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POLARITY PARTICLES AND THE ANATOMY OF N-WORDS*

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1 Introduction

Two major approaches to n-words, e.g., *no* and *never* in (1) below, have been pursued in the previous literature. The negative indefinite (NI) approach takes n-words to be indefinite expressions within the scope of a sentential negation operator (Penka, 2007, Zeijlstra, 2004, Tubau, 2008:a.o.) and analyzes sentence (1a) below as shown in (2). The negative quantifier (NQ) approach takes n-words to be negative quantifiers occurring in otherwise positive sentences (Zanuttini, 1991, Haegeman, 1995:a.o.) and proposes an analysis along the lines of (3).[1]

(1) a. *No* student stepped forward.
 b. Susan *never* saw this movie.

(2) $\neg\exists x(student'(x) \wedge step\text{-}forward'(x))$

(3) $Nx(student'(x) \wedge step\text{-}forward'(x))$

If we had a way to detect the presence of sentential negation, it would be possible to tease these two approaches apart. The crucial starting point for this paper is the observation that sentential negation affects the distribution of polarity particles (*yes*, *no*) in confirming responses to a previously made assertion:[2]

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[1]From the point of view of this paper, de Swart and Sag (2002) fall under the NI analysis in that for them the same polyadic negative quantifier occurs in both ordinary negative sentences and sentences involving n-words in English, the only difference between them being the addicity of this quantifier. We are concerned here with differentiating analyses where n-words and sentential negation are treated as involving essentially the same operator and analyses in which they are not. For the sake of simplicity we refer to the former as NI and to the latter as NQ approaches.

[2]See Kramer and Rawlins (2009) for discussion related to this point.

(4) a. A: Paul stepped forward.
    b. B: Yes / *No, Paul stepped forward.

(5) a. A: Paul did not step forward.
    b. B: Yes / No, Paul did not step forward.

Thus, the NI approach – but not the NQ approach – predicts that sentences with n-words like (6) pattern with negative sentences like (5) above rather than with positive sentences like (4):

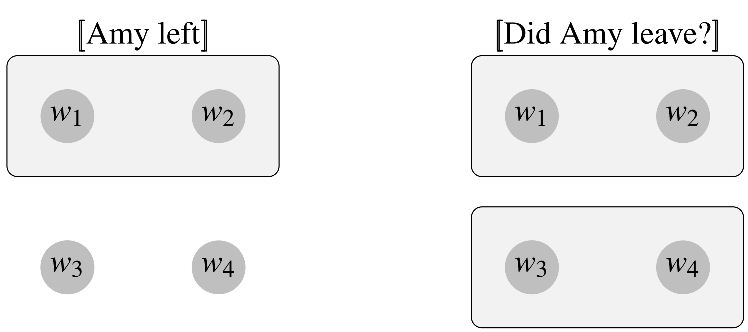
(6) a. A: No student stepped forward.
    b. B: Yes / No, no student stepped forward.

The two main goals of this paper are (*i*) to test whether sentential negation indeed affects the distribution of polarity particles as indicated in (4) and (5) and (*ii*) to test whether the prediction made by the NI theory is borne out. After a brief outline of the grammar of polarity particles in section 2, section 3 describes an experiment testing polarity particle patterns in responses to sentences without n-words, section 4 describes an experiment testing polarity particle patterns in responses to sentences with n-words and section 5 concludes. The appendix provides more details about the statistical modeling of the data.

2 The grammar of polarity particles

Polarity particles occur in responses to both assertions – *Amy left. {Yes, she did. / No, she didn't.}* – and polar questions – *Did Amy leave? {Yes, she did. / No, she didn't.}*. We take both assertions and polar questions to express proposals to update the common ground of a conversation in one or more ways (Groenendijk and Roelofsen, 2009, Farkas and Bruce, 2010:a.o.). Polarity particles in turn are seen as marking certain types of responses to a given proposal.

To flesh out this basic idea, we need to formally characterize a suitable notion of proposals and specify how polarity particles are interpreted given the proposal they address. We work within the framework of inquisitive semantics, which takes the proposition expressed by a sentence to capture not simply its informative / truth-conditional content, but more generally, the proposal made when uttering that sentence. Propositions represent a set of one or more potential updates of the common ground and are defined as sets of possibilities, where each possibility is a set of possible worlds. The figures below exemplify the propositions expressed by an assertion and a question: w_1 and w_2 are worlds where Amy left and w_3 and w_4 are worlds where Amy did not leave. The proposition expressed by a sentence φ is denoted by $[\varphi]$.

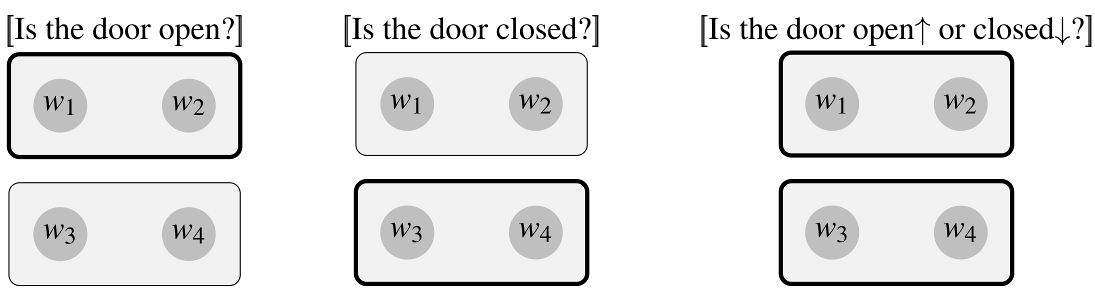


In uttering a sentence φ, a speaker (*i*) provides the information that the actual world is contained in at least one of the possibilities in $[\varphi]$, and (*ii*) requests a response from other participants that provides enough information to establish at least one of the proposed updates.

For many purposes, it is sufficient to simply represent proposals as sets of possibilities. But to account for the distribution and interpretation of polarity particles, we need a more fine-grained representation. To see this, consider the following three questions below. The propositions expressed by these questions consist of the same two possibilities, the possibility that the door is open and the possibility that the door is closed. However, polarity particles used in responses to these questions have a different distribution and interpretation.

(7)	Is the door open?	Yes ⇒ open	/	No ⇒ closed
(8)	Is the door closed?	Yes ⇒ closed	/	No ⇒ open
(9)	Is the door open↑ or closed↓?	# Yes	/	# No

In order to capture these contrasts, we make a distinction between highlighted and non-highlighted possibilities (Roelofsen and van Gool, 2010, Pruitt and Roelofsen, 2011, Farkas, 2011, Farkas and Roelofsen, 2011). Intuitively, highlighted possibilities are foregrounded and are explicitly mentioned: (7) highlights the possibility that the door is open, (8) highlights the possibility that the door is closed and (9) highlights both of these possibilities. This is depicted in the figures below, where w_1 and w_2 are worlds where the door is open while w_3 and w_4 are worlds where the door is closed; highlighted possibilities are displayed with a thick border.



Highlighted possibilities serve as antecedents for subsequent anaphoric expressions – and polarity particles are such anaphoric expressions. As a first step then, we assume that a *yes* answer to an initiative ψ presupposes that there is exactly one highlighted alternative for ψ and if this presupposition is met, *yes* confirms the highlighted alternative. A *no* answer simply rejects all the highlighted possibilities for ψ.

This enables us to account for the contrast between (7), (8), and (9). In the case of (7), there is exactly one highlighted alternative so *yes* is licensed and it confirms the highlighted alternative, conveying that the door is open; *no* is also licensed and it denies the highlighted alternative conveying that the door is closed. In the case of (8), there is again exactly one highlighted alternative and the reasoning goes through just as before except that the highlighted alternative is different. Finally, in the case of (9), there are two highlighted alternatives so *yes* is not licensed because its presupposition is not met and *no* is infelicitous because it signals that the door is neither open nor closed, which is contradictory.

Treating polarity particles as anaphoric to highlighted possibilities makes two additional correct predictions: (*i*) they can only be used in responses, not 'out of the blue', and (*ii*) they cannot be used in response to *wh*-questions, assuming that such questions do not highlight any possibilities.

However, the distinction between highlighted and non-highlighted possibilities is not sufficient for a full account of polarity particles. The two sentences below are entirely equivalent in the system considered so far: they express the same proposition and highlight the same possibility. However, they do not license the same polarity particles.

(10) Susan failed the exam. Yes, she failed. / *No, she failed.

(11) Susan didn't pass the exam. Yes, she didn't pass. / No, she didn't pass.

This contrast can only be accounted for semantically if we make our notion of propositions / proposals even more fine-grained: we will make a distinction between positive and negative possibilities (see Farkas and Roelofsen 2011). Negative possibilities are introduced by sentential negation. That is, $[\![\text{not } \varphi]\!]$ consists of a single highlighted and negative $[\text{H},-]$ possibility: the complement of $\bigcup[\![\varphi]\!]$. For instance, (11) above expresses a proposition consisting of a single $[\text{H},-]$ possibility. In contrast, (10) express a proposition consisting of a single $[\text{H},+]$ possibility.

Polarity particles in English do double duty: they may signal whether the antecedent possibilities are confirmed or rejected or whether the antecedent possibilities are supposed to be positive or negative.[3] In (10), *yes* signals that the response is confirming or that the antecedent is positive; *no* is not licensed because it can only be used to signal that the response is rejecting or that the antecedent is negative, and neither is the case here. In (11), *yes* can be used because it signals confirmation, while *no* can be used because it signals that the antecedent is negative.

To capture the idea that polarity particles do double duty, we assume that they are used to realize either an absolute or a relative polarity feature (see Pope 1976, Farkas and Bruce 2010, Farkas 2010, Farkas and Roelofsen 2011). An absolute polarity feature marks a response as being positive or negative ($[+]$ or $[-]$), while a relative polarity feature marks a response as having the same absolute polarity as the antecedent or the reverse ([SAME] or [REVERSE]). Thus, there are four possible feature value combinations:

	response	relation with antecedent
[SAME,+]	$+$	same
[SAME,−]	$-$	same
[REVERSE,+]	$+$	reverse
[REVERSE,−]	$-$	reverse

We take polarity features to be hosted by a syntactic node PolP, which always attaches to a clausal node that we call its prejacent. The prejacent may be partially or fully elided. Alternatively, a fully elided prejacent can be treated as a null pro-sentence.

We take the semantic contribution of features in PolP to be purely presuppositional. If the presuppositions of PolP are met, it contributes the identity function $\lambda p.\ p$:

- [SAME,+] presupposes a unique [H,+] alternative α on the Table and presupposes that its prejacent confirms this alternative ($[\![\text{prejacent}]\!] = \{\alpha_{[+]}\}$)[4]

[3] The issue of whether the response signals information relevant to the polarity of the antecedent or the response itself is immaterial for English and therefore we ignore it here. For data showing that the polarity of the response is relevant, see Farkas (2010).

[4] We assume a discourse model of the kind specified in Farkas and Roelofsen (2011), building on Farkas and Bruce (2010). In this model, a discourse context includes a stack of propositions called the Table representing the proposals

- [SAME,−] presupposes a unique [H,−] alternative α on the Table and presupposes that its prejacent confirms this alternative ($[\![\text{prejacent}]\!] = \{\alpha_{[-]}\}$)
- [REVERSE,+] presupposes a non-empty set of [H,−] alternatives A on the Table and presupposes that its prejacent rejects all these alternatives ($[\![\text{prejacent}]\!] = \{\overline{\bigcup A}_{[+]}\}$)
- [REVERSE,−] presupposes a non-empty set of [H,+] alternatives A on the Table and presupposes that its prejacent rejects all these alternatives ($[\![\text{prejacent}]\!] = \{\overline{\bigcup A}_{[-]}\}$)

Now that we have specified the semantic contribution of the polarity feature combinations, the next question to address is which particles can be used to realize which features. In English, [SAME] and [+] can be realized by *yes*, while [REVERSE] and [−] can be realized by *no*. That is, as mentioned above, polarity particles in English do double duty: they are used to realize both absolute and relative polarity features. Given a certain feature combination, features that are more marked have higher 'realization needs': (*i*) [−] is marked relative to [+]; (*ii*) [REVERSE] is marked relative to [SAME]; and (*iii*) the absolute polarity of [REVERSE] responses is marked because it contrasts with the polarity of the antecedent.

This account makes the following predictions for English:

(12) a. [SAME,+] can only be realized by *yes*.
b. [REVERSE,−] can only be realized by *no*.
c. [SAME,−] can be realized by *yes* or *no*.
d. [REVERSE,+] can be realized by *yes* or *no*.

(13) a. In the case of [SAME,−], we expect a preference for *no* over *yes* because [−] is more marked than [SAME].
b. In the case of [REVERSE,+], both features have high realization needs; across languages we see different strategies to satisfy these needs

In English, [REVERSE,+] polarity phrases must have an explicit prejacent with verum focus, reflecting the contrastive positive polarity of the response:

(14) A: Peter didn't call. B: Yes, he DID. / No, he DID.

In sum, the two points directly relevant to our current purposes are as follows. First, particle distribution is sensitive to whether the initiative is positive or negative. In [SAME] responses to positive initiatives, only *yes* can be used. In [SAME] responses to negative initiatives, both *yes* and *no* can be used. Second, the polarity of the initiative correlates with the presence of sentential negation rather than with lexical negativity – recall the contrast between (10) and (11) above. We can therefore use polarity particles as a probe to detect sentential negation.

3 Experiment 1: basic distribution of polarity particles

Experiment 1 is designed to test two basic predictions of the theory specified above: (*i*) in [SAME] responses to positive assertions, only *yes* can be used; and (*ii*) in [SAME] responses to negative assertions, both *yes* and *no* can be used.

under consideration. We refer to alternatives that are contained in the *first* proposition on the Table simply as the 'alternatives on the Table.'

Method. We used online questionnaires to test people's preferences for the particle *yes* or *no* when they agree with a previously made assertion. Two typical experimental items are provided below:

(15) This substance will prevent the clay from twisting. [stimulus]
  a. ☐ Yes, it will. [response option 1]
  b. ☐ No, it will. [response option 2]

(16) At most six volunteers did not sign up for free housing. [stimulus]
  a. ☐ Yes, at most six of them didn't. [response option 1]
  b. ☐ No, at most six of them didn't. [response option 2]

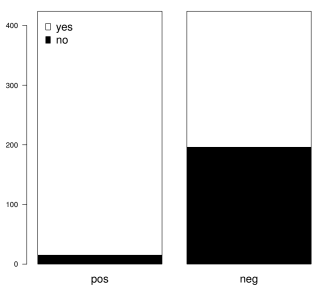
The dependent variable RESP encodes the choice of polarity particle in responses (factor with 2 levels: **yes**, **no**; 'success' level: **yes**). The three independent variables are as follows. First, STIM-POL encodes the polarity of the stimulus (factor with 2 levels: **pos**, **neg**; reference level: **pos**). If the stimulus is positive, we expect the subjects to overwhelmingly signal agreement with the particle *yes*; if the stimulus is negative, we expect the subjects to signal agreement with either *yes* or *no*. Second, NP-TYPE encodes the type of subject NP in the stimulus (factor with 4 levels: **ref**, **atmost**, **exactly**, **some**; reference level: **ref**). All stimuli have the structure 'subject + predication'; the subject NPs are referential or quantificational with 3 possible determiners: *some*, *at most n* and *exactly n*. We are interested in whether the referential vs. quantificational nature of the subject and their monotonicity properties affect particle choice. Finally, PART-POS encodes the position of the polarity particle in the response (factor with 2 levels: **ini**, **fin**; reference level: **ini**). The particle is placed either at the beginning of the response or at the end.

Item (15) above exemplifies the combination STIM-POL = **pos**, NP-TYPE = **ref**, PART-POS = **ini**, while item 16 exemplifies the combination STIM-POL = **neg**, NP-TYPE = **atmost**, PART-POS = **ini**.

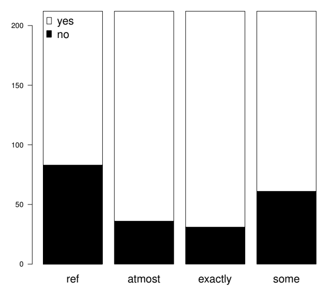
For each of the $16 = 2 \times 4 \times 2$ combinations, 3 stimulus sentences were generated for a total of 48. The sentences were randomly selected from the Brown Corpus and the Corpus of Contemporary American English and simplified in various ways (shortened etc.). A total of 53 subjects in an undergraduate class completed the online experiment for extra-credit. For each subject, we randomly selected 1 sentence for each of the 16 combinations. Total number of observations: $N = 53 \times 16 = 848$. We randomized both the order of the stimuli and the order of the two possible responses for each stimulus. The experiment presented in the next section together with another experiment with the same 'stimulus + choose 1 of 2 agreeing responses' format plus 7 items in which the responses disagreed with the stimulus were used as fillers.

Results. Barplots of STIM-POL by RESP and NP-TYPE by RESP are provided below, as well as a mosaic plot of NP-TYPE by STIM-POL by RESP.

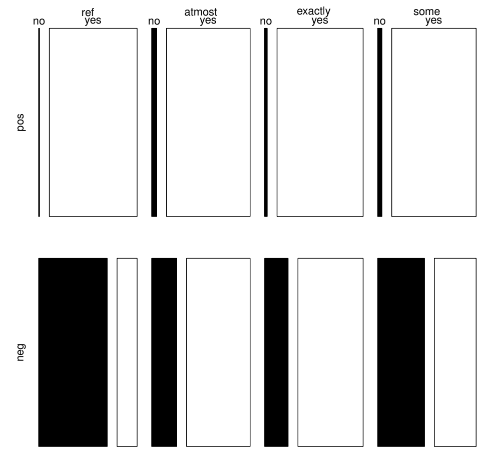
STIM-POL by RESP



NP-TYPE by RESP



NP-TYPE by STIM-POL by RESP



The main observation confirms our overall expectation: when the stimulus is positive, the response particle is overwhelmingly *yes* and when the stimulus is negative, the response particle is either *yes* or *no*.

We also see that when the stimulus is negative and the subject NP is referential, there is a preference for *no*; in contrast, when the stimulus is negative and the subject NP is *at most n* or *exactly n*, there is a preference for *yes* while a negative stimulus with a *some* subject NP exhibits no particular preference for either *yes* or *no*. At this point, we do not have an explanation for these fine-grained differences between the different kinds of subject NPs. Since these differences are not directly relevant to the goals of this paper, we will not discuss them further here.

Finally, the position of the particle in responses, e.g., *Yes, it will* versus *It will, yes*, was irrelevant for the choice of polarity particle, so we did not depict it graphically. This is as expected: particle choice was not predicted to depend on position.

Appendix A provides the details of the statistical analysis.

4 Experiment 2: polarity particles and n-words

Experiment 2 investigates whether sentences with n-words behave like negative sentences or like positive sentences with respect to the distribution of polarity particles in responses.

Method. Just as for experiment 1, we used online questionnaires to test whether people prefer to use *yes* or *no* in agreeing responses to a previously made assertion. Three examples of experimental items are provided below:

(17) None of the local bookstores are hiring full-time. [stimulus]
 a. ☐ Yes, none of them are. [response option 1]
 b. ☐ No, none of them are. [response option 2]

(18) The Neanderthals never crossed the Mediterranean. [stimulus]
 a. ☐ Yes, they never did. [response option 1]
 b. ☐ No, they never did. [response option 2]

(19) Infants sometimes do not learn to speak before the age of four. [stimulus]

a. ☐ Yes, they sometimes don't. [response option 1]
b. ☐ No, they sometimes don't. [response option 2]

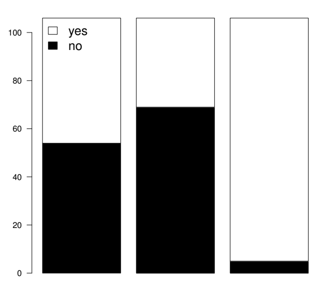
Just as before, the dependent variable RESP encodes choice of polarity particle in responses (factor with 2 levels: **yes**, **no**; 'success' level: *yes*). We have two independent variables. First, STIM-TYPE (factor with 3 levels: **some**, **none**, **somenot**; reference level: **somenot**) encodes the three types of stimuli we considered: (*i*) sentences with n-words but without sentential negation (**none**); (*ii*) sentences with an existential and sentential negation (**somenot**); and finally (*iii*) sentences with an existential and without sentential negation (**some**). If the stimulus is positive (STIM-TYPE = **some**), we expect that agreement is generally signaled with the particle *yes*. If the stimulus is negative (STIM-TYPE = **somenot**), we expect that agreement can be signaled with both *yes* and *no*. Crucially, we want to see whether sentences with n-words (STIM-TYPE = **none**) license both *yes* and *no* in agreeing responses – like negative sentences – or only *yes* – like positive sentences. The second independent variable is GRAM-FUN (factor with 2 levels: **S**(ubject), **A**(dverb); reference level: **S**) encoding the fact that we considered both nominal and adverbial n-words.

Item (17) above exemplifies the combination STIM-TYPE = **none**, GRAM-FUN = **S**. Item (18) exemplifies the combination STIM-TYPE = **none**, GRAM-FUN = **A**. Finally, item (19) exemplifies the combination STIM-TYPE = **somenot**, GRAM-FUN = **A**.

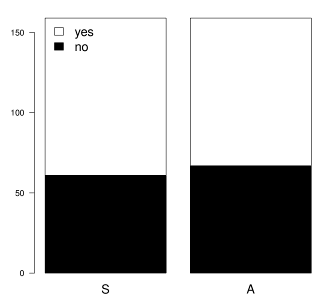
For each of the resulting $6 = 3 \times 2$ combinations, 3 stimulus sentences were generated for a total of 18. The sentences were randomly selected from the Brown Corpus and the Corpus of Contemporary American English and simplified in various ways (shortened etc.). A total of 53 subjects in an undergraduate class completed the online experiment for extra-credit. For each subject, we randomly selected 1 sentence for each of the 6 combinations. Total number of observations: $N = 53 \times 6 = 318$. For each subject, we randomized both the order of the stimuli and the order of the two possible responses for each stimulus. The experiment in the previous section together with another experiment with the same 'stimulus + choose 1 of 2 agreeing responses' format plus 7 items in which the responses disagreed with the stimulus were used as fillers.

Results. Barplots for STIM-TYPE by RESP and for GRAM-FUN by RESP are provided below, as well as a mosaic plot of STIM-TYPE by GRAM-FUN by RESP.

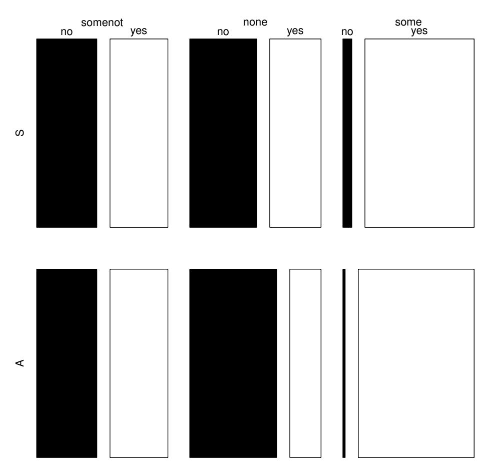
STIM-TYPE by RESP



GRAM-FUN by RESP



STIM-TYPE by GRAM-FUN by RESP



The main observation is that sentences with n-words license both *yes* and *no* in agreeing responses, just like negative sentences. In contrast, positive sentences only license *yes* in agreeing responses.

In addition, the mosaic plot indicates that the association between stimulus type and response particle does not vary by grammatical function: the pattern observed when aggregating over both subjects and adverbs is the same as the patterns we observe when we look at them separately.

Finally, n-words induce a stronger preference for *no* than neg+existentials, while positive existentials have a much stronger preference for *yes* than neg+existentials. These preferences are more pronounced for adverbs than for subjects.

Appendix B provides the details of the statistical analysis.

5 Conclusion

We have seen that negative sentences license both *yes* and *no* in agreeing responses, while positive sentences only license *yes* in agreeing responses. Sentences with n-words license both *yes* and *no* in agreeing responses, i.e., they behave like sentences with sentential negation. This is directly predicted by analyses that treat sentences involving n-words and sentences involving ordinary sentential negation as containing the same, possibly covert negative operator, and therefore the evidence supports the NI approach to n-words or, alternatively, the polyadic quantification approach. The pattern is not predicted, at least not without further stipulations, if n-words are simply treated as quantifiers as the NQ approach does.

A Statistical modeling of the results of Experiment 1

Given that the dependent variable RESP is binary, we use logistic regression models to analyze the data. The first model we consider is the full model as far as the fixed effects STIM-POL, NP-TYPE and PART-POS are concerned: main effects plus all two-way and three-way interactions; in addition, we consider intercept-only random effects for both subjects and items.

No term involving PART-POS (main effect or interaction) is significant. Dropping PART-POS (all 8 terms: the main effect, 4 two-way interactions, 3 three-way interactions) does not significantly increase the deviance ($p = 0.41$). Furthermore, the item random effects account for practically no variance, so we drop them. Therefore, we focus exclusively on the STIM-POL and NP-TYPE fixed effects and the subject random effects.

We investigate whether we need to add random effects for slopes in addition to the intercept random effects. Adding random effects for STIM-POL in addition to intercept random effects is highly significant ($p = 7.81 \times 10^{-8}$). Adding random effects for NP-TYPE in addition to the random effects for STIM-POL and the intercept is not significant ($p = 0.86$). Similarly, adding random effects for NP-TYPE to the model with intercept-only random effects is not significant, but adding random effects for STIM-POL in addition to random effects for NP-TYPE and the intercept is highly significant. Therefore, we will focus exclusively on the model with STIM-POL and NP-TYPE fixed effects (including interactions) and random effects for the intercept and the STIM-POL slope.

We check that we need all the fixed effects. Adding NP-TYPE to the model with STIM-POL as the only fixed effect and random effects for both the intercept and the STIM-POL slope is highly significant ($p = 6.81 \times 10^{-16}$). Similarly, adding the interaction between STIM-POL and NP-TYPE to the model with STIM-POL and NP-TYPE as additive fixed effects and with random effects for both the intercept and the STIM-POL slope is highly significant ($p = 3.15 \times 10^{-6}$).

Thus, our final mixed-effects logistic regression model is as follows. Fixed effects: STIM-POL, NP-TYPE and their interaction. Random effects: subject random effects for the intercept and the STIM-POL slope. The maximum likelihood estimates (MLEs) for this model are provided below:

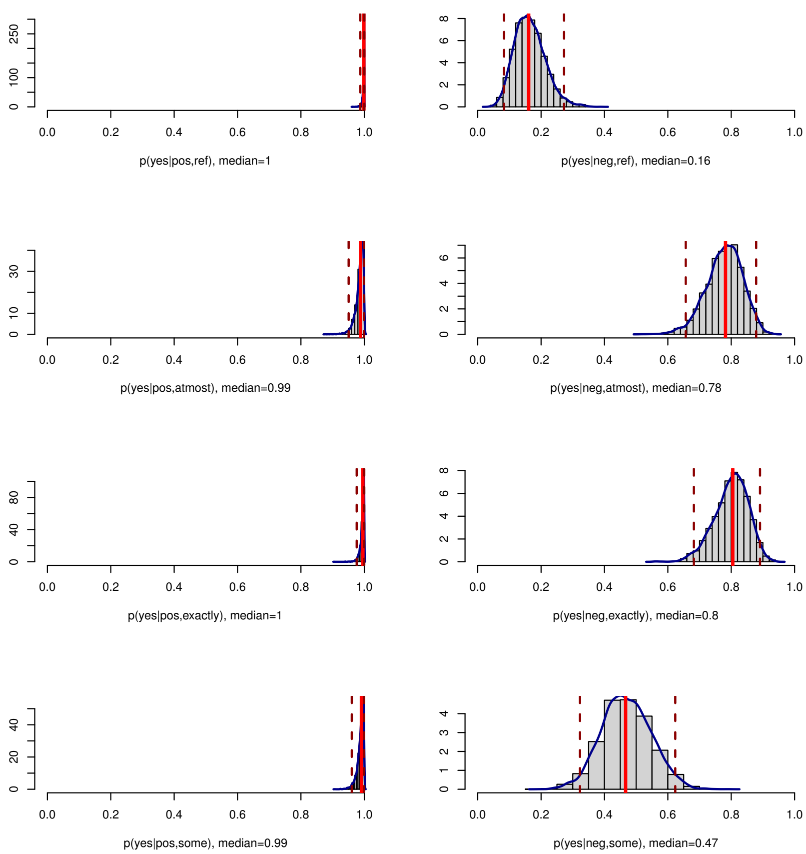
RANDOM EFFECTS		std.dev.	corr.	
	INTERCEPT	3.89		
	STIM-POL-**neg**	4.2	-0.95	
FIXED EFFECTS		estimate	std.error	p-value
	INTERCEPT	8.58	1.62	1.21×10^{-7}
	STIM-POL-**neg**	-10.21	1.66	7.44×10^{-10}
	NP-TYPE-**atmost**	-2.55	1.39	0.067
	NP-TYPE-**exactly**	-1.47	1.44	0.31
	NP-TYPE-**some**	-2.25	1.4	0.11
	STIM-POL-**neg** : NP-TYPE-**atmost**	5.43	1.44	1.61×10^{-4}
	STIM-POL-**neg** : NP-TYPE-**exactly**	4.47	1.49	2.74×10^{-3}
	STIM-POL-**neg** : NP-TYPE-**some**	3.74	1.44	9.45×10^{-3}

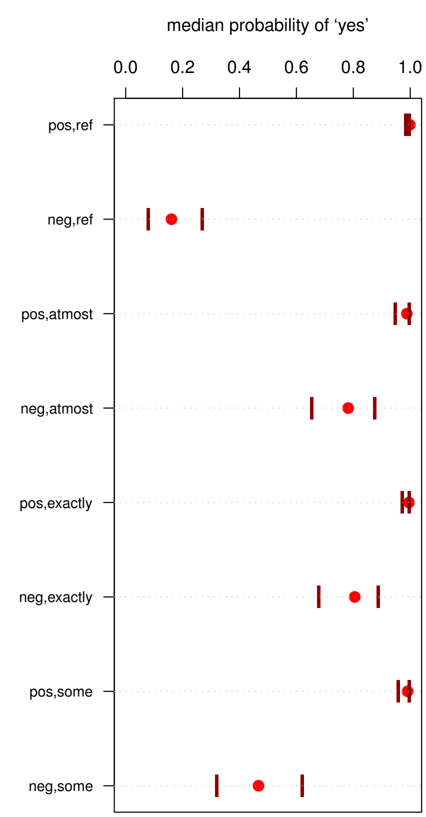
We observe the following. The intercept (i.e., a positive polarity sentence with a referential subject) indicates a highly significant preference for the particle ‘yes’. Changing the polarity of the sentence while keeping the subject referential contributes a strong preference for the particle ‘no’, as expected; however, the particle ‘yes’ is not ruled out, it is just overall dispreferred. For positive polarity sentences, changing the NP type of the subject does not contribute any significant preference for ‘yes’ (or ‘no’) compared to the preferences exhibited by positive sentences with referential subjects. For negative polarity sentences however, all non-referential NP types contribute strong preferences for the ‘yes’ particle (compared to referential NPs). This interaction between negative polarity and non-referential NP type was already visible in the mosaic plot above – and it is rather unexpected (discovering new fine-grained generalizations of this kind is one of the most important contributions that experimental methods and statistical modeling can make to formal semantics).

We will quantify all these ‘yes’ / ‘no’ preferences more precisely based on the Bayesian estimates of their posterior distributions. Priors for fixed effects: the priors for the intercept and the non-reference levels STIM-POL, NP-TYPE and their interaction are all independent normals $N(0,10^2)$. Priors for random effects: we assume a bivariate normal distribution for the intercept and STIM-POL-NEG random effects with correlation ρ between the two random effects $N\left(\begin{bmatrix}0\\0\end{bmatrix},\begin{bmatrix}\sigma^2 & \rho\sigma\tau\\ \rho\sigma\tau & \tau^2\end{bmatrix}\right)$. The priors for the intercept standard deviation σ and the STIM-POL-NEG standard deviation τ are independent uniforms $Unif(0,10)$ and the prior for ρ is $Unif(-1,1)$. MCMC estimation: 3 chains, 300000 iterations per chain, 50000 burnin, 125 thinning. As the table below shows, the means and standard deviations of the posterior distributions for the random and fixed effects are close to the MLEs (with some shrinkage):

RANDOM EFFECTS		mean	std.dev.
	σ	2.22	0.75
	τ	2.84	0.74
	ρ	-0.82	0.11
FIXED EFFECTS		mean	std.dev.
	INTERCEPT	6.72	1.39
	STIM-POL-**neg**	-8.39	1.43
	NP-TYPE-**atmost**	-2.18	1.13
	NP-TYPE-**exactly**	-1.14	1.22
	NP-TYPE-**some**	-1.91	1.15
	STIM-POL-**neg** : NP-TYPE-**atmost**	5.13	1.21
	STIM-POL-**neg** : NP-TYPE-**exactly**	4.22	1.29
	STIM-POL-**neg** : NP-TYPE-**some**	3.45	1.21

We plot below the posterior distributions of the preference for, i.e., probability of, a 'yes' response together with the median probability and 95% credible interval for each of the two stimulus polarities and the four NP types. The second plot juxtaposes the median probabilities and their 95% credible intervals for easier comparison.





B Statistical modeling of the results of Experiment 2

The first model we consider is the full model as far as the fixed effects STIM-TYPE and GRAM-FUN are concerned (main effects plus all two-way interactions) and intercept-only random effects for both subjects and items.

We investigate whether we need to add random effects for slopes in addition to the intercept random effects. Adding subjects and items random effects for STIM-TYPE slopes in addition to intercept random effects is not significant ($p = 0.38$). Adding subjects and items random effects for the GRAM-FUN slope in addition to intercept random effects is not significant ($p = 0.98$). Therefore, we will focus exclusively on the model with STIM-TYPE and GRAM-FUN fixed effects (including interactions) and intercept-only random effects for subjects and items.

We check that we need all the fixed effects. The interaction between STIM-TYPE and GRAM-FUN does not significantly reduce deviance ($p = 0.08$). Moreover, adding GRAM-FUN to the model that has STIM-TYPE as the only fixed effect is not significant ($p = 0.47$) and adding GRAM-FUN to the null (intercept) model is not significant either ($p = 0.93$). In contrast, adding STIM-TYPE to the null (intercept) model is highly significant ($p = 3.15 \times 10^{-8}$) and adding STIM-TYPE to the model that has GRAM-FUN as the only fixed effect is also highly significant ($p = 2.43 \times 10^{-8}$). Thus, we will consider models with STIM-TYPE as the only fixed effect from now on.

Random effects for items account for practically no variance, so we drop them.

Our final mixed-effects logistic regression model is as follows. Fixed effects: STIM-TYPE. Random effects: subject random effects for the intercept. The MLEs for this model are:

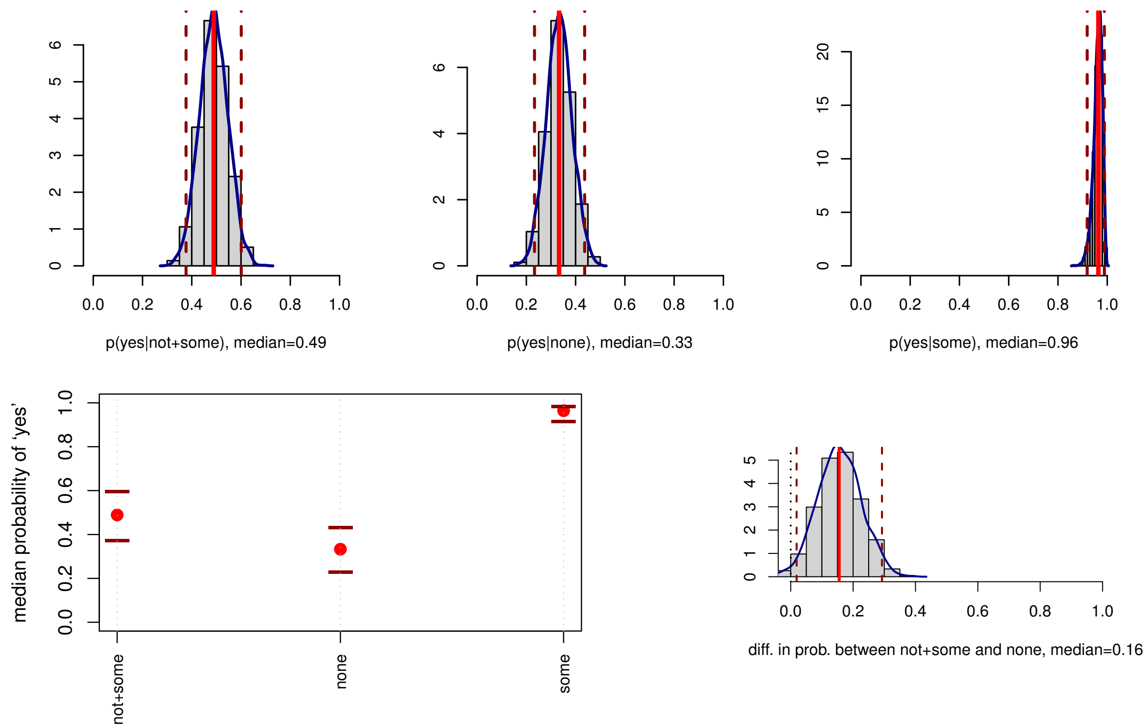
RANDOM EFFECTS		std.dev.		
	INTERCEPT	0.63		
FIXED EFFECTS		estimate	std.error	p-value
	INTERCEPT	-0.04	0.21	0.85
	STIM-TYPE-**none**	-0.64	0.29	0.025
	STIM-TYPE-**some**	3.22	0.52	8.76×10^{-10}

We observe the following. Negative quantifiers have a higher preference for 'no' than negation + existentials that is statistically significant. However, the intercept is not statistically significant: negation + existential sentences have no clear preference for 'yes' vs. 'no'. Finally, existential sentences have a significantly higher preference for 'yes' than negation + existential sentences.

We will quantify all these 'yes' / 'no' preferences more precisely based on the Bayesian estimates of their posterior distributions. Priors for fixed effects: the priors for the intercept and the non-reference levels of STIM-TYPE are all independent normals $N(0, 100^2)$. Priors for random effects: we assume a normal distribution $N(0, \sigma^2)$ for the intercept random effects; the prior for the standard deviation σ is uniform $Unif(0, 100)$. MCMC estimation: 3 chains, 225000 iterations per chain, 25000 burnin, 200 thinning. As the table below shows, the means and standard deviations of the posterior distributions for the random and fixed effects are very close to the MLEs:

RANDOM EFFECTS		mean	std.dev.
	σ	0.71	0.3
FIXED EFFECTS		mean	std.dev.
	INTERCEPT	-0.04	0.23
	STIM-TYPE-**none**	-0.66	0.3
	STIM-TYPE-**some**	3.37	0.55

We plot below the posterior distributions of the preference for, i.e., probability of, a ‘yes’ response together with the median probability and 95% credible interval for the three stimulus types. The second plot juxtaposes the median probabilities and their 95% credible intervals for easier comparison. The third plot shows the difference in probability of ‘yes’ between negation + existentials and negative quantifiers; since the 95% interval (0.019, 0.293) does not overlap 0, we are fairly confident that negative quantifiers have a higher preference for ‘no’.



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