Some (but not all) unattested determiners are unlearnable

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Abstract

A striking cross-linguistic generalisation about the semantics of determiners is that they never express nonconservative relations. To account for this one might hypothesise that the mechanisms underlying human language acquisition are not compatible with nonconservative determiner meanings. We stress that the cross-linguistic generalisation alone should not be taken as decisive evidence for this learnability hypothesis, by briefly discussing another determiner meaning that appears to be unattested but nonetheless learnable. We then report results from an experiment with four- and five-year-olds that support the learnability hypothesis more directly: children fail to learn a novel nonconservative determiner but succeed in learning a comparable conservative determiner.

1 Introduction

It is standardly assumed that a close relationship holds between (i) the learnability of languages with some property $P$, and (ii) the existence of languages with property $P$ as revealed by typological studies. If it is not possible for a human to acquire a language with $P$, then clearly no speakers will be found of any language with $P$. The inverse, though not logically necessary, is often also implicitly thought to be true: that if no natural language exists with $P$, then languages with $P$ are unlearnable. This is not without reason, of course. Since the question of how children manage to acquire their native languages as quickly as they do is still largely unanswered, linguists are interested in discovering possible constraints on the learner’s hypothesis space, for which typological generalisations would seem to make good candidates.¹ Assuming that we would like the formalisms used to describe natural language semantics to have the ability to express
all and only the languages that human beings can naturally acquire, discoveries about constraints on the learner’s hypothesis space in turn dictate which formalisms are too powerful and which are too weak.

We examine the relationship between learnability and typology in the area of determiner meanings. We present experimental evidence that a certain kind of unattested determiner — namely nonconservative determiners (defined below) — is not learnable by children. This result suggests that nonconservative determiners are unattested because they are unlearnable. We caution against taking the non-learnability of such determiners as a foregone conclusion on the basis of the typological facts alone, however, by discussing a determiner that is unattested — specifically, the determiner analogous to ‘most’ but meaning “less than half” rather than “more than half” — but nonetheless does appear to be learnable. In this case we require some other explanation, unrelated to learnability, for the typological generalisation.

Before continuing, two caveats are in order. First, there are two distinct senses of the term “learnable” that can be identified. One can imagine that it is impossible for children to acquire languages with property \(P\) because there is simply no way to encode or represent the corresponding grammars using the language faculty’s mental machinery; there is no state of the language faculty that corresponds to knowing a language with \(P\). We will adopt this more familiar sense of the term for concreteness. One can also imagine, however, that there might be some sense in which there are certain states of the language faculty that correspond to knowing languages with \(P\), but there is no pattern of “primary linguistic data” which leads the learner to such states. Distinguishing between these two scenarios is a potentially important but subtle issue beyond the scope of this paper. We adopt the former sense of “learnable” for ease of exposition and because it is the stronger hypothesis, while acknowledging (i) that our experimental results are equally compatible with the hypothesis that nonconservative determiners are unlearnable only in the second, weaker sense, and (ii) that the connection we make between the space of learnable languages and the formalisms that are appropriate for natural language semantics may be valid only on the first, stronger sense.

The second caveat is that, naturally, it is impossible to demonstrate definitively that anything is unlearnable, in either sense. The best we can do is to demonstrate that a certain word or meaning or construction is not acquired (or more precisely still: that there is no evidence of its being acquired), and contrast this with evidence that a relevant minimally different alternative \(\text{is successfully learned in analogous circumstances. This is exactly the form of the experiment that we will report.}\)

The rest of the paper proceeds as follows. In section 2 we review the relevant back-

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\(^1\)See Chomsky (1965, p.55), Chomsky (1975, p.37), among many others.
ground concerning determiners and conservativity. In section 3 we discuss some related findings concerning non-adult-like interpretations of quantificational expressions, which serve to emphasise that nature of the conservativity generalisation remains unclear. In section 4 we define two novel determiners, only one of which is conservative, and then in section 5 present an experiment comparing children’s abilities to learn these two determiners; the results show that children succeed only in the case of the conservative determiner. We conclude briefly in section 6.

2 Determiners and conservativity

The class of determiners includes words such as ‘every’, ‘some’ and ‘most’. These words can occur in the syntactic frame illustrated in (1).

\[
\text{Det} \quad \text{N} \quad \text{is/are brown} \\
\text{every} \quad \text{dog(s)} \hspace{1em}
\text{some} \hspace{1em}
\text{most}
\]

In the framework of generalised quantifier theory (Mostowski 1957), sentences with this form express a relation between two sets: the set of dogs, and the set of brown things. If we represent these sets by DOG and BROWN respectively, the truth conditions of the three sentences abbreviated in (1) can be expressed as in (2).

\[
\begin{align*}
\text{‘every dog is brown’ is true iff } & \text{DOG} \subseteq \text{BROWN} \\
\text{‘some dog is brown’ is true iff } & \text{DOG} \cap \text{BROWN} \neq \emptyset \\
\text{‘most dogs are brown’ is true iff } & |\text{DOG} \cap \text{BROWN}| > |\text{DOG} - \text{BROWN}|
\end{align*}
\]

An analogy can be made between the syntactic role of determiners and that of a transitive verb such as ‘like’. A determiner expresses a relation between two sets, much as a transitive verb expresses a relation between two individuals: (3) indicates that a particular relation holds between John and Mary.

\[
\text{NP} \quad \text{V} \quad \text{NP} \\
\text{John} \quad \text{likes} \quad \text{Mary}
\]

\footnote{We remain agnostic about many of the details of the syntax of these sentences, and for this reason limit our attention to quantifiers in subject positions. What is important is just that “determiner” is defined distributionally as something that combines with a noun to form a noun phrase.}
The transitive verb ‘like’ combines first with ‘Mary’ and then with ‘John’, resulting in a sentence that expresses a relation between the two corresponding individuals. If we ignore the linear order of the trees and consider only the hierarchical relations, we see that the determiners in (1) likewise combine first with ‘dog(s)’ and then with ‘is/are brown’, resulting in a sentence that expresses a relation between the two corresponding sets. We call ‘Mary’ and ‘dog(s)’ the internal arguments, and call ‘John’ and ‘is/are brown’ the external arguments.

Standard approaches to natural language semantics (eg. Heim & Kratzer (1998) and Larson & Segal (1995) among many others) postulate that knowing the meaning of a determiner is knowing which of all the conceivable two-place relations on sets the determiner expresses, just as knowing the meaning of the transitive verb ‘like’ is knowing that it expresses “the liking relation” on individuals. Thus the three determiners in (1) are associated with the following three relations on sets:

\[
\begin{align*}
R_{\text{every}}(X)(Y) & \equiv X \subseteq Y \\
R_{\text{some}}(X)(Y) & \equiv X \cap Y \neq \emptyset \\
R_{\text{most}}(X)(Y) & \equiv |X \cap Y| > |X - Y|
\end{align*}
\]

and so the sentence ‘every dog is brown’, for example, in which the internal argument of ‘every’ denotes the set DOG and the external argument of ‘every’ denotes the set BROWN, is true if and only if \(R_{\text{every}}(\text{DOG})(\text{BROWN})\) is true.

When the determiners of the world’s languages are analysed in this way, a surprising generalisation emerges (Barwise & Cooper 1981, Higginbotham & May 1981, Keenan & Stavi 1986): every attested determiner expresses a relation that is conservative, as defined in (5).\(^3\)

\[
\begin{align*}
\text{(5) A two-place relation on sets } R \text{ is conservative if and only if the following biconditional is true:} \\
R(X)(Y) & \iff R(X)(X \cap Y)
\end{align*}
\]

\(^3\)Two apparent counterexamples are ‘only’ and ‘many’. Closer examination quickly shows that ‘only’ is not a determiner, as defined distributionally. While at first ‘only dogs are brown’ looks superficially like ‘some dogs are brown’, ‘only’ can appear in many other positions where ‘some’ and ‘every’ cannot, eg. ‘dogs only/*some/*every are brown’, and ‘dogs are only/*some/*every brown’. The case of ‘many’ is less clear, complicated by context-dependence, but can also plausibly be made to fit with the conservativity generalisation; see for example Keenan & Stavi (1986) and Herburger (1997).
For example, consider the English determiner ‘every’. This determiner is conservative because the relevant biconditional holds.

\[ R_{\text{every}}(X)(Y) \iff X \subseteq Y \iff X \subseteq (X \cap Y) \iff R_{\text{every}}(X)(X \cap Y) \]

To think about this more intuitively we can express the crucial biconditional in natural language. Since the requirement entails that \( R_{\text{every}}(\text{DOG})(\text{BROWN}) \) holds if and only if \( R_{\text{every}}(\text{DOG})(\text{BROWN} \cap \text{DOG}) \) holds, and since \( (\text{BROWN} \cap \text{DOG}) \) is the set of brown dogs, the crucial biconditional is “every dog is brown if and only if every dog is a brown dog”. This is trivially true, and so ‘every’ is conservative.

Another intuitive view of what it means for ‘every’ to be conservative is that in order to determine whether a sentence like ‘every dog is brown’ is true, it suffices to consider only dogs. The brownness or otherwise of dogs is relevant, but the brownness of anything else is not. Barwise & Cooper (1981) call this “living on the internal argument”, since DOG is the set denoted by the internal argument of ‘every’ in this sentence. Other members of the set denoted by the external argument, BROWN, can be ignored.

We can now observe that both ‘some’ and ‘most’ are also conservative: to determine whether ‘some/most dogs are brown’ it is safe to ignore any brown things are not dogs. Alternatively, we can note that both the following biconditionals are true: (i) “some dogs are brown if and only if some dogs are brown dogs”, and (ii) “most dogs are brown if and only if most dogs are brown dogs”.

For comparison, consider a fictional determiner ‘equi’. The relation that this determiner expresses is illustrated in (6) (see also Crain et al. 2005, p.182).

\[
\begin{align*}
\text{a. } R_{\text{equi}}(X)(Y) & \equiv |X| = |Y| \\
\text{b. } \text{‘equi dogs are brown’ is true iff } |\text{DOG}| = |\text{BROWN}|
\end{align*}
\]

So ‘equi dogs are brown’ is true if and only if the number of dogs (in the relevant domain) is equal to the number of brown things. Note that brown things that are not dogs are relevant to the truth of this sentence. To verify this claim it does not suffice to consider only dogs, so ‘equi’ does not “live on” its internal argument. We can also observe the falsity of the crucial biconditional: \( |\text{DOG}| = |\text{BROWN}| \iff |\text{DOG}| = |\text{DOG} \cap \text{BROWN}| \), or “the number of dogs is equal to the number of brown things if and only if the number of dogs is equal to the number of brown dogs”. Thus ‘equi’ is not conservative.

The absence of nonconservative determiners is problematic for standard theories of semantics, on at least one view of what these theories aim to account for: ideally, it would

\[4\text{We systematically overload the term “conservative”, using it to apply both to relations as defined in (5) and to determiners that express such relations.}\]
be desirable for the mechanics of a semantic theory to allow determiners with all and only the meanings that the human language faculty allows. Following familiar reasoning about the relationship between innate properties of the language faculty and linguistic typology, a reasonable hypothesis to consider is that the lack of nonconservative determiners in the world’s languages derives from the inability of the human language faculty to associate the structure in (1) with the claim that a nonconservative relation holds between the set of dogs and the set of brown things. The overwhelming majority of current theories, however, are equally compatible with conservative and nonconservative determiners, essentially predicting that the language faculty should be able to associate the structure in (1) with either kind of relation (but see Pietroski (2005), Bhatt & Pancheva (2007) and Fox (2002) for some exceptions).\(^5\)

In this paper, we investigate whether children allow the structure in (1) to express nonconservative relations. If children permit (1) to be associated with a nonconservative meaning, then a semantic theory which permits nonconservative determiners would appear to be an accurate reflection of the workings of the human language faculty, and the lack of nonconservative determiners in natural languages would need to be explained by something else. However, in the experiment we report below, we find that children do not consider nonconservative meanings for novel determiners, supporting the hypothesis that the language faculty is unable to associate the structure in (1) with a nonconservative relation and strengthening the case that semantic theories should be revised to reflect this.

\(^5\)To elaborate, a theory of semantics might in principle allow the words of a certain syntactic category too small a range of possible meanings, or too large. A theory might allow determiners \textit{too small} a range of meanings by, for example, requiring that the structure \([\text{Det} \ X \ Y]\) is associated with a claim that a relation expressible first-order predicate logic holds between \(X\) and \(Y\). This would incorrectly exclude the meaning we need to associate with ‘most’, which requires a more powerful logic. Alternatively, a theory might allow determiners \textit{too large} a range of meanings by permitting the structure \([\text{Det} \ X \ Y]\) to either express a two-place relation between the set \(X\) and the set \(Y\), or a three-place relation between the set \(X\), the set \(Y\), and some other set. We never see the human language faculty making use of this latter three-place option, so we suppose that the option is not there and prefer theories that do not allow it. The case of conservativity is analogous: if we never see the human language faculty making use of the ability to learn nonconservative determiners, we would prefer theories that do not allow it.
3 Children’s interpretation of quantification: Other findings

3.1 Symmetric interpretations

The question of whether children can associate determiners with nonconservative meanings remains open, despite various much-discussed findings of non-adult-like “symmetric” interpretations of quantificational sentences. Inhelder & Piaget (1964, pp.60–74) found that some children will answer “no” to a question like (7) if there are blue non-circles present. When prompted, these children will explain this answer by pointing to, for example, some blue squares.

(7) Are all the circles blue?

Taken at face value it appears that these children are understanding (7) to mean that (all) the circles are (all) the blue things, as if $R_{all}(X)(Y) \equiv X = Y$. This is a clearly nonconservative relation, since answering (7) on this interpretation requires paying attention to non-circles. But there are at least two reasons to doubt that these children have associated this nonconservative relation with the determiner ‘all’.

First, similar “symmetric responses” have been observed with questions like (8) involving transitive predicates. Some children will answer “no” to (8) if there are elephants not being ridden by a girl (Philip 1991, 1995).

(8) Is every girl riding an elephant?

Consider the interpretation of ‘every’ that these children are using. If ‘every’ is analysed as a determiner with a conservative meaning, then answering (8) should require only paying attention to the set of girls (and which of the girls are riding an elephant), since this is the denotation of the internal argument ‘girl’. Clearly ‘every’ is not being analysed in this way by the children for whom the presence of unreidn elephants are relevant. However, these children are not analysing ‘every’ as a nonconservative determiner either. Such a determiner would permit meanings that required looking beyond the set of girls denoted by the internal argument and took into consideration the entire set denoted by the external argument, as the fictional ‘equi’ does; but crucially, the external argument would be ‘is riding an elephant’ and would therefore denote the set of elephant-riders, not the set of elephants. In other words, if children took ‘every’ to denote the nonconservative relation labelled $R_{all}$ above, it would be non-girl elephant-riders that trigger “no” responses to (8). This is not what was observed. On the assumption then that these symmetric responses to (7) and (8) are to be taken as instances of the one phenomenon, this phenomenon is more general than (and independent of) any specific details.
of determiners and conservativity.

Second, it has been argued that these symmetric interpretations of universal quantifiers are a methodological artefact. Crain et al. (1996) suggest that the experimental techniques used in studies finding symmetric interpretations made the target sentences pragmatically infelicitous in a way that led participants to accommodate by adopting non-adult-like interpretations. When this methodological flaw is corrected, Crain et al. found that children’s interpretations of sentences like (8) are essentially adult-like; see also Gualmini (2003).

3.2 Proportional determiners

Recall that the relationship between typological generalisations and learnability is only a “one way” implication: if it turns out to be correct that nonconservative determiners are unlearnable then it follows that no language will be found with nonconservative determiners, but the typological absence of nonconservative determiners does not in itself establish that they are unlearnable. Other determiner meanings may be learnable — that is, a child would acquire them if exposed to “the right” pattern of primary linguistic data — but nonetheless unattested because, for some unrelated reason, no language community uses such determiners. (Note that this learnable-but-unattested possibility exists independently of the distinction between the two senses of “learnable” noted in the introduction. ⁷)

An apparent example of this pattern is the determiner — let us call it ‘fost’ — that is analogous to ‘most’ but expresses “less than (half)” rather than “more than (half)”. This is defined in (9); compare with ‘most’ in (4).

\[
\begin{align*}
\text{(9)} & \quad \text{a. } R_{\text{fost}}(X)(Y) \equiv |X \cap Y| < |X - Y| \\
& \quad \text{b. ‘fost dogs are brown’ is true iff } |\text{DOG} \cap \text{BROWN}| < |\text{DOG} - \text{BROWN}|
\end{align*}
\]

This determiner is conservative, since it depends on the same two sets as ‘most’ does, but is nonetheless unattested (Hackl 2009). Like the typological finding about conservativity, this is rather striking when one considers that ‘fost’ is so minimally different from ‘most’,

⁶The relevant distinction is collapsed in (7) because the denotation of the determiner’s external argument, the verb phrase ‘are blue’, is (on standard assumptions) the same as that of this verb phrase’s own complement ‘blue’, namely the set of blue things.

⁷More precisely, there are (at least) three classes of logically possible unattested determiner meanings: (i) those which are unrepresentable or unencodable; (ii) those which are representable or encodable, but which no pattern of primary linguistic data leads the language acquisition device(s)/mechanism(s) to settle upon; and (iii) those which a child would acquire if exposed to “the right” pattern of primary linguistic data. The first two classes were discussed in the introduction, and we make no attempt to distinguish between them in this paper. The third class, which we discuss here, is easier to identify.
(an equivalent of) which, while not widespread, does appear in a number of natural languages.

This, in combination with the fact that ‘most’ is the only attested (monomorphemic) determiner that is not expressible in first-order logic (Barwise & Cooper 1981), prompted Hackl (2009) to suggest that ‘most’ may not be an atomic determiner, but rather a complex expression constructed from the morphemes ‘many’ and ‘-est’, in such a way that does not likewise permit ‘few’ and ‘-est’ to form a complex determiner with the meaning of ‘fost’. To illustrate the basic idea behind Hackl’s proposal, consider (10) and (11). If we accept the informal analysis of the standard superlative ‘highest’ in (10), then justifying the decomposition of ‘most’ into ‘many’ and ‘-est’ requires showing that the parallel (11) captures the correct meaning of ‘most’.

(10) ‘high-est mountain’ applies to a mountain \( m \) iff:
    for all mountains \( m' \) distinct from \( m \), \( m \) is higher than \( m' \)

(11) ‘many-est dogs’ applies to a plurality of dogs \( D \) iff:
    for all pluralities of dogs \( D' \) distinct from \( D \), \( D \) is more numerous than \( D' \)

The crucial point for Hackl is how we should understand “\( D' \) distinct from \( D \)” in (11). If two pluralities \( D' \) and \( D \) are “distinct” whenever there are individuals that belong to one but not the other (analogous to the condition for non-equality on sets), then ‘many-est dogs’ will only apply to the unique maximal plurality that contains all dogs; this is the only plurality that is more numerous than all distinct ones, including the distinct plurality that consists of 99% of the dogs, for example. This does not yield the desired meaning for ‘most’. If, on the other hand, \( D' \) and \( D \) are distinct only if they are disjoint (do not overlap at all), then ‘many-est dogs’ will apply to any plurality containing at least 50% of the dogs, as desired; the largest disjoint competitor to such a plurality is its complement, which is necessarily not more numerous.

Consider now the predictions of the “no overlap” understanding of distinctness when we construct a complex quantifier analogous to ‘many-est dogs’ but with ‘few’ in place of ‘many’. The expected meaning is given in (12).

(12) ‘few-est dogs’ applies to a plurality of dogs \( D \) iff:
    for all pluralities of dogs \( D' \) distinct from \( D \), \( D \) is less numerous than \( D' \)

This requires a plurality that is less numerous than all disjoint other pluralities. A plurality containing, say, four of the ten relevant dogs, for example, does not meet this condition, since there exist disjoint pluralities that contain only three dogs (or two dogs or one dog) that are less numerous. Hackl argues that in fact the result is “pathological in that no plurality can satisfy the condition” (p.83). But whatever the exact status of (12), it does not produce the meaning of ‘fost’ as defined in (9). Taken as a theory of the
meanings that humans can and cannot associate with sentences, the analysis of ‘most’ as in (11) therefore explains the otherwise puzzling absence of ‘fost’.

Other recent experimental results, however, cast doubt on the assumption that a sentence with the structure shown in (1) cannot be understood to mean that less than half of the dogs are brown, i.e. the assumption that ‘fost’ is unlearnable. Halberda et al. (submitted) found a number of children (age range 3;8 to 5;0, mean 4;3) who have learnt to understand the English word ‘most’ to mean what is described above as ‘fost’. These children, when presented with a picture of eight rabbits and three frogs, for example, consistently respond as if ‘most of the animals are frogs’ is true. This finding is unrelated to the central aims of Halberda et al.’s study, which examined the interaction between children’s understanding of ‘most’ and their counting abilities, without expecting to encounter any such ‘fost’-users; and it raises many interesting questions about how a child would come to associate the meaning of the fictional ‘fost’ with the word ‘most’, about what evidence prompts the child to move from this to an adult-like understanding of ‘most’, and so on. The interest for present purposes lies simply in the fact that a small but significant number of children (6 out of 77) have assigned a “wrong” meaning to a determiner in the ambient language, and that this assigned meaning is typologically unattested.

It therefore seems that the typological generalisation concerning the absence of ‘fost’ should not be put down to a learnability restriction. On this view, Hackl’s theory appears to be too restrictive. The right theory of semantic competence should be able to express the meaning of ‘fost’, even if no natural language makes use of this option. Of course, this leaves open the question of why it is that no natural language has a determiner with the meaning of ‘fost’,

but we adopt the assumption that its learnability is reason enough to strive for semantic theories in which it is expressible. There are other conceivable approaches: if the absence of ‘fost’ is for some pragmatic or functional reason, for example, one could choose to strive for a unified theory that enforces the pragmatic or functional pressures which prevent ‘fost’ from naturally occurring in just the same way that it enforces constraints that rule out unlearnable determiners (eg. nonconservative ones, according to the results we report below). But we take the goal of linguistic theory to be to characterise possible states of the human mind, and the results of Halberda et al. (submitted) suggest that human minds can (however rarely or temporarily) enter into a state where a word with the syntactic distribution of a determiner has the meaning of

\[8\] Note that ‘fewest’, whatever its precise relationship to ‘few’ and ‘-est’ may be, is not a determiner.

\[9\] We are interested in the possibility of finding even stronger support for the hypothesis that ‘fost’ is learnable through experimental investigation along the lines of what we report below, explicitly attempting to teach children unattested meanings.
The aim of the experiment reported below is to shed light on whether the cross-linguistic absence of nonconservative determiners is accidental in the way that the absence of ‘fost’ appears to be.

4 Two novel determiners: ‘gleeb’ and ‘gleeb’

The question we aim to address is whether children permit structures like (1) to have nonconservative meanings. To investigate this question, we attempted to teach children novel determiners. If children have no inherent restrictions on determiner meanings, then we would predict that they will be able to learn both novel conservative determiners and novel nonconservative determiners. However, if the typological generalisation that we observe reflects a restriction imposed by the language faculty, then we predict that children will succeed in learning novel conservative determiners, and will not succeed in learning novel nonconservative determiners.

In order to test these predictions we created two novel determiners, one conservative and one nonconservative. The conservative one, ‘gleeb’, expresses the relation $\mathcal{R}_{\text{gleeb}}$ as illustrated in (13).

$$\begin{align*}
\text{a. } & \mathcal{R}_{\text{gleeb}}(X)(Y) \equiv X \not\subseteq Y \equiv \neg (X \subseteq Y) \\
\text{b. } & \text{‘gleeb girls are on the beach’ is true iff GIRL} \not\subseteq \text{BEACH}
\end{align*}$$

So ‘gleeb girls are on the beach’ is the negation of ‘every girl is on the beach’: it is true if

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10Horn (1972) notes a generalisation that may be relevant here: languages seem not to lexicalise meanings that would extend the range of expressible propositions only to those that are already pragmatically implicated by certain other existing expressions (in other words, a language gets “only those lexical items it actually needs” (p.251)). His discussion centres around the possibility of lexicalising quantifiers along with negation, observing that across domains (e.g. nominal and modal quantification, the binary connectives) there is lexicalisation of $\neg \exists \equiv \forall \neg$ (e.g. ‘none’) but not of $\exists \neg \equiv \forall$. This is consistent with Horn’s generalisation since devices for expressing $\neg \forall$ on a given scale come for free from the scale’s existential quantifier, via implicature. As is (by now) commonly assumed, an assertion of ‘Some girls called’ implicates ‘Some girls didn’t call’ or, equivalently, ‘Not all girls called’. Simplifying somewhat, Horn predicts that if it is true that $\exists$ implicates $\exists$, then $\exists \neg \equiv \forall$ will not be lexicalised. This correctly predicts the absence of the quantifier meaning ‘not all’, on pragmatic grounds, not precluding its learnability. (This is, in fact, the conservative determiner we use as a “control” in the experiment reported below, and children do indeed succeed in learning it.) It likewise predicts the absence of ‘$\neg$most’, but does not predict the absence of ‘most$\neg$’, although both are unattested in natural languages. Since $\neg \mathcal{R}_{\text{most}}(X)(Y)$ and $\mathcal{R}_{\text{most}}(X)(\neg Y)$ differ in truth value only if $|Y \cap X| = |Y - X|$, a case which was not considered in the experiment of Halberda et al. (submitted), it is unclear which of these two meanings the children in Halberda et al.’s experiment were using and therefore whether the finding is consistent with Horn’s pragmatic restrictions or not.
and only if the set of girls (GIRL) is not a subset of the set of beach-goers (BEACH), so we might paraphrase it as ‘not all girls are on the beach’. For example, it is true in the scene shown in Figure 1(a), but false in the scene shown in Figure 1(b). Since ‘gleeb’ is the “negation” of the conservative determiner ‘every’, it is also conservative: anything on the beach that is not a girl is irrelevant to the truth of the sentence in (13b), so ‘gleeb’ does live on its internal argument, and the biconditional “not all girls are on the beach if and only if not all girls are girls on the beach” is true.

The novel nonconservative determiner, written ‘gleeb’ but pronounced identically to the conservative determiner ‘gleeb’, expresses the relation as illustrated in (14).

\[(14) \begin{align*}
\text{a. } R'_{\text{gleeb}}(X)(Y) &\equiv Y \nsubseteq X \equiv \neg(Y \subseteq X) \equiv R_{\text{gleeb}}(Y)(X) \\
\text{b. } \text{‘gleeb’ girls are on the beach’ is true iff BEACH } \nsubseteq \text{ GIRL}
\end{align*}\]

So ‘gleeb’ girls are on the beach is the “mirror image” of ‘not all girls are on the beach’: it is true if and only if not all beach-goers are girls. For example, it is true in the scene shown in Figure 1(b), but false in the scene shown in Figure 1(a). Since the “lived on” set (the beach-goers) is not expressed as the internal argument of ‘gleeb’ in (14b), ‘gleeb’ is not conservative. To determine whether the sentence in (14b) is true, one cannot limit one’s attention to the set of girls; beach-goers who are not girls are relevant. And the crucial biconditional, which we can paraphrase as “not all beach-goers are girls if and only if not all beach-going girls are girls”, is false since the first clause can be true while the second cannot.

Our experiment will compare children’s ability to learn ‘gleeb’ with their ability to learn ‘gleeb’, based on equivalent input. Note that the conditions expressed by these two determiners are just the “mirror image” of each other, with the subset-superset relationship reversed. By any non-linguistic measure of learnability or complexity, the two determiners seem likely to be equivalent, since each expresses the negation of an inclusion relation. Thus there is no reason to expect a difference in how easily they can be learnt — unless there are constraints on the semantic significance of specifically being the internal or external argument of a determiner, since this is all that distinguishes ‘gleeb’ from ‘gleeb’. A finding that children are able to learn ‘gleeb’ but not ‘gleeb’ would therefore be difficult to explain by any means other than such a restriction on the way internal and external arguments of determiners are interpreted.

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11 Suppose that \( R \) is conservative, and that \( R^*(X)(Y) \equiv \neg R(X)(Y) \). Then \( R^*(X)(Y) \) is equivalent to \( \neg R(X)(X \cap Y) \) by the conservativity of \( R \), and is therefore equivalent to \( R^*(X)(X \cap Y) \) by the definition of \( R^* \). Therefore \( R^* \) is also conservative.

12 The fact that ‘gleeb’ happens to live on its external argument makes it anticonservative — unlike ‘equi’, which is neither conservative nor anticonservative — but this is not relevant here.
Figure 1: Two sample cards. In the conservative condition, the puppet would like only the card in (a): ‘gleeb girls are on the beach’ is true in (a), but false in (b). In the nonconservative condition, the puppet would like only the card in (b): ‘gleeb’ girls are on the beach’ is false in (a), but true in (b).

5 Experiment: Conservativity and learnability

5.1 Design and methodology

Each participant was assigned randomly to one of two conditions: the conservative condition or the nonconservative condition. Participants in the conservative condition were trained on ‘gleeb’, and participants in the nonconservative condition were trained on ‘gleeb’; each participant was then tested on whether he/she had learnt the determiner he/she was exposed to.

To assess the participants’ success in learning, we used a variant of the “picky puppet task” (Waxman & Gelman 1986). The task involves two experimenters. One experimenter controls a “picky puppet”, who likes some cards but not others. The second experimenter places the cards that the puppet likes in one pile, and the cards that the puppet does not like in a second pile. The child’s task is to make a generalisation about what kinds of cards the puppet likes, and subsequently “help” the second experimenter by placing cards into the appropriate piles.

The experimental session was divided into two phases: warm-up and target. During the warm-up phase, the experimenter ensured that the child could carry out the basic task of sorting cards into piles according to “liking criteria”: for example, in the first such warm-up item the child would be told “The puppet only likes cards with yellow things on them”, and then asked to sort a number of cards into “like” and “doesn’t like”
piles accordingly. The warm-up phase contained three items; the particular cards and
the puppet’s liking criterion differed from item to item.

The target phase used cards like those shown in Figure 1, and was divided into a
training period and a test period. The child was told that the puppet had revealed to
the experimenter whether he liked or disliked some of the cards, but not all of them.
The child was told that the experimenter would sort what he/she could, but that the
child would then have to help by sorting the remaining cards that the puppet was silent
about. During the training period the experimenter sorted five cards, according to the
criterion appropriate for the condition: in the conservative condition, the child was told
that the puppet likes cards where ‘gleeb girls are on the beach’ (i.e. where not all girls are
on the beach), and in the nonconservative condition, the child was told that the puppet
likes cards where ‘gleeb’ girls are on the beach’ (i.e. where not all beach-goers are girls).
The experimenter placed each card into the appropriate pile in front of the participant,
providing either (15a) or (15b) as an explanation as appropriate.\(^\text{13}\)

\begin{align*}
(15) & \quad a. \text{The puppet told me that he likes this card because gleeb girls are on the} \\
& \hspace{1cm} \text{beach.} \\
& \quad b. \text{The puppet told me that he doesn’t like this card because it’s not true that} \\
& \hspace{1cm} \text{gleeb girls are on the beach.}^\text{14}
\end{align*}

Having placed all the training cards (the cards that “the puppet had told the exper-
imenters about”) in the appropriate piles, the experimenter turned the task over to the
child for the test period. The experimenter handed five new cards to the child, one at a
time, and asked the child to put the card in the appropriate pile, depending on whether or
not the child thought the puppet liked the card. The experimenters recorded which cards
the child sorted correctly and incorrectly according to the criterion used during training.
The cards that the experimenter had sorted during the training period remained visible
throughout the testing period.

The same training cards and the same testing cards were used in both conditions,
though whether the puppet liked or disliked the card varied from one condition to the
other. Table 1 shows, for each card, the number of girls and boys on the beach and
on the grass, and whether each condition’s relevant criterion is met or not. These were
designed to be as varied as possible, while maintaining the pragmatic felicity of the two
crucial target statements. The total number of characters on each card was also kept as
close to constant as possible: either five or six for each card. The number of training
\footnote{\text{13}We do not distinguish between the conservative ‘gleeb’ and the nonconservative ‘gleeb’ in writing
(15), to illustrate that the explanations were homophonous across the two conditions.}
\footnote{\text{14}Negation was always expressed in a separate clause to avoid any undesired scopal interactions.}
Table 1: The distribution of girls and boys on each card in the experiment

<table>
<thead>
<tr>
<th>Card</th>
<th>beach boys</th>
<th>beach girls</th>
<th>'gleeb girls are on the beach'</th>
<th>'gleeb′ girls are on the beach'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train 1</td>
<td>2</td>
<td>0</td>
<td>true</td>
<td>true</td>
</tr>
<tr>
<td>Train 2</td>
<td>0</td>
<td>2</td>
<td>false</td>
<td>false</td>
</tr>
<tr>
<td>Train 3</td>
<td>0</td>
<td>1</td>
<td>true</td>
<td>false</td>
</tr>
<tr>
<td>Train 4</td>
<td>2</td>
<td>3</td>
<td>false</td>
<td>true</td>
</tr>
<tr>
<td>Train 5</td>
<td>2</td>
<td>1</td>
<td>true</td>
<td>true</td>
</tr>
<tr>
<td>Test 1</td>
<td>3</td>
<td>0</td>
<td>true</td>
<td>true</td>
</tr>
<tr>
<td>Test 2</td>
<td>0</td>
<td>3</td>
<td>false</td>
<td>false</td>
</tr>
<tr>
<td>Test 3</td>
<td>2</td>
<td>3</td>
<td>true</td>
<td>true</td>
</tr>
<tr>
<td>Test 4</td>
<td>1</td>
<td>2</td>
<td>false</td>
<td>true</td>
</tr>
<tr>
<td>Test 5</td>
<td>1</td>
<td>2</td>
<td>true</td>
<td>true</td>
</tr>
</tbody>
</table>

cards that the puppet likes is the same in each condition (three), so the situation that the participant is presented with during the training phase is analogous across conditions.

The participants were 20 children, aged 4:5 to 5:6 (mean 5:0). Each condition contained 10 children. Ages of those in the conservative condition ranged from 4:5 to 5:5 (mean 4:11), and ages of those in the nonconservative condition ranged from 4:11 to 5:3 (mean 5:1); the two groups did not differ significantly in age ($t = 1.4141$, $df = 18$, $p = 0.17$).

5.2 Results

The results indicate that children exposed to the novel conservative determiner successfully learnt it, and that children exposed to the novel nonconservative determiner did not. The results are summarised in Table 2.

First we can consider how many cards children in the two conditions sorted correctly. If children never succeeded in learning the determiner’s meaning, we would expect performance to be at chance. For each condition, participants were classified into six groups according to the number of test cards sorted correctly (zero to five), and compared this grouping with the grouping expected under the assumption of chance performance.\(^{15}\) Children in the conservative condition performed significantly better than chance ($\chi^2 = 74.160$, $df = 5$, $p < 0.0001$), sorting an average of 4.1 cards correctly, whereas children in the nonconservative condition did not ($\chi^2 = 6.640$, $df = 5$, $p > 0.2488$), sorting an average of 3.1 cards correctly.

Alternatively, we can consider how many children in each condition performed “per-

\(^{15}\)This is computed via the binomial distribution, i.e. given $n$ participants (here $n = 10$), the number expected to give exactly $k$ correct responses is \(\binom{n}{k} \left(\frac{1}{2}\right)^n \left(\frac{1}{2}\right)^{n-k} = \binom{n}{k} \left(\frac{1}{2}\right)^n\).
\begin{table}
\centering
\begin{tabular}{|l|c|c|}
\hline
Condition & Conservative & Nonconservative \\
\hline
Cards correctly sorted (out of 5) & mean 4.1 & mean 3.1 \\
& (above chance, $p < 0.0001$) & (not above chance, $p > 0.2488$) \\
\hline
Subjects with “perfect” accuracy & 50\% & 10\% \\
\hline
\end{tabular}
\caption{Summary of results}
\end{table}

fectly”, sorting all five test cards correctly. Of the children in the conservative condition, five out of ten sorted all test cards correctly, whereas only one child out of ten in the nonconservative condition sorted all test cards correctly, indicating a marginally significant dependency between conservativity of the determiner and success in learning ($p = 0.07$, Fisher’s exact test).

The results are even more telling when we look more closely at the responses of the one child who sorted all five test cards correctly in the nonconservative condition. This child told the experimenters that the puppet was confused about which characters on the cards were boys and which were girls. Recall that in this condition the true criterion for the puppet to like a card was ‘gleeb’ girls are on the beach’, or equivalently ‘not all beach-goers are girls’. But another statement equivalent to these is ‘some boys are on the beach’. So if the child thought that the puppet intended the internal argument of the determiner in the crucial sentence to denote the set of boys, then she in fact learnt a conservative meaning for ‘gleeb’, with a meaning like ‘some’ has. One might even be tempted to suggest that she was led to believe that the puppet was confusing boys with girls because of a requirement that ‘gleeb’ be understood conservatively.

Of course, these results should only bear on the issue of determiner meanings to the extent that we are confident that the participants really did understand the relevant parts of the explanations in (15) to have the structure shown in (1). Had we found no difference between the conservative and nonconservative conditions, one might be hesitant to reject the hypothesis that determiners are restricted to conservative meanings, because of the possibility that participants were not analysing the crucial word as a determiner. But it is unlikely that we would have found results consistent with the independently motivated restriction to conservative determiner meanings if participants had not been using determiner structures.

\section{Conclusion}

We have examined the relationship between learnability and typology in determiner meanings. A strong correlation is often suspected to hold between learnability and typological generalisations, but recall that only in one direction is this connection logically necessary.
While an unlearnable determiner will of course not be found in any natural language, determiners which are not found in any natural language need not — despite familiar reasons to suspect so — necessarily be unlearnable. We presented an experiment that revealed no evidence of participants successfully learning a nonconservative determiner meaning, indicating that the conservativity generalisation constitutes an instance of the conventionally suspected correlation. This contrasts in particular with another unattested determiner, ‘fost’, which apparently is learnable. If these conclusions are correct we have identified two determiners that have the same typological status but differ in learnability; the typological absence of nonconservative determiners can be put down to unlearnability, but the same cannot be said of ‘fost’. This in turn gives us reason to prefer theories of natural language semantics that rule out nonconservative relations, but do not rule out “less than half”, as possible determiner meanings.

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