GLOSSA psycholinguistics

Schwab, J. (2022). Lexical variation in NPI illusions – NPI illusions as a scalar phenomenon. *Glossa Psycholinguistics* 1(1): 21, pp. 1–28. DOI: https://doi.org/10.5070/G6011106

eScholarship University of California

Lexical variation in NPI illusions – NPI illusions as a scalar phenomenon

Juliane Schwab, Department of Linguistics, University of Tübingen, Keplerstraße 2, 72074 Tübingen, Germany, juliane.schwab@uni-tuebingen.de

The illusory licensing of negative polarity items has been an insightful phenomenon for accounts of human sentence processing, as its extreme selectivity has proven problematic to explain in terms of parsing principles that underlie the establishment of other item-to-item dependencies. Using speeded acceptability judgments, I provide novel experimental evidence that the NPI illusion may be restricted to a particular type of NPI—illusory licensing was replicated for German *jemals* 'ever' but was not confirmed for the attenuating NPI *so recht* 'really'. I argue that this finding challenges all current accounts of the NPI illusion and propose an explanation that posits an interaction between a scalar NPI licensing mechanism and scalar properties of the illusory licensing context as the source of the NPI illusion.

1. Introduction

In illusory negative polarity item (NPI) licensing, an unlicensed NPI is temporarily perceived to be licensed in the presence of a negative element at a structurally irrelevant position. Thus, although the negation inside the relative clause (RC) in (1a) is not in a position from which it can license *ever*, the sentence is sometimes perceived to be more acceptable than an ungrammatical baseline condition (1c). The mechanisms underlying NPI illusions have initially been thought to reflect those involved in agreement attraction (Clifton Jr. et al., 1999; Dillon et al., 2013; Hammerly et al., 2019; Jäger et al., 2020; Patson & Husband, 2016; Pearlmutter et al., 1999; Staub, 2009) and reflexive binding errors (Clifton Jr. et al., 1999; Dillon et al., 2013; Hammerly et al., 2019; Jäger et al., 2015, 2020; Parker, 2019; Patil et al., 2016; Patson & Husband, 2016; Pearlmutter et al., 1999), which have been attributed to interference from partially matching elements in memory (Lewis & Vasishth, 2005). Converging evidence, however, suggests that NPI illusions are much more selective (De Dios Flores et al., 2017; Muller et al., 2019, 2020; Muller & Phillips, 2020; Orth et al., 2020a). Here, I further show that NPI illusions are sensitive to the type of NPI, arising for what we may call *strengthening* NPIs, but not for *attenuating* ones. I argue that this challenges current accounts of the illusion, and build on a proposal by Muller and Phillips (2020) to take into account the interaction between scalar NPI licensing mechanisms and scalar properties of the RC.

(1) a. *The lawyer that **no** client trusted has ever won a case.
b. **No** lawyer that the client trusted has ever won a case.
c. *The lawyer that the client trusted has ever won a case.

1.1 NPI illusions

NPIs like *ever* or *any* are expressions whose distribution is restricted to a range of, broadly speaking, negative or entailment-reversing environments, e.g., the scope of negation (2a/b) or downward-entailing operators (2b) (Ladusaw, 1979), and nonveridical contexts such as questions (2c) (Giannakidou, 1998). Without a licensor, NPIs are considered ungrammatical (2a). Nonetheless, comprehenders accept sentences like (1a), with a negation that does not scope over the NPI, at a higher rate than sentences without any negative element (1c). This effect was first reported for German (Drenhaus et al., 2005) and has been replicated in several languages and methodologies (English, speeded judgments: De Dios Flores et al., 2017; Muller et al., 2019; Muller & Phillips, 2020; Orth et al., 2020a; Xiang et al., 2009, 2013; EEG: Xiang et al., 2009; Turkish, EEG: Yanilmaz & Drury, 2018; Korean, untimed judgments: Yun et al., 2017). It has been termed a sentence processing *illusion* as the perception of acceptability is inconsistent with theoretical predictions about NPI licensing. The effect is often fleeting and may give way to an evaluation of unacceptability upon further reflection.

(2) a. The girl *has/has**n't** ever been to London.
b. **No/Not every** girl has ever been to London.
c. Has the girl ever been to London**?**

An early account of the NPI illusion (Vasishth et al., 2008) treats it as the result of similarity-based interference in the item-to-item dependency between NPI and licensor under a cue-based memory retrieval architecture (Lewis & Vasishth, 2005). Vasishth et al. (2008) argue that the illusion arises from erroneous retrieval of the embedded negation that partially matches retrieval cues set by the NPI. They argue that an NPI may set retrieval cues for its licenser such as +*negative* and +*c-command* (other feature combinations are conceivable). In the case of NPI illusions, there is no lexical licensor that matches all of these retrieval cues; however, the structurally irrelevant licensor inside of the RC provides a partial match (e.g., by carrying a +*negative* feature) that may result in erroneous retrievals as the NPI-licensing element within the sentence. Subsequent studies, however, put this account into question: For one, Parker and Phillips (2016) have shown that the NPI illusion, contrary to agreement attraction effects, can be reliably "turned off" by increasing the distance between the boundary of the RC containing the illusory licensor and the NPI. In addition, Muller et al. (2019, 2020) demonstrate that added material inside the RC does not have the same effect. Both findings are incompatible with predictions from cue-based retrieval (see Parker & Phillips, 2016 for modelling results). Secondly, Orth et al. (2020a) have shown that NPI illusions are absent with sentential negation (e.g., *The lawyer that the client did**n't** trust…*). Again, this is unpredicted under cue-based retrieval as both licensors can be assumed to carry the +*negative* feature relevant for NPI licensing. In light of these findings, several alternative accounts have emerged, which I briefly outline below (for a recent review, see Muller & Phillips, 2020).

First, Orth et al. (2020a) focus on their finding that the NPI illusion arises for quantificational licensors such as *no* or *not a single*, but not for sentential negation, to argue that the NPI illusion is a consequence of illicit quantifier raising engaged as part of standard parsing operations. Their *quantifier scope account* assumes that encountering an NPI within a sentence triggers a scope reanalysis for preceding quantificational elements. Although raising the negative quantifier inside of the RC to a matrix clause position is ungrammatical, the parser may nonetheless tentatively compute such a structure, thus putting the negation into an NPI-licensing position. Orth et al. argue that the temporary availability of this NPI-licensing parse results in the perception of acceptability for sentences like (1a); the illusion dissipates once the parser evaluates and rejects the structure as ungrammatical. The account is attractive as it can capture the NPI illusion's restriction to quantificational licensors. It also offers a straightforward expansion to illusions of ungrammaticality for positive polarity items, which have been reported by the same authors (Orth et al., 2020b; Orth & Yoshida, 2022). Although the account does not directly address the illusion's sensitivity to distance from the RC boundary, it may be compatible with this finding under the general assumption that lexical material inside the RC (including the quantifier) decays

in memory after the offset of the clause. As the quantifier's activation level decreases, it may be less likely to get reactivated for further parsing operations, including the quantifier raising that is presumed to generate the illusion.[1]

Alternatively, Xiang et al. (2009, 2013) propose that the NPI illusion arises from over-application of pragmatic rescuing mechanisms. The authors assume that licensing via pragmatic inference is a viable NPI licensing route in English (Giannakidou, 1998, 2006; Linebarger, 1987), such that *ever* in (3a), for instance, is licensed through the inference to the negative proposition. Similarly, the restrictive RC in (3b) is assumed to generate a contrastive implicature to an NPI-licensing proposition. They argue that although this inference is ultimately not close enough to the original proposition to render the NPI fully pragmatically licensed, its availability may give the sentence a temporary boost in acceptability. Although not initially proposed to capture the contrast between sentential negation and negative quantifiers, the account may also be able to capture the illusion's selectivity for quantificational licensors, as negative quantifiers make the contrastive inference more salient (Xiang et al., 2009, p. 53). Like the quantifier scope account, however, the *pragmatic rescuing account* does not address why distance from the RC boundary should affect whether pragmatic inferences are drawn (although, again, memory decay of RC material may be stipulated as a contributing factor). More importantly, a broader issue facing this account is that it requires further elaboration of the boundary between those conditions that allow for pragmatic rescuing as a legitimate licensing strategy and those that do not (for related arguments see Muller & Phillips, 2020; Orth et al., 2020a).

(3) a. I am **sorry** that I ever met him. → I wish that I had**n't** ever met him.
b. The lawyer that **no** client trusted has ever won a case. → The lawyer that **the** client trusted has **not** ever won a case

Finally, Parker and Phillips (2016) emphasise the role of the whole RC as *licensing environment* over the role of its embedded negation as *lexical licensor*. Note that this aligns more closely with the theoretical linguistic literature, in which many accounts of NPI licensing claim that NPIs are licensed by the semantic and pragmatic properties of the context in which they appear (Chierchia, 2006; Giannakidou, 1998, 2006; Israel, 1996, 2011; Kadmon & Landman, 1993; Krifka, 1995). Focusing on the role of distance from the RC boundary, the authors propose that the NPI illusion arises for NPIs appearing shortly after an RC because they tap into an incomplete encoding of the (illusory) licensing context. Unfortunately, this account suffers from the same problem facing cue-based retrieval, namely, an inability to account for the lack of NPI illusion with sentential negation. However, its crucial insight on the role of the clausal environment has inspired subsequent works: In a review of negative polarity illusions, Muller and Phillips (2020) sketch an *environment-based account* that argues that NPIs appearing shortly after an RC may be erroneously integrated into

[1] I would like to thank an anonymous reviewer for highlighting this possibility.

the RC phrasal context that provides a good fit to the relevant semantic or pragmatic features that license NPIs. NPI illusions are argued not to arise with increased distance from the RC, as the parser will eventually close off that clause for integration with further elements. The restriction to negative quantifiers in turn is assumed to be due to them being "more likely to be used to make strong, negative claims" than sentential negation, specifically "encourag[ing] inferences toward strengthening, whereas sentential negation merely allows such inferences" (Muller & Phillips, 2020, p. 668). Although the authors do not elaborate on these ideas, it suggests that they envisage an explanation according to which pragmatic strengthening of the negative context may support illusory licensing. Note, though, that within the theoretical linguistic literature it is typically the NPI, not the negation itself, that is assumed to contribute the alternatives over which the assertion is strengthened (Chierchia, 2006; Kadmon & Landman, 1993; Krifka, 1995). I discuss these NPI licensing accounts in the following section, and revisit details and amendments of this particular account of the NPI illusion in Section 4 of the paper.

To summarise, the literature offers multiple accounts of NPI illusions. The cue-based retrieval account views the NPI illusion as a result of a partial cue match between the NPI and the embedded negation but struggles to explain the full range of empirical results. Alternatively, the quantifier scope account posits the illusion as a consequence of illicit quantifier raising, whereas the pragmatic rescuing account sees it as result of overly eager pragmatic rescuing mechanisms. Both accounts can capture the restriction to negative quantifiers, but do not straightforwardly extend to the role of distance from the RC boundary. Finally, the environment-based account has the potential to capture both findings. Overall, however, none of the accounts reviewed so far attribute a particular role to the type of NPI involved in illusory licensing. Indeed, most existing studies have focused on a rather narrow set of weak strengthening NPIs like English *ever*, *any*, or related expressions in other languages (e.g., German *jemals* 'ever' or Turkish *kimse* 'anybody'). Contrasting the illusory licensing profiles of different types of NPIs, however, has potential to further our understanding of the processes underlying NPI illusions and, potentially, the mechanisms of NPI licensing in general. A distinction from the theoretical linguistic literature that is pertinent to current purposes is that between strengthening NPI (such as *ever* or *any*) and attenuating NPIs (such as *much* or *all that*), which, despite similar distributional restrictions, arguably differ in their licensing mechanism. In the following section, I provide a broad overview to contemporary NPI licensing accounts, with particular emphasis on the strengthening vs. attenuating subtype. This discussion will form the basis of the experiments reported in Sections 2 and 3.

1.2 Accounts of NPI licensing

A major question in the theoretical literature on NPIs concerns the property that unifies the diverse set of NPI licensors in (2). Therein, the veridicality-based account (Giannakidou, 1998, 2006) assumes that NPIs, in general, are sensitive to the veridicality of the environment they appear

in. Weak NPIs like *ever* are assumed to be licensed by (subjectively) nonveridical propositional environments, that is, ones where the truth of the proposition is not entailed or presupposed by the perspectival agent.[2] Affirmative propositions are veridical, therefore being unable to host NPIs, whereas negation is an anti-veridical operator (i.e., one that entails the falsity of the proposition it applies to), such that this account straightforwardly predicts licensing under negative operators (2a,b). In questions (2c), conditionals, and other non-veridical environments, the truth of the proposition is not entailed, again allowing them to host NPIs. Finally, as exploited in the pragmatic rescuing account of NPI illusions, Giannakidou's approach assumed that NPIs can occasionally appear in veridical environments, so long as an NPI-licensing non-veridical proposition is available via pragmatic inference from the asserted proposition, as in (3a).

Alternatively, scalar approaches to polarity sensitivity (Chierchia, 2006; Israel, 1996, 2011; Kadmon & Landman, 1993; Krifka, 1995) argue that NPIs are restricted to contexts in which they render the assertion stronger than any of its alternatives. These alternatives are lexically evoked by the NPI; *ever* in (4a), for instance, contributes alternatives that refer to more specific times. In negative contexts, the assertion with the NPI is stronger than its alternatives as all alternatives are logically entailed.

(4) a. The girl hasn't ever been to London. ⇒ The girl hasn't been to London (at more specific times, e.g., last week, last month, last year).
b. The girl hasn't been to London all that often. ⇏/⇐ The girl hasn't been to London (at all or with some lower frequency).

Formally, these accounts assume that the activation of lexically triggered alternatives (contributed by the NPI) requires them to be factored into the meaning of the sentence. Specifically, for Krifka (1995), lexical alternatives trigger a *scalar assertion* operator, which asserts the proposition *p* (in the first conjunct of (5)) and denies that there are any (true) more informative alternatives *p'* (in the second conjunct of (5)). In cases where the NPI is not licensed, e.g., in affirmative propositions, scalar assertion results in contradiction, rendering the sentence unassertable. In the case of (2a), for instance, contradiction arises because it involves asserting the unspecific proposition "The girl has ever (i.e. at some point) been to London" while denying that she has been to London at any more specific time. Alternatively, Chierchia (2006) proposes that the alternative-introducing NPI triggers application of an exhaustive operator, which denies all alternative propositions. Again, licensing fails in affirmative propositions, as exhaustification results in contradiction.

(5) $\mathrm{ScalAssert}(p,\mathrm{Alt}(p),c) = \{w \in c \mid w \in [\![p]\!]_c \wedge \neg(\exists p' \in \mathrm{Alt}(p)(w \in [\![p']\!]_c \wedge c + p +_{str} p' \neq c + p))\}$
(a reformulation of Krifka's 1995 *ScalAssert*, from Condoravdi, 2010, p. 897)

---

[2] A propositional operator *F* is veridical iff F_p entails or presupposes that *p* is true in some individual's epistemic model $M_E(x)$; otherwise *F* is nonveridical (Giannakidou, 2006, p. 589)

A second, less well-studied, type of NPI has the opposite requirement to strengthening NPI: Attenuating NPIs (Israel, 1996, 2011), such as *all that* in (4b), need to render an assertion less informative than alternatives; in (4b), for instance, the assertion leaves open all lower-degree alternatives, thus weakening it in comparison to alternatives such as the unmodified variant. Despite a distributional restriction to similar contexts (negation, downward-entailing environments, etc.), the mechanisms that are presumed to license attenuating and strengthening NPIs under scalar approaches to polarity sensitivity are thus arguably different: For strengthening NPIs, the mechanism involves negating all stronger alternatives, whereas for attenuating NPIs, it involves affirming the existence of a stronger alternative.

A recent account by Schwab and Liu (to appear), building on Krifka (1995) and Israel (1996, 2011) argues for the following formal licensing condition for attenuating NPIs: Attenuating NPIs evoke ordered alternatives much like their strengthening counterparts (for degree modifiers like *all that*, those are alternative degrees). However, contrary to strengthening NPIs, attenuating ones do not require the proposition *p* to be informationally stronger than alternatives, but require the existence of a stronger alternative *p'*. Again, this is provided in terms of a condition on the assertability of the proposition (6), such that the NPI-containing proposition *p* will only be assertable (without contradiction) if (per the second conjunct of (6)) there exists an alternative proposition *p'* that is compatible with the current context and that would have been more informative than the assertion of *p* (see Schwab & Liu, to appear for full formal details and Schwab & Liu, 2022 for additional empirical evidence from NPI licensing in conditionals).

(6) $\text{Licensing condition}(p,\text{Alt}(p),c) = \{w \in c \mid w \in [\![p]\!]_c \wedge \exists p' \in \text{Alt}(p)\ (\exists w' \in c | w' \in [\![p']\!]_c \wedge c + p +_{str} p' \neq c + p)\}$

With respect to on-line processing, it has been questioned whether comprehenders always need to engage the full licensing mechanism (of any of the proposed kinds) (Xiang et al., 2013; Parker & Phillips, 2016). Instead, they may rely on heuristics to ease their processing load, such as checking for a negation in the directly preceding clausal context (Parker & Phillips, 2016), or using a syntactic licensing mechanism for lexically negative licensors while relying on pragmatic mechanisms for other constructions (Xiang et al., 2013). At least with respect to the NPI illusion, however, its apparent selectivity for quantificational licensors suggests that it may not be the result of faulty reliance on either one of these heuristics—as this would predict NPI illusions from all lexically negative licensors, including sentential negation.

In this paper, I investigate whether lexical-semantic differences between the two types of NPIs mentioned above, strengthening and attenuating ones, impact on their sensitivity to NPI illusions. On the one hand, the cue-based retrieval account, the quantifier scope account, and the pragmatic rescuing account do not foresee such differences. The first conceives of NPI licensing as item-to-item dependency, in which the relevant licensing properties are lexical properties of the licensor. The second proposes that the source of the NPI illusion may not directly relate to

the licensing mechanism of NPIs at all, but to properties of the negative quantifier. In both cases, differences between strengthening and attenuating NPIs should therefore not play a role. One may entertain the possibility that attenuating and strengthening NPIs could set different types of retrieval cues; however this option seems far-fetched considering the observation that they share virtually the same set of lexical licensing elements. Finally, pragmatic rescuing, too, should be equally available to both types of (weak) NPIs, as the veridicality-based account of NPI licensing, on which pragmatic rescuing is based, does not draw a distinction between the mechanisms engaged for strengthening and attenuating NPIs, respectively. On the other hand, accounts of the NPI illusion that focus on a direct interaction between semantic and pragmatic properties of the intrusive RC and the licensing mechanism employed by the grammar may be compatible with differences between different types of NPIs. According to the environment-based account, a strong negative scalar RC can be mistaken for the licensing context of an NPI due to the NPI's lexical restriction to similarly structured scalar contexts. If this is a reflection (or a consequence) of the underlying scalar licensing mechanism engaged during sentence processing, strengthening and attenuating NPIs arguably differ along the lines outlined for scalar approaches above. Specifically, since attenuating NPIs do not strengthen the assertion they appear in, a strong negative scalar RC may not affect them to the same extent as it affects strengthening NPIs. The following experiments therefore tested for NPI illusions with strengthening and attenuating NPIs. Converging results from two experiments using subject- and object-extracted RC environments suggest that strengthening NPIs do, but attenuating NPIs do not, show illusory licensing from negative quantifiers. Implications of this finding are discussed in Section 4.

2. Experiment 1

The experiment was conducted using speeded acceptability judgments. It contrasted two German NPIs, the strengthening NPI *jemals* 'ever', for which illusory licensing has previously been observed (Drenhaus et al., 2005; Vasishth et al., 2008), and the attenuating NPI *so recht* 'really', which had not yet been tested in this regard. Both NPIs are weak NPIs; according to the German Collection of Distributionally Idiosyncratic Items (CoDII) (Sailer & Trawinski, 2006), they both appear in a similar range of NPI-licensing environments, including under sentential negation, negative quantifiers, downward-entailing operators, and in questions. They are also both adverbials, which allowed for the creation of maximally similar stimuli.

2.1 Method

2.1.1 Participants

The required sample size was estimated using a simulation-based prospective power analysis, following a procedure outlined in Vasishth et al. (2018). Prospective power was determined for

two effects of interest: (a) the NPI illusion, that is, the difference between the ungrammatical baseline and the illusory licensing condition, and (b) the illusion asymmetry, i.e., the interaction effect for two NPIs whose illusory licensing profiles may differ. Plausible effect sizes were extracted based on previous studies using the same methodology (Orth et al., 2020a; Parker & Phillips, 2016). To account for a range of possible results, the magnitude of the NPI illusion effect (measured as the difference in the proportion of sentences that were accepted) for the first NPI was set to vary between 0.06 and 0.10, which reflect small to moderate NPI illusion effects, while the illusion effect for the second NPI was presumed to be zero; the size of the interaction effect changed accordingly. I simulated 100 fake data sets for each assumed effect size (with consistent standard deviations and random effects estimates) and fit each of them with a maximal linear mixed effects model. To estimate statistical power, I determined the percentage of data sets for which the effects turned significant at the $\alpha < 0.05$ level.

The prospective power analysis indicated that a sample size of 72 participants (each seeing 42 items in six conditions as described below) would be sufficient to achieve more than 80% power for both effects (94% for the NPI illusion, 85% for the interaction), provided the real effect magnitude for the former is 0.08.[3] For an even smaller effect size of 0.06, power would still meet 70%. The planned sample size was therefore set to 72 participants. I recruited slightly more participants to account for data loss due to missing responses or low response accuracy.

96 people participated via Prolific (https://www.prolific.co/). Six were later removed due to low comprehension question accuracy on fillers (<80%); 13 were removed because they failed to reject filler items that contained grammatical violations in at least half of the ungrammatical filler trials. All 77 remaining participants were German native speakers (mean age = 27.84, age range = 18–60, 29 female, 3 non-binary, 45 male). The experiment duration was approximately 20 minutes; participants were reimbursed with £3.50.

2.1.2 Materials

The experimental materials comprised 42 items in six conditions, following a 2 × 3 factorial design with the factors NPI (*jemals* vs. *so recht*) and negation (no negation, RC negation, matrix clause negation). Of these conditions, only those using matrix negation (7b) are grammatical; the conditions without negation (7c) form the ungrammatical baseline, whereas illusory licensing may occur in the ones using negation in the subject-extracted RC (7a). Participants only saw one condition per item. Additionally, the experiment included 62 filler trials, 24 of which contained various grammatical violations (e.g., word omissions and subject-verb agreement errors) to balance out the ratio of grammatical to ungrammatical sentences.

[3] The code to reproduce the power analysis and a table listing all simulation results are available in the online supplementary materials.

(7) a. Der Bauer, der kein Pestizid verwendete, …
the farmer who no pesticide used…

b. Kein Bauer, der das Pestizid verwendete, …
no farmer who the pesticide used…

c. Der Bauer, der das Pestizid verwendete, …
the farmer who the pesticide used…
…war {**so recht/jemals**} von dem Ernteertrag begeistert.
…was {**really/ever**} by the crop_yield amazed
'{The/No} farmer who used {the/no} pesticide was {ever/really} amazed by the crop yield.'

2.1.3 Procedure

The experiment was implemented on Ibex Farm (Drummond, 2013). Sentences were presented word-by-word at a rate of 225 ms plus 25 ms for each character in a word to account for word length differences (Bader & Häussler, 2009). After each sentence, participants had three seconds to indicate via button press whether the sentence was acceptable ("1" for unacceptable, "7" for acceptable). If they failed to respond, a prompt asked them to be quicker next time, and the next trial started. 26 trials, distributed across fillers, additionally included an untimed yes/no comprehension question. After every 25 trials, a break screen allowed participants to halt the experiment and continue by pressing the space bar. The order of trials was pseudorandomised with all critical trials being separated by at least one filler trial.

2.1.4 Data analysis

Data were analysed using Bayesian logistic regression models with the *brms* package (Bürkner, 2017) in *R* (R Core Team, 2020). Trials in which participants failed to respond were discarded (1% of trials). Two models were fit to the data: The first contrasted the three conditions for each NPI, implemented using a Helmert-coded factor that compared the ungrammatical baseline to the illusory licensing condition and subsequently compared both former (ungrammatical) conditions to the grammatical condition. The second model was used to test for differences between the NPIs; it determined interaction effects by comparing the two illusory licensing effects (i.e., the difference between differences in the comparison of the ungrammatical baseline and the illusory licensing condition for *jemals* and *so recht*) and the difference between grammatical and ungrammatical conditions for the two NPIs, both using sum-coded contrasts. All models used the maximal random effects structure and *brms* default priors. Four chains were run using 4,000 iterations. I report posterior estimates, 95% credible intervals (CrIs), and posterior probabilities of the parameter values being bigger/smaller than 0.

2.1.5 Results

The proportion of accepted trials is visualised in **Figure 1**; posterior distributions for the estimated parameters are depicted in **Figure 2**.

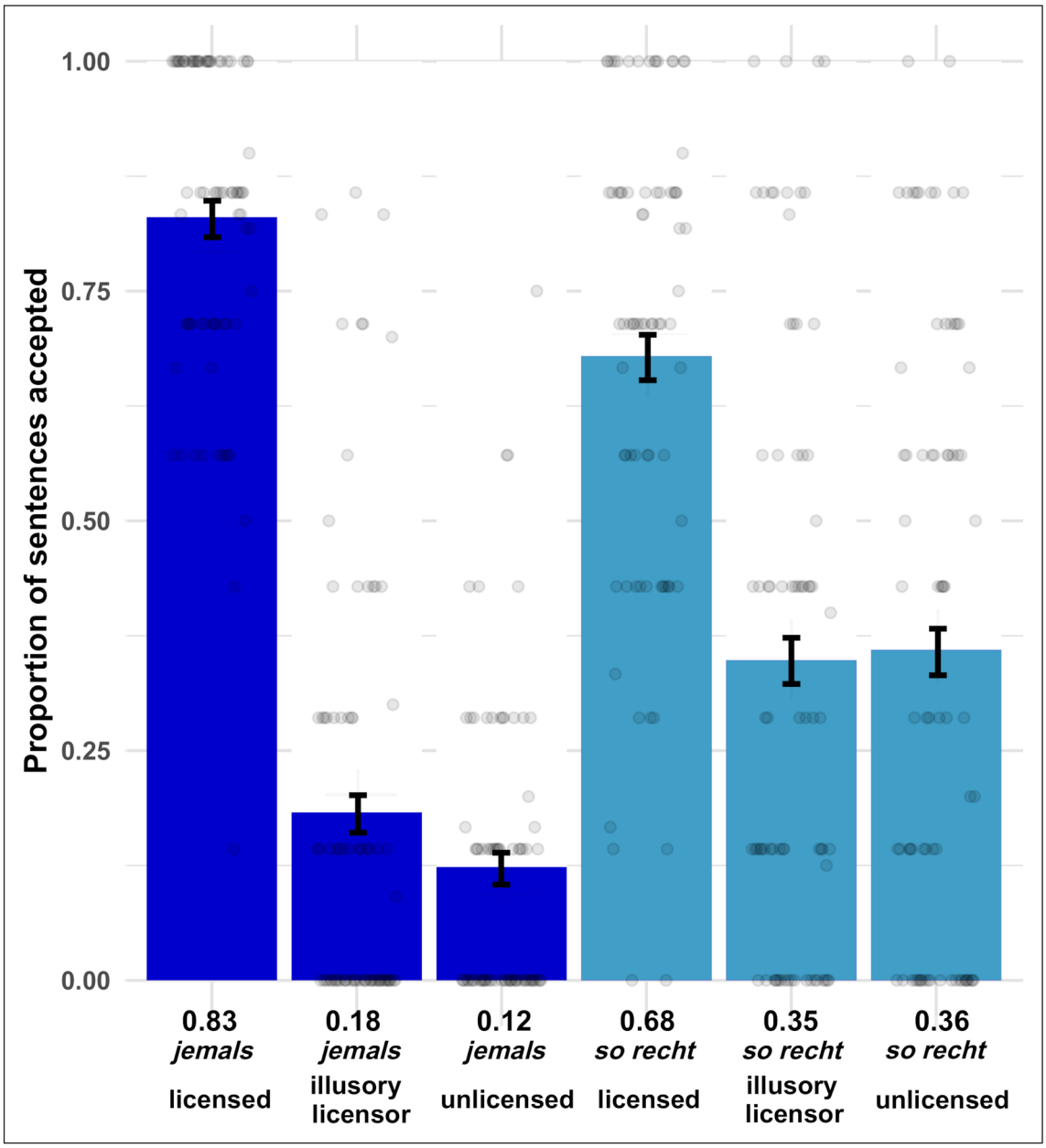

Figure 1: Mean proportion of trials in which the sentence was accepted. Dots show participants' mean response across trials; error bars show the standard error around the mean.

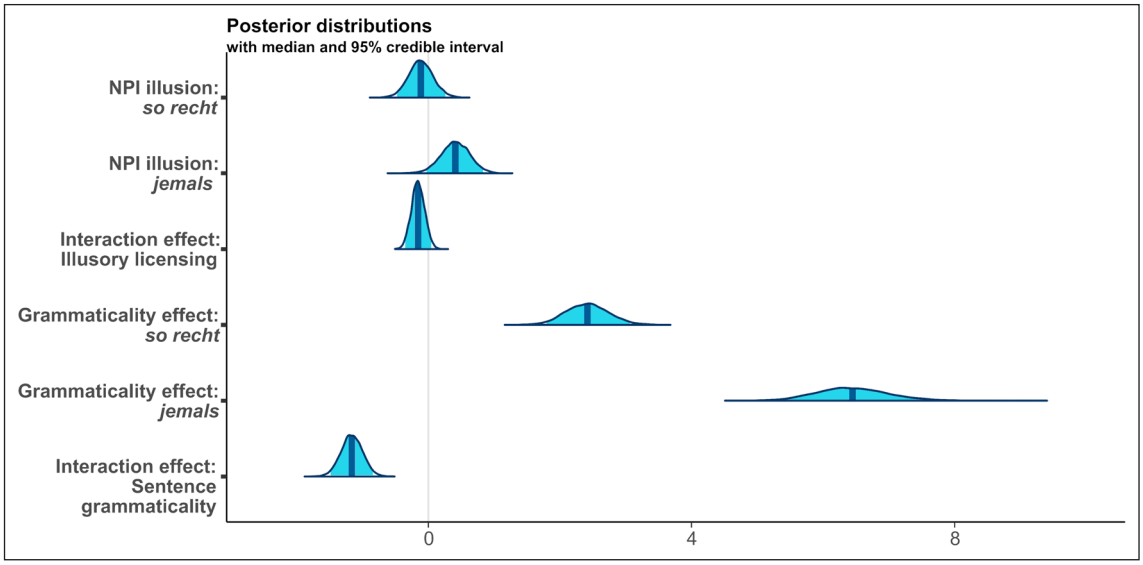

Figure 2: Posterior distributions for all fixed effects. The dark blue line shows the median posterior effect estimate; the light blue area indicates the 95% credible interval.

The first model provides clear support for a clear difference between grammatical and ungrammatical conditions for both NPIs (*jemals*: $\hat{\beta} = 6.45$, *CrI* = [5.45, 7.56], $P(\beta > 0) = 1$, *so recht*: $\hat{\beta} = 2.42$, *CrI* = [1.80, 3.06], $P(\beta > 0) = 1$). For *jemals*, the posterior additionally supports a small illusory licensing effect ($\hat{\beta} = 0.41$, *CrI* = [–0.03, 0.83], $P(\beta > 0) = 0.97$), such that the condition containing RC negation was accepted at a higher proportion than the ungrammatical baseline. Note, however, that the 95% CrI includes 0 (see also **Figure 2**), such that there is a small, but non-negligible chance that illusory licensing for *jemals* is non-existent. For *so recht*, the posterior is widely distributed over both sides of zero, which is inconclusive about the true size and direction of the effect ($\hat{\beta} = 0.41$, *CrI* = [–0.03, 0.83], $P(\beta > 0) = 0.97$). A second model compared the NPIs: The comparison between the two illusory licensing effects was weakly supportive (although again, the 95% CrI includes zero) of an interaction effect due to an asymmetric NPI illusion only for *jemals* ($\hat{\beta} = -0.16$, *CrI* = [–0.35, 0.04], $P(\beta < 0) = 0.94$); the comparison between the grammatical baselines and the ungrammatical conditions for the two NPIs is in line with an interaction as the difference is larger for *jemals* than *so recht* ($\hat{\beta} = -1.16$, *CrI* = [–1.49, –0.84], $P(\beta < 0) = 1$).

To quantify the evidence in favour of NPI illusion effects for *jemals* and *so recht,* as well as for the interaction effect, I also conducted Bayes factor analyses using the bridge sampling method implemented in the *bayes_factor* function in the R package *brms*. I compared models with the respective illusion effects (H_1) to reduced models in which the effects were assumed to be 0 (i.e., the effect term was removed; H_0). The analyses suggested moderate evidence in favour of an NPI illusion with *jemals* ($BF_{10} = 9.65$) and slightly favoured the null hypothesis for the NPI *so recht*

(BF_{10} = 0.43). The Bayes factor on the interaction effect, however, was inconclusive (BF_{10} = 1.16).

2.1.6 Discussion

The results of Experiment 1 are compatible with the NPI illusion previously reported for German *jemals*, although the posterior estimates and the Bayes factor suggest that the effect may be smaller than previously reported. For the attenuating NPI *so recht* and the interaction effect between the two NPIs, the results are inconclusive; due to the width of the posterior distributions, they are compatible both with the possibility that *so recht* and *jemals* show similar NPI illusions, and with the possibility that there is no NPI illusion for *so recht*.

In addition, licensed uses of *so recht* were generally accepted to a lower degree than licensed uses of *jemals*. On the one hand, this may reflect the fact that *so recht* generally disprefers negative quantifiers as licensor; however, this possibility seems less likely given that previous studies suggest that negative quantifiers are highly accepted as licensors of this NPI (Schaebbicke et al., 2021; Schwab et al., 2021). On the other hand, it may reflect issues with the stimulus design, such that some of the (grammatical) materials may have been less plausible with a degree modifier like *so recht* than with a temporal adverbial like *jemals*, therefore getting rejected by participants. Conversely, the acceptance of ungrammatical conditions was also higher for *so recht* compared to *jemals*. Similar findings have been reported by Schwab et al. (2021), which they attribute to the pragmatics of attenuating/strengthening NPIs: Whereas unlicensed strengthening NPIs, in the scalar framework, result in contradictions due to the uninformativeness of the assertion, unlicensed attenuating NPIs result in assertions that are more informative than their alternatives (e.g. *Mary is all that happy*, which entails alternative propositions with lower degrees of happiness). Comprehenders may be more hesitant to reject such informative assertions as unacceptable even when they fail to conform to the licensing requirement of the NPI. In general, despite their shared sensitivity for negation-like contexts, NPIs can differ greatly from another, both across and within subtypes (strengthening/attenuating). This complicates the interpretation of direct comparisons between acceptance rates for two NPIs.

All in all, despite planning for sufficient power, the experiment failed to deliver the desired insight on the status of the NPI illusion with strengthening compared to attenuating NPIs. One possible reason for this failure is that the effect estimates the power analysis was based on might have been overinflated. They reflected effect sizes found in previous studies on English *ever* (Orth et al., 2020a; Parker & Phillips, 2016), (a) for which the size of the NPI illusion effect may simply be bigger than for German *jemals*, or (b) which themselves may have overestimated the true effect size due to insufficiently large sample sizes. Another possibility is that factors of the study design led to a diminishment of the NPI illusion effect. For one, the present experiment

used subject-extracted RCs, whereas most previous studies in English used object-extracted ones (De Dios Flores et al., 2017; Muller et al., 2020; Orth et al., 2020a; Parker & Phillips, 2016; Xiang et al., 2009, 2013). So far, evidence regarding differences due to the hierarchical position of the illusory licenser within the RC is mixed, with Orth et al. (2020a) suggesting that there are no differences between subject- or object-extracted RCs, whereas Muller et al. (2019) suggest that the NPI illusion effect may be smaller for the subject-extracted ones. In any case, as the subject position has higher prominence in terms of its grammatical status than the object (e.g., operationalised by its base-level activation in a cue-based retrieval architecture, Engelmann et al., 2019), placing the negative quantifier at the RC subject position may increase its likelihood of being misretrieved (if we pursue a cue-based retrieval account of the NPI illusion), and may render it more salient as an alternative-generating scalar expression (as relevant under a scalar account of NPI illusions). In the follow-up experiment below, stimulus material was therefore adjusted to object-extracted RCs, both in an attempt to maximise the likelihood of detecting an NPI illusion effect and to increase comparability with previous studies on the NPI illusion.

Secondly, word presentation times in previous studies on German and English ranged from 275 ms (Orth et al., 2020a) to 300 ms per word (Drenhaus et al., 2005; Parker & Phillips, 2016; Xiang et al., 2009). This is slightly faster than in the presented experiment, where all words with more than 3 characters were presented for more than 300 ms (incremented by 25 additional milliseconds per word character). Since the NPI illusion is a fleeting phenomenon, a second adjustment for the follow-up experiment was therefore to reduce the presentation times for each word.

3. Experiment 2

3.1 Method

Experiment 1 was conducted to test for differences in the NPI illusion effects for *jemals* and *so recht*. However, despite prior sample size estimation through a prospective power analysis, the results remained inconclusive. This is both because the mean posterior estimate for the illusion effect for *jemals* was smaller than observed in the previous experiments that were used to estimate the required sample size, and because the posterior distributions on all relevant effects were relatively wide, that is, imprecise in their estimation of the true effect. Experiment 2 therefore was planned around determining the relevant parameter estimates with a desired level of precision—where higher precision indicates increased certainty about the size of the true effect (or lack thereof) (Kruschke & Liddell, 2018). I employed a sequential sampling paradigm whereby data collection continued until the width of the 95% CrI for the interaction effect between the NPI illusions for *jemals* and for *so recht* was less than 90% of the width of the region of practical equivalence (ROPE), an interval around zero within which parameter values may be considered as practically equivalent to the null value (Kruschke & Liddell, 2018). Within the

Bayesian framework, sequential sampling has been proposed as an alternative to fixed sample size studies by a range of authors (Lakens, 2014; Moerbeek, 2021; Schönbrodt et al., 2017; Schönbrodt & Wagenmakers, 2018), who suggest stopping rules such as a pre-specified threshold value for the Bayes factor (Moerbeek, 2021; Schönbrodt et al., 2017) or properties of the CrI, like its in- or exclusion of the ROPE or its width relative to the ROPE (Kruschke, 2011; Kruschke & Liddell, 2018). Here, I follow the latter suggestion as it is centred around precision in estimation rather than (dis-)confirming the null hypothesis (Kruschke, 2011). The ROPE was determined at the first analysis of collected data using the R function *rope_range* implemented in the package *bayestestR*. It ranged from –0.18 to 0.18. Data collection therefore stopped as soon as the width of the CrI on the interaction effect for the NPI illusion with *jemals* and *so recht* was lower than 0.32.

3.1.1 Participants

A total of 134 participants took part in the study via Prolific (https://www.prolific.co/). Of those, seven were later removed due to low comprehension question accuracy on fillers (< 80%); another seven were removed for failing to identify at least half of the ungrammatical fillers as such. All 120 remaining participants were German native speakers (mean age = 30.9, age range = 18–59, 52 female, 6 non-binary, 62 male). The experiment duration was approximately 20 minutes; participants were reimbursed with £3.50.

3.1.2 Materials

As with the previous experiment, the experimental materials comprised 42 items in six conditions, following a 2 × 3 factorial design with the factors NPI (*jemals* vs. *so recht*) and negation (no negation, RC negation, matrix clause negation). Of these conditions, only those using matrix negation (8b) are grammatical; the conditions without negation (8c) form the ungrammatical baseline, whereas illusory licensing may occur in the conditions using negation in the RC (8a). In contrast to Experiment 1, I used object-extracted RCs in the test materials. This reflects the structure that was used in most previous studies on the NPI illusion in English (De Dios Flores et al., 2017; Muller et al., 2020; Orth et al., 2020a; Parker & Phillips, 2016; Xiang et al., 2009, 2013). As discussed above, the results from Experiment 1 suggest that the NPI illusion effect in the tested construction with subject-extracted RCs may be relatively small. By revising the test materials, I aimed to maximise the expected effect size, therefore increasing the chances of finding evidence for intrusive licensing with the tested NPIs – presuming that there is a true underlying effect. Participants only saw one condition per item. Additionally, the experiment included the same 62 filler trials as Experiment 1.

(8) a. Der Sänger, den kein Label unterstützte, …
the singer whom no label supported…

b. Kein Sänger, den das Label unterstützte, …
no singer whom the label supported…

c. Der Sänger, den das Label unterstützte, …
the singer whom the label supported…
…war {**so recht/jemals**} in der Musikbranche erfolgreich.
…was {**really/ever**} in the music_business successful
'{The/No} singer whom {the/no} label supported was {ever/really} successful in the music business.'

3.1.3 Procedure

The experiment was implemented on the PCIbex farm (Zehr & Schwarz, 2018). The experimental procedure was the same as for Experiment 1, except that the presentation time for each word was reduced by 25 ms, such that sentences were presented word-by-word at a rate of now 200 ms plus 25 ms for each character to account for word length differences (Bader & Häussler, 2009). This is closer to the presentation times reported for previous studies on German and English, which ranged from 275 ms (Orth et al., 2020a) to 300 ms per word (Drenhaus et al., 2005; Parker & Phillips, 2016; Xiang et al., 2009). The adjustment for word length, however, was maintained as German is more variable than English with respect to the orthographic length of words (Marian et al., 2012).

3.1.4 Data analysis

Data analysis procedures were the same as for Experiment 1. Trials in which participants failed to respond were discarded (1.4% of trials).

3.1.5 Results

The proportion of trials that were accepted by participants is visualised in **Figure 3**; posterior distributions for the estimated parameters are depicted in **Figure 4**.

For both NPIs, the first model supports a clear difference between grammatical and ungrammatical conditions (*jemals*: $\hat{\beta} = 4.84$, *CrI* = [4.19,5.54], $P(\beta > 0) = 1$, *so recht*: $\hat{\beta} = 2.90$, CrI = [2.38,3.46], $P(\beta > 0) = 1$). For *jemals*, the posterior additionally supports an illusory licensing effect ($\hat{\beta} = 0.58$, CrI = [0.28,0.89], $P(\hat{\beta} > 0) = 1$), such that the condition containing RC negation was accepted at a higher proportion than the ungrammatical baseline. For *so recht*, the posterior is centred around zero, suggesting a lack of support for an NPI illusion ($\hat{\beta} = –0.09$, CrI = [–0.37,0.20], $P(\beta > 0) = 0.28$). The comparison between the two illusory licensing effects in the second model was supportive of an interaction effect due to an asymmetric NPI illusion only for *jemals* ($\hat{\beta} = –0.20$, CrI = [–0.35, –0.05], $P(\beta < 0) =$

0.996); the comparison between the grammatical baselines and the ungrammatical conditions for the two NPIs is in line with an interaction as the difference is larger for *jemals* than *so recht* ($\hat{\beta} = -0.56$, CrI $= [-0.80, -0.33]$, $P(\beta < 0) = 1$).

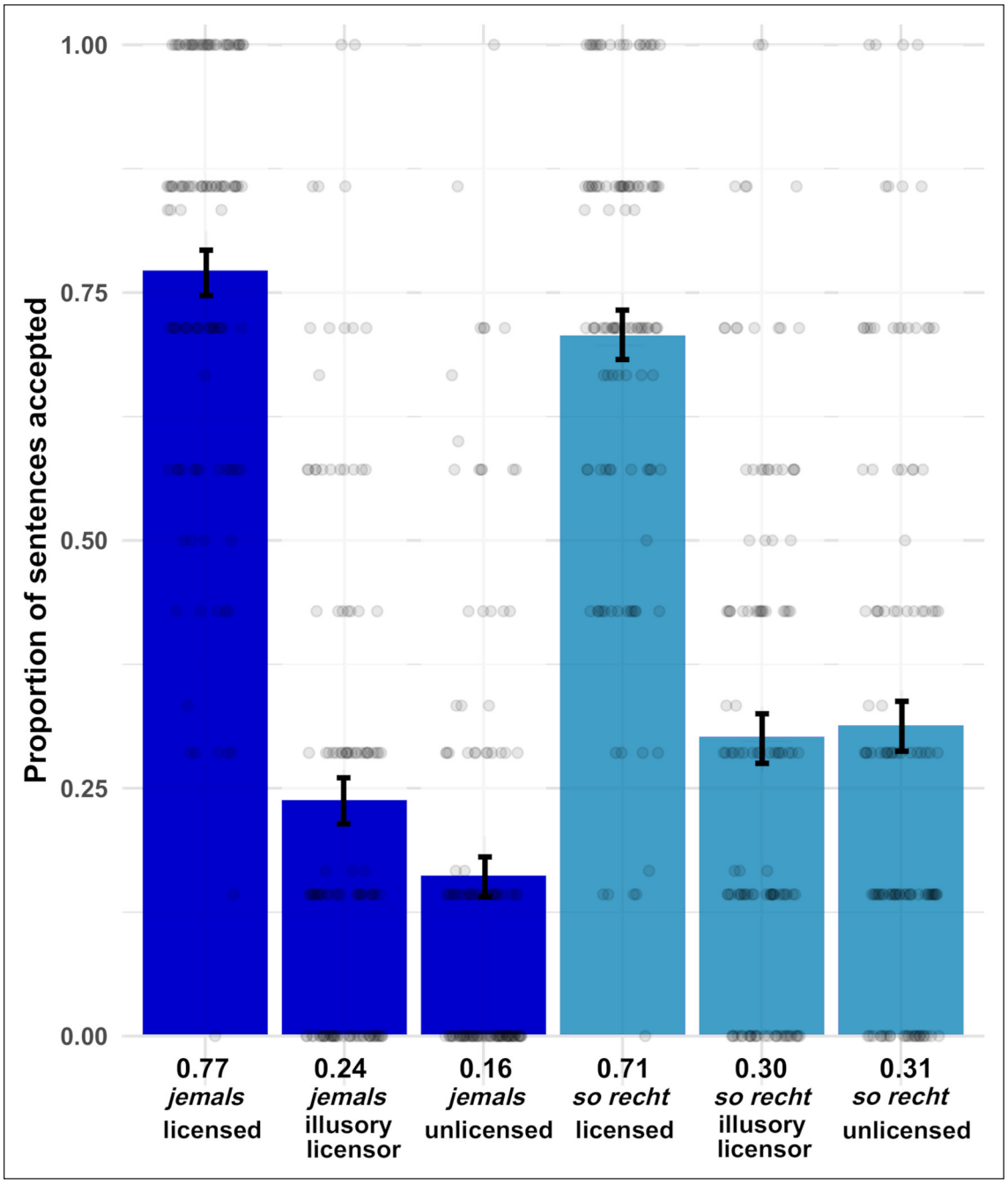

Figure 3: Mean proportion of trials in which the sentence was accepted. Dots show participants' mean response across trials; error bars show the standard error around the mean.

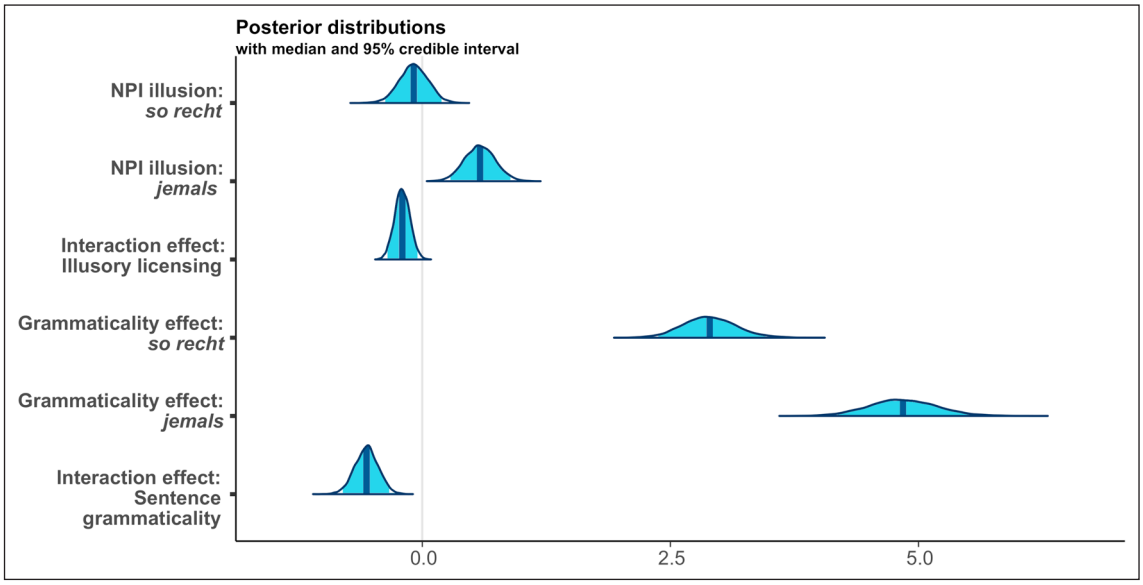

Figure 4: Posterior distributions for all fixed effects. The dark blue line shows the median posterior effect estimate; the light blue area indicates the 95% credible interval.

To quantify the evidence in favour of NPI illusion effects for *jemals* and *so recht*, as well as for their interaction, I again conducted Bayes factor analyses following the same procedure as outlined for Experiment 1. The analyses suggested very strong evidence for an NPI illusion with *jemals* ($BF_{10} = 987.4$), and moderate evidence for the null hypothesis (i.e., no NPI illusion) for *so recht* ($BF_{10} = 0.33$). They further indicated moderate evidence in favour of the interaction effect predicted under asymmetric NPI illusion profiles ($BF_{10} = 6.54$).

3.1.6 Discussion

The results of Experiment 2 reliably confirm the NPI illusion effect for *jemals* while providing evidence *against* the NPI illusion with *so recht*. In addition, the observed means on the grammatical baseline conditions for both NPIs are more comparable than before, which resolves some of the questions around the comparison between *jemals* and *so recht* raised after Experiment 1. While ungrammatical baseline instances of *so recht* continue to be accepted at a higher rate than the corresponding condition with *jemals*, this may be attributable to pragmatic differences in the informativity of propositions containing unlicensed instances of strengthening and attenuating NPIs, as noted in the discussion of Experiment 1. Note also that the posterior distributions for all effects are generally compatible with those obtained in the previous experiment. The most important change in the results is that the increased sample size led to higher precision in the posterior estimates, which in turn enables stronger conclusions on the true effect sizes. Experiment 2 thereby succeeds in providing clear evidence in favour of asymmetric NPI illusion profiles for attenuating and strengthening NPIs,

such that only the latter display illusory licensing from negative quantifiers inside an RC. As far as the secondary change in the experiment is concerned, namely, the switch to object-extracted RCs and the reduction in the speed of word presentation, these factors did not lead to any substantial alterations to the estimated effects. In particular, object-extracted RCs did not increase the estimated size of the NPI illusion effect for *jemals*, in line with Orth et al.'s (2020a) results for English *ever*.

4. General discussion

The above experiments aimed to shed light on NPI illusions by contrasting two NPIs whose licensing mechanisms arguably differ. Altogether, both experiments replicate the NPI illusion previously observed for German *jemals* but show no illusion for the attenuating NPI *so recht*. Since neither the cue-based retrieval, quantifier scope, nor pragmatic rescuing account of NPI illusions predict that the two types of NPIs should differ in their illusory licensing profiles (see the end of Section 1.2), this challenges these accounts or at least puts into question whether they are applicable to NPIs in general, or instead restricted only to strengthening NPIs like *ever* or *jemals*. Alternatively, the present findings favour accounts that emphasise the semantic/pragmatic properties of the (illusory) licensing context. Below, I argue in favour of an environment-based account of NPI illusions inspired by Muller and Phillips (2020). Specifically, I propose that NPI illusions are a consequence of a scalar licensing mechanism that is intercepted in the presence of a nearby clausal context of appropriate scalar strength.

Before turning to that proposal, it deserves to be emphasised that whether and to what extent the present findings generalise to other NPIs needs to be further investigated. The implications drawn from the present study are based on the comparison of just one representative NPI from each subtype. In principle, the empirical results may therefore relate to differences between these two NPIs that have nothing to do with their strengthening or attenuating nature, although care was taken to match the tested NPIs as closely as possible. *Jemals*, for instance, is more frequent and appears to be acquired earlier during childhood than *so recht* (see Schwab et al., 2021, for corpus and experimental data on their frequency and acquisition). Although such differences have not been discussed with respect to the NPI illusion so far (and will not play a role in my account), they deserve attention in future investigations. In the following, I outline a potential explanation of my empirical findings that aims to provide a systematic account of NPI illusions with strengthening and attenuating NPIs based on the theoretical linguistic literature. To further test this and other proposals of the NPI illusion, however, it is imperative that future work expand the empirical landscape by testing for NPI illusions in a range of additional languages, constructions, and with other strengthening and attenuating NPIs. Indeed, the need to replicate NPI illusions on a broader scale holds true across the literature, which has so far narrowly focused on just a few NPIs (e.g., *ever*, *any*, *jemals*, *kimse* 'anybody') and licensing contexts. The predictions generated by the following proposal may act as a steppingstone to inspire further work.

Having taken this into consideration, I propose that the observed difference between *jemals* and *so recht* is a direct result of an interaction between the respective scalar (licensing) mechanisms invoked by strengthening and attenuating NPIs and scalar properties of the RC. Specifically, as outlined in section 1.2, scalar approaches to polarity sensitivity contend that NPIs like *ever* or *jemals* are licensed in contexts in which they render the assertion stronger than its lexically evoked alternatives (Chierchia, 2006; Israel, 1996; Kadmon & Landman, 1993; Krifka, 1995). This relation is arguably reversed for attenuating NPIs, which are restricted to contexts in which the asserted proposition is weaker than its alternative(s) (Israel, 1996, 2011; Schwab & Liu, to appear). Under scalar accounts, NPIs thus (a) lexically evoke alternatives, for instance, more specific time points for *ever/jemals* or alternative degrees for *all that/so recht*, and (b) trigger an operation that evaluates the informational strength of the asserted proposition in relation to its triggered alternatives (see (5) and (6), although my proposal is in principle compatible with other formalisations of this mechanism). Notably, as the latter mechanism operates over propositions, it either needs to be delayed until the end of the sentence or has to operate over underspecified sentence representations. EEG studies on the processing of NPIs attest to an immediate neurophysiological response to unlicensed NPIs, commonly resulting in a biphasic N400/P600 pattern indicative of semantic and syntactic violations (Liu et al., 2019; Xiang et al., 2016; Yanilmaz & Drury, 2018; Yurchenko et al., 2013). I therefore assume that the licensing of NPIs is determined during incremental sentence processing, albeit based on an underspecified propositional representation.

The assumption that scalar NPIs trigger a mechanism that relates the asserted proposition to its alternatives invites the question whether this mechanism could be subverted by the co-activation of other scalar propositions. Note that RCs containing negative quantifiers instantiate such a context: The quantifier *no* (also *not a single*, *very few*, *not any*, which elicit NPI illusions: De Dios Flores et al., 2017; Muller et al., 2019; Orth et al., 2020a) is a negative scalar element situated at the endpoint of a Horn scale (Horn, 1972). As such, it optionally activates its scale mates (Chierchia, 2004; Repp & Spalek, 2021; Singh, 2019). According to Horn (1972), direct alternatives to *no/none* are other quantifiers situated on the negative scale, e.g., *few* or *not all*. Thus, in (1a), for instance, the negative scalar quantifier *no* in the RC asserting that *no client trusted the lawyer* may optionally trigger alternatives such as *few/not all clients trusted the lawyer*. Note further that in doing so, the proposition with the negative quantifier is stronger than any of those alternatives. This is an exact reflection of how the NPI-containing proposition and its alternatives need to relate to each other to license strengthening NPIs, whereas it does not reflect the relation in informational strength required to license attenuating NPIs.

I propose that NPI illusions emerge because the RC proposition and its scalar alternatives are still highly activated when an NPI appears shortly after the RC boundary. The NPI itself evokes a set of scalar alternatives, which triggers a scalar licensing mechanism taking a proposition *p*

and structured alternatives Alt(*p*) as its arguments. On most instances, the parser will correctly supply this mechanism with the NPI-containing proposition together with its lexically evoked alternatives. Shortly after the offset of an RC containing a scalar element, however, there may be increased competition around the relevant set of propositions, rendering the parser susceptible to mistakes. This is because the processing of an RC proposition containing a scalar element may immediately trigger the computation of its scalar alternatives (cf. Chierchia, 2004, with respect to a theoretical perspective on the computation of embedded scalar meanings). Encountering an NPI shortly after having moved out of this propositional context renders both the main clause (NPI-containing) proposition and its scalar alternatives and the embedded RC proposition together with its alternatives highly salient. On some instances, depending on fluctuating activation levels for the relevant representations, therefore, the parser may correctly activate the scalar licensing mechanism that is triggered by the presence of scalar alternatives, but may falsely supply the scalar RC proposition and its alternatives as the relevant arguments to this mechanism. In consequence, for strengthening NPIs, the mechanism invoked by the presence of scalar alternatives determines that the asserted proposition (in this case, the RC containing a negative quantifier) is stronger than its scalar alternatives. The proposition is therefore held to be assertable, the NPI *ipso facto* licensed. Of course, with increased time, the parser may re-evaluate this decision, ultimately concluding that the NPI is not licensed. For attenuating NPIs, the same process occurs, yet the fact that the RC proposition is stronger than its alternatives goes contrary to the underlying licensing requirement. As such, the attenuating NPI will be (correctly) classified as unlicensed, even though that conclusion happens to be based on the wrong proposition. Note, with regard to the theoretical accounts this proposal is based on, that most scalar approaches to NPI licensing assume that it is a component of the NPI's lexical semantics to obligatorily evoke a set of scalar alternatives. It is the presence of such alternatives, in turn, that is assumed to trigger a mechanism that operates over a proposition (typically the NPI-containing one) and its alternatives and restricts the proposition's assertability to contexts in which it stands in a particular (informativity-based) relation to its scalar alternatives. As such, the licensing mechanism is at least partially dissociated from the activation of lexically evoked alternatives to the NPI, thus arguably opening the door for NPI illusion effects as outlined above.

Muller and Phillips (2020, p. 688) have previously argued that comprehenders mistake the RC context for the licensing context of the NPI and that NPI illusions are restricted to negative quantifiers because they make "strong, negative claims". This left unspecified a principled explanation as to why strong negative claims should be *necessary* for NPI illusions and does not capture why attenuating NPIs would be immune to this. The present proposal builds on their general idea that the scalar strength of the RC matters, but specifies an account that straightforwardly explains why NPI illusions are restricted to strengthening NPIs (because of their particular scalar licensing mechanism), captures the fact that the illusion only emerges for NPIs

appearing shortly after the RC boundary (because the scalar RC meaning and its alternatives are still highly salient), and is compatible with the illusion's restriction to quantificational licensors (because they are scalar elements).

Lastly, the proposed account is falsifiable on the basis of a series of predictions: For one, it predicts that NPI illusions are restricted to intrusive propositional environments whose scalar structure reflects the scalar strength required by the respective NPI. As such, NPI illusions (a) need not be restricted to quantificational scalar RCs and (b) are predicted to re-emerge for attenuating NPIs provided that the RC environment contains a scalar proposition that is weaker than its alternatives. An immediate challenge to the former prediction is provided by Orth et al. (2020a), who report a lack of NPI illusions from RCs containing *never*. *Never* is a scalar element that is stronger than its evoked alternatives (*not this week, not this year*). Thus, on my account, an RC proposition containing *never* is predicted to give rise to NPI illusions for strengthening NPIs – contrary to the reported finding. In defence of my proposal, these findings will need to be empirically fortified with replication studies testing other strengthening NPIs. For the tested NPI *ever*, a lack of NPI illusions from a scalar RC proposition containing *never* may well be compatible with my proposal as both the matrix and the RC proposition activate alternatives on the temporal scale. Re-activating one of these propositions along with its lexically evoked scalar alternatives may always spread activation to the other proposition on the same scale, thus rendering it less likely that a comprehender would falsely reactivate and supply the RC proposition (and its alternatives) to the licensing mechanism and simultaneously ignore the main clause proposition.

In relation to both the former and the latter prediction, a crucial question is whether it matters that the intrusive RC in typical NPI illusion constructions contains a lexically negative (potentially NPI licensing) element. On the proposed account, this is not assumed to play a role – instead, all scalar environments of appropriate strength are predicted to lead to illusory licensing. However, it is possible, as hinted at in Section 1.2, that comprehenders sometimes rely on heuristics, such as the presence of a lexically negative element directly preceding the NPI, in addition to the proper licensing mechanism. Although the findings of previous studies on NPI illusion, the present study included, suggest that reliance on such heuristics is not sufficient to explain the NPI illusion, their co-activation along with the proper licensing mechanism could increase the susceptibility to illusory licensing from lexically negative elements. If that is the case, NPI illusions are predicted to be weaker or absent with (appropriately structured) scalar environments that are non-negative; otherwise, negativity of the scalar environment should not matter.

Finally, NPIs show substantial distributional variation (see Schaebbicke et al., 2021 on variation among German NPIs), suggesting that their licensing constraints may not be uniform. In the theoretical literature, Giannakidou (1998, 2006, 2007), for instance, has advocated for a variation approach to polarity sensitivity. Crucially, not all NPIs may be scalar in nature.

The present account aims to provide an explanation for NPI illusions with strengthening and attenuating NPIs. If such illusions are found for non-scalar NPIs, I contend that these effects must be based on a different mechanism.

In summary, I have shown that the attenuating NPI *so recht* is not susceptible to illusory licensing from negative quantifiers, have argued that this challenges current accounts of the illusion, and have proposed an account that attributes the source of the NPI illusion to scalar licensing mechanisms interacting with the scalar RC environment. My proposal (i) tacitly endorses scalar approaches to polarity sensitivity—at least for the subset of NPIs that have been tested so far, and (ii) assumes that the sentence processing mechanism engaged on-line reflects the theoretically postulated licensing constraint. It also establishes a new set of predictions that may stimulate a broad-scale cross-linguistic evaluation of NPI illusions for strengthening and attenuating NPIs in scalar and non-scalar intrusive environments.

Data availability statement

All stimulus materials, code and data associated with the study (including supplementary materials) are available at the following repository: https://osf.io/s9rt8/.

Ethics and consent

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments. Informed consent was obtained from all individual participants included in the study. The study was approved by the ethics committee of Osnabrück University.

Funding Information

This work was funded by the DFG-funded Research Training Group "Computational Cognition" (DFG-GRK 2340).

Acknowledgements

This work has benefitted from valuable comments of the audiences at AMLaP 2021 and the workshop "Linguistic Illusions in Sentence Processing". I thank Mingya Liu for insightful discussions and for comments on a previous version of this manuscript. Finally, I gratefully acknowledge the valuable insights from the anonymous reviewers of this manuscript, whose feedback substantially improved its contents.

Competing interests

The author has no competing interests to declare.

References

Bader, M., & Häussler, J. (2009). Resolving number ambiguities during language comprehension. *Journal of Memory and Language*, *61*(3), 352–373. DOI: https://doi.org/10.1016/j.jml.2009.05.005

Bürkner, P. C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software*, *80*(1), 1–28. DOI: https://doi.org/10.18637/jss.v080.i01

Chierchia, G. (2004). Scalar implicatures, polarity phenomena and the syntax/pragmatics interface. In A. Beletti (Ed.), *Structures and Beyond* (pp. 39–109). Oxford University Press.

Chierchia, G. (2006). Broaden your views: Implicatures of domain widening and the 'logicality' of language. *Linguistic Inquiry*, *37*(4), 535–590. DOI: https://doi.org/10.1162/ling.2006.37.4.535

Clifton Jr., C., Frazier, L., & Deevy, P. (1999). Feature manipulation in sentence comprehension: 2703. *Rivista Di Linguistica*, *11*(1), 11–40.

Condoravdi, C. (2010). NPI licensing in temporal clauses. *Natural Language & Linguistic Theory*, *28*(4), 877–910. DOI: https://doi.org/10.1007/s11049-010-9115-z

De Dios Flores, I., Muller, H., & Phillips, C. (2017). *Negative polarity illusions: Licensors that don't cause illusions, and blockers that do*. Poster presented at the 30th Annual CUNY Conference on Human Sentence Processing, Cambridge, MA.

Dillon, B., Mishler, A., Sloggett, S., & Phillips, C. (2013). Contrasting intrusion profiles for agreement and anaphora: Experimental and modeling evidence. *Journal of Memory and Language*, *69*(2), 85–103. DOI: https://doi.org/10.1016/j.jml.2013.04.003

Drenhaus, H., Frisch, S., & Saddy, D. (2005). Processing negative polarity items: When negation comes through the backdoor. In S. Kepser & M. Reis (Eds.), *Linguistic evidence—Empirical, theoretical, and computational perspectives* (pp. 145–164). Mouton de Gruyter. DOI: https://doi.org/10.1515/9783110197549.145

Drummond, A. (2013). *Ibex farm*. http: spellout.net/ibexfarm

Engelmann, F., Jäger, L. A., & Vasishth, S. (2019). The effect of prominence and cue association on retrieval processes: A computational account. *Cognitive Science*, *43*(12). DOI: https://doi.org/10.1111/cogs.12800

Giannakidou, A. (1998). Polarity sensitivity as (non) veridical dependency. In *Linguistik Aktuell/Linguistics Today*. John Benjamins. DOI: https://doi.org/10.1075/la.23

Giannakidou, A. (2006). *Only*, emotive factive verbs, and the dual nature of polarity dependency. *Language*, *82*(3), 575–603. DOI: https://doi.org/10.1353/lan.2006.0136

Giannakidou, A. (2007). The landscape of EVEN. *Natural Language & Linguistic Theory*, *25*(1), 39–81. DOI: https://doi.org/10.1007/s11049-006-9006-5

Hammerly, C., Staub, A., & Dillon, B. (2019). The grammaticality asymmetry in agreement attraction reflects response bias: Experimental and modeling evidence. *Cognitive Psychology*, *110*, 70–104. DOI: https://doi.org/10.1016/j.cogpsych.2019.01.001

Horn, L. R. (1972). *On the semantic properties of logical operators in English*. PhD thesis. University of California, Los Angeles.

Israel, M. (1996). Polarity sensitivity as lexical semantics. *Linguistics and Philosophy*, *19*(6), 619–666. DOI: https://doi.org/10.1007/BF00632710

Israel, M. (2011). *The grammar of polarity: Pragmatics, sensitivity, and the logic of scales*. Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511975288

Jäger, L. A., Engelmann, F., & Vasishth, S. (2015). Retrieval interference in reflexive processing: Experimental evidence from Mandarin, and computational modeling. *Frontiers in Psychology*, *6*. DOI: https://doi.org/10.3389/fpsyg.2015.00617

Jäger, L. A., Mertzen, D., Van Dyke, J. A., & Vasishth, S. (2020). Interference patterns in subject-verb agreement and reflexives revisited: A large-sample study. *Journal of Memory and Language*, *111*. DOI: https://doi.org/10.1016/j.jml.2019.104063

Kadmon, N., & Landman, F. (1993). Any. *Linguistics and Philosophy*, *16*(4), 353–422. DOI: https://doi.org/10.1007/BF00985272

Krifka, M. (1995). The semantics and pragmatics of polarity items. *Linguistic Analysis*, *25*(3–4), 209–257. DOI: https://doi.org/10.3765/salt.v4i0.2462

Kruschke, J. K. (2011). *Doing Bayesian data analysis: A tutorial with R and BUGS*. Academic Press.

Kruschke, J. K., & Liddell, T. M. (2018). The Bayesian new statistics: Hypothesis testing, estimation, meta-analysis, and power analysis from a Bayesian perspective. *Psychonomic Bulletin and Review*, *25*(1), 178–206. DOI: https://doi.org/10.3758/s13423-016-1221-4

Ladusaw, W. A. (1979). *Polarity sensitivity as inherent scope relations*. PhD thesis. University of Texas.

Lakens, D. (2014). Performing high-powered studies efficiently with sequential analyses. *European Journal of Social Psychology*, *44*(7), 701–710. DOI: https://doi.org/10.1002/ejsp.2023

Lewis, R. L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science*, *29*(3), 375–419. DOI: https://doi.org/10.1207/s15516709cog0000_25

Linebarger, M. C. (1987). Negative polarity and grammatical representation. *Linguistics and Philosophy*, *10*(3), 325–387. DOI: https://doi.org/10.1007/BF00584131

Liu, M., König, P., & Mueller, J. L. (2019). Novel ERP evidence for processing differences between negative and positive polarity items in German. *Frontiers in Psychology*, *10*, 376. DOI: https://doi.org/10.3389/fpsyg.2019.00376

Marian, V., Bartolotti, J., Chabal, S., & Shook, A. (2012). Clearpond: Cross-linguistic easy-access resource for phonological and orthographic neighborhood densities. *PLoS ONE*, *7*(8), e43230. DOI: https://doi.org/10.1371/journal.pone.0043230

Moerbeek, M. (2021). Bayesian updating: Increasing sample size during the course of a study. *BMC Medical Research Methodology*, *21*(1), 137. DOI: https://doi.org/10.1186/s12874-021-01334-6

Muller, H., De Dios Flores, I., & Phillips, C. (2019). *Not (just) any licensors cause negative polarity illusions*. Poster presented at the 32nd Annual CUNY Conference on Human Sentence Processing, Boulder, CO.

Muller, H., Joly, C., De Dios Flores, I., Resnik, P., & Phillips, C. (2020). *Timing and (mis) interpretation of NPI illusions*. Poster presented at the 33rd Annual CUNY Conference on Human Sentence Processing, Amherst, MA.

Muller, H., & Phillips, C. (2020). Negative polarity illusions. In V. Déprez & M. T. Espinal (Eds.), *The Oxford handbook of negation* (pp. 655–676). Oxford University Press. DOI: https://doi.org/10.1093/oxfordhb/9780198830528.013.42

Orth, W., & Yoshida, M. (2022). *NPI and PPI illusion: A multi-methodological investigation*. Poster presented at the 35th Annual Conference on Human Sentence Processing, Santa Cruz, CA.

Orth, W., Yoshida, M., & Sloggett, S. (2020a). Negative polarity item (NPI) illusion is a quantification phenomenon. *Journal of Experimental Psychology: Learning Memory and Cognition*. DOI: https://doi.org/10.1037/xlm0000957

Orth, W., Yoshida, M., & Sloggett, S. (2020b). *Polarity illusions are quantifier illusions*. Poster presented at the 26th Architectures and Mechanisms for Language Processing AMLaP Conference. Potsdam, Germany.

Parker, D. (2019). Cue combinatorics in memory retrieval for anaphora. *Cognitive Science*, *43*, e12715. DOI: https://doi.org/10.1111/cogs.12715

Parker, D., & Phillips, C. (2016). Negative polarity illusions and the format of hierarchical encodings in memory. *Cognition*, *157*, 321–339. DOI: https://doi.org/10.1016/j.cognition.2016.08.016

Patil, U., Vasishth, S., & Lewis, R. L. (2016). Retrieval interference in syntactic processing: The case of reflexive binding in English. *Frontiers in Psychology*, *7*. DOI: https://doi.org/10.3389/fpsyg.2016.00329

Patson, N. D., & Husband, E. M. (2016). Misinterpretations in agreement and agreement attraction. *Quarterly Journal of Experimental Psychology*, *69*(5), 950–971. DOI: https://doi.org/10.1080/17470218.2014.992445

Pearlmutter, N. J., Garnsey, S. M., & Bock, K. (1999). Agreement processes in sentence comprehension. *Journal of Memory and Language*, *41*(3), 427–456. DOI: https://doi.org/10.1006/jmla.1999.2653

R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

Repp, S., & Spalek, K. (2021). The role of alternatives in language. *Frontiers in Communication*, *6*, 111. DOI: https://doi.org/10.3389/fcomm.2021.682009

Sailer, M., & Trawinski, B. (2006). The collection of distributionally idiosyncratic items: A multilingual resource for linguistic research. *Proceedings of the 5th International Conference on Language Resources and Evaluation, LREC 2006*, 471–474.

Schaebbicke, K., Seeliger, H., & Repp, S. (2021). The diverse landscape of negative polarity items: On the use of German NPIs as experimental diagnostics. *Journal of Psycholinguistic Research*, *50*, 1461–1486. DOI: https://doi.org/10.1007/s10936-021-09793-0

Schönbrodt, F. D., & Wagenmakers, E. J. (2018). Bayes factor design analysis: Planning for compelling evidence. *Psychonomic Bulletin and Review*, *25*(1), 128–142. DOI: https://doi.org/10.3758/s13423-017-1230-y

Schönbrodt, F. D., Wagenmakers, E. J., Zehetleitner, M., & Perugini, M. (2017). Sequential hypothesis testing with Bayes factors: Efficiently testing mean differences. *Psychological Methods*, *22*(2), 322–339. DOI: https://doi.org/10.1037/met0000061

Schwab, J., & Liu, M. (to appear). Attenuating NPIs in indicative and counterfactual conditionals. In D. Gutzmann & S. Repp (Eds.), *Proceedings of Sinn und Bedeutung 26*. University of Cologne.

Schwab, J., & Liu, M. (2022). Processing attenuating NPIs in indicative and counterfactual conditionals. *Frontiers in Psychology*, *13*, 3083. DOI: https://doi.org/10.3389/fpsyg.2022.894396

Schwab, J., Liu, M., & Mueller, J. L. (2021). On the acquisition of polarity items: 11- to 12-year-olds' comprehension of German NPIs and PPIs. *Journal of Psycholinguistic Research*, *50*, 1487–1509. DOI: https://doi.org/10.1007/s10936-021-09801-3

Singh, R. (2019). Context, content, and the occasional costs of implicature computation. *Frontiers in Psychology*, *10*(OCT), 2214. DOI: https://doi.org/10.3389/fpsyg.2019.02214

Staub, A. (2009). On the interpretation of the number attraction effect: Response time evidence. *Journal of Memory and Language*, *60*(2), 308–327. DOI: https://doi.org/10.1016/j.jml.2008.11.002

Vasishth, S., Brussow, S., Lewis, R., & Drenhaus, H. (2008). Processing polarity: How the ungrammatical intrudes on the grammatical. *Cognitive Science*, *32*(4), 685–712. DOI: https://doi.org/10.1080/03640210802066865

Vasishth, S., Mertzen, D., Jäger, L. A., & Gelman, A. (2018). The statistical significance filter leads to overoptimistic expectations of replicability. *Journal of Memory and Language*, *103*, 151–175. DOI: https://doi.org/10.1016/j.jml.2018.07.004

Xiang, M., Dillon, B., & Phillips, C. (2009). Illusory licensing effects across dependency types: ERP evidence. *Brain and Language*, *108*(1), 40–55. DOI: https://doi.org/10.1016/j.bandl.2008.10.002

Xiang, M., Grove, J., & Giannakidou, A. (2013). Dependency-dependent interference: NPI interference, agreement attraction, and global pragmatic inferences. *Frontiers in Psychology*, *4*. DOI: https://doi.org/10.3389/fpsyg.2013.00708

Xiang, M., Grove, J., & Giannakidou, A. (2016). Semantic and pragmatic processes in the comprehension of negation: An event related potential study of negative polarity sensitivity. *Journal of Neurolinguistics*, *38*, 71–88. DOI: https://doi.org/10.1016/j.jneuroling.2015.11.001

Yanilmaz, A., & Drury, J. E. (2018). Prospective NPI licensing and intrusion in Turkish. *Language, Cognition and Neuroscience*, *33*(1), 111–138. DOI: https://doi.org/10.1080/23273798.2017.1371779

Yun, J., Lee, S. Y., & Drury, J. (2017). Negative polarity illusion in Korean. *Proceedings of WAFL 13*.

Yurchenko, A., den Ouden, D. B., Hoeksema, J., Dragoy, O., Hoeks, J. C. J., & Stowe, L. A. (2013). Processing polarity: ERP evidence for differences between positive and negative polarity. *Neuropsychologia*, *51*(1), 132–141. DOI: https://doi.org/10.1016/j.neuropsychologia.2012.10.028

Zehr, J., & Schwarz, F. (2018). *PennController for Internet Based Experiments (IBEX)*. DOI: https://doi.org/10.17605/OSF.IO/MD832