More free choice and more inclusion
An experimental investigation of free choice in non-monotonic environments

Nicole Gotzner, Jacopo Romoli, and Paolo Santorio

Background: free choice, exclusion and inclusion. Disjunctions in the scope of possibility modals, as in (1), give rise to a conjunctive inference, generally labeled 'free choice'(Kamp 1974).

(1) Iris can eat cake or ice-cream. $\rightsquigarrow$ *Iris can eat cake and she can eat ice-cream*

An influential approach tries to derive free choice inferences as a kind of scalar implicature. Standard algorithms for computing implicatures proceed by negating alternatives to a sentence and adding the information so obtained to the assertion (*exclusion*). Approaches in this vein have been successful at capturing free choice and related phenomena (Fox 2007, Chemla 2010, Klinedinst 2007, Santorio and Romoli 2017, Franke 2011 a.o.). But recent experimental findings have challenged exclusion-based approaches. In particular, Chemla (2009) shows that free choice occurs robustly in the scope of both universal quantifiers as in (2) and negative existentials as in (3).

(2) Every girl can eat cake or ice-cream $\rightsquigarrow$ *every girl can eat cake and every girl can eat ice-cream*

(3) No girl must eat both cake and ice-cream $\rightsquigarrow$ *every girl can avoid cake and every girl can avoid ice-cream*

(2) is predicted by exclusion-based approaches (together with the assumptions that implicatures can be computed locally), but (3) is not. On these grounds, Bar-Lev and Fox 2017 (BL&F) propose a novel theory of free choice, which can also account for (3). BL&F's account directly adds some information to the assertion (*inclusion*), in addition to the standard exclusion of alternatives. More precisely: BL&F's algorithm works by including all alternatives that are not innocently excludable (in the sense of Fox 2007) and that are compatible with the assertion and the negation of the innocently excludable alternatives.[1]

A novel case. We investigated a similar pair of sentences involving disjunction in the scope of non-monotonic quantifiers as in (4) and (5). (4) is generally assumed to have a reading (call it 'THE-ONE-FREE-CHOICE') on which disjunction is read conjunctively in the upward entailing component of the quantifier, and disjunctively in the downward entailing one. This reading suggests that one girl has free choice between cake and ice-cream, and no other girl can eat either of the two. Both exclusion- and inclusion-based theories of free choice can predict this reading.[2]

(4) Exactly one girl can eat cake or ice-cream. $\rightsquigarrow$ *One girl can eat cake and she can eat ice-cream <u>and all of the others cannot eat either one</u>.* THE-ONE-FREE-CHOICE

(5) Exactly one girl cannot eat cake or ice-cream. ?$\rightsquigarrow$ *One girl cannot eat either cake or ice-cream <u>and all of the others can eat cake and can eat ice-cream</u>* ALL-OTHERS-FREE-CHOICE

At the same time, predictions are different for (5). Exclusion-based theories do *not* predict (5) to have a reading (call it 'ALL-OTHERS-FREE-CHOICE') suggesting that one girl cannot eat either cake

[1] More formally, innocent exclusion (IE), innocent inclusion (II) and exhaustification are defined as follows:

(i) $\textsc{ie}(p, C) = \bigcap\{C' \subseteq C : C'$ is a maximal subset of C s.t. $\{\neg q : q \in C'\} \cup \{p\} \neq \bot\}$

(ii) $\textsc{ii}(p, C) = \bigcap\{C'' \subseteq C : C''$ is a maximal subset of C s.t. $\{r : q \in C''\} \cup \{p\} \cup \{\neg q : q \in \textsc{ie}(p, C)\} \neq \bot\}$

(iii) $\textsc{exh}(C)(p)(w) = \forall q \in \textsc{ie}(p, C)[\neg q(w)] \wedge \forall r \in \textsc{ii}(p, C)[r(w)]$

[2] For instance in Fox's 2007 theory this reading arises by global recursive exhaustification; see Spector 2007 for an analogous case with the multiplicity inference of plurals.

or ice-cream and all of the others have free choice between the two.[3] The free choice reading in (5) can, instead, be predicted via an inclusion algorithm like the one in BL&F (see also Santorio 2017 for a similar algorithm), assuming that the alternatives to (5) also include the existential *Some girl can/cannot eat cake* and *Some girl can/cannot eat ice-cream*. (This assumption naturally follows from a number of accounts of alternatives, e.g. Katzir's (2007).) As illustrated in Fig. 2, the alternatives *Exacly one girl is not allowed to have cake/ice-cream* end up being includable. Their inclusion is the source of the ALL-OTHERS-FREE-CHOICE reading of (5). (This derivation also generalises to *exactly n* cases, provided the corresponding existential alternatives are in the set of alternatives and the alternatives *exactly* n' for n's different from *n* are instead not part of that set.) Given the similarity between the two sentences and the difference in predictions between exclusion-based and inclusion-based theories, the pair in (4)/(5) can serve as an important test for theories of free choice.

The Experiment: We investigated this pair of sentences experimentally using an inferential task, building on recent experimental work with free choice inferences (Chemla 2009, Gotzner and Romoli 2017 a.o.). The design was a 2x4 with each of the two types of sentences (4) and (5), call it 'POSITIVE' and 'NEGATIVE,' respectively, presented in four inference conditions: TRUE, FALSE, COMPATIBLE and FREE-CHOICE. The first two conditions are simple baseline for truth and falsity, while the third one is a baseline for compatibility with the target sentence, i.e. the presented statement is simply compatible with the sentence but not an inference (cf. Gotzner and Romoli 2017). The comparison between the compatible and the free choice condition in both the POSITIVE and NEGATIVE variants is a measure of their potential free choice readings.[4] An example of each condition is given in Table 1. In our experiments, 60 participants saw sentences like (4) and (5) across the four inference conditions (in four different scenarios). We asked participants if and to what extent they would infer a given candidate inference on a scale from 0 to 100%, with 0% representing that a statement did not follow and 100% that it definitely followed.

Results & Discussion: The graph in Fig.1 below shows the mean % of YES responses across conditions. We ran a mixed model analysis with sum coding of all factors. The model revealed main effects for all comparisons, with the true condition being rated highest, followed by the free choice, compatible, and false conditions (all p-values $<.0001$). Crucially, the free choice condition was endorsed more than the compatible condition in both polarity conditions. While there was a significant interaction across polarity in the false condition ($p <.01$), no interaction between the POSITIVE and NEGATIVE cases in the FREE-CHOICE conditions was found ($p = .35$). These results suggest that (4) has a reading with free choice, as predicted by most exclusion-based implicature theories: the free choice condition was differing from both the compatible and the false condition. Crucially, we found parallel differences in the case of (5), suggesting that participants computed the free choice inference to a similar extent in the positive and negative polarity conditions.

Conclusion We tested sentences like (4) and (5) to investigate the status of their potential THE-ONE-FREE-CHOICE and ALL-OTHERS-FREE-CHOICE readings. In our results, we found clear evidence for both readings. These results are challenging for the exclusion-based implicature theories of free choice, but in line with inclusion-based accounts like BL&F 2017, which can predict both readings. The pair in (4) and (5) constitutes, therefore, a further important argument for inclusion-based accounts.

[3]For instance in Fox 2007 when (5) is globally exhaustified the key alternatives (*Exactly one cannot take syntax*, *Exactly one cannot take semantics*) are excludable and their negation doesn't lead to the above reading. It is easy to show that also local exhaustification in the scope of the quantifier doesn't help i.e. it gives rise to readings that are too weak in the upward-entailing component of the meaning.

[4]To ensure that the compatible condition really served as a baseline for compatibility we had two versions of the compatible conditions with identical sentences but different polarity in the second conjunct. Therefore, if participants were to endorse one version they certainly would not endorse its negation. Ratings of the two versions did not differ significantly, therefore in the graph below we present an average of the two versions of the compatible condition.

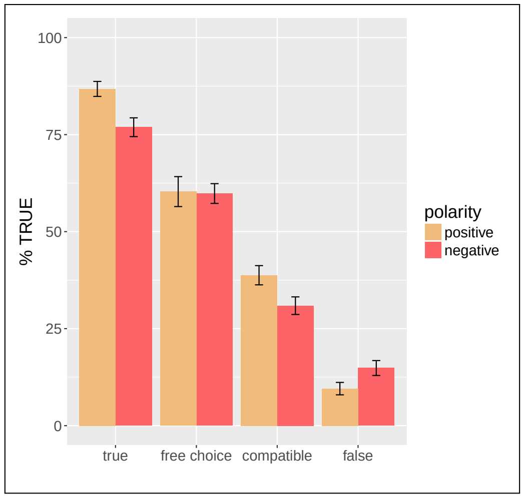

Figure 1: % YES by polarity (POSITIVE VS. NEGATIVE) and inference condition (TRUE, FREE CHOICE, COMPATIBLE and FALSE). The rate of endorsement reflects the degree to which a candidate inference follows. Error bars represent SEM.

Table 1: Example stimuli for the sentences 'Exactly one student can/can't take Spanish or calculus'

Inference condition	**Polarity**	**Candidate Inference**
True	negative	Only one student cannot take Spanish or calculus
True	positive	Only one student can take Spanish or calculus
Compatible 1	negative	One student can take neither Spanish nor calculus, and all others can take logic
Compatible 1	positive	One student can take either Spanish or calculus, and all others can take logic
Compatible 2	negative	One student can take neither Spanish nor calculus, and all others cannot take logic
Compatible 2	positive	One student can take either Spanish or calculus, and all others cannot take logic
Free choice	negative	One student can take neither Spanish nor calculus, and all others can choose between the two
Free choice	positive	One student can choose between Spanish and calculus and all others can take neither one
False	negative	All students can take Spanish and all students can take calculus
False	positive	No student can take Spanish and no student can take calculus

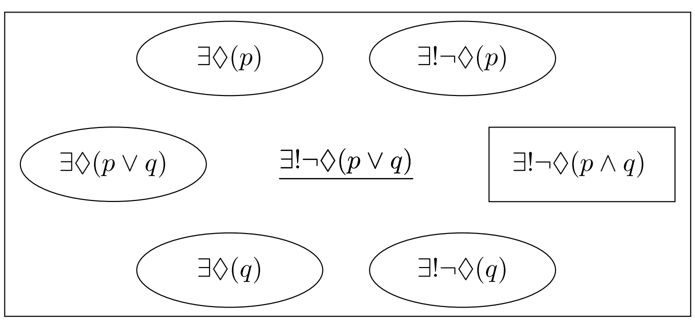

Figure 2: The alternatives for (5) which give rise to ALL-OTHERS-FREE-CHOICE. The innocently excludable (IE) alternative is in a rectangle; the innocently includable (II) alternatives are in ellipsis. The alternatives $\exists\neg\Diamond p$ and $\exists\neg\Diamond q$ are omitted because innocuous.

Selected references

Bar-Lev & Fox 2017 *Universal Free choice and innocent inclusion*; Chemla 2009 *Universal implicatures and free choice effects: experimental data*; Fox 2007 *Free choice and the theory of scalar implicatures*; Santorio 2017 *Alternatives and truth-makers in conditional semantics*