NALL is Learnable

Background. No language in the world appears to have a single word to lexicalize the Negative Existential (O) *not all* (Horn 1972), while the other three corners of *Square of Oppositions* (see Fig. 1) are attested: Universal (A) *all*, Negative Universal (E) *no*, and Existential (I) *some*. The **nall* problem has received various synchronic accounts. **Cognitive approaches** attribute the absence of *nall* to its markedness due to negation (Horn 1972; Katzir and Singh 2013) or its undefinability in a logic system (Sbardolini 2023). **Communicative approaches**, however, treat *nall* as inefficient because it yields uninformativity (Enguehard and Spector 2021) or instability (Bar-lev and Katzir 2023). **Diachronic accounts** (Hoeksema 1999; Zeijlstra 2022) argue that *not + all* could, in principle, serve as input for lexicalization, but it never emerges because *nall* is weakening and thus functionally ill-motivated: for example, *nall man didn't come* is weaker than *all man didn't come*, whereas *no man didn't come* is stronger than *some man didn't come*. This study investigates quantifier learnability using artificial languages and shows that ***nall* is indeed learnable and as learnable as *some***.

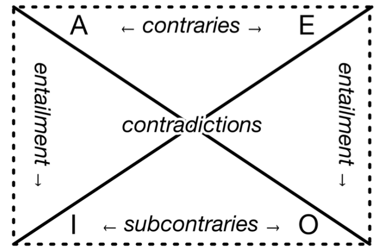

Figure 1: Square of Oppositions

Methods. To investigate the learnability of the four quantifiers and adjudicate between theories, we conducted an Artificial Language Learning experiment using the Ease-of-Learning paradigm (Culbertson 2023; Maldonado and Culbertson 2022; a.o.), with English as the base language.

Stimuli: Each stimulus consisted of a fix-ordered array of four images, differing only in the number of animals completing an event (0/2/3/n out of n), paired with a sentence containing a novel word expressing a quantificational meaning (see Fig. 2). We included four conditions, each with six quantificational meanings—four targets (*all*, *some*, *no*, *nall*) and two controls (*exactly 2*, *exactly 3*)—and six novel forms randomly selected from *bol*, *dak*, *fim*, *gip*, *sut*, *teg*, *vob*, and *zat*.

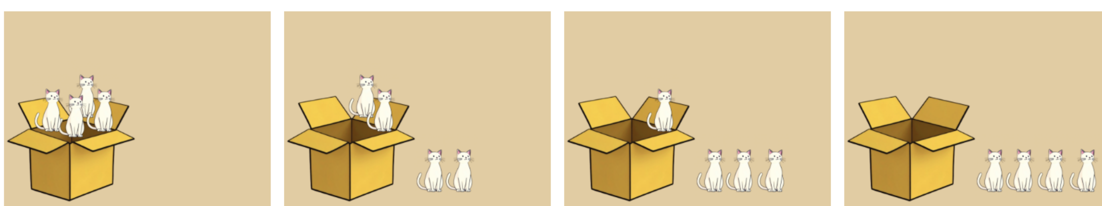

Figure 2: Sample stimulus for the sentence: **"Sut cat(s) jumped out of the box."**

Procedure: Participants completed two training sessions followed by a testing session. In Session I, they first read sentences and saw images that can describe a sentence being highlighted, and then were asked to select the word used in the sentence and received feedback on their selection. In Session II, they selected images matching the sentence and received feedback on correctness and what the correct choice should be. In the Testing Session, participants select the images for new items. We used three animals in training and four new animals in testing. Each animal-quantifier combination was presented once in Session I, twice in Session II, and once in Testing Session. In each session, the order of the trials was randomized. The study concluded with a survey asking participants to report what they think the novel words mean in English.

Participant: We recruited 93 native English speakers via Prolific (age- and gender-balanced). They were asked to provide demographic and language background information.

Survey results. Responses were coded as 1 if they were semantically equivalent to the correct quantifier meaning, and 0 otherwise. Participants who gave incorrect answers for control items were excluded. Results are reported for both unfiltered ($n = 93$) and filtered ($n = 45$) datasets.

(1) Numbers of correct responses in ...

a. unfiltered data: 49 (*all*), 30 (*some*), 21 (*nall*), 69 (*no*), 52 (*exactly 2*), 55 (*exactly 3*).
b. filtered data: 28 (*all*), 17 (*some*), 16 (*nall*), 42 (*no*), 45 (*exactly 2*), 45 (*exactly 3*).

Testing results. For each trial, responses were recorded for each image as checked/unchecked and transformed to 1/0. A trial was accurate if all four image selections were correct. We calculate accuracy for each quantifier condition. Participants whose accuracy for control items was below 80% were excluded. We report results for both unfiltered ($n = 93$) and filtered ($n = 48$) datasets.

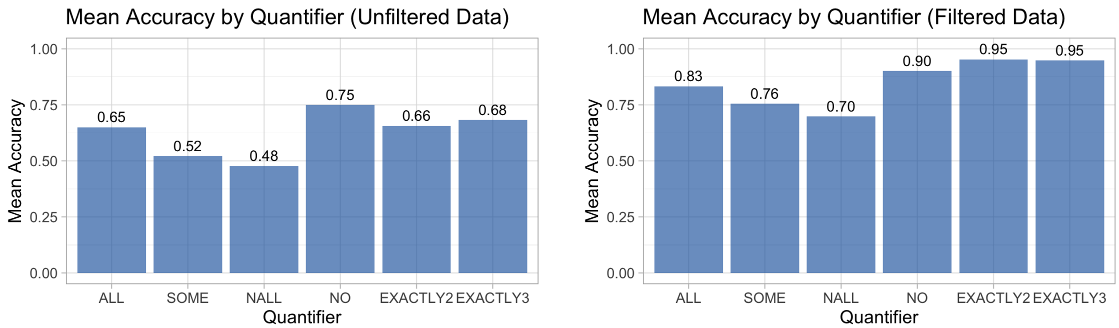

Figure 3: Mean Accuracy by Quantifier in unfiltered and filtered data

To examine whether participants' accuracy varied across quantifiers, we fit a generalized linear mixed-effects model (GLMM) using `lme4` in R. The model predicted ACCURACY from QUANTIFIER (reference level: *all*) with random intercepts for PARTICIPANT, ITEM, and CONDITION (novel forms). We computed estimated marginal means (EMMs) from the fitted GLMM and conducted Tukey-adjusted pairwise comparisons. In the unfiltered data, **accuracy for *no* was significantly higher than for *all*** ($z = -3.86, p = .0007$), whereas ***some* and *nall* were significantly lower than *all*** ($z = 4.85, p < .0001$; $z = 6.38, p < .0001$). **Accuracy did not differ significantly between *some* and *nall*** ($z = 1.67, p = .34$). In the filtered data, the effect of *all* was reduced: it differed only marginally from *no* and *some*. Other effects remained unchanged. Taken together, the results reveal a clear learning accuracy hierarchy: ***no*** $>$ ***all*** $>$ ***some*** $\approx$ ***nall***.

Discussion. Our experimental results showed that (i) *some* and *nall* are learnable to a similar extent, and (ii) the negation-containing quantifier *no* is more easily learned than *all*. These findings suggest that the alleged markedness of negation does not significantly affect quantifier learnability, challenging theories that attribute the **nall* gap to cognitive markedness.

Our results are consistent with previous experimental work, which indicates that *nall* is learnable. For example, Zhou et al. (2024), in their artificial language learning experiment with the Extrapolation paradigm, show that *nall* is not cognitively marked (and may even be preferred to *some*). Furthermore, Hunter et al. (2009) show that *nall*, as a conservative quantifier, can be acquired by English-speaking children (ages: 4;5–5;5).

Although our findings do not decisively adjudicate between communicative and diachronic accounts, we are conducting a follow-up study on the three-quantifier inventories, comparing English speakers' accuracies of learning $\{$*all*, *no*, *some*$\}$ vs. $\{$*all*, *no*, *nall*$\}$. Since the communicative approach argues that the former inventory is favored due to higher communicative efficiency, it would expect participants to achieve higher learning accuracies in that condition.

Finally, we are replicating this study in two additional languages: Mandarin, which lacks dedicated forms of *no* and uses plain negation instead, and Farsi, where the combination of *not* and *all* is ungrammatical. Data collection is ongoing, with results expected in early 2026.

Bar-Lev, M. & R. Katzir. 2022. Communicative stability and the typology of logical operators. *Linguistic Inquiry.* **Culbertson, J. 2023.** Artificial language learning. *Oxford handbook of experimental syntax.* **Enguehard, E. & B. Spector. 2021.** Explaining gaps in the logical lexicon of natural languages: A decision-theoretic perspective on the square of Aristotle. *Semantics and Pragmatics.* **Hoeksema, J. 1999.** Blocking effects and polarity sensitivity. *JFAK. Essays Dedicated to Johan van Benthem on the Occasion of his 50th Birthday.* **Horn, L. 1972.** *On the semantic properties of logical operators in English.* PhD thesis, UCLA. **Hunter, T., Lidz, J., Wellwood, A., & Conroy, A. 2009.** Restrictions on the meaning of determiners: Typological generalisations and learnability. *Semantics and Linguistic Theory.* **Katzir, R. & Raj Singh. 2013.** Constraints on the lexicalization of logical operators. *Linguistics and Philosophy.* **Maldonado, M., & Culbertson, J. 2022.** Person of interest: Experimental investigations into the learnability of person systems. *Linguistic Inquiry.* **Sbardolini, G. 2023.** The logic of lexical connectives. *Journal of Philosophical Logic.* **Zeijlstra, H. 2022.** *Negation and Negative Dependencies.* **Zhou, R., Spector, B., & Maldonado, M. 2024.** An experimental assessment of the nall lexical gap. *Proceedings of the Amsterdam Colloquium.*