

Conservativity and learnability of determiners

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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 unsuited to nonconservative determiner meanings. We present experimental evidence that four- and five-year-olds fail to learn a novel nonconservative determiner but succeed in learning a comparable conservative determiner, consistent with the learnability hypothesis.

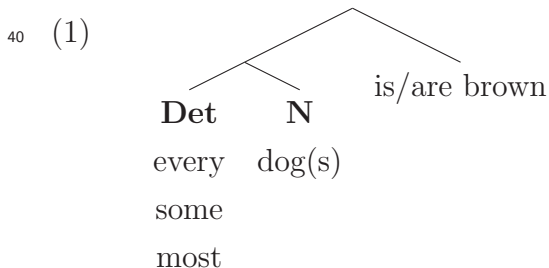
1 Introduction

Testing children's abilities to acquire novel words tells us about the word meanings that children are likely to entertain as hypotheses, and therefore to some extent about the range and limits of the word meanings permitted by the language faculty. We examine children's learning of novel determiner meanings, in order to investigate whether a well-established typological generalisation might derive from a constraint on language learning. Specifically, all attested natural language determiners are conservative (defined below), and we compare children's abilities to learn a conservative determiner with their abilities to learn a nonconservative one. Striking as the typological generalisation may be, it does not logically entail any asymmetry in the status of conservative and nonconservative determiners in the learner's hypothesis space; in principle one can imagine alternative explanations based on some pragmatic or functional reason. We find, however, that children succeed in learning a novel conservative determiner but fail to learn a novel nonconservative determiner, which is consistent with the hypothesis that the typological generalisation results from constraints on children's hypothesis space of determiner meanings.

29 The rest of the paper proceeds as follows. In section 2 we review the relevant back-
 30 ground concerning determiners and conservativity. In section 3 we discuss some related
 31 findings concerning non-adult-like interpretations of quantificational expressions, which
 32 serve to emphasise that the nature of the conservativity generalisation remains unclear.
 33 In section 4 we define two novel determiners, only one of which is conservative, and then
 34 in section 5 present an experiment comparing children’s abilities to learn these two de-
 35 terminers; the results show that children succeed only in the case of the conservative
 36 determiner. We conclude briefly in section 6.

37 2 Determiners and conservativity

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

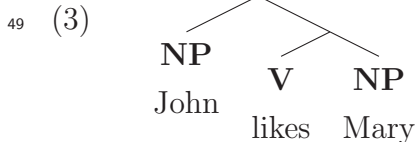


41 In the framework of generalised quantifier theory (Mostowski 1957), sentences with this
 42 form express a relation between two sets: the set of dogs, and the set of brown things.
 43 If we represent these sets by DOG and BROWN respectively, the truth conditions of the
 44 three sentences abbreviated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

- (2) ‘every dog is brown’ is true iff $\text{DOG} \subseteq \text{BROWN}$
 ‘some dog is brown’ is true iff $\text{DOG} \cap \text{BROWN} \neq \emptyset$
 ‘most dogs are brown’ is true iff $|\text{DOG} \cap \text{BROWN}| > |\text{DOG} - \text{BROWN}|$

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

¹We 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.



50 The transitive verb ‘like’ combines first with ‘Mary’ and then with ‘John’, resulting in
 51 a sentence that expresses a relation between the two corresponding individuals. If we
 52 ignore the linear order of the trees and consider only the hierarchical relations, we see
 53 that the determiners in (1) likewise combine first with ‘dog(s)’ and then with ‘is/are
 54 brown’, resulting in a sentence that expresses a relation between the two corresponding
 55 sets. We call ‘Mary’ and ‘dog(s)’ the *internal* arguments, and call ‘John’ and ‘is/are
 56 brown’ the *external* arguments.

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

(4)

$$\mathcal{R}_{\text{every}}(X)(Y) \equiv X \subseteq Y$$

$$\mathcal{R}_{\text{some}}(X)(Y) \equiv X \cap Y \neq \emptyset$$

$$\mathcal{R}_{\text{most}}(X)(Y) \equiv |X \cap Y| > |X - Y|$$

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

66 When the determiners of the world’s languages are analysed in this way, a surprising
 67 generalisation emerges (Barwise & Cooper 1981, Higginbotham & May 1981, Keenan &
 68 Stavi 1986): every attested determiner expresses a relation that is conservative, as defined
 69 in (5).²

(5) A two-place relation on sets \mathcal{R} is *conservative* if and only if the following bicon-
 ditional is true:

$$\mathcal{R}(X)(Y) \iff \mathcal{R}(X)(X \cap Y)$$

²Two 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 conservative³ because the relevant biconditional holds.

$$\mathcal{R}_{\text{every}}(X)(Y) \iff X \subseteq Y \iff X \subseteq (X \cap Y) \iff \mathcal{R}_{\text{every}}(X)(X \cap Y)$$

To think about this more intuitively we can express the crucial biconditional in natural language. Since the requirement entails that $\mathcal{R}_{\text{every}}(\text{DOG})(\text{BROWN})$ holds if and only if $\mathcal{R}_{\text{every}}(\text{DOG})(\text{BROWN} \cap \text{DOG})$ 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 that are not dogs. Alternatively, we can note that both of 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) (sometimes known as the “Härtig Quantifier”; see also Crain et al. 2005, p.182).

- (6) a. $\mathcal{R}_{\text{equi}}(X)(Y) \equiv |X| = |Y|$
 b. ‘equi dogs are brown’ is true iff $|\text{DOG}| = |\text{BROWN}|$

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.

³We systematically overload the term “conservative”, using it to apply both to relations as defined in (5) and to determiners that express such relations.

99 The absence of nonconservative determiners is problematic for standard theories of
100 semantics, on at least one view of what these theories aim to account for: ideally, it would
101 be desirable for the mechanics of a semantic theory to allow determiners with all and only
102 the meanings that the human language faculty allows. Following familiar reasoning about
103 the relationship between innate properties of the language faculty and linguistic typology,
104 a reasonable hypothesis to consider is that the lack of nonconservative determiners in the
105 world’s languages derives from the (in)ability of the human language faculty to associate
106 the structure in (1) with the claim that a nonconservative relation holds between the
107 set of dogs and the set of brown things. The overwhelming majority of current theories,
108 however, are equally compatible with conservative and nonconservative determiners, es-
109 sentially predicting that the language faculty should be able to associate the structure in
110 (1) with either kind of relation (but see Pietroski (2005), Bhatt & Pancheva (2007) and
111 Fox (2002) for some exceptions).⁴

112 In this paper, we investigate whether children allow the structure in (1) to express
113 nonconservative relations. If children permit (1) to be associated with a nonconserva-
114 tive meaning, then a semantic theory which permits nonconservative determiners would
115 appear to be an accurate reflection of the workings of the human language faculty, and
116 the lack of nonconservative determiners in natural languages would need to be explained
117 by something else. However, in the experiment we report below, we find no evidence
118 that children consider nonconservative meanings for novel determiners, supporting the
119 hypothesis that the language faculty is ill-equipped to associate the structure in (1) with a
120 nonconservative relation and strengthening the case that semantic theories should be re-
121 vised to reflect this. Of course, the children’s failure to learn a nonconservative determiner
122 meaning in our experiment is not equivalent to observing that no child in any experiment
123 could ever learn a nonconservative determiner meaning. But the results are consistent

⁴To 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 *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 in 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 *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 fixed 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.

Keenan & Stavi (1986) quantify the degree to which allowing nonconservative meanings would allow “too large” a hypothesis space (if this flexibility is indeed unnecessary): given a domain of n entities, there are $2^{(4^n)}$ possible determiner meanings, only $2^{(3^n)}$ of which are conservative.

124 with the hypothesis that the underlying cause of this failure is the nonconservativity of
125 the putative determiner’s meaning, whether this meaning is completely unlearnable in
126 some sense or just difficult to activate in these tasks.

127 3 Children’s symmetric interpretations of quantifi- 128 cational sentences

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

135 (7) Are all the circles blue?

136 Taken at face value it appears that these children are understanding (7) to mean that
137 (all) the circles *are* (all) the blue things, as if $\mathcal{R}_{\text{all}}(X)(Y) \equiv X = Y$. This is a clearly
138 nonconservative relation, since answering (7) on this interpretation requires paying at-
139 tention to non-circles. But there is little or no reason to think that these children have
140 associated this nonconservative relation with the determiner ‘all’.

141 Importantly, similar “symmetric responses” have been observed with questions like
142 (8) involving transitive predicates. Some children will answer “no” to (8) if there are
143 elephants not being ridden by a girl (Philip 1991, 1995); see Geurts (2003), Drozd
144 (2005/2006) for review.

145 (8) Is every girl riding an elephant?

146 Consider the interpretation of ‘every’ that these children are using. If ‘every’ is analysed as
147 a determiner with a conservative meaning, then answering (8) should require only paying
148 attention to the set of girls (and which *of the girls* are riding an elephant), since this
149 is the denotation of the internal argument ‘girl’. Clearly ‘every’ is not being analysed
150 in this way by the children for whom the presence of unriden elephants is relevant.
151 However, these children are not analysing ‘every’ as a *nonconservative determiner* either.
152 Such a determiner would permit meanings that required looking beyond the set of girls
153 denoted by the internal argument and take into consideration the entire set denoted by
154 the external argument, as the fictional ‘equi’ does; but crucially, the external argument
155 would be ‘is riding an elephant’ and would therefore denote the set of *elephant-riders*, not
156 the set of elephants.⁵ So allowing the nonconservative relation \mathcal{R}_{all} above into the child’s

157 hypothesis space would leave room for an interpretation of (8) on which the presence of
 158 non-girl elephant-riders triggers a “no” response, but would do nothing to explain the
 159 relevance of unriden elephants. On the assumption then that these symmetric responses
 160 to (7) and (8) are to be taken as two distinct instances of a single phenomenon, this
 161 phenomenon is more general than (and independent of) any specific details of determiners
 162 and conservativity.

163 4 Two novel determiners: ‘gleeb’ and ‘gleeb’

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

172 In order to test these predictions we created two novel determiners, one conservative
 173 and one nonconservative. The conservative one, ‘gleeb’, expresses the relation $\mathcal{R}_{\text{gleeb}}$ as
 174 illustrated in (9).

- 175 (9) a. $\mathcal{R}_{\text{gleeb}}(X)(Y) \equiv X \not\subseteq Y \equiv \neg(X \subseteq Y)$
 176 b. ‘gleeb girls are on the beach’ is true iff GIRL $\not\subseteq$ BEACH

177 So ‘gleeb girls are on the beach’ is the negation of ‘every girl is on the beach’: it is true if
 178 and only if the set of girls (GIRL) is *not* a subset of the set of beach-goers (BEACH), so
 179 we might paraphrase it as ‘not all girls are on the beach’. For example, it is true in the
 180 scene shown in Figure 1(a), but false in the scene shown in Figure 1(b). Since ‘gleeb’ is
 181 the “negation” of the conservative determiner ‘every’, it is also conservative:⁶ anything
 182 on the beach that is not a girl is irrelevant to the truth of the sentence in (9b), so ‘gleeb’
 183 does live on its internal argument, and the biconditional “not all girls are on the beach
 184 if and only if not all girls are girls on the beach” is true.

⁵The 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.

⁶Suppose that \mathcal{R} is conservative, and that $\mathcal{R}^*(X)(Y) \equiv \neg\mathcal{R}(X)(Y)$. Then $\mathcal{R}^*(X)(Y)$ is equivalent to $\neg\mathcal{R}(X)(X \cap Y)$ by the conservativity of \mathcal{R} , and is therefore equivalent to $\mathcal{R}^*(X)(X \cap Y)$ by the definition of \mathcal{R}' . Therefore \mathcal{R}^* is also conservative.

185 The novel nonconservative determiner, written ‘gleeb’ but pronounced identically to
186 the conservative determiner ‘gleeb’, expresses the relation $\mathcal{R}'_{\text{gleeb}}$ as illustrated in (10).

- 187 (10) a. $\mathcal{R}'_{\text{gleeb}}(X)(Y) \equiv Y \not\subseteq X \equiv \neg(Y \subseteq X) \equiv \mathcal{R}_{\text{gleeb}}(Y)(X)$
188 b. ‘gleeb’ girls are on the beach’ is true iff BEACH $\not\subseteq$ GIRL

189 So ‘gleeb’ girls are on the beach’ is the “mirror image” of ‘not all girls are on the beach’:
190 it is true if and only if not all beach-goers are girls. For example, it is true in the scene
191 shown in Figure 1(b), but false in the scene shown in Figure 1(a). Since the “lived on” set
192 (the beach-goers) is not expressed as the *internal* argument of ‘gleeb’ in (10b), ‘gleeb’ is
193 *not* conservative.⁷ To determine whether the sentence in (10b) is true, one cannot limit
194 one’s attention to the set of girls; beach-goers who are not girls are relevant. And the
195 crucial biconditional, which we can paraphrase as “not all beach-goers are girls if and
196 only if not all beach-going girls are girls”, is false since the first clause can be true while
197 the second cannot.

198 Our experiment will compare children’s ability to learn ‘gleeb’ with their ability to
199 learn ‘gleeb’’, based on equivalent input. Note that the conditions expressed by these
200 two determiners are just the “mirror image” of each other, with the subset-superset
201 relationship reversed. By any non-linguistic measure of learnability or complexity, the
202 two determiners seem likely to be equivalent, since each expresses the negation of an
203 inclusion relation. Thus there is no reason to expect a difference in how easily they can
204 be learnt — *unless* there are constraints on the semantic significance of specifically being
205 the internal or external argument of a determiner, since this is all that distinguishes ‘gleeb’
206 from ‘gleeb’’. A finding that ‘gleeb’ and ‘gleeb’ differ in learnability would therefore be
207 difficult to explain by any means other than such a restriction on the way internal and
208 external arguments of determiners are interpreted.

209 5 Experiment: Conservativity and learnability

210 5.1 Design and methodology

211 Each participant was assigned randomly to one of two conditions: the conservative con-
212 dition or the nonconservative condition. Participants in the conservative condition were
213 trained on ‘gleeb’, and participants in the nonconservative condition were trained on
214 ‘gleeb’; we then tested each participant’s understanding of the determiner he/she was
215 exposed to.

⁷The 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.



(a)



(b)

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).

216 To assess the participants’ understanding of these novel determiners, we used a variant
 217 of the “picky puppet task” (Waxman & Gelman 1986). The task involves two experi-
 218 menters. One experimenter controls a “picky puppet”, who likes some cards but not
 219 others. The second experimenter places the cards that the puppet likes in one pile, and
 220 the cards that the puppet does not like in a second pile. The child’s task is to make a
 221 generalisation about what kinds of cards the puppet likes, and subsequently “help” the
 222 second experimenter by placing cards into the appropriate piles.

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

230 The target phase used cards like those shown in Figure 1, and was divided into a
 231 training period and a test period. The child was told that the puppet had revealed to
 232 the experimenter whether he liked or disliked some of the cards, but not all of them.
 233 The child was told that the experimenter would sort what he/she could, but that the
 234 child would then have to help by sorting the remaining cards that the puppet was silent
 235 about. During the training period the experimenter sorted five cards, according to the

236 criterion appropriate for the condition: in the conservative condition, the child was told
237 that the puppet likes cards where ‘gleeb girls are on the beach’ (i.e. where not all girls are
238 on the beach), and in the nonconservative condition, the child was told that the puppet
239 likes cards where ‘gleeb’ girls are on the beach’ (i.e. where not all beach-goers are girls).
240 The experimenter placed each card into the appropriate pile in front of the participant,
241 providing either (11a) or (11b) as an explanation as appropriate.⁸

- 242 (11) a. The puppet told me that he likes this card because gleeb girls are on the
243 beach.
244 b. The puppet told me that he doesn’t like this card because it’s not true that
245 gleeb girls are on the beach.⁹

246 We avoided using the novel determiner in the partitive-like construction ‘gleeb of the
247 girls’ because this seemed likely to bias in the direction of restricting the relevant domain
248 to the set of girls, independently of conservativity (consider for example ‘Of the girls, I
249 have met Mary and Susan’).

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

258 The same training cards and the same testing cards were used in both conditions,
259 though whether the puppet liked or disliked the card varied from one condition to the
260 other. Table 1 shows, for each card, the number of girls and boys on the beach and
261 on the grass, and whether each condition’s relevant criterion is met or not. These were
262 designed to be as varied as possible, while maintaining the pragmatic felicity of the two
263 crucial target statements. The total number of characters on each card was also kept as
264 close to constant as possible: either five or six for each card. The number of training
265 cards that the puppet likes is the same in each condition (three), so the situation that the
266 participant is presented with during the training phase is analogous across conditions.

267 The participants were 20 children, aged 4;5 to 5;6 (mean 5;0).¹⁰ Each condition
268 contained 10 children. Ages of those in the conservative condition ranged from 4;5 to
269 5;5 (mean 4;11), and ages of those in the nonconservative condition ranged from 4;11 to

⁸We do not distinguish between the conservative ‘gleeb’ and the nonconservative ‘gleeb’ in writing (11), to illustrate that the explanations were homophonous across the two conditions.

⁹Negation was always expressed in a separate clause to avoid any undesired scopal interactions.

Card	beach		grass		‘gleeb girls are on the beach’	‘gleeb’ girls are on the beach’
	boys	girls	boys	girls		
Train 1	2	0	1	2	true	true
Train 2	0	2	3	0	false	false
Train 3	0	1	2	3	true	false
Train 4	2	3	0	0	false	true
Train 5	2	1	1	2	true	true
Test 1	3	0	0	2	true	true
Test 2	0	3	3	0	false	false
Test 3	2	3	0	2	true	true
Test 4	1	2	2	0	false	true
Test 5	1	2	0	2	true	true

Table 1: The distribution of girls and boys on each card in the experiment

270 5;3 (mean 5;1); the two groups did not differ significantly in age ($t = 1.4141$, $df = 18$,
271 $p = 0.17$).

272 5.2 Results

273 The results indicate that children exposed to the novel conservative determiner showed
274 significant understanding of it during the test phase, and that children exposed to the
275 novel nonconservative determiner did not. The results are summarised in Table 2.

276 First we can consider how many cards children in the two conditions sorted correctly.
277 If children never succeeded in learning the determiner’s meaning, we would expect per-
278 formance to be at chance. For each condition, participants were classified into six groups
279 according to the number of test cards sorted correctly (zero to five), as shown in Fig-
280 ure 2, and the distribution compared with the grouping expected under the assumption
281 of chance performance.¹¹ Children in the conservative condition performed significantly
282 better than chance ($\chi^2 = 74.160$, $df = 5$, $p < 0.0001$), sorting an average of 4.1 cards
283 correctly, whereas children in the nonconservative condition did not ($\chi^2 = 6.640$, $df = 5$,
284 $p > 0.2488$), sorting an average of 3.1 cards correctly.

¹⁰It is plausible that by this age, children are generally able to use “real” English quantificational determiners in a manner that can be considered adult-like for the purposes of comparisons with this experimental setup. Detailed questions about their knowledge of quantificational determiners are difficult to answer, because many studies have found that they will behave in a non-adult-like manner in situations involving scalar implicatures or scopal ambiguities; see Gualmini (2003), Papafragou & Musolino (2003), Musolino & Lidz (2006), among many others. But the way in which ‘gleeb’ and ‘gleeb’ are used in our experiment seems unlikely to involve any of these complications. Note also that whatever is responsible for the “symmetric” interpretations discussed in section 3 seems unlikely to interfere here since there is no plural in the determiner’s external argument ‘are on the beach’.

¹¹This is computed via the binomial distribution, i.e. the proportion of participants expected to give

Condition	Conservative	Nonconservative
Cards correctly sorted (out of 5)	mean 4.1 (above chance, $p < 0.0001$)	mean 3.1 (not above chance, $p > 0.2488$)
Subjects with “perfect” accuracy	50%	10%

Table 2: Summary of results

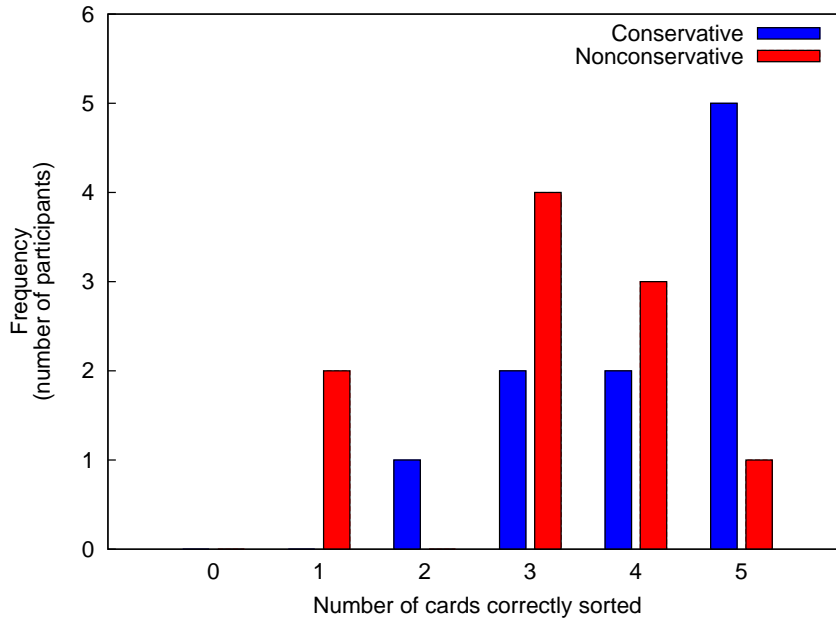


Figure 2: Distribution of participants in each condition according to how many cards were correctly sorted

285 Alternatively, we can consider how many children in each condition performed “per-
286 fectly”, sorting all five test cards correctly. Of the children in the conservative condition,
287 five out of ten sorted all test cards correctly, whereas only one child out of ten in the non-
288 conservative condition sorted all test cards correctly, indicating a marginally significant
289 dependency between conservativity of the determiner and success in learning ($p = 0.07$,
290 Fisher’s exact test).

291 One might wonder whether participants may have ended up with above chance per-
292 formance in the conservative condition “by accident”, by interpreting the novel word
293 according to some other meaning which happens to line up reasonably well with the
294 intended ‘gleeb’ on the particular test cards we constructed. The full details of the par-
295 ticipants’ responses, given in Table 3, don’t support this scepticism. We have compared
296 the responses of each participant with those that would be expected if various alter-
297 native potential interpretations are assigned to the novel word, and given the number
298 of matching responses for each: ‘all’, ‘none’ and ‘some’ are the obvious determiners;

exactly k correct responses out of 5 is $\left(\frac{1}{2}\right)^k \left(\frac{1}{2}\right)^{5-k} \binom{5}{k} = \frac{1}{2^5} \binom{5}{k}$.

Subject	Test 1	Test 2	Test 3	Test 4	Test 5	all	none	some	some+	only	gleeb
C-01	Yes	No	Yes	No	Yes	0	3	2	4	1	5
C-02	Yes	No	Yes	No	Yes	0	3	2	4	1	5
C-03	Yes	No	No	No	No	2	5	0	2	3	3
C-04	Yes	No	Yes	Yes	Yes	1	2	3	3	0	4
C-05	Yes	No	No	No	No	2	5	0	2	3	3
C-06	Yes	No	Yes	No	Yes	0	3	2	4	1	5
C-07	No	Yes	Yes	Yes	Yes	3	0	5	3	2	2
C-08	Yes	No	Yes	No	Yes	0	3	2	4	1	5
C-09	Yes	No	Yes	No	Yes	0	3	2	4	1	5
C-10	Yes	No	Yes	Yes	Yes	1	2	3	3	0	4

Subject	Test 1	Test 2	Test 3	Test 4	Test 5	all	none	some	some+	only	gleeb'
NC-01	No	Yes	Yes	No	No	3	2	3	3	4	1
NC-02	No	No	Yes	No	Yes	1	2	3	5	2	3
NC-03	Yes	No	Yes	No	Yes	0	3	2	4	1	4
NC-04	Yes	No	No	Yes	Yes	2	3	2	2	1	4
NC-05	No	No	Yes	No	Yes	1	2	3	5	2	3
NC-06	Yes	No	No	Yes	Yes	2	3	2	2	1	4
NC-07	No	Yes	Yes	Yes	Yes	3	0	5	3	2	3
NC-08	Yes	No	Yes	Yes	Yes	1	2	3	3	0	5
NC-09	No	Yes	Yes	Yes	Yes	3	0	5	3	2	3
NC-10	No	Yes	Yes	No	No	3	2	3	3	4	1

Table 3: Responses of each subject to each test card, with counts of the number of responses that are consistent with various potential meanings

299 ‘some+’ indicates the interpretation like that of ‘some’ but with the ‘not all’ pragmatic
300 implicature enforced (i.e. ‘some but not all’); and ‘only’ refers to the interpretation (not
301 representable by a conservative determiner) that reverses the inclusion expressed by ‘all’
302 (i.e. ‘only girls are on the beach’). The final column shows the number of responses that
303 were consistent with the determiner the participants were trained on, either ‘gleeb’ or
304 ‘gleeb’ as appropriate.

305 The relevant question is whether there are participants in the conservative condition
306 whose responses seem to be underlyingly driven by some incorrect (non-‘gleeb’) interpre-
307 tation but look reasonably consistent with ‘gleeb’ as a side-effect. The only participants
308 for whom any non-‘gleeb’ interpretation had more matches than ‘gleeb’ itself (namely
309 C-03, C-05 and C-07) were the three with the *lowest* scores with respect to ‘gleeb’ (three,
310 three and two). So the higher scores of four and five with respect to ‘gleeb’ were not
311 “piggy-backing” on some other determiner with which the responses were actually more
312 consistent. Because of the similarity between the target ‘gleeb’ and the ‘some+’ candidate
313 (they differ only on one card, Test 1), high scores on ‘gleeb’ certainly do correlate with
314 high scores on ‘some+’; but on the one card where these hypotheses do differ, only one
315 participant (C-07) sided with ‘some+’, and so this is the only participant where ‘some+’
316 has more matches (three) than ‘gleeb’ has (two).

317 This informal analysis can be verified by computing Bayes factors in order to identify
 318 the candidate interpretations that best fit the participants’ response patterns. For each
 319 candidate interpretation i , let H_i be the hypothesis that interpretation i is adopted by the
 320 participant. We assume an “error rate” p_e , such that if a participant adopts interpretation
 321 i then we assume that for each card the probability of sorting the card in accordance with i
 322 is actually only $(1-p_e)$; without this assumption, $\Pr(D|H_i)$ would be zero for any response
 323 pattern D that contains even a single response that disagrees with i . Then for a particular
 324 response pattern D containing c_i responses in accordance with interpretation i , we can
 325 ask whether hypothesis H_i is “substantially more supported” (Jeffreys 1961) than H_j by
 326 asking whether the Bayes factor $K_{ij} = \frac{\Pr(D|H_i)}{\Pr(D|H_j)}$ is greater than 3, where $\Pr(D|H_i) = (1 -$
 327 $p_e)^{c_i} p_e^{(5-c_i)}$. We can also compare hypothesis H_i with a random-guessing hypothesis H_{rand} ,
 328 where $\Pr(D|H_{\text{rand}}) = (\frac{1}{2})^5$ for any D . We have no principled way of choosing p_e precisely,
 329 but for any $p_e < 0.25$ the result is that a hypothesis H_i is more substantially supported
 330 than any other (including random guessing) if and only if it is the only interpretation
 331 with $c_i = 5$. On this basis we would conclude that five participants correctly adopted
 332 ‘gleeb’ in the conservative condition and one participant correctly adopted ‘gleeb’ in
 333 the nonconservative condition; three other participants (C-03, C-05 and C-07, already
 334 mentioned above) adopted other interpretations in the conservative condition, and four
 335 did so in the nonconservative condition. The responses of the remaining participants —
 336 two in the conservative condition, and five in the nonconservative condition — either
 337 support the random guessing hypothesis if $p_e \lesssim 0.01$, or remain unclassified otherwise.
 338 This classification of participants is illustrated in Figure 3.¹²

339 The results are perhaps even more telling when we look more closely at the responses
 340 of the one child who sorted all five test cards correctly in the nonconservative condition
 341 (NC-08). This child told the experimenters that the puppet was confused about which
 342 characters on the cards were boys and which were girls. Recall that in this condition
 343 the true criterion for the puppet to like a card was ‘gleeb’ girls are on the beach’, or
 344 equivalently ‘not all beach-goers are girls’. But another statement equivalent to these is
 345 ‘some boys are on the beach’. So if the child thought that the puppet intended the internal
 346 argument of the determiner in the crucial sentence to denote the set of boys, then she in
 347 fact learnt a *conservative* meaning for ‘gleeb’, with a meaning like ‘some’ has. One might

¹²Some more of the relevant thresholds for various settings of error rate are as follows. For $p_e < 0.25$,
 $K_{ij} > 3$ iff $c_i - c_j > 0$; for $0.25 \leq p_e \lesssim 0.366$, $K_{ij} > 3$ iff $c_i - c_j > 1$. For $p_e \lesssim 0.377$, H_i is substantially
 more supported than H_{rand} simply iff $c_i = 5$; for larger values of p_e , no H_i is ever substantially more
 supported than H_{rand} . In the other direction, H_{rand} is substantially more supported than H_i : (i) for
 $p_e \lesssim 0.011$, iff $c_i < 5$, i.e. iff any responses disagree with i ; or (ii) for $0.011 \lesssim p_e \lesssim 0.125$, iff $c_i < 4$, i.e. iff
 more than one response disagrees with i . Note however that there is no participant for whom all $c_i < 4$,
 so H_{rand} can only be substantially more supported than all other hypotheses if $p_e \lesssim 0.011$.

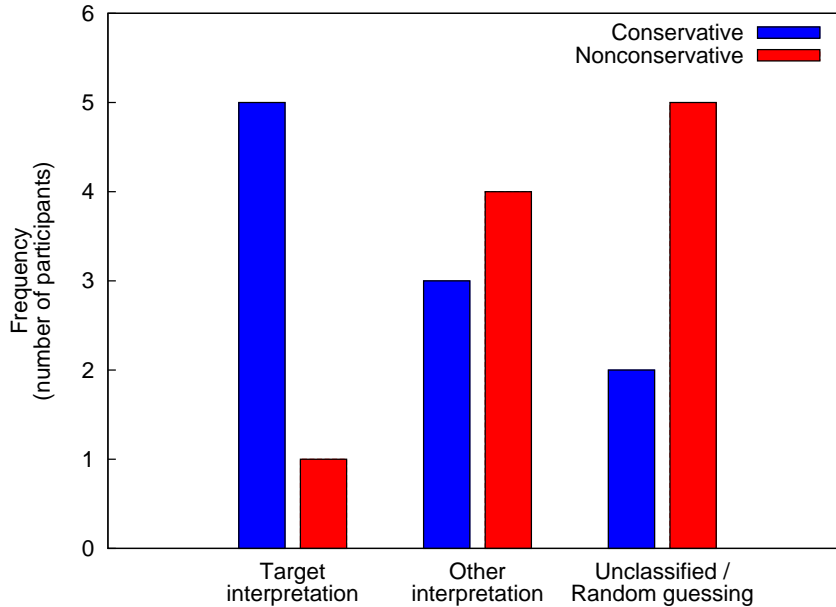


Figure 3: Classification of participants according to Bayes factors

348 even be tempted to suggest that she was led to believe that the puppet was confusing
 349 boys with girls *because of* a requirement that ‘gleeb’ be understood conservatively.

350 5.3 Discussion and potential objections

351 Here we will consider some potential concerns and remaining open questions.

352 First, these results should of course only bear on the issue of determiner meanings to
 353 the extent that we are confident that the participants really did understand the relevant
 354 parts of the explanations in (11) to have the structure shown in (1). Nothing in the design
 355 of the experiment itself eliminates the possibility that the participants might have been
 356 trying to identify an interpretation for some different structural analysis of the crucial
 357 utterance, or for this utterance as an unanalysed whole. Had we found no difference
 358 between the conservative and nonconservative conditions, one might be hesitant to reject
 359 the hypothesis that determiners are restricted to conservative meanings, because of these
 360 possibilities. But it is unlikely that we would have found results consistent with the
 361 independently motivated restriction to conservative determiner meanings if participants
 362 had not been using determiner structures.

363 Second, taking the results to contribute to an explanation of the typology of deter-
 364 miners requires us to assume that the way children approached our word-learning task
 365 is relevantly similar to the way children naturally acquire the lexicon of their native lan-
 366 guage. We don’t intend to claim that our participants came away from the experiment
 367 with the novel conservative determiner as a new fully-fledged member of their mental

368 lexicon, or that they could *never* learn to use the novel nonconservative determiner no
369 matter how much training they received; and we can't offer any explicit theory of exactly
370 what relationship our task bears to "natural" word-learning. Our conclusion that learn-
371 ability plays a role in explaining the typological generalisation is based on the assumption
372 that the asymmetry between children's responses to the two determiners we tested would
373 carry over to situations of natural word-learning, but nothing in the methodology we
374 adopted guarantees this.

375 Third, one might object to our inferring, from an asymmetry between 'gleeb' and
376 'gleeb'', that there is a general asymmetry between the class of conservative determiners
377 and the class of nonconservative determiners. In other words, perhaps it is not the
378 conservative/nonconservative distinction that is the underlying cause of the asymmetry
379 we discovered between 'gleeb' and 'gleeb'', but rather some other distinction between
380 these two novel determiners.¹³ Because the two determiners were pronounced identically,
381 an alternative would necessarily need to refer to their semantics, possibly in interaction
382 somehow with the determiners' arguments 'girl' and '(are) on the beach'. One such
383 alternative explanation is that participants in the conservative condition succeeded not by
384 recognising that the puppet likes cards where $GIRL \not\subseteq BEACH$, but rather by recognising
385 that the puppet *dislikes* cards where $GIRL \subseteq BEACH$. In order for this idea to account
386 for the asymmetry we found between the two conditions, there would need to be reason
387 to believe that the nonconservative condition made it less feasible to adopt the equivalent
388 strategy, namely recognising that the puppet dislikes cards where $BEACH \subseteq GIRL$. Since
389 the conditions are equally mathematically complex, an alternative explanation unrelated
390 to conservativity would need to suppose that the difference between these two "disliking"
391 criteria stems from somewhere else, perhaps from the ways in which *they* can be expressed
392 in English. More specifically, one might look for an independently plausible reason for
393 'all girls are on the beach' (an expression of the disliking criterion in the conservative
394 condition) to be more accessible than 'only girls are on the beach' (the disliking criterion
395 in the nonconservative condition). In principle one might attribute this to either: (i) the
396 fact that the 'all' sentence better matches the intended determiner syntax of the 'gleeb'
397 sentence, since 'all' (but not 'only') is a determiner; or (ii) a simple asymmetry in these
398 children's knowledge of the two words 'all' and 'only'.

¹³To test this possibility one would need to run some variation of our experiment with another pair of well-matched determiners, one conservative and one nonconservative. Our determiners were chosen to be the (intuitively) simplest possible: 'gleeb' is the only determiner in the "square of opposition" (arguably the four "simplest" determiners) that does not exist as a lexical item in English, and so experiments with other determiners would likely require significantly more training items (to allow participants to identify the intended meaning) and significantly more test items (to assess participants' conclusions). Even determiners of the form 'at least n ' or 'exactly n ', arguably the next simplest, will unfortunately

399 To repeat, however, recall that any of these alternative explanations of the asymme-
400 try between ‘gleeb’ and ‘gleeb’ in our experiment will leave open the existing typological
401 question of why nonconservative determiners are unattested. Results that failed to distin-
402 guish between ‘gleeb’ and ‘gleeb’ in an experimental setting might not, one could argue,
403 have told strongly *against* the learnability hypothesis, because of the kinds of concerns
404 just discussed. But with the observations from our experiment and the typological gener-
405 alisation both at hand, the hypothesis that conservative and nonconservative determiners
406 differ in learnability seems appealing. Additionally, the asymmetry between children’s
407 acquiring ‘gleeb’ and ‘gleeb’ in our experiment does not demonstrate that ‘gleeb’ is
408 completely unlearnable. Rather what we see here is simply an advantage for learning the
409 conservative ‘gleeb’ over the nonconservative ‘gleeb’. It may be that conservative rela-
410 tions have an advantage (eg. a higher prior probability of being a determiner meaning)
411 without there being an absolute prohibition on nonconservative relations as determiner
412 meanings. If this were the case, then perhaps the lack of nonconservative determiners in
413 natural languages derives from their relative likelihood (as compared to their conserva-
414 tive counterparts) and not from an absolute prohibition in the formal system underlying
415 determiner meanings. In either case, however, there would be a critical link between
416 learnability and typology, whether that link is absolute or gradient.

417 Finally, we have mentioned that the typological generalisation alone arguably pro-
418 vides only very weak evidence for an asymmetry in the learnability status of conservative
419 and nonconservative determiners; hence the significance of work that tries to investigate
420 learnability more directly. The distinction between the role of typological evidence and
421 more direct “learnability evidence” in reaching conclusions about the language learner’s
422 hypothesis space would be particularly clearly brought out if we could identify clear cases
423 of both (i) typologically unattested patterns which, evidence suggests, have an explana-
424 tion in learnability asymmetries, and (ii) typologically unattested patterns which appear
425 to have no such explanation. If our conclusions here are correct, then nonconservative
426 determiners constitute an instance of the first pattern. Other recent work with children
427 suggests a possible instance of the second pattern, also in the domain of determiner
428 meanings: Halberda et al. (submitted) report results suggesting that some children as-
429 sign the meaning “less than half” to the determiner pronounced ‘most’ in English. This
430 meaning is conservative but nonetheless unattested, and is at least considered to be a
431 possible meaning for ‘most’ in a particular experimental context, suggesting that it is

not be suitable, since there is no nonconservative “mirror image” of these determiners: in these cases, $\mathcal{R}(X)(Y)$ and $\mathcal{R}(Y)(X)$ are equivalent. One candidate we identified was the determiner meaning “less than half” and its nonconservative mirror-image — but these did not give meaningful results in pilot studies we ran, presumably because of the significantly increased complexity.

432 available as a possible determiner meaning, even if not the correct meaning for the word
433 pronounced ‘most’. If correct, this would mean that the typological absence of this de-
434 terminer would need some other sort of explanation, perhaps relating to pragmatic or
435 functional pressures. We mention this here as an indicator of possible directions for fu-
436 ture work following on from the experiment reported here, and to caution against the
437 temptation to take the learnability asymmetry between conservative and nonconservative
438 determiners as a foregone conclusion on the basis of the typological facts alone.

439 **6 Conclusion**

440 We have examined the relationship between learnability and typology in determiner mean-
441 ings. We presented an experiment that revealed no evidence of participants successfully
442 learning a nonconservative determiner meaning, indicating that the typological generali-
443 sation concerning conservativity derives (at least in part) to an asymmetry in learnability.
444 This in turn gives us reason to prefer theories of natural language semantics that rule out
445 nonconservative relations as possible determiner meanings.

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