conditionals than from under negation and modals. These results 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.

==== THIS IS AS FAR AS I've COME ====

The data was analyzed using a mixed effects linear regression (using `lme4, lmertest` in `R`; Bates et al., 2015; Kuznetsova and Christensen, 2016; Team, 2014), with `be_annoyed` and `negation` as reference levels, and random intercepts for participants and items. We found highly significant main effects of `operator`: For our baseline `be_annoyed`, both `conditional` and `modal` are clearly less projective than negation, thereby supporting the claim that the embedding context does matter. We also found many interactions of `operator` and `verb` across the board, suggesting that the effect of embedding context diffes by verb. Notably, *'discover'* is more projective in polar questions and conditional antecedents than under negation, patterning opposite to Karttunen's claims about semi-factives. For the emotive predicate *'be annoyed'* no significant effect is found for `question` (vs `negation`), as would be expected based on Karttunen, but we do find unexpected differences between `negation` > `conditional, modal`. *know* shows effects that would be incompatible with a characterization as either factive or semi-factive: `question` > `conditional, negation` > `modal`. If *'know'* is a factive predicate, no difference would be expected. If it is semi-factive, we would, again, expect higher projectivity under negation than in questions and conditionals.

Discussion.

We observe that projection varies by predicate (e.g., the CC of *be annoyed* is more projective than that of *discover*; replicating the results of Degen and Tonhauser, 2022).

No categorical distinction between factive and non-factive predicates either

add discussion about verb classes here

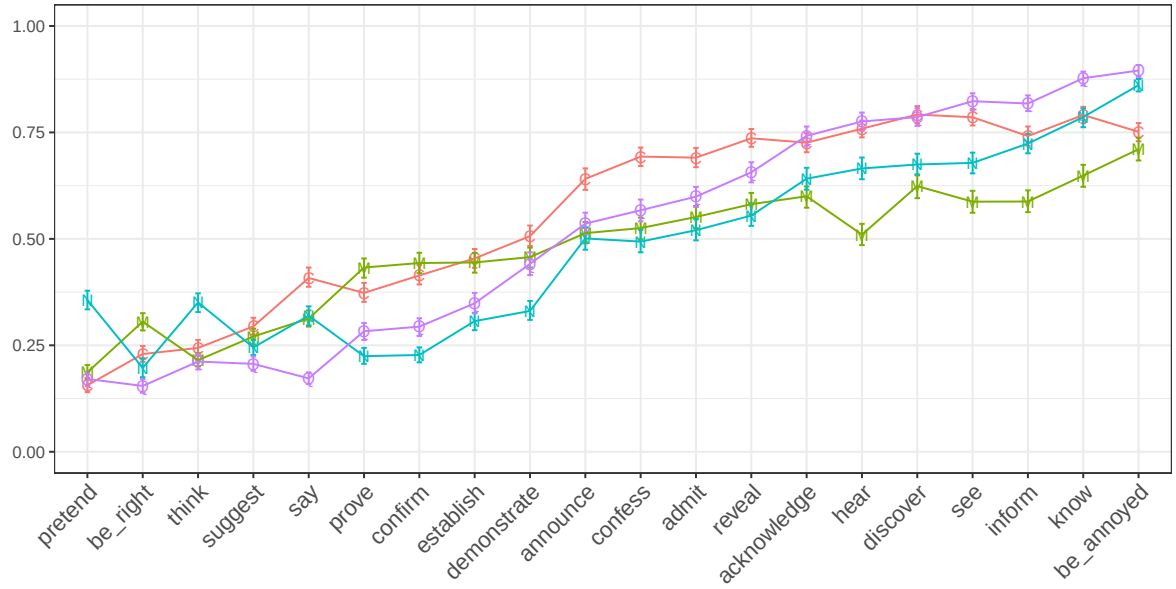

Figure 1: Mean certainty ratings by predicate and operator with 95% bootstrapped confidence intervals. Embedding operator coded by letter and color: `N` (blue): negation, `M` (green): modals, `C` (red): conditional antecedents, `Q` (purple): polar questions.

References

Douglas Bates, Martin Mächler, Ben Bolker, and Steve Walker. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1):1–48, 2015. doi: 10.18637/jss.v067.i01.

David Beaver. Have you noticed that your belly button lint colour is related to the colour of your clothing? In Rainer Bäuerle, Uwe Reyle, and Thomas Zimmermann, editors, *Presuppositions and Discourse: Essays offered to Hans Kamp*, pages 65–99. Oxford: Elsevier, 2010. doi: 10.1163/9789004253162.

Judith Degen and Judith Tonhauser. Are there factive predicates? An empirical investigation. *Language*, 98(3):552–591, 2022.

Kajsa Djärv and Hezekiah Akiva Bacovcin. Prosodic effects on factive presupposition projection. *Semantics and Linguistic Theory*, 27:116–133, 2017. doi: 10.3765/salt.v27i0.4134. Publisher: Ithaca, NY: CLC Publications.

Kajsa Djärv, Jérémy Zehr, and Florian Schwarz. Cognitive vs. emotive factives: An experimental differentiation. In *Proceedings of Sinn und Bedeutung*, volume 21, pages 367–386, 2018. Issue: 1.

Joan B. Hooper and Sandra A. Thompson. On the applicability of root transformations. *Linguistic inquiry*, 4(4):465–497, 1973. Publisher: JSTOR.

Lauri Karttunen. Some observations on factivity. *Research on Language & Social Interaction*, 4 (1):55–69, 1971. Publisher: Taylor & Francis.

Per Bruun Brockhoff Kuznetsova, Alexandra and Rune Haubo Bojesen Christensen. lmertest package (version 2.0.33), 2016.

E. Allyn Smith and Kathleen Currie Hall. The relationship between projection and embedding environment. In *Proceedings of the 48th Meeting of the Chicago Linguistics Society*. Citeseer, 2014.

R Core Team. R: A Language and Environment for Statistical Computing, 2014. URL `https://www.r-project.org/`.

Judith Tonhauser, David I. Beaver, and Judith Degen. How projective is projective content? Gradience in projectivity and at-issueness. *Journal of Semantics*, 35(3):495–542, 2018. Publisher: Oxford University Press.

Table 1: Model output w `be_annoyed/n` as baseline

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.8669958	0.0114402	1479.204	75.7850523	0.0000000
opc	-0.1155850	0.0156641	26227.368	-7.3789836	0.0000000
opm	-0.1564480	0.0155858	26288.139	-10.0378702	0.0000000
opq	0.0249138	0.0143090	56826.915	1.7411232	0.0816674
verbsuggest	-0.6162683	0.0134941	54372.895	-45.6694112	0.0000000
verbacknowledge	-0.2204417	0.0134948	54373.777	-16.3352724	0.0000000
verbadmit	-0.3402430	0.0134933	54371.874	-25.2156750	0.0000000
verbannounce	-0.3607504	0.0134931	54371.547	-26.7359958	0.0000000
verbbe_right	-0.6638924	0.0134936	54372.293	-49.2003974	0.0000000
verbconfess	-0.3681695	0.0134949	54373.904	-27.2820517	0.0000000
verbconfirm	-0.6338363	0.0134931	54371.657	-46.9746939	0.0000000
verbdemonstrate	-0.5307026	0.0134935	54372.157	-39.3301466	0.0000000
verbdiscover	-0.1864716	0.0134942	54372.992	-13.8186520	0.0000000
verbestablish	-0.5542561	0.0134933	54371.853	-41.0764079	0.0000000
verbhear	-0.1956794	0.0134938	54372.473	-14.5014554	0.0000000
verbinform	-0.1374428	0.0134945	54373.345	-10.1851106	0.0000000
verbknow	-0.0748953	0.0134936	54372.288	-5.5504197	0.0000000
verbpretend	-0.5049533	0.0134944	54373.218	-37.4195409	0.0000000
verbprove	-0.6364950	0.0134935	54372.138	-47.1704273	0.0000000
verbreveal	-0.3057814	0.0134937	54372.418	-22.6609884	0.0000000
verbsay	-0.5419725	0.0134925	54370.770	-40.1685159	0.0000000
verbsee	-0.1827512	0.0134932	54371.791	-13.5438968	0.0000000
verbthink	-0.5101198	0.0134930	54371.491	-37.8062103	0.0000000
opc:verbsuggest	0.1594325	0.0190634	54372.626	8.3632939	0.0000000
opm:verbsuggest	0.1766113	0.0189718	54372.046	9.3091498	0.0000000
opq:verbsuggest	-0.0737648	0.0192906	54372.717	-3.8238781	0.0001315
opc:verbacknowledge	0.1945569	0.0190630	54372.333	10.2059764	0.0000000
opm:verbacknowledge	0.1100553	0.0189729	54373.070	5.8006461	0.0000000
opq:verbacknowledge	0.0672935	0.0192909	54372.991	3.4883599	0.0004864
opc:verbadmit	0.2803349	0.0190626	54371.933	14.7060204	0.0000000
opm:verbadmit	0.1810708	0.0189717	54371.994	9.5442376	0.0000000
opq:verbadmit	0.0440050	0.0192896	54371.832	2.2812856	0.0225354
opc:verbannounce	0.2503929	0.0190639	54373.132	13.1343759	0.0000000
opm:verbannounce	0.1633026	0.0189721	54372.338	8.6075049	0.0000000
opq:verbannounce	0.0017532	0.0192899	54372.121	0.0908892	0.9275810
opc:verbbe_right	0.1424317	0.0190623	54371.698	7.4718895	0.0000000
opm:verbbe_right	0.2582399	0.0189717	54371.967	13.6118412	0.0000000
opq:verbbe_right	-0.0776846	0.0192897	54371.974	-4.0272512	0.0000565
opc:verbconfess	0.3111230	0.0190643	54373.455	16.3196605	0.0000000
opm:verbconfess	0.1837114	0.0189741	54374.125	9.6821973	0.0000000
opq:verbconfess	0.0393640	0.0192890	54371.320	2.0407459	0.0412809
opc:verbconfirm	0.2963833	0.0190629	54372.237	15.5476205	0.0000000
opm:verbconfirm	0.3663333	0.0189721	54372.324	19.3090505	0.0000000
opq:verbconfirm	0.0312870	0.0192902	54372.377	1.6219108	0.1048282
opc:verbdemonstrate	0.2854366	0.0190647	54373.829	14.9719656	0.0000000
opm:verbdemonstrate	0.2783816	0.0189716	54371.830	14.6736292	0.0000000

Table 2: Model output w `discover/n` as baseline

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.6805242	0.0114403	1479.217	59.4849565	0.0000000
opc	0.1114249	0.0156639	26226.686	7.1134644	0.0000000
opm	-0.0562056	0.0155855	26286.826	-3.6062779	0.0003112
opq	0.1011420	0.0143103	56828.295	7.0677830	0.0000000
verbbe_annoyed	0.1864716	0.0134942	54372.998	13.8186521	0.0000000
verbsuggest	-0.4297967	0.0134937	54372.361	-31.8516905	0.0000000
verbacknowledge	-0.0339702	0.0134936	54372.308	-2.5174950	0.0118221
verbadmit	-0.1537714	0.0134942	54372.985	-11.3953857	0.0000000
verbannounce	-0.1742788	0.0134947	54373.649	-12.9145926	0.0000000
verbbe_right	-0.4774208	0.0134935	54372.079	-35.3816304	0.0000000
verbconfess	-0.1816980	0.0134936	54372.192	-13.4655376	0.0000000
verbconfirm	-0.4473648	0.0134944	54373.311	-33.1517710	0.0000000
verbdemonstrate	-0.3442310	0.0134928	54371.247	-25.5121517	0.0000000
verbestablish	-0.3677846	0.0134928	54371.167	-27.2579106	0.0000000
verbhear	-0.0092079	0.0134940	54372.798	-0.6823676	0.4950095
verbinform	0.0490288	0.0134942	54373.066	3.6333114	0.0002801
verbknow	0.1115762	0.0134931	54371.668	8.2691029	0.0000000
verbpretend	-0.3184818	0.0134943	54373.176	-23.6011440	0.0000000
verbprove	-0.4500234	0.0134934	54372.042	-33.3512833	0.0000000
verbreveal	-0.1193099	0.0134941	54372.880	-8.8416323	0.0000000
verbsay	-0.3555009	0.0134943	54373.168	-26.3444678	0.0000000
verbsee	0.0037204	0.0134930	54371.450	0.2757288	0.7827574
verbthink	-0.3236483	0.0134936	54372.197	-23.9853913	0.0000000
opc:verbbe_annoyed	-0.2270099	0.0190632	54372.453	-11.9082963	0.0000000
opm:verbbe_annoyed	-0.1002424	0.0189726	54372.798	-5.2835253	0.0000001
opq:verbbe_annoyed	-0.0762282	0.0192898	54372.017	-3.9517423	0.0000777
opc:verbsuggest	-0.0675773	0.0190625	54371.851	-3.5450396	0.0003929
opm:verbsuggest	0.0763690	0.0189709	54371.211	4.0255864	0.0000569
opq:verbsuggest	-0.1499930	0.0192910	54373.069	-7.7752981	0.0000000
opc:verbacknowledge	-0.0324529	0.0190617	54371.116	-1.7025196	0.0886637
opm:verbacknowledge	0.0098129	0.0189711	54371.417	0.5172570	0.6049789
opq:verbacknowledge	-0.0089347	0.0192902	54372.396	-0.4631724	0.6432426
opc:verbadmit	0.0533251	0.0190632	54372.508	2.7972739	0.0051554
opm:verbadmit	0.0808284	0.0189728	54372.916	4.2602367	0.0000205
opq:verbadmit	-0.0322232	0.0192908	54372.883	-1.6703960	0.0948468
opc:verbannounce	0.0233831	0.0190642	54373.367	1.2265427	0.2199998
opm:verbannounce	0.0630602	0.0189726	54372.754	3.3237576	0.0008887
opq:verbannounce	-0.0744750	0.0192926	54374.465	-3.8602856	0.0001134
opc:verbbe_right	-0.0845782	0.0190620	54371.360	-4.4370099	0.0000091
opm:verbbe_right	0.1579976	0.0189719	54372.163	8.3279685	0.0000000
opq:verbbe_right	-0.1539128	0.0192901	54372.283	-7.9788617	0.0000000
opc:verbconfess	0.0841131	0.0190632	54372.437	4.4123417	0.0000102
opm:verbconfess	0.0834691	0.0189719	54372.142	4.3996174	0.0000109
opq:verbconfess	-0.0368642	0.0192905	54372.632	-1.9110088	0.0560087
opc:verbconfirm	0.0693734	0.0190644	54373.529	3.6388992	0.0002741
opm:verbconfirm	0.2660910	0.0189728	54372.917	14.0248948	0.0000000
opq:verbconfirm	0.0449413	0.0192914	54373.472	2.3295974	0.0198311

Table 3: Model output w `know/n` as baseline

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.7921005	0.0114401	1479.182	69.2391632	0.0000000
opc	-0.0013151	0.0156638	26226.099	-0.0839558	0.9330922
opm	-0.1434448	0.0155855	26286.727	-9.2037503	0.0000000
opq	0.0818736	0.0143093	56827.205	5.7217106	0.0000000
verbdiscover	-0.1115762	0.0134931	54371.661	-8.2691029	0.0000000
verbbe_annoyed	0.0748953	0.0134936	54372.286	5.5504198	0.0000000
verbsuggest	-0.5413729	0.0134928	54371.215	-40.1230775	0.0000000
verbacknowledge	-0.1455464	0.0134940	54372.778	-10.7859911	0.0000000
verbadmit	-0.2653476	0.0134936	54372.243	-19.6647018	0.0000000
verbannounce	-0.2858550	0.0134935	54372.051	-21.1847253	0.0000000
verbbe_right	-0.5889971	0.0134936	54372.234	-43.6501264	0.0000000
verbconfess	-0.2932742	0.0134933	54371.896	-21.7347532	0.0000000
verbconfirm	-0.5589410	0.0134943	54373.134	-41.4204989	0.0000000
verbdemonstrate	-0.4558072	0.0134931	54371.605	-33.7807521	0.0000000
verbestablish	-0.4793608	0.0134938	54372.501	-35.5245129	0.0000000
verbhear	-0.1207841	0.0134931	54371.608	-8.9515418	0.0000000
verbinform	-0.0625474	0.0134940	54372.811	-4.6351853	0.0000036
verbpretend	-0.4300580	0.0134939	54372.685	-31.8704317	0.0000000
verbprove	-0.5615997	0.0134934	54372.014	-41.6202578	0.0000000
verbreveal	-0.2308861	0.0134943	54373.179	-17.1098402	0.0000000
verbsay	-0.4670771	0.0134939	54372.578	-34.6140392	0.0000000
verbsee	-0.1078558	0.0134932	54371.715	-7.9933523	0.0000000
verbthink	-0.4352245	0.0134933	54371.896	-32.2547883	0.0000000
opc:verbdiscover	0.1127399	0.0190628	54372.122	5.9141311	0.0000000
opm:verbdiscover	0.0872392	0.0189719	54372.145	4.5983336	0.0000043
opq:verbdiscover	0.0192684	0.0192895	54371.810	0.9989027	0.3178463
opc:verbbe_annoyed	-0.1142699	0.0190629	54372.206	-5.9943630	0.0000000
opm:verbbe_annoyed	-0.0130032	0.0189709	54371.180	-0.6854301	0.4930755
opq:verbbe_annoyed	-0.0569598	0.0192897	54371.974	-2.9528580	0.0031498
opc:verbsuggest	0.0451626	0.0190614	54370.865	2.3693169	0.0178244
opm:verbsuggest	0.1636081	0.0189713	54371.561	8.6239932	0.0000000
opq:verbsuggest	-0.1307246	0.0192896	54371.847	-6.7769511	0.0000000
opc:verbacknowledge	0.0802870	0.0190639	54373.059	4.2114778	0.0000254
opm:verbacknowledge	0.0970521	0.0189731	54373.215	5.1152465	0.0000003
opq:verbacknowledge	0.0103337	0.0192900	54372.183	0.5357031	0.5921659
opc:verbadmit	0.1660650	0.0190633	54372.568	8.7112405	0.0000000
opm:verbadmit	0.1680676	0.0189725	54372.674	8.8584875	0.0000000
opq:verbadmit	-0.0129548	0.0192897	54371.901	-0.6715939	0.5018451
opc:verbannounce	0.1361230	0.0190629	54372.249	7.1407107	0.0000000
opm:verbannounce	0.1502994	0.0189716	54371.859	7.9223393	0.0000000
opq:verbannounce	-0.0552066	0.0192897	54371.911	-2.8619784	0.0042117
opc:verbbe_right	0.0281618	0.0190625	54371.883	1.4773357	0.1395915
opm:verbbe_right	0.2452367	0.0189720	54372.236	12.9262410	0.0000000
opq:verbbe_right	-0.1346444	0.0192901	54372.308	-6.9799743	0.0000000
opc:verbconfess	0.1968531	0.0190627	54372.016	10.3266157	0.0000000
opm:verbconfess	0.1707082	0.0189737	54373.731	8.9971020	0.0000000
opq:verbconfess	0.0175959	0.0192891	54371.441	0.9122160	0.3616590