Most is easy but *least* is hard: Novel determiner learning in 4-year-olds

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Abstract

Some linguistic features are more readily learned than others, and are thereby more likely to be maintained in diachronic language change, giving rise to typological universals. Less readily learned features may give rise to typological gaps. We consider an apparent typological gap—that a morphologically superlative determiner (e.g., *gleebest* in *gleebest of the cows*) with a negative meaning is cross-linguistically unattested—and ask whether it reflects an underlying learning bias. We find 4-year-olds know that such determiners indicate quantity (replicating Wellwood, Gagliardi, & Lidz, 2016), but only when positive ('most'), but not negative ('least'). Importantly, the observed bias is not specific to the apparent typological gap: same-age children showed difficulty learning the negative meaning of a non-superlative determiner, though such meanings are attested. The data thus suggest that children are generally biased against negativity, consistent with much prior work on conceptual bias and language learning/processing.

Keywords: learning bias; language universals; linguistic typology; cognitive bias; word learning; determiners

Introduction

Learning is biased—not every logical possibility is equally considered by learners. In language acquisition, for example, Subject-Verb-Object (SVO) word orders are more readily learned than Verb-Subject-Object (VSO) ones (Tily, Frank, & Jaeger, 2011; Tabullo et al., 2012); word categories with suffixes are better identified than those with prefixes (St. Clair, Monaghan, & Ramscar, 2009), and patterns of harmonic word order are more easily learned than non-harmonic ones[1] (Christiansen, 2000; Culbertson & Newport, 2015; Culbertson, Smolensky, & Legendre, 2012). Probing such biases can offer important insights into learnability—how a language is acquired by learners at a given time, and typology—how common formal patterns emerge across languages over time.

In fact, a close relationship between linguistic typology and learnability has long been assumed (Chomsky, 1965; Hawkins, 2004; Newmeyer, 2005; Tesar & Smolensky, 1998): An easier-to-learn linguistic property is more likely to be maintained in diachronic change and manifested in more languages; an unlearnable property is more likely to die out over time and leave a typological gap. Similarly, a pattern common to many languages is more likely to be learnable, and a typological gap might reflect a hard-to-learn property. Therefore, linguistic typology (universals and gaps) could provide an important window into the discovery of learning biases, whether or not they turn out to be specifically linguistic; in turn, the discovery of such biases will advance our understanding of language acquisition and language change.

In this paper, we explore a potential learning bias in the context of an apparent typological gap. Negative superlative determiners are cross-linguistically unattested, i.e., there are no successful correspondents of (1) involving an element like *least/fewest* (Hackl, 2009). This holds despite the fact that superlative determiners with a positive polarity, like *most* in (2), and non-superlative determiners with a negative meaning, like *less* in (3), are both grammatical. We ask: Does the typological gap represented by (1) reflect an underlying learning bias, and if so, what is its nature? We approach this question by asking whether a negative superlative determiner (i.e., one specified [-pos, +supl]) is hard to learn by young children, in comparison to its positive counterpart ([+pos, +supl] and its non-superlative counterpart ([-pos, -supl]).

(1) * Least of the cows are by the barn. [-pos, +supl]

(2) Most of the cows are by the barn. [+pos, +supl]

(3) Less of the cows are by the barn. [-pos, -supl]

We put forward 4 hypotheses. The null hypothesis (H0) states that there is no learning bias with respect to our case of interest, and an appropriate meaning for (1) is as learnable as those of (2) and (3). Our experimental hypotheses (H1-H3), on the other hand, assert the existence of some form of learning bias. H1 states that it is negativity (i.e., [-pos]) and superlativity (i.e., [+supl]), together, that impose a learning challenge, such that (1) is hard to learn but both (2) and (3) are not. H2 states that the learning bias is one specifically against negativity (irrespective of superlativity), such that both (1) and (3) are hard to learn. H3 specifically biases against superlativity, rendering (1) and (2) difficult.

With respect to the learnability-typology relation, these hypotheses have different implications. While H0 implies no such relation, H1 implies a one-to-one direct correspondence—that is, the learning bias straightforwardly leads to the observed typological pattern. H2 and H3, however, are more nuanced: Learnability does not directly map to typology. Take H2, for example: A bias against negativity would predict learning difficulties in both (1) and (3), but over time, only a gap for (1) has developed. This nuance is actually in line with natural language data: For instance,

[1] (Non)harmonic word orders refer to the consistency of modifier positioning relative to head nouns. An example harmonic language is English, in which adjectival and numeral modifiers both precede the head nouns (e.g., *red car* and *one car*).

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despite their learning challenges, VSO word orders are still manifested in 9% of the world's languages (Tily et al., 2011), and non-harmonic patterns 4% (Culbertson et al., 2012; Culbertson & Newport, 2015). After all, the relation between typology and learnability is probabilistic rather than absolute.

Between the two nuanced hypotheses (H2 and H3), we have less confidence in H3, namely, a particular difficulty with superlativity. Wellwood, Gagliardi, and Lidz (2016) have observed that English-acquiring 4-year-olds are able to learn a novel superlative determiner when its polarity is positive (e.g., when *gleebest* in *gleebest of the cows* means the same as 'most'). Thus, while we might not expect H3 to be borne out, it is important to include it for continuity with this prior research as well as to support a replicability test.

H2's bias against negativity is in good company. Many studies have reported that statements with negative meanings take longer to process (e.g., Just & Carpenter, 1971; Clark & Chase, 1972; Trabasso, Rollins, & Shaughnessy, 1971), including for sentential negation (e.g., *The dots are (not) red)*) but also as a matter of lexical semantics (e.g., quantifiers *few*/*many*, prepositions *below* vs. *above*, comparative adjectives *shorter* vs. *longer*) (Just & Carpenter, 1971; Deschamps, Agmon, Loewenstein, & Grodzinsky, 2015; Clark & Chase, 1972; Tucker, Tomaszewicz, & Wellwood, 2018). The negativity disadvantage also appears in acquisition. For many plausible positive and negative pairs, evidence reveals that the positive member is acquired earlier/more easily than the negative counterpart, including adjectives (e.g., *high*/*low*) (Barner & Snedeker, 2008; Donaldson & Wales, 1970; Smith Cooney, & McCord, 1986; Ryalls, 2000; Townsend, 1976; see Johnston, 1985, for a review), prepositions (e.g., *before*/*after*) (Clark, 1971; Museyibova, 1961; Sokhin, 1971), and quantifiers (e.g., *more*/*less*). Researchers have suggested that children can treat *less* as meaning *more* (e.g., Donaldson & Balfour, 1968; Donaldson & Wales, 1970; Clark, 1973; Palermo, 1973, 1974), and Carey (1978) showed children were similarly biased given a lexically neutral item; e.g., given the options of addition and reduction, children tended to perform addition when asked to "make it so I have *tiv* tea".

Despite the bulk of literature on a negativity bias, how it plays out specifically with respect to the syntactic category of *determiner* is not known, nor has any link between its learnability and the previously reviewed typological pattern been established. The present study takes up these issues. In a novel determiner learning task, we examine and compare the learnability of the unattested negative superlative determiner [-pos, +supl], and its aforementioned counterparts, [+pos, +supl] and [-pos, -supl].

Given our focus on learnability, it is important to clarify what we will consider to be successful learning. The literature on word learning highlights as a central challenge that any word form is compatible with multiple possible meanings (Grimshaw, 1981; Pinker, 1989)—for instance, given a novel word *doke* used in a context where an entity performs an action, the possible meanings minimally include one pertaining to the salient entity and another to the salient action. In such cases, learners routinely overcome the challenge by using heuristics relating the word's syntactic category and its semantic category. In the above example, hearing *doke* as a noun (e.g., "a doke") would lead to preference for the entity meaning, while hearing it as a verb (e.g., "it's doking") would support the action meaning (e.g., He & Lidz, 2017; de Carvalho, He, Lidz, & Christophe, 2019; Imai et al., 2008, Waxman & Booth, 2001). Following this tradition, we consider successful learning of a determiner to minimally consist in knowing its broad semantic category—that it denotes quantity—a pattern that robustly holds for natural language determiners (Barwise & Cooper, 1981; Gajewski, 2002; van Benthem, 1989).

Our learnability question, therefore, can be operationalized as follows. For a novel determiner used in a context in which both a quantity meaning and an alternative non-quantity meaning are available, will young children entertain quantity——the target semantic category of determiners——rather than the alternative? Importantly here, we should like to know whether children can do so with respect to the unattested negative superlative determiner [-pos, +supl], and how preferences here would compare to its two counterparts, [+pos, +supl] and [-pos, -supl].

As for the alternative meaning, we chose 'quality' following Wellwood et al. (2016). In that study, in a context where a salient quantity (e.g., number of cows) and a salient quality (e.g., degree of the cows' spottiness) were both available, 4-year-olds readily entertained the quantity reading and rejected the quality reading when they heard a novel determiner (e.g., *gleebest* in "Gleebest of the cows are by the barn"), while the opposite was observed when they heard a novel adjective (e.g., *gleebest* in "The gleebest cows are by the barn"). These results establish that children this age know that determiners name quantities. However, Wellwood et al. made only positive meanings available (e.g., 'more cows', 'more spotty'), so the question of the learnability of determiners of different types (i.e., [-pos, +supl], [+pos, +supl], [-pos, -supl]) is left unaddressed. We take this question up with the current study. In our novel determiner learning task, we will interpret children's preference for quantity over quality as evidence for successful learning. If, for a particular type of determiner, children nevertheless preferred a quality reading, that would be strong evidence for unsuccessful learning.

Current Study

Participants

Thirty-nine English-learning children (range: 48.43-60.03 months; mean: 53.77 months) participated (Condition 1: n = 14, Condition 2: n = 13, Condition 3: n = 12). Participants were recruited from the Evanston and Chicago area, and had at least 80% exposure to English, according to parental report. None had known developmental delays or disorders.

Table 1: Structure of Training Trials in Main Experiment

		Scene information	
Cond.	**Language**	**Quantity**	**Quality**
1 [-pos, +supl]	Gleebest of the cows are by the barn.	Barn cows are fewer than field cows.	Barn cows are less spotty than field cows.
2 [+pos, +supl]	Gleebest of the cows are by the barn.	Barn cows outnumber field cows.	Barn cows are more spotty than field cows.
3 [-pos, -supl]	Gleeb of the cows are by the barn.	Barn cows are fewer than field cows.	Barn cows are less spotty than field cows.

Design & Stimuli

Children were exposed to sentences containing a novel determiner during Training, and their interpretations were assessed at Test. Training stimuli varied by condition (between participants), and Test stimuli were identical for all.

During Training, the linguistic stimuli were sentences providing an unambiguous determiner context (i.e., in *X of the Y* where Y is a noun, X must be a determiner); and the determiner either had the typical English superlative morpheme *-est* attached (i.e., [+supl]) or not (i.e., [-supl]); see (4)-(5). The visual stimuli were scenes depicting two groups of cows. A group by the barn, compared to a group in the field, either had a greater (i.e., [+pos]) number of cows, consistent with a positive reading (e.g., 'most'), or fewer number of cows (i.e., [-pos]), consistent with a negative reading (e.g., 'least').

(4) Gleebest of the cows are by the barn.

(5) Gleeb of the cows are by the barn.

To allow us to assess children's learning of the novel determiners, in addition to the quantity-based reading (i.e., number of cows), the extra-linguistic context also made available an alternative quality-based reading (i.e., degree of spottiness). Whenever the cows by the barn outnumbered the cows in the field, it was also true that the barn cows were spottier than the field cows; similarly, when the barn cows were fewer in number than the field cows, it was also true that they were less spotty. In other words, the novel words were always potentially ambiguous. The different combinations of linguistic and extralinguistic stimuli led to three conditions (Table 1).

Given the potential ambiguity, would children prefer quantity (the target semantics of determiners) over quality, and would that vary by condition? To evaluate this, at Test we used unambiguous visual stimuli—the barn cows either exclusively outnumbered the field cows, or were exclusively spottier than the field cows, but never both.

Picky-puppet game

The above design was wrapped up in a picky-puppet game where a puppet liked some cards but not others. The puppet's preference was introduced during Training and children's understanding of the puppet's preference was assessed at Test. There were 6 training cards (Figure 1) and 12 test cards (Figure 2), presented to each child in a pseudo-randomized order.

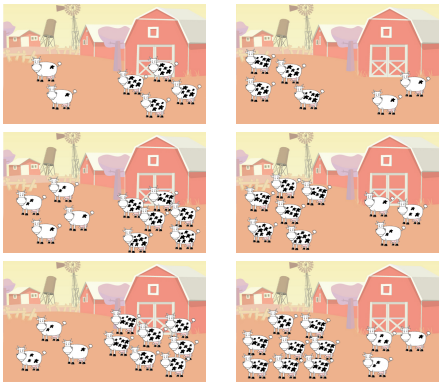

Figure 1: Training stimuli (6 cards total): barn cows outnumber field cows and are more spotty (L); barn cows are fewer than field cows and less spotty (R).

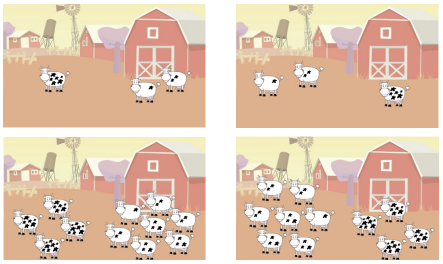

Figure 2: Test stimuli (4/12 trials): barn cows outnumber field cows but less spotty (L); barn cows are fewer than field cows but more spotty (R).

During Training, children were introduced to a puppet, Alfred the dragon, and were shown 6 cards displaying two groups of cows, one at a time. In Condition 1 ([-pos, +supl]), children first heard a statement about Alfred's preference: "Alfred likes the cards where gleebest of the cows are by the barn, but he wouldn't tell us what *gleebest* means." Then for each card, they learned whether Alfred liked it or not, and why. For example, for each card in the right column of Figure 1, they were told that "Alfred likes this card, because gleebest of the cows are by the barn," and for each in the left column, they learned "Alfred doesn't like this card, because it's not true that gleebest of the cows are by the barn." Compared to Condition 1, children in Condition 2 ([+pos, +supl]) heard the same preference statement containing *gleebest*, but were shown the opposite like-versus-dislike pattern. Children in Condition 3 ([-pos, -supl]) were shown the same preference pattern as in Condition 1, but heard a different preference statement, one that replaced *gleebest* with *gleeb*.

Then, at Test, children saw 12 new cards, identical across conditions. For each card, children were asked to decide whether Alfred would like it or not: A question was asked verbally (e.g., "Do you think Alfred would like this card?")

and children were directed to sort each card into one of two piles, a *likes* pile indicated by a checkmark and a *dislikes* pile indicated by a cross-mark. Recall that during Training, Alfred's preference was consistent with either number of cows or degree of spottiness; at Test, these two dimensions were pit against each other, and thus children's choices would reflect which interpretation they entertained based on Training. Take a child in Condition 1 for example: (S)he was trained that Alfred liked cards where the barn cows were fewer in number and less spotty than the field cows. For a test card in the left column of Figure 2, if (s)he decided that Alfred liked it, it would suggest (s)he had entertained a quality-based reading and inferred Alfred liked it when the barn cows were less spotty; if, however, (s)he decided Alfred disliked that card, it must be because (s)he inferred Alfred liked the barn cows to be greater in number (the target quantity-based reading).

Measurement & Predictions

As discussed in the Introduction, learnability was operationalized as the child's ability to choose the target meaning over the alternative. Thus, we took as our dependent variable children's choices at Test. For each test card, we coded a quantity-based choice (i.e., target) as 1 and a quality-based choice (i.e., alternative) as 0. With this measurement, we would like to answer two questions: a) how learnability varied across conditions—in particular, how Condition 1 might differ from the other two conditions; and b) whether each condition was learnable. Cross-conditional comparison was conducted to address (a), and comparison to chance level (i.e., 0.5)[2] for each condition was conducted to address (b).

Prior work (Wellwood et al., 2016) has shown that children in our tested age range know that determiners denote quantities, all else equal. Therefore, H0, which asserts no learning bias, would predict no cross-conditional difference and above-chance performance for each condition. H1 states that a combination of negativity and superlativity leads to difficulty. Hence it would predict a difference between Condition 1 ([-pos, +supl]) and each of the other two conditions—specifically, above-chance performance for Condition 2 ([+pos, +supl]) and Condition 3 ([-pos, -supl]), but not Condition 1. H2, which asserts a bias against negativity, irrespective of superlativity, would predict a difference of Condition 1 from Condition 2, but not from Condition 3, and specifically, above-chance performance for Condition 2 only. H3, asserting a bias against superlativity, would predict similar difficulty in Condition 1 and Condition 2, and above-chance performance for Condition 3 only. See Table 2.

[2]Wellwood et al. (2016) assessed adults' attention to the number of cows vs. their spottiness independent of the linguistic stimuli, and found that differences in quantity were more salient than differences in quality. If we assume perceptual salience is constant for adults and children (a non-trivial assumption), a 0.5 chance level would actually bias against quantity. If we nonetheless observed below-chance performance, that would be strong evidence for low learnability.

Table 2: Predictions of Main Experiment

	Condition		
Hypothesis	**1**	**2**	**3**
H0: no learning bias	✓	✓	✓
H1: bias against negative superlative D	×	✓	✓
H2: bias against negative D	×	✓	×
H3: bias against superlative D	×	×	✓

Analyses & Results

All statistical analyses were performed in R version 3.6.1, with the lme4 package (Bates, Sarkar, Bates, & Matrix, 2007). We adopted a significance level of 0.05.

To look for cross-conditional differences, we entered data (binary variable: 0 vs. 1) from all conditions into a mixed-effect logistic regression model, with participant and trial as random factors and age (in months; centered around its mean) as a continuous predictor. A significant difference between Condition 1 and Condition 2 was revealed ($p = 0.019$). But there was no difference between Condition 1 and Condition 3 ($p = 0.91$). Although our main interest was in how Condition 1 differed from each of the other two conditions, we also compared Condition 2 and 3 to gain a fuller picture, and a significant difference was found ($p = 0.016$). No age effect was found ($p = 0.78$).

To assess the learnability of each condition, we entered data (binary variable: 0 vs. 1) from each condition into a separate mixed-effect logistic regression model. We compared quantity-based responses to chance by evaluating the intercept parameter. Above-chance performance was only found in Condition 2, ($p = 0.0014$). The other two conditions both yielded chance-level performance (Condition 1, $p = 0.70$; Condition 3, $p = 0.59$). An age effect was found only in Condition 2 ($p = 0.022$), and the positive parameter estimate (i.e., 0.26) suggested that performance increased with age.

Figure 3 illustrates the aggregated data in each condition, i.e., taking the data point from each test card of each participant (1 or 0), averaging them across all test cards and then across all participants. The mean aggregated score in Condition 1 was 0.55 ($SD = 0.30$), in Condition 2, 0.76 ($SD = 0.22$), and in Condition 3, 0.53 ($SD = 0.21$).

Discussion

Results were consistent with H2. Determiners with negative polarity were hard to learn, whether superlative-marked (Condition 1) or not (Condition 3). In Condition 2, when the novel superlative determiner denoted a positive quantity, children readily picked up its meaning, and their ability to do so improved as they grew older. Clearly, learning is biased; in the present case, the nature of this bias seems to be against negativity, regardless of superlativity.

A Control Experiment

One could argue that children's difficulties in the negative conditions could reflect lack of knowledge of a negative com-

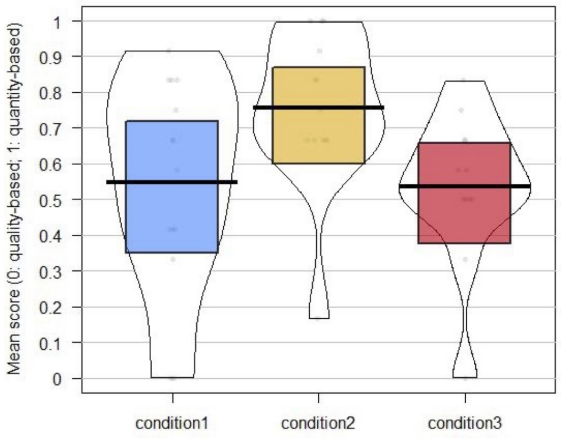

Figure 3: Results of Main Experiment

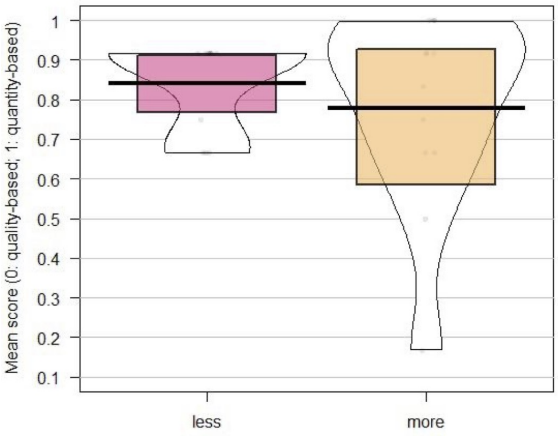

Figure 4: Results of Control Experiment

Table 3: Structure of Training Trials in Control Experiment

		Scene information	
Condition	**Language**	**Quantity**	**Quality**
"less"	There are less cows by the barn than in the field.	Field cows outnumber barn cows.	Field cows spottier than barn cows.
"more"	There are more cows by the barn than in the field.	Barn cows outnumber farm cows.	Barn cows spottier than field cows.

parative (e.g., a word like *less*). We assessed this possibility in a control experiment, identical to the main experiment except we used only existing English in the training sentences: instead of a novel word, one condition ("less") featured *There are less cows by the barn than in the field*, and another condition ("more") featured *There are more cows by the barn than in the field* (see Table 3). Twenty-four similar-age children participated (12 in each condition; recruited in the Los Angeles area). Children succeeded in both conditions ($ps < 0.001$), and no between-condition difference was found ($p = 0.66$) (Figure 4). These results weigh against an objection based on the distribution of known words.

However, one could maintain that children's difficulty with the negative meaning of *gleebest* arises because sentences like (1) never appear in their input. Such a consideration, though, could cast doubt on just about any novel word learning task: if children fail to learn a new word, that is because they do not have existing words on which to base the relevant hypotheses. But children at the relevant age do appear to readily introduce new word meanings into their lexicon. An underexplored possibility in this vein, then, is that such readiness to accommodate new meanings varies in degree with respect to the open- versus closed-class distinction. We should like to see this possibility explored in future work.

General Discussion

In a novel-word learning paradigm, we showed that 4-year-olds readily entertained a quantity reading for a novel determiner if the learning environment supported a positive reading. This finding successfully replicates Wellwood et al. (2016), robustly demonstrating children's knowledge of the basic semantics of determiners at this stage. Adding to that, we found that when the context supported a negative quantity reading, children lost confidence in their understanding and guessed at chance between the target quantity reading and an alternative quality reading. We consider these findings to have important implications in three respects.

First, these findings clearly refute the null hypothesis (H0) that learning is unbiased. Despite the lay view that bias isn't good, language acquisition research has long recognized that they can facilitate rather than hinder learning. Any finite linguistic experience is consistent with infinite possibilities, whether of meanings or structures (Chomsky, 1965; Quine, 1960); without bias, learners would be 'lost in thought' (Gleitman, 1990, p.12). Biases are ubiquitous in development and manifested in many linguistic domains. For example, related to word learning: Meanings for whole objects are learned earlier than meanings for their parts (Markman, 1990); new words are more readily generalized to entities with the same shape than with the same texture/color (Landau, Smith, & Jones, 1998); nouns are hypothesized to label objects, and verbs events (e.g., Waxman & Booth, 2001; He & Lidz, 2017; de Carvalho et al., 2019). Children take determiners to be quantity-denoting (Wellwood et al., 2016) and conservative in meaning (Hunter & Lidz, 2013; but see Spenader & de Villiers, 2019). Our findings add more empirical evidence to this literature and highlight another bias in word learning, one that we observe with determiners but which likely applies more generally, as we discuss below.

Second, while refuting H0 provides evidence that the typological gap in (1) reflects some learning bias and so is not merely coincidental, evaluation of the three experimental hypotheses (H1-H3) sheds further light on the finer relation between typology and learnability. Our results support H2—that learners are biased against a negative meaning of a deter-

miner, whether or not it is superlative. This could suggest a non-absolute mapping between typology and learnability. If biases are preferences, they would not carve up the learner's hypotheses in an all-or-none manner, rather merely point to some possibilities as more likely. Children may acquire the meanings/patterns consistent with their learning biases earlier in development, but eventually they must also acquire those that are bias-inconsistent but nonetheless alive in their language (see, for example, Arunachalam & He, 2018 and He & Wittenberg, 2020, for discussion on the acquisition of nouns that apply to events, rather than objects). In other words, despite the negativity bias, children eventually must know that sentences like (3) ([-pos, -supl]) are grammatical! This concurs with Culbertson et al.'s (2012) view that learning biases are probabilistic, and that even bias-violating structures are learnable, just less likely to arise.

Typological patterns develop over generations of language users, and are the products of many factors, not just a single learning bias. Probabilistic rather than deterministic biases are, therefore, more likely to result in typological gaps over time, but not always so. The bias against negativity, after all, seems to only support a final gap in negative superlative determiners. There must be room for other constraints, potentially ones specifically imposed by the language faculty. Regardless, it seems clear that the same bias may play at least a partial role in explaining other typological gaps—for instance, languages regularly feature a positive quantifier like *all*, but not its conceivable negative counterpart **nall* (meaning 'not all'); similarly, despite the existence of the positive connectives *and* and *both*, **nand* (meaning 'not and') and **noth* (meaning 'not both') are not observed (Horn, 1972). Characterizing these gaps adequately will require careful attention to the balance between learning biases and other constraints.

Last but not least, our findings are consistent with a long-recognized bias in language processing and language acquisition between positive-negative pairs. In many cases, the negative element of a pair is slower to process and later to acquire (see Introduction). We showed that upon hearing *Gleeb(est) of the cows are by the barn*, children readily entertained the positive meaning—larger in number—but not the negative one. We speculate, along the lines of traditional explanations (e.g., Clark & Chase, 1972), that this is so because the positive meaning is default, and computing the negative meaning involves a further step. In the case of explicit negation (e.g., *This is not my book*), this second step of negating the positive is quite explicit, and is costly (e.g., Wason, 1959; Clark & Chase, 1972). In the implicit case, where the negative meaning is part of a lexical item (e.g., *few*), computation of the meaning of such an already-acquired word might be more or less autonomous, but still involve a cost (e.g., Just & Carpenter, 1971; Deschamps et al., 2015). Before the meaning of a given item is acquired, then, the challenge would manifest as decreased learnability. Our study measured learnability by its outcome—whether a target meaning is learned or not. Another way of measuring learnability would be to evaluate the process of learning—for example, how many training trials it takes for a particular meaning to be successfully learned. Future work might explore this, and would potentially serve as a more direct index for the computational steps involved.

A deeper question regarding the negativity bias is: What makes a word/phrase positive or negative? It has been suggested that the way our linguistic systems encode content is closely related to our perceptual encodings (see Clark & Chase, 1972). For instance, *in front* counts as positive as it describes the visible perceptual field, whereas *behind* is negative in describing the area out of sight (Clark, 1971; Leech, 1970); *high* is positive because height is usually measured as distance upward from the ground and *high* implies a greater degree of such distance, whereas *low* implies less (Vendler, 1967; Clark, 1969; Clark & Chase, 1972, Givon, 1970). If so, we may expect the scope of the bias to extend beyond language. In fact, Tucker et al. (2018) provide evidence that the same bias is evident in mathematics, with the common underlying mechanism being an additional computational step involved in computing the negative from the positive (but see Deschamps et al., 2015, for a different argument). To better understand this issue, more studies examining potential perceptual asymmetries absent in natural language are called for.

Another issue to be elaborated in future work is the development from a broad category of determiners to, for example, the English word *most*. Past work has shown that this word is not acquired until 5-7 years of age (e.g., Barner, Chow, & Yang, 2009; Katsos et al., 2016; Papafragou & Schwarz, 2006; Suillivan, Bale, & Barner, 2018; but see Halberda, Taing, & Lidz, 2008, for evidence of earlier acquisition), yet our findings demonstrated at least that a superlative-marked, novel determiner was readily acquired with a few exposures (in the positive polarity; replicating Wellwood et al., 2016). To be sure, what children succeeded in here was in recognizing that *gleebest* was a determiner, and associating it with its target semantic category, quantity. From this knowledge to a complete comprehension of the actual word *most*, there are additional steps to take—for instance, *most* might involve knowledge of comparison between a subset and superset, not tested in the current study. The developmental trajectory between knowledge of the broad semantic category and a full-blown semantics for *most* calls for further specification.

To summarize, learning proceeds with biases. These biases, likely shaped by the processes by which humans represent and reason about the world, shape not only the trajectories of our language development as children but also the typological patterns we can observe across the world's languages. We find evidence for this not only in preschooler's acquisition of familiar categories like nouns and verbs, but also in that of novel determiners, as in the current study. Determiner *most* is easy, but determiner *least* is hard—explaining why that should be so requires careful attention not only to a bias that plausibly stems from general properties of human cognition, but also to how language packages extralinguistic cognitive information.

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References

Arunchalam, S., & He, A. X. (2018). Children's acquisition of nouns that denote events. In *Proceedings of the 42nd boston university conference on language development.* Somervillle, MA: Cascadilla Press.

Barner, D., Chow, K., & Yang, S. J. (2009). Finding one's meaning: A test of the relation between quantifiers and integers in language development. *Cognitive Psychology*, *58*, 195-219.

Barner, D., & Snedeker, J. (2008). Compositionality and statistics in adjective acquisition: 4-year-olds interpret tall and short based on the size distributions of novel noun referents. *Child Development*, *79*, 594–608.

Barwise, J., & Cooper, R. (1981). Generalized quantifiers and natural language. *Linguistics and Philosophy*, *4*, 159–219.

Bates, D., Sarkar, D., Bates, M. D., & Matrix, L. (2007). *lmer4: Linear mixed–effects models using s4 classes. (r package version 0.99875-9)* (Tech. Rep.).

Carey, S. (1978). *Less* may never mean *more*. In R. N. Campbell & P. T. Smith (Eds.), *Recent advances in the psychology of language: Language development and mother-child interaction* (p. 109-131). Plenum.

Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.

Christiansen, M. H. (1963). Using artificial language learning to study language evolution: Exploring the emergence of word order universals. In J. Dessalles & L. Ghadakpour (Eds.), *The evolution of language: 3rd international conference.* Paris: Ecole Nationale Superieure des Telecommnunications.

Clark, E. (1969). *Language acquisition: The child's spontaneous descriptions of events in time* (Doctoral dissertation). University of Edinburgh.

Clark, E. V. (1971). On the acquisition of the meaning of before and after. *Journal of Verbal Learning and Verbal Behavior*, *10*, 266-275.

Clark, E. V. (1973). Non-linguistic strategies and the acquisition of word meanings. *Cognition*, *2*, 161-182.

Clark, H. H., & Chase, W. G. (1972). On the process of comparing sentences against pictures. *Cognitive Psychology*, *3*, 472-517.

Culbertson, J., & Newport, E. L. (2015). Harmonic biases in child learners: In support of language universals. *Cognition*, *139*, 71-82.

Culbertson, J., Smolensky, P., & Legendre, G. (2012). Learning biases predict a word order universal. *Cognition*, *122*(3), 306-329.

de Carvalho, A., He, A. X., Lidz, J., & Christophe, A. (2019). Prosody and function words cue the acquisition of word meanings in 18-month-old infants. *Psychological Science*, *30*, 319-332.

Deschamps, I., Agmon, G., Lewenstein, Y., & Grodzinsky, Y. (2015). The processing of polar quantifiers, and numerosity perception. *Cognition*, *143*, 115-128.

Donaldson, M., & Balfour, G. (1968). Less is more: A study of language comprehension in children. *Early Child Development and Care*, *59*, 461-471.

Donaldson, M., & Wales, R. (1970). On the acquisition of some relational terms. In J. R. Hayes (Ed.), *Cognition and the development of language* (p. 235-268). John Wiley & Sons.

Gajewski, J. (2002). *L-analycity in natural language.* (Unpublished manuscript, MIT)

Givón, T. (1970). Notes on the semantic structure of english adjectives. *Language*, 816-837.

Gleitman, L. (1990). The structural sources of verb meanings. *Language Acquisition*, *1*(1), 3-55.

Grimshaw, J. (1981). Form, function, and the language acquisition device. In C. L. Baker & J. J. McCarthy (Eds.), *The logical problem of language acquisition* (p. 165-182). Cambridge: MIT Press.

Hackl, M. (2009). On the grammar and processing of proportional quantifers: *most* versus *more than half*. *Natural Language Semantics*, *17*, 63-98.

Halberda, J., Taing, L., & Lidz, J. (2008). The development of "most" comprehension and its potential dependence on counting ability in preschoolers. *Language Learning and Development*, *4*(2), 99-121.

Hawkins, J. A. (2004). *Efficiency and complexity in grammars*. Oxford: Oxford University Press.

He, A. X., & Lidz, J. (2017). Verb learning in 14-and 18-month-old english-learning infants. *Language Learning and Development*, *13*, 335-356.

He, A. X., & Witternberg, E. (2020). The acquisition of event nominals and light verb constructions. *Language and Linguistics Compass*, *14*, e12363.

Horn, L. (1972). *On the semantic properties of the logical operators in English*. Bloomington, IN: Indiana University Linguistics Club.

Hunter, T., & Lidz, J. (2013). Conservativity and learnability of determiners. *Journal of Semantics*, *30*(3), 315-334.

Imai, M., Li, L., Haryu, E., Okada, H., Hirsh-Pasek, K., Golinkoff, R. M., & Shigematsu, J. (2008). Novel noun and verb learning in chinese-, english-, and japanese-speaking children. *Child Development*, *79*, 979-1000.

Johnston, J. (1985). Cognitive prerequisites: The evidence from children learning english. In D. I. Slobin (Ed.), *The crosslinguistic study of language acquisition* (p. 960-1004). Hillsdale, NJ: Erlbaum.

Just, M. A., & Carpenter, P. A. (1971). Comprehension of negation with quantification. *Journal of Verbal Learning and Verbal Behavior*, *10*, 244-253.

Katsos, N., Cummins, C., Gavarró, M. J., Kraljević, A., Hrzica, J. K., ..., & Noveck, I. (2016). Cross-linguistic pat-

terns in the acquisition of quantifiers. *Proceedings of the National Academy of Sciences*, *113*, 9244-9249.

Landau, B., Smith, L., & Jones, S. (1998). Object perception and object naming in early development. *Trends in Cognitive Science*, *2*, 19-24.

Leech, G. (1969). *Towards a semantic description of english*. Bloomington: Indiana University Press.

Markman, E. M. (1990). Constraints children place on word meanings. *Cognitive Science*, *14*, 57-77.

Museyibova, T. A. (1961). The development of an understanding of spatial relations and their reflection in the language of children of pre-school age. In B. G. Anan'yev & B. F. Lovov (Eds.), *Problems of spatial perception and spatial concepts.* Moscow: Prosveshchenie.

Newmeyer, F. J. (2005). *Possible and probable language: A generative perspective on language typology*. Oxford: Oxford University Press.

Palermo, D. S. (1973). More about less: A study of language comprehension. *Journal of Verbal Learning and Verbal Behavior*, *12*, 211-221.

Palermo, D. S. (1974). Still more about the comprehension of" less.". *Developmental Psychology*, *10*, 827.

Papafragou, A., & Schwarz, N. (2006). Most Wanted. *Language Acquisition*, *13*(3), 207-251.

Pinker, S. (1989). *Learnability and cognition. The acquisition of argument structure*. Cambridge, Massachusetts: MIT Press.

Quine, W. V. (1960). *Word and object*. Cambridge MA: MIT Press.

Ryalls, B. O. (2000). Dimensional adjectives: Factors affecting children's ability to compare objects using novel words. *Journal of Experimental Child Psychology*, *76*, 26-49.

Smith, L. B., Cooney, N. J., & McCord, C. (1986). What is "high?" The development of reference points for "high" and "low". *Child Development*, *57*, 583-602.

Sokhin, F. A. (1971). On the formation of linguistic generalization in the course of speech development. *Early Child Development and Care*, *1*, 37-52.

St. Clair, M. C., Monaghan, P., & Ramscar, M. (2009). Relationships between language structure and language learning: The suffixing preference and grammatical categorization. *Cognitive Science*, *33*, 1317-1329.

Suillivan, J., Bale, A., & Barner, D. (2018). Most preschoolers don't know most. *Language Learning and Development*, *14*, 320-338.

Tabullo, A., Arismendi, M., Waiselboim, A., Primero, G., Vernis, G., Segura, E., ... Yorio, A. (2012). On the learnability of frequent and infrequent word orders: An artificial language learning study. *Quarterly Journal of Experimental Psychology*, *65*, 1848-1863.

Tesar, B., & Smolensky, P. (1998). Learnability in optimality theory. *Linguistic Inquiry*, *29*, 229-268.

Tily, H., Frank, M., & Jaeger, T. (2011). The learnability of constructed languages reflects typological patterns. In *Proceedings of cognitive science society* (p. 1364-1369).

Townsend, D. J. (2018). Do children interpret 'marked'comparative adjectives as their opposites? *Journal of Child Language*, *3*, 385-396.

Trabasso, T., Rollins, H., & Shaughnessy, E. (1971). Storage and verification stages in processing concepts. *Cognitive Psychology*, *2*, 239-289.

Tucker, D., Tomaszewicz, B., & Wellwood, A. (2018). Decomposition and processing of negative adjectival comparatives. In E. Castroviejo Miró, G. Sassoon, & L. McNally (Eds.), *The semantics of gradability, vagueness, and scale structure: Experimental perspectives* (p. 243-273). Springer.

van Benthem, J. (1989). Logical constants across types. *Notre Dame Journal of Formal Logic*, *3*.

Vendler, Z. (1967). *Linguistics in philosophy*. Ithaca: Cornell University Press.

Wason, P. C. (1959). The processing of positive and negative information. *Quarterly Journal of Experimental Psychology*, *11*, 217-242.

Waxman, S. R., & Booth, A. E. (2001). Seeing pink elephants: Fourteen-month-olds' interpretations of novel nouns and adjectives. *Cognitive Psychology*, *43*, 217-242.

Wellwood, A., Gagliardi, A., & Lidz, J. (2016). Syntactic and lexical inference in the acquisition of novel superlatives. *Language Learning and Development*, *12*(3), 262-279.