The Relationship between Distributivity and Spreading

Chapter 4

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Abstract

There are two major puzzles in quantification acquisition research: children’s spreading errors and their non-adult-like distributivity interpretations. Musolino (2009) connects both phenomena and argues that children’s non-adult-like distributivity interpretations might have the same origin as their well-known spreading errors. Dotlačil (2010), on the other hand, argues that children’s non-adult-like distributivity interpretations are caused by their failure to draw implicatures, which he believes cause the adult collective preference. The development of the adult-like collective interpretation may therefore be linked to cognitive resources, as it has been argued that implicature calculation requires working memory. Musolino’s account (2009) predicts a relationship with working memory as well. His account is based on a processing model developed by Geurts (2003) that attributes children’s spreading errors to their processing limitations. Under this account children are assumed to treat strong quantifiers as if they were weak, because weak quantifiers are easier to process. To examine the possible relationship between spreading and distributivity interpretations, we investigated the two phenomena in the same children, also assessing their working memory capacity. The results show a large age gap between the disappearance of spreading errors and the emergence of a collective preference. In addition, we only found a significant effect of working memory on the non-distributive DPs in distributive contexts and not on the spreading conditions. Both findings suggest that children’s spreading errors and distributivity interpretations have different origins and therefore challenge Musolino’s (2009) processing account.¹

¹ Please note that this chapter refers to the pragmatic account as the implicature account and to the processing account as the weak-strong account.
1 Introduction

One of the major questions about quantifier interpretation is how children develop adult-like distributivity preferences for the many different definite plural types (DPs). Consider the following sentences:

(1) Each boy is building a snowman.
(2) The boys are building a snowman.

Adults recognize that each semantically marks distributive events, and will accept (1) with scenes like Figure 1. At the same time, they reject the use of each with collective scenes like Figure 2. They will also disprefer distributive interpretations with subject DPs with all or the, that do not mark distributivity, and will for example reject sentences like (2) with scenes like Figure 1. On the other hand, children up to the age of eight seem to initially not realize that each has a distributivity requirement, and will accept (1) with both distributive (Figure 1) and collective (Figure 2) scenes. Furthermore, young children also accept both distributive and collective readings with non-distributive DPs like all and the, sometimes even showing an across-the-board preference for distributive readings.

There are two explanations in the literature for children's distributivity interpretations and how children become adult-like in their distributivity preferences. One explanation is that children's non-adult distributivity preferences might be related to another common error children make with universal quantification: spreading errors. This explanation is intuitively appealing, given that both phenomena involve similar sentences, and it has already been explored as a possible explanation by Musolino (2009). Musolino extends Geurts' (2003) account for spreading errors, the weak-strong account, to a subset of non-adult distributivity preferences.
The second explanation instead argues that adult distributivity preferences in some cases arise via a conversational implicature (Dotlačil, 2010). This account does not relate children’s non-adult preferences to other quantification errors. We will refer to this explanation as the implicature account.

The present study examines both the implicature account and the weak-strong account. We do this by investigating whether there is a relationship between children’s distributivity interpretations and their spreading errors, testing both phenomena in the same population of children. Additionally, because both accounts predict a relationship between adult-like responses and working memory, we also conducted a word span task.

2 Background

2.1 The weak-strong account

Musolino (2009) outlines how Geurts’ (2003) explanation for another well-known error in children’s interpretation of universal quantifiers, so-called spreading errors or overexhaustive pairing errors, might be extended to explain children’s non-adult distributivity preferences as well.

Children up to the age of 9 will reject sentences like (1) with a scene like Figure 3, mentioning the extra snowman as the reason for the sentence being incorrect. Spreading errors have been extensively studied experimentally (e.g., Crain et al., 1996; Drozd, 2001; Philip, 1995; Roeper et al., 2004), and there are a number of competing theoretical accounts. Because distributivity preferences and spreading errors are all related to understanding the semantics of quantifiers and all occur until quite late in children’s language development, it is plausible that they have a similar origin.

Geurts (2003) points out that an initial tendency to process both strong and weak quantifiers as if they were weak, might be the cause of spreading errors. Weak quantifiers, like some and two, can have a less complex, two-part semantic structure, and are thus easier to process than strong quantifiers like each and all, which have a tripartite structure. Consider the following examples (3) (4) and (5).

Semantically, generalized quantifier theory (Barwise & Cooper, 1981) analyzes quantifiers as signaling different types of relations between two sets: the restrictor set, contributed by the subject, and the scopal set, contributed by the predicate.

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2 Weak quantifiers can be identified by their ability to occur in existential (“there are”) contexts. Thus some is weak and each is strong, e.g., There are some boys building a snowman vs. *There are each boy building a snowman.
However, while all quantifiers can be analyzed as relational, weak quantifiers do not require a relational interpretation. (3) and (4) can be interpreted as simply saying that at least one individual (e.g., (3)), or at least four individuals (e.g., (4)), have both the property of being a boy and being a snowman builder.

(3) **Some** boys are building a snowman.
(4) **Four** boys are building a snowman.
(5) **Each** boy is building a snowman.

A strong quantifier like (5) does require a relational interpretation between two sets. In addition, this relation is asymmetrical, which means that the restrictor set and the scopal set cannot be interchanged. Thus, *each boy is building a snowman* is different from *each snowman builder is a boy*. Correctly identifying the restrictor set is therefore necessary for the correct interpretation of a strong quantifier. Because of the tripartite structure, strong quantifiers are cognitively more demanding to process than weak quantifiers.

Geurts (2003) argues that children’s spreading errors are caused by processing limitations, leading children to initially treat strong quantifiers as if they were weak, leaving the restrictor position semantically underdetermined.3 Faced with this underspecified semantic representation, Geurts (2003) suggests that children identify the restrictor set by pragmatics. If the children interpret ‘the boys’ as the most salient discourse referent they will show adult-like responses, but if they find ‘the snowmen’ most salient, spreading errors will occur. If the snowmen become the restrictor, the children will interpret (5) as if it were: *each snowman is being built by a boy*, leading to a false rejection of the sentence, which is called a spreading error.4

(6) **Three** boys are holding each balloon.
(7) **Three** boys are holding two balloons.

Musolino (2009) builds on the intuition that children’s non-adult-like distributivity interpretations might have the same cause as spreading errors. Taking Geurts’ (2003) account as a basis, he shows how the account could be extended to explain the non-adult interpretation preferences in his study. Musolino (2009) used a truth-value judgement task with children between ages four and six to study sentences with numerically quantified subjects with either the quantifier *each* (6) or another numerically quantified expression (7) as the object.

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3 Note that Geurts’ (2003) account is only one of several explanations for spreading errors. See also for example Philip (1995) and Roeper et al. (2004) for alternative accounts.

4 For a more detailed discussion of Geurts’ (2003) account, see Chapter 6 Section 3.
In particular, Musolino (2009) suggests that a failure to correctly identify the restrictor set might explain why children strongly accepted a distributive interpretation (Figure 4) with sentences like (6) (90% compared to adults 31%). Additionally, it could explain why children accepted cumulative interpretations (Figure 5) much more often than adults did (54% compared to 17% acceptance with adult subjects). A cumulative interpretation can be understood as a combination of a distributive and a collective interpretation, as in Figure 5, where two boys are holding one balloon together and one boy is holding a balloon individually.

Briefly, if the children were to treat the three boys as the restrictor (rather than the balloons, which is the adult interpretation) they will interpret (6) as *Each of the three boys is holding a balloon*, which would be true for both the distributive reading (Figure 4) and the cumulative reading (Figure 5). Note that there is a general preference for adults (and children) to give *each* a distributive reading.

In general, Musolino’s (2009) subjects were very accepting, with the biggest outlier being the cumulative reading. This reading was only accepted 54% of the time by the children, though this was still much higher than the 17% acceptance rate of the adults.

Musolino extends Geurts’ (2003) explanation to object *each* items like (6), but because numerically quantified expressions are actually weak quantifiers Geurts’ (2003) account cannot offer an explanation for some of the other non-adult interpretations. For example, it does not explain why children rejected the cumulative readings with sentences like (7) (76% of the time compared to 21.9% for adults). Also, if children understand that *each* marks distributivity, why do they allow distributive readings in cases in which there is no distributive marker? Musolino’s (2009) extension also does not explain why children would choose different sets as restrictor sets in different situations and does not elaborate on how pragmatics influence the final interpretation.

Extending the weak-strong account to explain children’s non-adult-like collective interpretations of subject *each* DPs such as (5) seems possible. In this case, the account would be that children will misinterpret *each* in (5) as a weak quantifier with an unspecified restrictor set, and then by pragmatic reasoning determine that
restrictor set. If the child considers the snowman the most salient discourse entity, this account predicts that the child will interpret a sentence like (5) as *each snowman is being built by a boy*. A collective situation can be considered marginal for the truth of this sentence (considered true in cases where there is only one snowman). Therefore, non-adult-like acceptances of collective interpretations with a distributive marker can be explained by an error in mapping the syntax to the correct semantics. This account has the advantage over the implicature account that is does not rely on the claim that children have an inadequate or incomplete understanding of the semantics of *each*.

If the intuition that non-adult distributivity interpretations are related to spreading errors is correct, we would expect them to occur approximately at the same time, and to disappear at the same time as well. If this is the case, we need to look for an explanation that can handle both distributivity preferences and spreading errors. The weak-strong account is a useful candidate since it has already been applied to a subset of non-adult distributive interpretations in Musolino (2009).

### 2.2 The implicature account

An alternative account of children’s non-adult distributivity interpretations attributes it to a lack of pragmatic reasoning. Dotlačil (2010) argues that adult preferences for collective interpretations with non-distributive DPs are derived via a conversational implicature. For adults, *each* clearly marks distributivity. When a speaker describes a scene but does not use a distributive marker, adults will reason that if a distributive interpretation was intended, then the speaker would have used a distributive quantifier such as *each*. Via an implicature, DPs with a definite article like *the boys* are preferentially interpreted as collective, because they become pragmatically dispreferred with distributive interpretations, even if they are semantically neutral regarding distributivity.

This account then explains, children’s non-adult acceptance of distributive readings when there is no distributive marker, and their acceptance of collective readings when a distributive marker is present, as originating from an initial state where children do not know that *each* requires a distributive interpretation. Children must first realize that semantically *each* requires distributivity. After reaching this realization they can calculate implicatures based on the absence of distributive markers by inferring that a sentence with a definite article is intended to express a collective meaning. A number of studies (Brooks & Braine, 1996; de Koster et al., 2017; Pagliarini et al., 2012; Syrett & Musolino, 2013) have suggested that children initially do not understand that *each* marks distributivity, treating DPs with *each*

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5 *Each* and other universal quantifiers seem to have a felicity requirement that the restrictor set should be plural. This account would have to ignore this requirement.
similarly to DPs headed by all and the. For this reason, the implicature account predicts that only when children begin to reject collective contexts with each, will they be able to begin to calculate implicatures based on each’s distributivity requirement in relation to other DP types. Some experimental research has backed up this claim. Pagnialini et al. (2012) for Italian and de Koster et al. (2017) for Dutch have shown a correlation between the rejection of each with collective contexts and the rejection of the with distributive contexts.

The implicature account thus does not predict any relation between spreading errors and adult-like distributivity preferences. It also differs from the weak-strong account in that it does not simply see non-adult preferences as stemming entirely from a processing difficulty, but rather ascribes errors to the fact that children do not yet know that each lexically encodes distributivity, as well as to a processing delay in implicature calculation, which is known to require cognitive resources.

2.3 Working memory

Both accounts predict a relationship between the adult interpretation and working memory capacity. The weak-strong account essentially proposes that children treat strong quantifiers as if they are weak, because weak quantifiers are easier to process due to their less complex (semantic) structure. This proposal is backed up by findings of Just (1974) and Meyer (1970), who found that participants showed shorter response times when interpreting weak quantifiers compared to strong quantifiers. Connecting this to spreading errors and distributivity interpretations, one would expect children to make fewer spreading errors and more often show the adult collective preference when they have a higher working memory capacity.

The implicature processing literature has concluded that implicatures are not default inferences. Their calculation takes time, requires memory resources and probably occurs after the calculation of the literal (semantic) interpretation (e.g., Bott et al., 2012; Bott & Noveck, 2004). Marty and Chemla (2013) have also shown that participants calculated fewer implicatures under high working memory load. From these findings we expect that children with a higher working memory capacity should show the adult collective preference or at least show a higher rate of rejections of distributive contexts in combination with plural definites.

To examine these working memory predictions we carried out a word span memory task with all participants.
3 Method

3.1 Participants

185 monolingual Dutch-speaking children, divided into eight different age groups from 4 to 11 years old participated in the experiment. Table 1 reports the distribution of the children and their characteristics. They were recruited from two primary schools in Groningen, the Netherlands, and carried out the experiment in a quiet room in their school. Twelve adults (mean age 20.2), mainly university students, served as a control group. They received a small monetary compensation for participating in the experiment.

Table 1. Characteristics of child participants per age group

<table>
<thead>
<tr>
<th>Age-Group</th>
<th>Total</th>
<th>Age Range</th>
<th>Mean Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>16</td>
<td>4;1 – 4;11</td>
<td>4;7</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>5;1 – 5;10</td>
<td>5;5</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>6;0 – 6;11</td>
<td>6;6</td>
</tr>
<tr>
<td>7</td>
<td>20</td>
<td>7;0 – 7;10</td>
<td>7;5</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>8;1 – 8;10</td>
<td>8;5</td>
</tr>
<tr>
<td>9</td>
<td>30</td>
<td>9;0 – 9;11</td>
<td>9;5</td>
</tr>
<tr>
<td>10</td>
<td>24</td>
<td>10;0 – 10;10</td>
<td>10;4</td>
</tr>
<tr>
<td>11</td>
<td>26</td>
<td>11;0 – 11;11</td>
<td>11;5</td>
</tr>
</tbody>
</table>

3.2 Word Span Task

A word span task was performed to test predictions related to memory. We used an adapted version of the Schlichting Test of Language Production (Schlichting et al., 1995), with sequences of one to nine words. All words were obtained from the Lexilijst (Schlichting et al., 1995), which is designed for children between 1;9 and 2;3 years old. The words were mainly monosyllabic with a CVC-structure (consonant-vowel-consonant) and can be found in the Appendix Section of Chapter 4 at the end of this thesis.

Participants were asked to repeat word sequences after they were read aloud by the experimenter. Every new word sequence consisted of a practice item plus three test items. The test was terminated when a participant incorrectly repeated three items in a row. The maximum score that could be obtained was 25.
3.3 Linguistic Task

The linguistic task was a sentence-picture verification task in a 2x4 design with the factors **sentence** and **picture**. It aimed to test the relationship between children’s distributivity interpretations and their spreading errors.

3.3.1 Design and Procedure

(8) De jongens wassen een boot.
   The boy.PL wash.PL a boat.SG
   *The boys are washing a boat.*

(9) Elke jongen wast een boot.
   Each boy.SG wash.SG a boat.SG
   *Each boy is washing a boat.*

The task included two sentence types (definite, quantifier) and four picture types (collective, distributive, extra object, extra subject), resulting in eight test conditions. Sentences started either with the plural definite *de* ‘the’ (8) or with the universal quantifier *elke* ‘each’ (9). Both sentence types had the same Subject-Verb-Indefinite Object structure. The following eight Dutch verbs were used: *vasthouden, dragen, tillen, trekken, duwen, verven, wassen* and *bouwen* (in English: *hold, carry, lift, push, pull, paint, wash* and *build*). All sentences can be found in the Appendix Section of Chapter 4 at the end of this thesis.

The four picture types used were: a **collective** picture (Figure 6), an exhaustive **distributive** picture (Figure 7), a distributive picture with an **extra object** (Figure 8) and a distributive picture with an **extra subject** (Figure 9). Subjects were boys, girls, monkeys or dogs and every picture contained a different object. Responses to the collective and distributive picture inform us about children’s distributivity interpretations, while responses to the extra object and extra subject picture tell us whether children make spreading errors.

Each participant saw four items per condition, plus twelve control items. The test session started with four practice items. During the experiment, participants were presented with one picture at a time while a recorded sentence was played. They were instructed to verify whether the sentence matched the picture or not, and were also asked to justify their ‘no’ responses.
3.3.2 Predictions

Table 2 shows the predicted responses for each of the eight conditions for children and adults. Conditions The-Collective and Each-Distributive are straightforward: we expect both children and adults to fully accept these conditions. The conditions Each-Collective and The-Distributive will give us more insight into children’s distributivity interpretations: we expect young children to accept both conditions, while we expect adults to reject these conditions. Adults are expected to reject Each-Collective, since the quantifier each is a very strong marker for distributivity, indicating that the collective interpretation with each is infelicitous. Young children, until the age of 8 years old, have been argued to have an incomplete understanding of the quantifier each (Brooks & Braine, 1996; Syrett & Musolino, 2013). Each is not yet a strong distributive marker to them, leading to the acceptance of the condition Each-Collective.
Table 2. Predicted responses per condition for both children and adults

<table>
<thead>
<tr>
<th>Condition</th>
<th>Child</th>
<th>Adult</th>
<th>Condition</th>
<th>Child</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>The - Collective</td>
<td>yes</td>
<td>yes</td>
<td>Each – Collective</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>The - Distributive</td>
<td>yes</td>
<td>no</td>
<td>Each – Distributive</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>The - Extra Object</td>
<td>no</td>
<td>?</td>
<td>Each - Extra Object</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>The - Extra Subject</td>
<td>no</td>
<td>?</td>
<td>Each - Extra Subject</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

It has been found that adults, unlike children, show a collective preference for definite plurals such as *the* (Dotlačil, 2010; Frazier et al., 1999; Kaup et al., 2002). Recall from the Background section (Section 2) that Dotlačil (2010) has argued that the adult collective preference with the definite article comes from a conversational implicature. Under this account, adults realize that the speaker could have used a distributive marker if they intended a distributive meaning, and thus interpret the lack of a distributive marking as collective. We therefore predict adults to reject condition The-Distributive. Children, on the other hand, do not show such a collective preference and fully accept distributive situations. We therefore predict that they will accept condition The-Distributive.

The condition Each-Extra Object directly tests whether children show spreading errors. Based on the previous research literature, we predict young children to reject condition Each-Extra Object.

Condition Each-Extra Subject examines a different type of error with universal quantification, namely so-called *underexhaustive* errors. These errors result from an incorrect acceptance of *each* in combination with an extra subject not performing the action (Figure. 9). It has been found that underexhaustive errors only occur at a very young age (until age 6) and that they precede spreading errors (Geurts, 2003). This condition will show us at what age children understand that *each* has an exhaustivity requirement.

The question marks for the conditions The-Extra Object and The-Extra Subject in Table 2 signal ambiguity. A rejection of these conditions has two potential explanations. Condition The-Extra Object could either be rejected due to the extra object, which would indicate a spreading error, or could be rejected due to a collective preference, preferring all subjects to perform the action together. Condition The-Extra Subject could be rejected because of a collective preference, but also because of an exhaustivity preference, preferring all boys to perform the action. For these reasons, we will not discuss these conditions further here.
4 Results

Table 3 presents the descriptive results. It shows that even the youngest children fully accepted conditions Each-Distributive and The-Collective as predicted. Table 3 also shows that by age 7, children reached the adult interpretation for conditions Each-Collective and Each-Subject. This indicates that by age 7 children have a complete understanding of each; they notice that each marks distributivity and correctly reject situations in which an extra subject is not performing the action. Looking at Table 3, it becomes clear that there is only one condition in which the children in our sample did not reach the adult interpretation at all yet, namely condition The-Distributive. Children rejected this condition in only 40% of the cases at age 11, not yet approaching the adult rejection rate of 75%.

Table 3. Proportion of adult-like-responses per age group and condition. Age at which adult performance is reached is indicated by the gray cells. The results of conditions The-Extra Object and The-Extra Subject are omitted due to ambiguity (see Section 3.3.2).

<table>
<thead>
<tr>
<th>Condition</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each - Distributive</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>The - Collective</td>
<td>0.97</td>
<td>0.99</td>
<td>0.99</td>
<td>0.98</td>
<td>0.98</td>
<td>0.99</td>
<td>1.0</td>
<td>0.97</td>
<td>1.0</td>
</tr>
<tr>
<td>Each - Collective</td>
<td>0.14</td>
<td>0.21</td>
<td>0.35</td>
<td>0.64</td>
<td>0.82</td>
<td>0.69</td>
<td>0.81</td>
<td>0.83</td>
<td>0.65</td>
</tr>
<tr>
<td>The - Distributive</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.12</td>
<td>0.34</td>
<td>0.40</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Each - Extra Object</td>
<td>0.52</td>
<td>0.36</td>
<td>0.33</td>
<td>0.56</td>
<td>0.57</td>
<td>0.73</td>
<td>0.97</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Each - Extra Subject</td>
<td>0.59</td>
<td>0.79</td>
<td>0.80</td>
<td>0.95</td>
<td>0.90</td>
<td>0.96</td>
<td>1.0</td>
<td>1.0</td>
<td>0.98</td>
</tr>
</tbody>
</table>

The results of condition Each-Extra Object show that spreading errors become infrequent at age 9, and are virtually non-existent by age 10. There seems to be a gap between the disappearance of spreading errors (age 9) and the rejection of The-Distributive (after age 11). This gap of about two years is difficult to reconcile with the idea that both phenomena share the same cause.

Besides this, we also found an age gap of about one year between the correct interpretation of Each-Collective (age 7) and the disappearance of spreading errors (age 9). So children already seem to understand that each requires distributivity before they stop spreading. This result suggests that it is unlikely that there is a relationship between the non-adult-like acceptance of each in the collective context and spreading errors, contra the extended weak-strong account.
The data was analyzed using Generalized Additive Mixed Modeling (Wood, 2006) and the R-packages 'mgcv' and 'itsadug' (van Rij et al., 2015). We included the maximal random effect structure licensed by the data, which consist of random intercepts for PARTICIPANTS and ITEMS. The best-fitting model included the nonlinear interactions AGE BY CONDITION and MEMORY BY CONDITION. The results are visualized in Figure 10. Both graphs show summed effects; random effects are canceled out. The graphs are transformed back to proportion scale and shading shows the confidence intervals. Note that the graphs show the proportion of adult-like responses, which means rejection rates for conditions The-Distributive, Each-Collective and Each-Extra Subject and acceptance rate for Each-Extra Object. The graphs only show the results of the children.

![Figure 10](image.png)

**Figure 10.** Children’s proportion of adult-like-responses plotted against age in years (left) and memory score (right).

The left graph in Figure 10 shows that condition The-Distributive is significantly different from the other conditions and has not reached the adult interpretation (a rejection rate of 75%), unlike the other conditions. The right graph in Figure 10 and summary statistics show that memory only had a significant effect on condition The-Distributive (p<0.001), with no effect in the other conditions (taking into account the confidence intervals, those conditions are almost straight lines). Higher memory scores are related to a greater likelihood of rejecting the The-Distributive condition. In sum, memory score was only significantly related to children’s distributivity interpretations and not to their spreading errors (condition Each-Extra Object).
5 Discussion

This study focused on two accounts explaining children’s distributivity interpretations: the weak-strong account linking these interpretations to spreading errors, and Dotlačil’s (2010) implicature account. We collected new data to shed more light on the origin of children’s interpretation errors by testing the same population of children on their distributivity interpretations and their tendency to make spreading errors. We further assessed their auditory memory.

Now we can answer two questions: 1) are children’s distributivity interpretations and spreading errors related, and 2) is there evidence of implicature calculation in the development of an adult-like preference for definite articles with collective readings?

Looking at the results, we found an age gap of more two years between the development of an adult collective preference with the and the disappearance of spreading errors, which is unlikely if these errors share the same cause. Spreading errors become infrequent at age 9. At this age, children still incorrectly almost fully accept the The-Distributive condition (88%). On the other hand, rejection of the distributive context with the definite DP only begins to show at age 11, and even at that age children have not yet reached the adult rejection rate. Examining individual children, we found children that showed zero spreading errors but fully accepted distributive situations in combination with the definite plural the. This is unexpected if both phenomena have the same origin.

When we look more closely at the predictions that the weak-strong account specifically makes in relation to working memory, we do not find support for this account in our results. Recall that the weak-strong account predicts that spreading errors are caused by a misinterpretation of strong quantifiers as if they were weak. This is believed to be due to children having insufficient cognitive capacity to get the semantically more complex strong interpretation. This explanation suggests that a higher working memory score should correlate with lower rates of spreading. However, our results did not show an effect of memory scores for the Each-Extra Object spreading condition, which is unexpected if the weak-strong account is correct. Also note that we did find an effect of memory with the The-Distributive condition, so we believe the word span task was sufficiently sensitive.

In sum, given the large gap between the age at which spreading errors disappear and the age at which adult-like distributivity interpretations emerge, we did not find evidence to support a common origin of distributivity interpretation preferences and spreading errors. Additionally, our results do not show an effect of memory in predicting spreading errors, which is counter the predictions the weak-strong account makes in its explanation of spreading.
Now let us turn to how our results relate to Dotlačil's (2010) implicature account. First, we should note that adults do not fully reject the condition The-Distributive, showing a rejection rate of 75%. However, if the rejection of The-Distributive is calculated via a conversational implicature, this rate is not inconsistent. Rates of implicature calculation have been shown to vary across different lexical items, with most types of implicatures calculated between 30% to 70% of the time (cf., van Tiel et al., 2016). In fact, Pagliarini et al. (2012) and de Koster et al. (2017) both found adult rejection rates of around 50% for the exact same condition (definite subject with distributive picture). This means our adult results fit with the implicature account.

The implicature account assumes that the calculation of the implicature involved in the rejection of the The-Distributive condition requires working memory. This suggests that a lower memory score will correlate with an inability to calculate this implicature, which would result in the acceptance of the distributive context. Consistent with the predictions of the implicature account, we only found a significant effect of memory scores on the condition where the implicature calculation is assumed to take place, namely the The-Distributive condition.

Children's justifications of their 'no' responses, which we asked for consistently, also suggest that children rejected The-Distributive items because they calculated an implicature. Many children gave clarifications like: 'the computer did not say each, so I say no', or 'they should all wash one boat together, not each their own boat', or 'it would have been better if there was one boat with three boys washing it, but I'm not sure'. These clarifications strongly suggest that the children were reasoning about other options. In some cases they even asked us if they were allowed to consider other options.

Also note that the justifications of the rejections of the spreading condition Each-Extra Object were consistent with our predictions. Virtually all rejections were justified by pointing at the extra object: ‘No, because that boat does not have a boy’, or ‘No, there is one boat without a boy’, a result that has been shown in other studies as well. The justifications of the children are in line with the weak-strong account because they suggest a focus on the object and/or predicate.

However, we also noticed that most of the children either show spreading errors at every item, or show no spreading errors at all. This is inconsistent with the weak-strong account, because we would expect both correct and incorrect responses in children using a weak-quantifier interpretation strategy. With an unspecified restrictor set, both the subject noun and the object noun could in theory contribute the restrictor set. It is quite unexpected that children who are confused about which set is the restrictor would consistently interpret it as the set contributed by the predicate. Of course, visually it could be that the type of drawings we used made the
extra object consistently more salient. However, we know that children still show spreading in cases where materials are presented verbally, suggesting that it is more than visual salience that leads children to treat the object or the predicate rather than the subject noun as the restrictor set.

In sum, we found evidence against the weak-strong account of spreading and against a common origin of spreading and non-adult-like distributivity interpretations, and evidence supporting an implicature account.

We are able to draw these conclusions because, we tested spreading and distributivity interpretations in the same population of children. However, our results would have been stronger if we could have tested the same children at several moments during their development. The implicature account predicts that children need to have a correct understanding of each as a prerequisite for the calculation of the implicature, predicting that we should see that children first reject Each-Collective and then begin to reject The-Distributive. Whereas Pagliarini et al. (2012) and de Koster et al. (2017) found a correlation between these two conditions, it would be stronger if we could confirm this pattern in a longitudinal study.

6 Conclusions

We found an age gap between the end of spreading errors and the beginning of adult-like distributivity interpretations. This suggests that these two phenomena do not have a similar origin. We also did not find a relationship between memory scores and the tendency to spread, contrary the prediction of the weak-strong account. Furthermore, we do not have a clear picture of what semantic knowledge children have about each. More research is needed both into the origin of spreading and into children’s lexical-semantic knowledge of quantifiers.

We did find an effect of memory scores on the rejection of definite DP subjects with distributive pictures, consistent with the implicature account. In addition, children’s justifications for their rejection of the The-Distributive condition suggest they were calculating an implicature.

In sum, our results support the implicature account explaining children’s distributivity interpretations.