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Children's comprehension of distributive universal quantification

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Abstract

Our study explores why children are prone to assign a wider range of interpretations to sentences with distributive universal quantifiers *each* and *every* than adults. Musolino (2009) proposed that children are more permissive than adults because they are prone to assign quantifier spreading interpretations to universally quantified sentences. Our results support the alternative hypothesis that children are more permissive because they are prone to assign cumulative interpretations to universally quantified sentences in a wider range of contexts than adults. Our results reveal that both children and adults assign cumulative interpretations to sentences with universally quantified objects (*Three cowboys are pulling every horse*), but children also tend to assign cumulative interpretations to sentences with universally quantified subjects (*Every cowboy is pulling two horses*). We show that children perform similarly with sentences with universally quantified NPs and sentences with numerical NPs (*Three cowboys are pulling two horses*). We argue that children are more permissive than adults because they are less likely than adults to perceive singular subject-verb agreement as a cue to distributive interpretation. We present a formal semantic model to explain our findings and discuss the implications of our model for recent acquisition research.

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Keywords: Distributivity; Universal quantification; Language acquisition; Quantifier spreading

1. Introduction

Children's comprehension of sentences with the universal quantificational expressions *all*, *each*, and *every* has been a central topic in developmental linguistics for more than two decades. Much of the research in this area has focused on children's logical reasoning with universally quantified sentences and the logical properties of universally quantified NPs (Chierchia et al., 2001; Crain, 2012; Gualmini, 2005; Gualmini et al., 2008; Lidz and Musolino, 2002; Musolino and Lidz, 2006; Musolino, 2009; Syrett and Lidz, 2009, and many others) or children's symmetrical judgments of universally quantified sentences (Crain et al., 1996; Drozd, 1996; Drozd and van Loosbroek, 2006; Gouro et al., 2001; Kang, 2001; Philip, 1995, and many others). A recently emerging line of research has focused on children's sensitivity to distributive quantification and the extent to which children access the distributive, collective, and cumulative interpretations adults assign to quantified sentences (Brooks and Braine, 1996; Musolino, 2009; Pagliarini et al., 2012; Syrett and Musolino,

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2015). Although this research has now firmly established that children systematically differ from adults in the way they interpret sentences with the distributive quantifiers *each* and *every* under certain experimental conditions, few formal accounts have yet emerged to describe the linguistic processes and representations underlying children's performance or to what extent these linguistic processes and representations might differ from those of adults.

With our experiment, we take a modest step toward addressing these issues by exploring children's sensitivity to the distributive and cumulative interpretations of sentences with numerical NPs and NPs headed by the distributive determiner *every*. In a recent paper, Musolino (2009) reported that children are prone to accept sentences with *each* as descriptions of contexts depicting cumulative relations. To explain these results, Musolino argued that children tend to assign quantifier spreading interpretations to these sentences analogous to the quantifier spreading interpretations proposed under Geurts (2003) weak quantifier account of children's symmetrical judgments. We designed an experiment to test the predictions of the quantifier spreading account as well as the predictions of an alternative account which claims that children assign cumulative interpretations to universally quantified sentences when they accept them as descriptions of cumulative relations (the Cumulative Interpretation Hypothesis). Our results, we argue, support the cumulative interpretation account. We show that both children and adults are prone to accept sentences with universally quantified objects like *Three cowboys are pulling every horse* as descriptions of cumulative contexts but that children are more permissive than adults in accepting sentences with universally quantified subjects like *Every cowboy is pulling two horses* as well as descriptions of these contexts. We argue that children perform differently than adults not because they employ different linguistic processes and representations than adults do but because they are not as sensitive as adults to singular subject-verb agreement as a grammatical cue to distributive interpretation. We present a formal linguistic model based on Checking Theory (Szabolcsi, 1997) which explains our results with both children and adults, followed by a discussion of the implications of our model for recent research on the acquisition of distributive universal quantification.

We begin by describing our theoretical assumptions.

2. Distributive and cumulative sentence interpretations

Our study concerns the distributive and cumulative interpretations of sentences with two numerical NPs (numNP sentences) like (1) and sentences with matrix subject and object NPs headed by the distributive determiner *every* (*everyNP* sentences) like (2) and (3).¹

- (1) Three cowboys are pulling two horses.
- (2) Every cowboy is pulling two horses.
- (3) Three cowboys are pulling every horse.

A sentence is understood as distributive if a predicate is interpreted as a property of each individual of the plurality to which the predicate applies (Champollion, 2015; Lasersohn, 1998; Schwarzschild, 1996, and many others). (1) has at least two distributive interpretations. The surface scope (SS) distributive interpretation describes situations in which the property of pulling two horses is a property of each individual member of a set of cowboys, where each cowboy is pulling a different pair of horses. The inverse scope (IS) distributive interpretation describes situation in which the property of being pulled by three cowboys is a property of each individual member of a set of horses, where each horse is pulled by a different trio of cowboys. (1) can also receive a scopeless non-distributive cumulative interpretation if the individuals in the set denotations of the two numNPs are understood as exhaustively paired in a cross-product relation denoted by the predicate (Scha, 1981; Schein, 1993, and many others, see Champollion, 2015 for discussion). The cumulative interpretation of (1) describes situations in which each cowboy is pulling at least one horse and each horse is being pulled by at least one cowboy.

An *EveryNP* in matrix subject position, as in (2), enforces the distributive interpretation of a sentence where *EveryNP* supplies the plurality argument for the distributive relation. Thus, (2) can be used to assert that the property of pulling two horses is a property of each individual cowboy, where cowboys are pulling different pairs of horses. (2) cannot be used to describe situations in which each individual horse is being pulled by a different trio of cowboys (IS distributive interpretation) or situations where individual cowboys and horses are paired in a cross-product relation (the cumulative interpretation). Sentences including *EveryNP* direct objects like (3) typically receive IS distributive interpretations (Ioup, 1975) and generally do not receive cumulative interpretations. However, it is widely accepted in the semantics literature that exceptional cases of *EveryNP* object sentences exist which naturally receive cumulative interpretations (e.g.,

¹ Sentences like (1)–(3) also have collective interpretations (see Champollion, 2015 for a detailed summary). For example, (1) can be used to assert that a group of cowboys as a group pulled the same two horses. We do not investigate children's comprehension of collective interpretations in our experiment (but see below for a review of recent developmental research).

Brasoveanu, 2013; Kratzer, 2000; Matthewson, 2001; Schein, 1993; Tunstall, 1998). Kratzer (2000) observed, for example, that the sentence *Three copy editors caught every mistake in the manuscript*, in addition to its IS distributive interpretation, can also describe situations in which each of three copy editors caught at least one mistake and each of a maximal set of mistakes was caught by at least one of the three copy editors. We return to such cases below.

3. Children's performance with distributive quantification

Developmental linguistic research has established that children are more permissive than adults when they assign interpretations to sentences with distributive universal quantifiers under certain experimental conditions. Relevant findings come from two lines of research. First, numerous studies of children's well-known symmetrical judgments (Philip, 1995) have shown that children consistently judge universally quantified sentences differently than adults on Truth-Value Judgment Tasks when an incomplete one-to-one relation between sets of individuals is depicted in referential context (see Drozd, 2001; Geurts, 2003; Smits, 2010 for reviews).² Exhaustive Pairing (Drozd, 2001), the most often reported symmetrical judgment, is commonly elicited when a child is asked to judge if a sentence like *Every girl is driving a car* describes a referential context depicting each of three girls driving a different car when a driverless car is also present (commonly referred to as the Extra Object context). Whereas adults accept the sentence on this task, children are prone to reject it on the grounds that there is no girl for the driverless car. Exhaustive Pairing judgments dramatically decrease if the salience of the extra object as representative of an incomplete distributive relation is reduced or if the extra object is removed altogether (e.g., Brinkmann et al., 1996; Drozd, 2001; Drozd and van Loosbroek, 2006; Gouro et al., 2001; Philip, 1995; Sugisaki and Isobe, 2001).

A second line of more recent research has shown that children tend to accept sentences with distributive universal quantifiers as descriptions of collective actions and cumulative relations (Brooks and Braine, 1996; Musolino, 2009; Pagliarini et al., 2012; Syrett and Musolino, 2015). Using a picture choice task, Brooks & Braine (1996, Experiment 2) found that 4–5-year old children asked to match sentences like *Each man is building a boat* with a picture depicting a collective action (3 men building a single boat) or a distributed action (3 men each building his own boat) chose the collective picture 41% of the time, while adults did so only 0.8% of the time (see also Pagliarini et al., 2012). Syrett and Musolino (2015, Experiment 4) reported that 4–5-year-old children accepted sentences like *Two boys each pushed a car* as a description of a videoed collective action (two boys pushing a the same toy car across a table) 86.7% of the time. Of particular relevance to our study is an experiment conducted by Musolino (2009). Musolino elicited 4–6-year-old children's judgments of numNP and *each*NP object sentences like *Three boys are holding two balloons* and *Three boys are holding each balloon* as descriptions of computer narrated vignettes depicting cumulative relations (e.g., two boys holding the same balloon, a third boy holding a different balloon), SS distributive relations (e.g., three boys each holding a different pair of balloons), IS distributive relations (two sets of three boys each holding a different balloon) and collective (referred to as “*each-all*”) contexts (a group of three boys holding the same two balloons). Musolino reported that the children accepted numNP sentences as descriptions of SS distributive, IS distributive and collective outcomes at adult-like levels but rejected numNP sentences significantly more often than adults as descriptions of cumulative vignettes (76.6% versus 21.9% of the time, respectively). Musolino concluded from these results that children access the variety of interpretations of numNP sentences expected of adults, although they have a relatively stronger preference than adults for SS distributive interpretations of numNP sentences. Musolino also reported that the children and adults accepted *each*NP object sentences as descriptions of IS distributive outcomes at similarly high rates (84.3% and 100%, respectively), revealing that children access the IS distributive interpretations of *each*NP object sentences when depicted in context. However, the children also accepted *each*NP object sentences as descriptions of cumulative and SS distributive outcomes 54.6% and 90.6% of the time and significantly more often than the adults, who did so 17.1% and 31.2% of the time, respectively.

Children's Exhaustive Pairing judgments have generated numerous linguistic explanations using a variety of theoretical approaches (e.g., Philip, 1995; Roeper and de Villiers, 1991; Crain et al., 1996; Drozd, 2001; Kang, 2001;

² One indication that being a strong quantifier alone is insufficient to capture Musolino's findings is Musolino's logical form in (19). (19) is derived by applying Geurts' quantifier spreading analysis of (10) directly to (15). Musolino (2009:39) intended (19) to express that each of three boys is holding a balloon, a relational interpretation which correctly predicts that children will accept (15) as a description of Musolino's SS distributive and cumulative vignettes. However, a closer look shows that (19) actually expresses that each trio of boys *x*, not each boy *x*, has the property of holding a balloon. To reflect Musolino's intended interpretation, (19) would have to be modified so that *each* quantifies over singular individuals rather than sets of individuals. Geurts' analysis in (15) avoids this problem because the object NP in (10) is singular and contributes a singular individual variable into semantic representation. It is this singular variable that *every* binds when it spreads to the object NP. These observations suggest that it is the inherent distributivity of *each* rather than its status as a strong quantifier that Musolino's intended interpretation of (19) appeals to. Surprisingly, although Musolino acknowledges this issue in a footnote and notes that his intended interpretation can in principle be captured in Geurts' system, the issue is never resolved.

Geurts, 2003; Berent et al., 2008; Rakhlin, 2007; Smits, 2010). However, the only linguistic account to have so far emerged to explain children's performance in the more recent studies was made by Musolino (2009). Musolino proposed, extending Geurts (2003) account of children's symmetrical judgments, that children performed differently than adults in his experiment because they tend to analyze universal quantifiers as weak quantifiers (the Weak Quantifier account). One main goal of our experiment is to explore the predictions of this account.

4. The Weak Quantification account

Musolino argued that children performed differently from adults with *each*NP object sentences in his experiment because they are prone to misapply semantic processing strategies dedicated to proportional construals of weak quantifiers to derive distributive interpretations for universal quantifiers. Geurts (2003) original account draws on the well-known distinction between strong quantifiers (e.g., *each*, *every*, *most*, *neither*) and weak quantifiers (e.g., *many*, *some*, *two*) (Milsark, 1977). Strong quantifiers denote relations between a quantifier's domain and its nuclear scope, each of which is often represented independently in tripartite semantic representations of the form [_s [quantifier] [restrictor] [nuclear scope]] (Diesing, 1992; Heim, 1982; Heim and Kratzer, 1998; Partee, 1995, see also Kamp, 1981 and Kamp and Reyle, 1993). In the semantic representation of (4) in (5), the lexical meaning of the quantificational determiner *every* supplies the quantifier in the representation, the nominal complement to the quantifier in *Every*NP supplies the restrictor, and the remainder of the sentence supplies the nuclear scope.

- (4) Every girl is driving a car.
 (5) [_s [every] [x is a girl] [there is a car y & x is driving y]]

Tripartite structures also represent the proportional construals of NPs with weak quantifiers (weakNPs) like *Two girls* in (6) (Kamp and Reyle, 1993; Partee, 1995). In Geurts' system, (6) receives a default existential or cardinal interpretation ('There are two girls driving a car'), which is represented by the bipartite structure in (7). When a proportional construal ('two of the girls') is called for by context, an empty domain is introduced into the semantic representation, forming the tripartite representation in (8). An additional processing step transforms the denotation of the subject's common noun into the quantifier's domain, yielding (9).

- (6) Two girls are driving a car.
 (7) [_s [two] [x is a girl & there is car y & x is driving y]]
 (8) [_s [two] [...]] [x is a girl & there is car y & x is driving y]]
 (9) [_s [two] [x is a girl] [there is car y & x is driving y]]

Drawing on an earlier proposal by Drozd (2001), Geurts proposed that a similar weak quantifier processing strategy underlies Exhaustive Pairing judgments. Geurts argued that children grasp the relational meaning of universal quantifiers but are prone to map strong quantifiers like the universal quantifiers initially to bipartite structures associated with weak quantifiers because they are simpler (require fewer embedded semantic representations) than tripartite structures. Under Geurts' account, (10) is initially mapped to the semantic representation in (11). Children then introduce an empty restrictor to establish the requisite tripartite structure, as in (12). At this stage, children resort to pragmatic information to select the quantifier's domain argument. If girls are perceived as contextually salient, they are interpreted as given information restricting the quantificational domain, yielding the adult-like (13). If the cars are perceived as contextually salient, they are interpreted as given and selected as the restrictor for the quantifier via a process known as 'quantifier spreading,' yielding (14) (see Roeper and de Villiers, 1991; Philip, 1995; Kang, 2001 for variations of quantifier spreading analyses).

- (10) Every girl is driving a car.
 (11) [_s [every] [x is a girl & there is car y & x is driving y]]
 (12) [_s [every] [...]] [x is a girl & there is car y & x is driving y]]
 (13) [_s [every] [x is a girl] [there is a car y & x is driving y]]
 (14) [_s [every] [y is a car] [there is a girl x & x is driving y]]

(14) describes situations in which every car is being driven by a girl, thereby capturing the Exhaustive Pairing judgment of (10).

Musolino (2009) extended Geurts' account to explain why children accepted (15) as a description of SS distributive and cumulative vignettes in his experiment. Musolino proposed that children first analyze *each* as a weak quantifier and

map the sentence to the bipartite semantic structure in (16). They then establish an empty domain, as in (17), and map (17) either to an adult-like semantic representation, shown in (18), or to a representation derived by quantifier spreading, shown in (19). Musolino's (2009:39) intended interpretation of (19) is "for each of the three boys, there is a balloon that that boy is holding." Crucially, this construal captures the children's performance, since Musolino's SS distributive and cumulative vignettes depict cross-product relations between boys and balloons.

- (15) Three boys are holding each balloon.
- (16) [_S [each] [y is a balloon & there are three boys x & x hold y]]
- (17) [_S [each] [...]] [y is a balloon & there are three boys x & x hold y]]
- (18) [_S [each] [y is a balloon] [there are three boys x & x hold y]]
- (19) [_S [each] [x is three boys] [y is a balloon & x hold y]]

5. Experiment

Our experiment had two main goals. First, we wanted to explore further the Weak Quantification account. Although a core claim of the account is that children are prone to analyze universal quantifiers as weak quantifiers, neither Geurts nor Musolino directly compared children's performance with sentences with weakNPs and universally quantified NPs to determine to what extent children's interpretations of the quantifier types are similar or different. Moreover, a closer look at the Weak Quantifier account leaves a number of questions unanswered. One question concerns why the adults in Musolino's experiment accepted *each*NP object sentences as descriptions of SS distributive and cumulative vignettes so often (31.2% and 17.1%, respectively). Musolino (2009:41) suggested that the adults were simply less prone than the children to adopt a weak quantifier processing strategy on these trials. But this suggestion leaves unanswered why the adults would resort to a malfunctioning mapping strategy involving quantifier spreading, an otherwise unattested strategy for quantifier domain selection, when presented with simple judgment tasks. A related issue concerns how Musolino's referential contexts could have motivated both adults and children to adopt quantifier spreading analyses of *each*NP sentences. Geurts suggested that the single extra object in the Extra Object contexts used to elicit Exhaustive Pairing judgments led children to perceive the objects in referential context as topical and to construe the objects as the intended domain for the universal quantifier. But Musolino's vignettes do not depict incomplete one-to-one relations, raising the question why an adult or child would consider the objects rather than the actors in his vignettes as topical. A third question is whether children respond similarly with universally quantified sentences on Exhaustive Pairing tasks and tasks with cumulative contexts. Musolino's account entails that Exhaustive Pairing judgments and children's judgments of *each*NP object sentences both reflect quantifier spreading interpretations. But this has not yet been tested. A final question concerns *each* versus *every*. Musolino observed that Geurts' account should apply as much to *each* as to *every* since both are strong quantifiers. However, it is well-known that *each* and *every* have different lexical properties and logical behaviors. In the semantics literature, *each* is claimed to be inherently distributive, to direct attention to individuals, and to have the strongest tendency among quantifiers for highest scope. *Every*, in contrast, is claimed not to be obligatorily distributive, to stress completeness or exhaustiveness of a domain, and to have a relatively weaker tendency than *each* to take highest scope (e.g., Beghelli and Stowell, 1997; Ioup, 1975; Tunstall, 1998; Vendler, 1967). This raises the possibility that Musolino's findings with *each*NP objects reflect properties which distinguish *each* from *every* rather than the properties they share as strong quantifiers.²

With our experiment, we explore the predictions of Geurts' original Weak Quantification account. Using a Truth-Value Judgment Task technique (Crain and McKee, 1985), we directly compared children's and adults' judgments of sentences with *every*NPs and numNPs like (1)–(3) as descriptions of pictures depicting SS distributive and cumulative contexts similar to the final scenes in Musolino's vignettes. If children and adults are prone to process strong NPs as weakNPs because it is easier to do so, we expect them to show similar performance with *Every*NPs, whether they are in matrix subject position, as in (2), or in object position, as in (3). In our experiment, we collected participants' reasons for rejecting our test sentences to provide additional insights into to what extent children's and adults assign similar interpretations to these sentences across context types. We used *every* rather than *each* to avoid the issues we observed with Musolino's account and to provide new data to compare with Musolino's results. We also compared children's performance on Exhaustive Pairing trials with their performance on cumulative context trials to investigate if children analyze universally quantified sentences similarly on both trial types, as Musolino's account predicts.

Our second main goal was to explore an alternative hypothesis which we call the Cumulative Interpretation (CI) Hypothesis. The CI Hypothesis claims that children are prone to accept sentences with universally quantified object NPs when presented with SS distributive and cumulative contexts because they are prone to assign cumulative interpretations to these sentences under these conditions. As we mentioned above, numNP sentences like (1) and marked cases of *every*NP object sentences like (21) can receive cumulative interpretations, which we represent by the

Table 1
Examples of sentence-picture pairs used in the experimental and control conditions.

Sentence type	Sentence example	Context type
<i>Experimental conditions</i>		
<i>3/2</i>	3 pirates are waving 2 swords.	Distributive (Fig. 1)
	3 cowboys are pulling 2 horses.	Cumulative (Fig. 2)
<i>Every/2</i>	Every pirate is waving 2 swords.	Distributive (Fig. 1)
	Every cowboy is pulling 2 horses.	Cumulative (Fig. 2)
<i>3/Every</i>	3 pirates are waving every sword.	Distributive (Fig. 1)
	3 cowboys are pulling every horse.	Cumulative (Fig. 2)
<i>Every/a</i>	Every man is fixing a bicycle.	Extra object (Fig. 3)
<i>Control condition</i>		
<i>Every/a</i>	Every boy is climbing a tree.	Extra Agent (Fig. 4)

logical forms in (20) and (22). The CI Hypothesis claims that children assign a similar logical form to (23), given in (24), when they accept it as a description of an SS distributive or cumulative context.³

- (1) Three cowboys are pulling two horses.
- (20) 'There is a set of three cowboys X and a set of two horses Y and for each x in X there is a y in Y such that x is pulling y and for each y in Y there is an x in X such that x is pulling y.'
- (21) Three copy editors caught every mistake in the manuscript (Kratzer, 2000).
- (22) 'There is a set of three copy editors X & a maximal contextually salient set of mistakes in the manuscript Y and for each x in X, there is a y in Y such that x caught y and for each y in Y, there is an x in X such that x caught y.'
- (23) Three boys are holding each/every balloon.
- (24) 'There is a set of three boys X & a maximal contextually salient set of balloons Y and for each x in X, there is a y in Y such that x is holding y and for each y in Y, there is an x in X such that x is holding y.'

The CI Hypothesis presents a plausible alternative to the Weak Quantifier account. The key observation is that cumulative interpretations of sentences like (23) describe SS distributive and cumulative contexts. The logical form in (24), for example, makes (23) true if each of three boys is holding either different pairs of balloons (SS distributive context) or one or both of two balloons (cumulative context). Second, the CI hypothesis doesn't appeal to malfunctioning mapping processes or domain selection procedures or to unattested logical forms to explain children's and adults' performance.

5.1. Participants

Three groups of children, Group 1 (mean age 5.2, range 4.7–6.1), Group 2 (mean age 7.1, range 6.2–7.9), and Group 3 (mean age 8.6, range 7.10–9.6) recruited from state schools in the London area participated in the experiment. A group of 12 healthy adults aged between 18 and 45 who worked in a range of occupations from education to business and banking in the London area also participated in the study.

5.2. Design and materials

Our main experiment used a 3 (sentence type: *3/2*; *Every/2*; *3/Every*) × 2 (picture type: distributive, cumulative) design. A further experimental sentence type *Every/a* was paired with an extra object picture type to test for Exhaustive Pairing. The *Every/a* sentence type was also paired with the extra agent picture type as a control condition (see Table 1).

12 different test booklets were created. Each booklet included a different randomly chosen collection of 6 trials from each of the 7 experimental conditions. 30 different hand-drawn pictures were distributed to the 3 context types represented in Figs. 1–3 (see Appendix). Of these, 12 pictures depicting 3 actors each associated with a different pair of entities (Fig. 1) provided the distributive context pictures for each of the first three experimental conditions with *Every/2*,

³ The logical forms in (22) and (24) assume that *Every*NPs contribute maximal contextually salient sets of individuals to semantic representations (Brasoveanu, 2013; Matthewson, 2001:177–178). However, our analysis does not rely on this. *Every*NPs have also been semantically analyzed in the literature as collective definites (Landman, 2000), variables over witness sets (Szabolcsi, 1997), and groups (Beghelli and Stowell, 1997:75), any of which could replace the maximal contextually salient sets in our logical forms.

Fig. 1. Distributive context.

Fig. 2. Cumulative context.

Fig. 3. Extra object context.

3/Every, and 3/2 sentence types. 12 pictures depicting 2 of 3 actors each associated with a different object or animal and a third actor associated with both (Fig. 2) provided the cumulative context pictures for the three sentence types. Six 'extra object' contexts depicting 3 actors associated with 3 of 4 different entities (Fig. 3) were each paired with an *Every/a* sentence, yielding the seventh experimental condition. Three drawn "extra agent" contexts (Fig. 4), each depicting 3 of 4 agents associated with an object, were paired with an *Every/a* sentence as control trials. Participants who understood that universal quantifiers are used to quantify exhaustively over a domain were expected to reject the sentences in these conditions. 25 filler trials and 3 warm-up trials were added to the 3 control items and experimental trials to yield a total of 73 trials per booklet. The order of presentation of the entire set of trials except the warm-up trials was pseudo-randomly ordered. 6 different pseudo-randomly ordered sets of trials were created and distributed across participants.

Fig. 4. Extra agent context.

5.3. Procedure

Each participant was tested individually in a quiet area. After the experimenter and participant were seated, the experimenter explained that she was going to show the participant some pictures, which she should look at very carefully. The experimenter then said that she was going to say something about each picture and that the participant was to say *yes* if what she says is right and *no* if what she says is wrong. The test booklet was then opened to the first picture.

Warm-up trials were used to get participants used to the nature of the task. Participants were encouraged to give both *yes* and *no* responses to questions about pictures on warm-up trials and were given extra prompting when correct responses were not given. Participants were told *That's good/fine* after a correct or incorrect *yes* response. After a correct or incorrect *no* response, participants were asked if they could say why they said *no*. Participants were told *That's good/fine* after each explanation. Before presenting each sentence during the test phase of the experiment, the experimenter introduced the contents of the corresponding picture to the participant by pointing out the actors and the objects mentioned in the test sentence. Test sentences were presented immediately after the introductions, with slight prosodic emphasis on the numerals or quantifiers in the sentence. Participants' responses were recorded on a DAT tape recorder using an ECT external microphone, for later transcription.

5.4. Coding of justifications

Justifications of *no* responses were assigned to one of six categories to gain insight into participants' judgments.

1. **REFERENCE TO SUBSETS** justifications refer to subsets of actors in a picture who were performing the action (the reference set (refset)) or not performing the action (the complement set (compset)) described in a test sentence. Examples include denying that 3 cowboys are pulling 2 horses describes a cumulative picture because only 1 cowboy is pulling 2 horses (refset) or because 2 cowboys are pulling only 1 horse (compset).
2. **MATCH OBJECT** justifications indicate that the cardinality of a direct object NP does not match the actual number of objects in a picture. Examples include replacing 3 pirates are waving 2 swords with 3 pirates are waving 6 swords as a description of a distributive context.
3. **ADD QUANTIFIER** justifications replace the cardinal predicate in a subject NP with a distributive determiner or add the adverb *each* to a test sentence. Examples include replacing 3 pirates are waving 2 swords with *Each pirate is waving 2 swords* or 3 pirates are *each* waving 2 swords as a description of a distributive context.
4. **SHIFT QUANTIFIER** justifications shift the universal quantifier to a different position in the sentence to create a sentence form whose interpretation matches the referential context. Examples include replacing the sentence 3 cowboys are pulling every horse with 3 cowboys are each pulling 2 horses or *Every cowboy is pulling 2 horses* on a distributive context trial.
5. **REPLACE QUANTIFIER** justifications replace the universal quantifier with an appropriate cardinal predicate. Examples include transforming 3 cowboys are pulling every horse into 3 cowboys are pulling 2 horses given a cumulative context.

6. OTHER justifications explain in some other way that the sentence did not match a pictured context. For example, one participant rejected the sentence *3 men are sitting on every box* given a distributive context by explaining “because the men ain’t long enough to sit on all of the boxes.”

Reference to subsets, add quantifier, shift quantifier and replace quantifier justifications all indicate a distributive interpretation of a test sentence. Match object justifications indicate a cumulative interpretation of the test sentence.

5.5. Predictions

According to previous literature, numNP sentences have SS distributive and cumulative interpretations (henceforth we replace ‘SS distributive’ with the simpler ‘distributive’). Musolino (2009:33) reported that adults accepted numNP sentences as descriptions of distributive and cumulative contexts 82.8% and 78.1% of the time, respectively, while children did so 78.1% and 23.4% of the time. Since our materials are highly similar to Musolino’s and no other comparable results are available, we used Musolino’s findings as our predictions for adult and child performance with numNP sentences in our experiment. Classical theories of universal quantification analyze *every* as an inherently relational quantifier. These accounts predict that adults should accept *Every/2* sentences as descriptions of distributive contexts and reject them as descriptions of cumulative contexts and reject *3/Every* sentences as descriptions of both distributive and cumulative trials, given the assumption that *3/Every* sentences are not exceptional cases. More recent accounts claim that *everyNP* object sentences can receive cumulative interpretations, although these are highly marked. This raises the possibility that adults may, in principle, assign *3/Every* sentences cumulative interpretations in our experiment.

Geurts’ Weak Quantifier account claims that children should find *Every/2* sentences ambiguous depending on whether the NP complement of the *everyNP* (adult-like) or the numNP (quantifier spreading) is selected to supply the quantifier’s restrictor. Children should accept *Every/2* sentences as descriptions of distributive contexts if they find the denotation of the NP complement in *everyNP* a salient restrictor for the quantifier. But they should reject *Every/2* sentences as descriptions of cumulative contexts, since neither the adult-like nor the quantifier spreading interpretations of these sentences describe cumulative contexts. If children are prone to analyze *EveryNPs* in object position as weakNPs, they should also find *3/Every* sentences ambiguous. Children should reject *3/Every* sentences as descriptions of both distributive and cumulative contexts, since neither the adult-like nor the quantifier spreading interpretations of these sentences describe these contexts. If children are prone to process universal quantifiers as weak quantifiers on Exhaustive Pairing trials as well as on trials with distributive and cumulative contexts, as Musolino’s account predicts, then we should find similar performance from children on all three trial types.

The CI Hypothesis claims that children are prone to assign cumulative interpretations to sentences with universally quantified object NPs when presented with contexts which are consistent with their cumulative interpretations. This predicts that children should tend to accept *3/Every* sentences when presented with cumulative and SS distributive contexts. The CI Hypothesis also predicts that children will perform similarly with *3/Every* and *3/2* sentences in our experiment. We have already seen that whether a *3/Every* sentence like (21) or a numNP sentence like (1) receives a distributive or cumulative interpretation is largely determined by pragmatic context. Thus, we expect children who are prone to assign cumulative interpretations to *3/2* sentences to be prone to assign cumulative interpretations to *3/Every* sentences under the same conditions. If children are also prone to assign cumulative interpretations to sentences with universally quantified subjects, they should tend to accept *Every/2* sentences as descriptions of cumulative contexts as

Table 2
Mean accurate response and standard deviations (in parentheses) for *3/2*, *Every/2*, and *3/Every* conditions for all groups.

Sentence type, context type, and expected judgment	Group			
	Group 1	Group 2	Group 3	Adult
<i>3/2</i>				
Cumulative (yes)	.58 (.32)	.57 (.34)	.59 (.45)	.68 (.31)
Distributive (yes)	.93 (.11)	.94 (.08)	.91 (.25)	.53 (.35)
<i>Every/2</i>				
Cumulative (no)	.49 (.25)	.65 (.33)	.65 (.33)	.87 (.20)
Distributive (yes)	.93 (.17)	.93 (.11)	.95 (.15)	.99 (.05)
<i>3/Every</i>				
Cumulative (no)	.43 (.29)	.54 (.37)	.30 (.39)	.57 (.27)
Distributive (no)	.34 (.36)	.57 (.37)	.52 (.41)	.63 (.33)

Table 3
Mixed models analysis.

	Estimate	Std. Error	t-Value
(Intercept)	0.67963	0.07225	9.406
Group 1	−0.10105	0.09599	−1.053
Group 2	−0.04765	0.09695	−0.491
Group 3	−0.10199	0.09678	−1.054
Distributive	−0.13763	0.06988	−1.969
3/Every	−0.09607	0.14683	−0.654
Every/2	0.19773	0.10927	1.810
Group1-Distributive	0.50420	0.08717	5.784*
Group2-Distributive	0.36746	0.08901	4.128*
Group3-Distributive	0.48587	0.08916	5.450*
Group1-3/Every	0.05938	0.19913	0.298
Group2-3/Every	−0.25791	0.20006	−1.289
Group3-3/Every	−0.14789	0.20011	−0.739
Group1-Every/2	−0.17777	0.14105	−1.260
Group2-Every/2	−0.25515	0.14225	−1.794
Group3-Every/2	−0.17855	0.14195	−1.258
Distributive-3/Every	0.15085	0.10309	1.463
Distributive-Every/2	0.24526	0.10522	2.331*
Group1:Distributive-3/Every	−0.57336	0.12317	−4.655*
Group2:Distributive-3/Every	−0.26996	0.12578	−2.146*
Group3:Distributive-3/Every	−0.52595	0.12645	−4.159*
Group1:Distributive:Every/2	−0.28079	0.12316	−2.280*
Group2:Distributive:Every/2	−0.09514	0.12573	−0.757
Group3:Distributive: Every/2	−0.27434	0.12542	−2.187*

well and perform similarly with *Every/2*, *3/2* and *3/Every* sentences. Finally, the CI Hypothesis leads us to expect children to perform differently on Extra Object trials and our main condition trials. Extra Object trials depict the distributive interpretations of our *Every/a* sentences, thus ruling out a cumulative interpretation. Thus similar performance on Exhaustive Pairing and cumulative context trials would be unexpected given the CI Hypothesis.

5.6. Results

All of the participants passed the control condition and were included in the analyses. Mean accuracy scores and standard deviation values (in parentheses) for the experimental conditions are shown in Table 2. *Yes* was chosen as the accurate judgment of *3/2* sentences and *no* as the accurate judgment for *3/Every* sentences on both cumulative and distributive context trials, following standard grammaticality assessments in the semantic literature.

A mixed models logistic regression analysis testing for fixed effects of age group (Group 1, Group 2, Group 3, Adult), sentence type (*Every/2*, *3/Every*, *3/2*), picture type (distributive, cumulative) and including subject, picture item, and sentence item as random effects was conducted using the R statistics software package (R Core Development Team, 2005). The intercept represents the accuracy of the adult group's judgments of *3/2* sentences on cumulative context trials. Each level of each predictor was coded as a distinct variable. The dependent variable was accurate judgments. The results for this model are presented in Table 3. Following standard conventions, we consider a *t* value significant (*) if it is above 2.00.

We discuss these results in the context of our predictions by sentence type.

5.6.1. 3/2 sentences

Our Group 1, Group 2, and Group 3 results in Table 3 show that these age groups did not represent significant predictors of *3/2* sentence judgment accuracy on cumulative context trials when compared to adult *3/2* judgment accuracy on these trials (intercept). This result is consistent with the Table 2 data, which shows highly similar accuracy rates for *3/2* sentence judgments on cumulative context trials. Our results also show that distributive context did not represent a significant predictor of accuracy of adults' judgments of *3/2* sentences. This result is also consistent with Table 2 data, which shows that adults accepted *3/2* sentences on cumulative and distributive context trials 68% and 53% of the time, respectfully. However, our results revealed significant interactions between distributive context and age

groups 1, 2 and 3 (Group1-Distributive: $SE = 0.08717$, $t = 5.784$; Group2-Distributive, $SE = 0.08901$, $t = 4.128$; Group3-Distributive: $SE = 0.08916$, $t = 5.450$) (all $p < .001$). These interactions indicate that the children's 3/2 sentence judgments were significantly more accurate on distributive context trials than on cumulative context trials. Interactions test whether the effect of one predictor A depends on the level of another predictor B by comparing differences between base levels of A and B represented in the intercept with alternative levels of A and B. The Group1-Distributive interaction in Table 3 shows that the difference in accuracy between Group 1's 3/2 judgments on distributive and cumulative trials is significantly larger than the difference in accuracy between the adults' 3/2 judgments on distributive and cumulative trials. The data in Table 2 clarify this finding by showing that Group 1 children's judgments of 3/2 sentences were accurate more often on distributive context trials (93%) than on cumulative context trials (58%) and that the difference is significantly bigger than the difference between the adults' judgments on these trials (68% and 53%, respectively). Similarly, the significant Group2-Distributive and Group3-Distributive interactions in Table 3 show that these groups' 3/2 sentence judgments were also more accurate on distributive than on cumulative context trials.

We analyzed adults justifications to gain more insight into why they performed differently than the children on distributive context trials. The results show that adults justified their rejections differently depending on context type. All age groups justified their rejections of 3/2 sentences on cumulative context trials by referring to subsets 90% of the time. This indicates that both the children and the adults rejected 3/2 sentences because they assigned them distributive interpretations which did not match a cumulative context (see Section 5.4). On distributive context trials, however, adults justified their rejections either by adding a universal quantifier to a sentence in order to make the distributive interpretation explicit (e.g., 3 cowboys are each pulling 2 horses) (62% of the time) or by replacing the numNP object with a numNP matching the number of objects in referential context in order to make the cumulative interpretation explicit (e.g., 3 cowboys are pulling 6 horses) (32% of the time). These results suggest that distributive contexts led adults to replace ambiguous 3/2 sentences with alternatives which unambiguously matched their analysis of referential context but that these contexts had no such effect on the children. We return to this finding below.

5.6.2. Every/2 sentences

The Group1-Every/2, Group2-Every/2, and Group3-Every/2 interaction values in Table 3 indicate that differences in judgment accuracy between Every/2 and 3/2 sentences on cumulative trials across age groups were not significantly different. These results are consistent with Table 2, which shows similar accuracy levels overall for Every/2 and 3/2 sentences on cumulative context trials. Participants justified their rejections of Every/2 sentences on cumulative context trials 90% of the time again by referring to subsets, indicating that participants almost always rejected sentences on these trials because they assigned a distributive interpretation to the Every/2 sentence. On the very few trials where children rejected Every/2 sentences in distributive contexts, they justified their rejections by replacing the direct object with a numNP (6 swords), suggesting a preference for a cumulative interpretation of the sentence.

We found a significant interaction between Every/2 sentence and distributive context ($SE = 0.10522$, $t > 2.331$, $p < .05$). This interaction indicates that for adults, the difference in judgment accuracy between Every/2 and 3/2 sentences is significantly larger on distributive context trials (99% versus 53%, as shown in Table 2) than on cumulative context trials (87% versus 68%). In other words, this result suggests a significant advantage for adults when Every/2 sentences are matched with distributive contexts. We also found significant triple interactions between Every/2 sentence, distributive context and Group 1 ($SE = 0.12316$, $t = -2.280$, $p < .05$) and between Every/2 sentence, distributive context and Group 3 ($SE = 0.12542$, $t = -2.187$, $p < .05$). These interactions suggest that the effect of distributive context on adult judgment accuracy is even stronger for Groups 1 and 3. This effect is also evident in Table 2. As shown in this table, the children overall were less accurate than adults when judging Every/2 and 3/2 sentences on cumulative context trials but overall more accurate than adults when judging these sentences on distributive context trials. These results produced relatively wider differences in accuracy with Every/2 and 3/2 sentences on distributive and cumulative context trials for the children than for the adults.

These results together support the CI Hypothesis. The results show that children are indeed prone to accept Every/2 sentences on cumulative context trials, as the hypothesis predicts. Moreover, the justifications results suggest that children tend to analyze 3/2 and Every/2 sentences similarly on cumulative context and distributive context trials. These results are inconsistent with the Weak Quantification account, which predicts high accuracy scores from children given Every/2 sentences.

5.6.3. 3/Every sentences

We found no significant effect of 3/Every sentence and no significant simple interactions involving age group with 3/Every sentence, and therefore no differences between judgment accuracy levels for 3/2 and 3/Every sentences on cumulative context trials across age groups. Furthermore, we found no significant distributive-3/Every sentence interaction. In other words, for adults, the difference in 3/Every judgment accuracy rates on distributive and cumulative

trials (57% and 63%, respectively) is no different than for 3/2 sentences (53% and 68%, respectively). These results show that the adults and the children were prone to assign cumulative interpretations to 3/Every sentences as well as to 3/2 sentences on cumulative context trials, as the CI Hypothesis predicts.

However, our results also revealed significant triple interactions between 3/Every sentence and distributive context for each of the child age groups (Group1-Distributive-3/Every: $SE = 0.12317$, $t = -4.655$, $p < .01$; Group2-Distributive-3/Every: $SE = 0.12578$, $t = -2.146$, $p < .05$; Group3-Distributive-3/Every: $SE = 0.12645$, $t = -4.159$, $p < .01$). These interactions show that the Distributive-3/Every interaction values for adults and children significantly differ. Unlike the adults, the children were accurate much less often with 3/Every sentences than with 3/2 sentences on distributive context trials. As shown in Table 2, the children accepted 3/2 sentences on distributive context trials at ceiling levels (>90% accuracy) but rejected 3/Every sentences on distributive context trials significantly less often (46.7% accuracy).

Participants' justifications reveal a pattern similar to the pattern we reported for 3/2 sentences. Participants overall justified their rejections of 3/Every sentences in cumulative contexts primarily by referring to subsets (78%), again indicating distributive interpretations of these sentences. In contrast, participants explained their rejections on distributive context trials with Shift Quantifier (63%) and reference to subsets (23%) justifications. The Shift Quantifier justifications indicate that participants found the form of the test sentence unacceptable or infelicitous and produced a sentence form with an interpretation that makes the distributive interpretation of the sentence true. Shift Quantifier justifications were produced as often by the children as by the adults.

These results also support the CI Hypothesis. Our results suggest that both children and adults are prone to assign cumulative interpretations to 3/Every sentences on both cumulative and distributive context trials. Furthermore, children are no more or less accurate in their judgments of 3/Every sentences than they are with 3/2 sentences on cumulative context trials. The Weak Quantification account, in contrast, makes the wrong prediction that children and adults should reject 3/Every sentences on these trials since they are incompatible with the strong interpretation of the universal quantifier.

5.6.4. Correlational analyses

Two series of correlational analyses were conducted to test the predictions of our hypotheses. One set of analyses was conducted to determine if the children who tended to accept 3/2 sentences in cumulative contexts also tended to accept Every/2 and 3/Every sentences in cumulative contexts and 3/Every sentences in distributive contexts, as predicted by the CI Hypothesis. Significant pair-wise correlations were found between the rates of acceptance of 3/2 sentences on cumulative context trials and each of the other sentence-context combinations as well as between the rates of acceptance of the remaining pairs (Table 4). The strengths of these correlations were, however, moderate and accounted for 30% or less of the variance.

A second set of correlational tests was conducted to determine if the children who were prone to accept Every/2 sentences on cumulative context trials were also prone to reject Every/a sentences on Exhaustive Pairing tasks, as the Weak Quantification account predicts.

Children's performance on the Exhaustive Pairing condition is indicated in Table 5.

Correlational tests revealed no significant correlations between children's performance with Every/2 and Every/a sentences when all child groups were taken together (Spearman's $r = -.084$, $p > .05$) or when each child group was taken individually (Group 1: $r = .12$, $p = .34$; Group 2: $r = -.008$, $p = .49$; Group 3: $r = -.23$, $p = .24$). In addition, no

Table 4
Pairwise correlational values for selected comparisons.

	Cum-Every/2	Cum-3/Every	Dist-3/Every
Cum-3/2	.61 **	.52 **	.41 **
Cum-Every/2		.50 **	.41 **
Cum-3/Every			.60 **

** $p < .01$. Cum = cumulative context, Dist = distributive context.

Table 5
Mean yes response on Every/a condition for all groups.

Test sentence type	Group			
	Group 1	Group 2	Group 3	Group 4
Every/a	.28 (.36)	.34 (.39)	.63 (.39)	.92 (.13)

correlations were found between the children's acceptance rates for 3/2 sentences on cumulative context trials and their rejection rates of *Every/a* sentences on Exhaustive Pairing tasks across child groups ($r = -.008$, $p = .48$). All tests were one-tailed. This result does not support the prediction.

6. Summary and discussion

6.1. Adults' results

6.1.1. 3/2 sentences

In line with the semantic literature, the adults in our experiment assigned both distributive and cumulative interpretations to 3/2 sentences. These results are comparable to results reported by Gil (1982), who found that Dutch and Hebrew adults matched 3/2 sentences like *Three girls saw two boys* with cumulative contexts on a questionnaire 44% of the time. Gil suggested that his results were a joint product of fuzzy semantic judgments, speakers' dialectal and idiolectal preferences, and inherent variability in individual linguistic behaviors, but did not specify what these judgments and preferences were. Musolino found that adults accepted 3/2 sentences as descriptions of cumulative vignettes 78.1% of the time, roughly consistent with our findings, and as descriptions of SS distributive vignettes 82.8% of the time. To account for his results, Musolino proposed that adults preferred a distributive interpretation of a 3/2 sentence due to the frequency of this interpretation in the input but revised this initial parse to match 3/2 sentences with cumulative contexts. However, he presented no evidence for this analysis. To check if Musolino's proposal could explain our results, we counted the number of trials out of 6 that each adult agreed that a 3/2 sentence described a cumulative context. Given that revisions are computationally expensive, under Musolino's proposal we would expect adults to strongly favor distributive interpretations of 3/2 sentences, with some adults rejecting 3/2 sentences on all 6 cumulative context trials. We found instead that 6 of the 12 adults (50%) accepted 3/2 sentences on cumulative context trials at ceiling (on 5–6 trials) while only 2 adults (17%) rejected them on these trials at ceiling levels. This finding suggests an overall adult preference for cumulative rather than distributive interpretations of 3/2 sentences on cumulative context trials. Our justifications data also show that adults rejected 3/2 sentences on distributive context trials 32% of the time in order to replace the sentence with a form which made the cumulative interpretation unambiguous (e.g., *3 pirates are waving 6 swords*). This result is unexpected if adults preferred distributive interpretations of 3/2 sentences, as Musolino contends. Although more research is needed, we conclude on the basis of our present findings that the adults in our experiment were initially prone to assign cumulative interpretations to 3/2 sentences.

6.1.2. EveryNP sentences

On the vast majority of *Every/2* sentence trials, adults accepted *Every/2* sentences on distributive context trials and rejected them on cumulative context trials, in line with the semantics literature. However, the adults accepted 3/*Every* sentences on distributive and cumulative context trials 37% and 43% of the time, respectively. Moreover, adults' performance with 3/*Every* sentences is statistically no different from their performance with 3/2 sentences on cumulative context trials. These results suggest that the adults assigned cumulative interpretations to 3/*Every* sentences when presented with cumulative contexts, in line with the CI Hypothesis.

There is at present no consensus regarding the grammatical and pragmatic conditions which might induce cumulative interpretations of *everyNP* object sentences (see Matthewson, 2001). We suggest that the morphosyntactic features of these sentences are likely to have played a role in reducing the salience of the distributive interpretations of these sentences in our experiment. Singular subject-verb agreement in sentences like our *Every/2* sentences provides a salient clue to speakers that the predicate is to be construed as a distributed property (Beghelli and Stowell, 1997). The absence of singular agreement in our 3/*Every* sentences may have reduced the salience of the predicate as a distributed property and, as a consequence, the salience of the *EveryNP* as the plurality argument of a distributive relation. A second factor is the pragmatic conditions we used in our experiment. Tunstall (1998) argued that sentences with *each*-phrases and *every*-phrases are used in different ways because they are licensed by different pragmatic conditions. Sentences with *Each*-phrases are licensed by contexts involving differentiated events which distinguish each individual in the quantifier's restrictor as having a property (The Differentiation Condition) and are used to emphasize differentiation. Sentences with *Every*-phrases are licensed by contexts involving partially distributive events which distinguish subsets (including individuals) in the quantifier's restrictor as having the property denoted by the predicate (the Event Distributivity Condition). According to Tunstall, the Event Distributivity Condition invites speakers to use *every* by default to 'direct attention to the set as a whole' and 'to emphasize, rather than just convey, universality and exhaustiveness' when distributivity is not perceived as relevant or intended (Tunstall, 1998:125; Vendler, 1967). Tunstall argued further that emphasizing universality or exhaustiveness can de-emphasize distributivity to such a degree that distributive meaning is lost altogether. Such a case is *They showed him every consideration*, where *every* is used to mean 'all possible' or 'the

utmost degree of" (Tunstall, 1998:103). We propose that the adults in our experiment were prone to accept *3/Every* sentences because neither the cumulative nor the SS distributive contexts we presented them with modeled the distributive interpretations of our *3/Every* sentences or provided cues that these interpretations were relevant or intended. This led adults, in our view, to infer that the *everyNP* objects in these sentences were not being used distributively.

One remaining question concerns the semantic representations underlying adults' cumulative judgments of *3/Every* sentences. We address this issue in Section 7.

6.2. Children's results

6.2.1. *3/2* sentences

The children overall accepted *3/2* sentences on distributive context trials 94% of the time. This is comparable to the 78.1% acceptance rate on similar trials reported by Musolino (2009). These results, together with our *Every/2* results, show that children have no trouble deriving the tripartite semantic structures necessary for representing distributive interpretations when presented with contexts which make distributive relations explicit and unambiguous. However, one striking result of our experiment is that while adults very often rejected a *3/2* sentence to replace it with an unambiguous version with *each*, the children never did. One possible explanation for this result is that the children, like the adults, compared *3/2* sentences with *each*-alternatives but were more tolerant than the adults of the infelicity of using an ambiguous form (see Katsos and Bishop, 2011 for relevant discussion). But our results with *3/Every* sentences show that children rejected *3/Every* sentences on distributive context trials in order to replace them with *each/every*-alternatives as often as adults. This suggests that the children were as able and willing as the adults to produce *every*-sentences as alternatives and were as intolerant as adults of ambiguous forms.

A more likely explanation in our view is that the children accepted *3/2* sentences on distributive context trials at ceiling levels because they were much less likely than adults to recall *each* sentences as more informative alternatives to *3/2* sentences and therefore less likely to compute the scalar implicatures that led adults to produce negative judgments. Adults typically understand a statement such as *Some students passed* to imply that the more informative statement *All students passed* does not obtain on the grounds that a cooperative speaker would have used the more informative statement if it were true (Grice, 1989; Horn, 1972). It is now well established that children often do not compute the scalar implicatures which motivate adults to reject less informative statements when a more informative statement is true in context (e.g., Chierchia et al., 2001; Noveck, 2001; Papafragou and Musolino, 2003, and many others). However, recent studies suggest that children are less likely to compute scalar implicatures if the more informative alternatives are not accessible or available (Barner et al., 2011; Pagliarini et al., 2012). For example, Barner et al. found that while 4-year-old children were generally unable to reject the sentence *Only some of the animals are reading* as a description of a context in which a cat, a dog, and a cow are reading, they could reject the sentence *Only the cat and the dog are reading* given the same context. Barner et al. argued on the basis of their results that children are more likely to compute scalar implicatures when the more informative scalar alternative (e.g., 'a cat and a dog and a cow are sleeping') is contextually available than when the more informative scalar form must be recalled independent of context ('All of the animals are reading'). We suggest that an inability to recall context independent alternative forms may have also had an impact on our children's performance with *3/2* sentences. Interestingly, whereas adults in our experiment were prone to replace our *3/2* and *3/Every* sentences with alternative universally quantified forms whose distributive interpretations unambiguously matched our distributive contexts, the children produced such alternatives only for our *3/Every* sentences. This suggests that the children had a much weaker ability than the adults to recall alternative universally quantified forms if the universal quantifier had not already been available in the test sentence, supporting Barner et al.'s accessibility account.

6.2.2. *EveryNP* sentences

Our results with *EveryNP* sentences strongly favor the CI Hypothesis over the Weak Quantification account. Our results show that both children and adults are prone to accept *3/Every* sentences on both cumulative and SS distributive context trials and that children are prone to accept *Every/2* sentences on cumulative context trials. We also found significant correlations between children's performance between *Every/2*, and *3/Every* sentences and their performance with *3/2* sentences. These results strongly support the view that the children assigned cumulative interpretations to *EveryNP* sentences in our experiment, and at the same time, undermine the Weak Quantification account, which predicts that children assign quantifier spreading interpretations to *EveryNP* sentences. We also found no correlations between children's performance on our main conditions and on the Exhaustive Pairing condition and therefore no evidence that children were assigning quantifier spreading analyses to *EveryNP* sentences across these conditions, as the Weak Quantifier account predicts.

Overall, our results show that the children's performance is strikingly similar to that of adults. Our results show that children and adults performed differently on our main conditions only when presented with *Every/2* sentences on cumulative context trials. Why would children assign cumulative interpretations to *Every/2* sentences on these trials? One hypothesis is that *every*, as an inherently distributive determiner, is highly marked in English and across languages and is therefore relatively more difficult to acquire (e.g., Gil, 1995; Brooks and Braine, 1996). However, if this hypothesis were true, we would have expected the children to have produced more cumulative judgments of *3/Every* sentences than adults. Another possible hypothesis is that children were not as sensitive as adults to the processing principles and/or structural configurations that promote the distributive interpretations of *Every/2* sentences. A common view in the semantics literature is that semantic processing principles establish a processing preference for surface scope interpretations of sentences with multiple quantified NPs. For example, Tunstall (1998:56–59) proposed that quantified sentences preferentially receive surface scope interpretations due to a principle of General Processing Economy, which constrains the processor to do no more than is required by the grammar, and the Principle of Scope Interpretation (PSI), which specifies that the default scope interpretations of sentences with multiple quantified NPs is determined by surface structure c-command relations (see also Fox, 2000; Ioup, 1975). If the children in our experiment were less sensitive to or unable to consistently take advantage of the relevant processing principles, they would be less likely than adults to assign *EveryNP* sentences distributive interpretations. However, the children's performance with *3/2* sentences undermines this hypothesis. Our results showed no significant difference in accuracy between children's and adults' judgments of *3/2* sentences on cumulative context trials and no difference in their justifications for their negative responses. If the children were less sensitive than adults to the processing principles promoting distributive interpretations, we should have found significantly more accurate judgments (acceptance) of *3/2* sentences from children than from adults on cumulative context trials.

A more likely explanation in our view is that the children's judgments of *Every/2* sentences were less accurate than those of adults because they were less able to exploit singular agreement as a cue to distributive interpretation. Few studies have investigated children's performance with singular subject-verb agreement. Some studies have reported adult-like production performance with singular subject-verb agreement by age 4 (e.g., Brown, 1973; De Villiers and De Villiers, 1973; Rispoli, 2016). Other studies show children's adult-like comprehension of subject-verb agreement (Johnson et al., 2005; see also Soderstrom et al., 2002; Wood et al., 2009). For example, Johnson et al. (2005:317) reported that children asked to select a picture with one object (a duck swimming) or a picture with two objects (two ducks swimming) as the correct description of a sentence with singular agreement ('The duck swims in the water') or with plural agreement ('The ducks swim in the water') achieved 78% accuracy by age 6. However, these studies do not address singular agreement as a cue to distributive interpretation. *Each* and *every* constitute a marked minority of lexically singular quantificational determiners (Gil, 1982). Since plural NPs can also be interpreted distributively and are much more common, we deduce that children are much more likely to encounter plural NP subjects than singular NP subjects used distributively. Distributive predication is also a highly marked function for singular VP predicates. Although many exceptions exist, singular predicates are characteristically predicated of singular subject NPs with singular reference (*A girl is riding a horse*). Moreover, the processing preference for surface scope interpretations makes singular reference the unmarked interpretation of singular subject NPs in sentences like *A detective writes every report*. In sentences with plural subject NPs like *Most senators is not enough to get the legislation passed* and *Few problems is an amount I can live with*, the singular verb signals predication over singular collections. We conclude that singular predicates are rarely, if ever, used distributively when they occur with singular quantified subject NPs. Our experiment was not designed to test children's comprehension of singular agreement. However, our results clearly show that children are able to assign distributive interpretations to sentences with plural subject-verb agreement at adult-like levels. The one condition where children's performance significantly differed from adults' performance required children to assign distributive interpretations to sentences with singular subject-verb agreement.

7. A possible account for the children's performance

One syntactic model of distributive interpretation which makes the contribution of singular agreement to distributive interpretations explicit is the Target Landing Sites (TLS) Theory (Beghelli, 1995, 1997) or Checking Theory of scope (Beghelli and Stowell, 1997; Szabolcsi, 1997, 2010). Checking Theory proposes that quantified NPs (QPs) including *everyNPs* and *numNPs* fall into QP types based on their semantic and/or morphological properties. Each QP acquires its scope by moving into the specifier position of a functional projection in Logical Form (LF) in order to check features associated with its QP type (Beghelli and Stowell, 1997:77; Szabolcsi, 1997:114). The functional projections and QPs relevant to our account are given in Fig. 5 (RefP = Referential Phrase, AgSP = Subject Agreement Phrase, DistP = Distributive Phrase, ShareP = Share Phrase, AgrOP = Object Agreement Phrase, DQP = Distributive-Universal QP, GQP = Group-denoting QP and CQP = Counting QP). Following standard assumptions in the quantifier scope

Fig. 5. Functional projections in Logical Form.

literature (May, 1981), we assume that a QP1 takes scope over another QP2 in a sentence if QP1 c-commands QP2 at LF.

DQPs are QPs headed by *each* or *every*. *Each* itself is not analyzed as a distributive operator, as in classical accounts, but is lexically coded with a ‘strong’ distributivity feature [+Dist] which obligates *each*DQP to move to [Spec, DistP] to check its [+Dist] feature against a distributivity operator $\forall$ hosted by the head of DistP. *Every* has an underspecified variant of the [Dist] feature which allows *every*DQPs to receive a wider range of interpretations than *each*DQPs (see below). GQPs, including numNPs and other indefinite NPs, introduce restricted variables into semantic representations which are checked at LF by moving the GQP to a functional projection with an existential operator head $\exists$ (RefP or ShareP). GQPs scoping from RefP receive wide scope and presuppositional, specific, or topical interpretations. GQPs which scope from their Case positions in AgrSP and AgrOP receive non-specific construals (Beghelli and Stowell, 1997:75). GQPs moving to [Spec, ShareP] receive dependent construals by virtue of their association with a c-commanding DQP in DistP.

The distributive interpretations we elicited in our experiment are represented in Checking Theory by the LFs in (25) and (26). Importantly, DQPs must move not only to DistP to check their [Dist] features but also to RefP to check their set variables (domains of quantification) and to receive a distributive key (distributor) construal (Beghelli and Stowell, 1997:85,88). As shown in (25), the DQP *Every cowboy* is base generated in AgrSP and moves to RefP to check its set variable before moving to DistP to check its [Dist] feature. *Every cowboy* takes scope over the GQP *two horses*, which has moved from AgrOP to ShareP to check its set (or plural individual) variable and to receive its dependent construal. The inverse scope interpretation of (3) in (26) is derived by moving *every horse* from its object position to AgrOP before moving again to RefP and DistP. The numNP subject *three cowboys* is base generated in AgrSP and reconstructs (moves to a scope position lower in the representation) to ShareP to receive its dependent NP construal.

(2) Every cowboy is pulling two horses.

(25) [RefP t_1 [AgrSP t_1 [DistP Every cowboy₁ [ShareP two horses₂ [AgrOP t_2 [VP t_1 is pulling t_2]]]]]]

(3) Three cowboys are pulling every horse.

(26) [RefP t_2 [AgrSP t_1 [DistP every horse₂ [ShareP three cowboys₁ [AgrOP t_2 [VP t_1 are pulling t_2]]]]]]

DQPs are endowed with a [+singular agreement] feature which allows DQPs access to DistP (Beghelli, 1997:382). Plural GQPs do not have access to DistP. However, numNP sentences like (1) can receive Pseudo-Distributive (PD) interpretations if a (covert) *each* operator occurs in the LF structure. The PD distributive interpretation of (1) in (27) is derived by adjoining a covert *each* operator to ShareP. The numNP object *two horses* moves from its base object position through AgrOP to ShareP, where it receives its dependent interpretation as PD Share NP. *Three cowboys* moves to RefP from AgrSP where it receives its interpretation as the subject of distributive predication or PD distributor (distributive key) (Beghelli and Stowell, 1997:94, see also Szabolcsi, 1997:116,126).

- (1) Three cowboys are pulling two horses. (distributive)
 (27) $[_{\text{RefP}} \text{Three cowboys}_1 [_{\text{AgrSP}} t_1 [_{\text{each}} [_{\text{ShareP}} \text{two horses}_2 [_{\text{AgrOP}} t_2 [_{\text{VP}} t_1 \text{ are pulling } t_2]]]]]]$

To our knowledge, cumulative interpretations have not received a Checking/TLS theory analysis. Cumulative interpretations have been analyzed using complex quantifiers (Scha, 1981), linear scope models (Kroch, 1974), branching scope models (Liu, 1990; Schein, 1993) and syntactic polyadic cumulativity operators on predicates (Krifka, 1986; Beck and Sauerland, 2000). Here, we assume that cumulative interpretations of numNP and *every*NP sentences involve predicates restricted to cumulated relations (Beck and Sauerland, 2000; Krifka, 1986; Sternefeld, 1998). Following Beck and Sauerland, we assume that a binary cumulativity operator ******- adjoined to a relational predicate applies to restrict the denotation of the predicate to cumulative relations between sets, as defined in (28).

- (28) $[**R](X)(Y) = 1$ if $\forall x \in X, \exists y \in Y R(x)(y)$ and $\forall y \in Y, \exists x \in X R(x)(y)$
 'A relation *R* between two sets *X* and *Y* is cumulative if for every *x* in *X* there is a *y* in *Y* such that *R*(*x*)(*y*) and for every *y* in *Y* there is an *x* in *X* such that *R*(*x*)(*y*)'

With this assumption in mind, we propose the LF in (29) as the semantic representation for the cumulative interpretation of (1).

- (1) Three cowboys are pulling two horses. (cumulative)
 (29) $[_{\text{AgrSP}} \text{three cowboys}_1 [_{\text{AgrOP}} \text{two horses}_2 [_{\text{VP}} \exists t_1 \text{ are } **\text{pulling } t_2]]]]$

(29) follows recent work that bare numerals like *two* and *three* are interpreted by default as cardinality predicates and numNPs as restricted variables (Diesing, 1992; Heim, 1982; Kamp and Reyle, 1993; Landman, 2000, 2004). In Checking/TLS theory, numGQPs with cardinal interpretations occur in AgrXP and receive in situ interpretations (Beghelli, 1997:372). This is captured in (29) by introducing an unselective existential quantifier in VP (Diesing, 1992) to bind the traces (variables) left by moving the two numGQPs to AgrXP, where they check their agreement features (Beghelli and Stowell, 1997:75, 78, 89–90). We assume that a PD distributive interpretation of this sentence is ruled out by the cumulated verb, which recruits the plural individuals supplied by the numGQPs as the two arguments of a cumulated relation, thereby preventing their interpretations as arguments of a distributive relation.

Non-distributive uses of *every*NPs are discussed by Beghelli (1997) and Beghelli and Stowell (1997). Beghelli and Stowell proposed that *every*NP can be prevented from moving to RefP (and further to DistP) if its set variable is bound by a closer unselective operator, such as a negative or generic operator (see also Aoun and Li, 1993). Such a case is the LF for (30) in (31), where the negative operator in NegP binds the trace/set variable introduced by the *every*NP object (Beghelli, 1997:383). Beghelli and Stowell (1997:83,101) propose that, in cases like (30), *every*NP is interpreted as a universal restricted variable rather than a QP and takes scope from its Theta position in VP (see Beghelli, 1997:383 for a similar treatment).

- (30) John didn't read every book.
 (31) $[_{\text{AgrSP}} \text{John}_1 [_{\text{NegP}} \text{didn't } [_{\text{AgrOP}} \text{every book}_2 [_{\text{VP}} t_1 \text{ read } t_2]]]]$

We propose a similar account of cumulative interpretations of *every*NP sentences like (2) and (3), given in (32) and (33). We assume that *every*NP does not move to DistP if it is a thematic argument of a cumulated predicate. Because the cumulativity operator takes the predicate rather than the set variables of the two NPs as its argument, the set variables themselves are not bound by the cumulativity operator and are free to be bound via existential closure.

- (2) Every cowboy is pulling two horses. (cumulative)
 (32) $[_{\text{AgrSP}} \text{Every cowboy}_1 [_{\text{AgrOP}} \text{two horses}_2 [_{\text{VP}} \exists t_1 \text{ is } **\text{pulling } t_2]]]]$
 (3) Three cowboys are pulling every horse. (cumulative)
 (33) $[_{\text{AgrSP}} \text{Three cowboys } [_{\text{AgrOP}} \text{every horse}_2 [_{\text{VP}} \exists t_1 \text{ are } **\text{pulling } t_2]]]]$

This account explains how an inconsistent perception or weak grasp of singular subject-verb agreement might have led to differences between children's and adults' performance with *Every/2* sentences on cumulative context trials. Under Checking/TLS Theory, *every*NP has access to DistP because it is singular. Children who do not always perceive or grasp singular agreement features as a cue to strong distributive interpretation will be less likely to derive strong distributive interpretations of *Every/2* sentences and be prone to accept *Every/2* sentences as descriptions of cumulative contexts.

Otherwise, both adults and children derive cumulative and distributive interpretations for *every*NP sentences in the same way and at similar rates.

One issue raised by this account is which distributive interpretation children assign to *Every*/2 sentences. We have been assuming that children, like adults, assign strong distributive interpretations to *Every*/2 sentences when they reject them on cumulative context trials and accept them on distributive context trials. But an alternative possibility is that children assign PD interpretations to *Every*/2 sentences on these trials. We did not design our experiment to test for this possibility. However, we consider it unlikely given our results with *3/Every* sentences. Our results showed that children and adults rejected *3/Every* sentences on distributive and cumulative context trials equally often and gave similar explanations for why they did so. These results strongly suggest to us that the children, like the adults, assigned strong distributive interpretations to these sentences on these trials. If the children assigned PD interpretations and adults strong distributive interpretations to these sentences, the absence of significant variation in judgments and explanations would be a mystery.

Another issue we need to address has to do with the difference between *each* and *every*. The CI Hypothesis is a hypothesis about sentences with *every*NPs. However the logic of the hypothesis applies straightforwardly to Musolino's results with *each*NP object sentences. Musolino's *each*NP object sentences, like our *3/Every* sentences, lack the singular subject-verb agreement feature that signals distributive interpretations. We assume that Musolino's distributive and cumulative vignettes, like our distributive and cumulative contexts, did not support the inference that a distributive interpretation was important or intended. As a result, participants in Musolino's experiment inferred on many trials that the *each*NP was not being used distributively and assigned a cumulative interpretation to the *each*NP object sentence.

However, one might object to this analysis on the grounds that *each*NPs and *every*NPs behave differently in direct object position. Although there are convincing examples that *every*NP objects can be used non-distributively, there is widespread agreement in the semantic literature that *each*NPs cannot (e.g., Kratzer, 2000; Landman, 2000; Tunstall, 1998). Virtually all exceptional cases of *every*NP object sentences observed in the literature, including *Three video games taught every quarterback two new plays* (Schein, 1993), *The Fijians and the Peruvians won every game*, and *Three copy editors caught every mistake in the manuscript* (Kratzer, 2000) lose their cumulative interpretations when *each* replaces *every* (see Kratzer, 2000 for discussion). These observations suggest to us that *Each*NP must be used distributively and that its set denotation is generally unavailable as an argument of a cumulated relational verb (see Beghelli and Stowell, 1997 for more examples).

The situation is complicated by apparent examples of non-distributive uses of *each*NPs. According to our intuitions, (34) can be true if three psychologists among them interviewed 15 refugees. Similarly, (35) can be true if three museums among them bought the last two remaining paintings by Chirico at auction, with one museum buying one and a second and third museum buying the second. (36) can be true of a situation in which three chefs among them prepared six items for the dessert menu, with each chef preparing different desserts.

- (34) Three psychologists interviewed each refugee.
- (35) Three museums bought each remaining Chirico.
- (36) Three chefs prepared each dessert in the menu.

If our intuitions are correct, one might conjecture that these sentences have cumulative interpretations. But an alternative hypothesis suggested by Tunstall's (1998) theory is that they 'trivially satisfy' the distributive meaning of *each*. Tunstall argued that *each* and *every* are subject to different lexical licensing conditions (see above). *Each* is subject to the Differentiation Condition in (37), which makes *each* infelicitous in contexts where total distributivity of event structures does not hold.

(37) The Differentiation Condition (DC)

A sentence containing a quantified phrase headed by *each* can only be true of event structures which are totally distributive. Each individual object in the restrictor set of the quantified phrase must be associated with its own subevent, in which the predicate applies to that object, and which can be differentiated in some way from the other subevents.

Tunstall argued that the DC motivates speakers to use *each* to emphasize that an event is differentiated in an interesting or meaningful way. However, the DC can also be trivially satisfied if the subevents are differentiated merely "by having a different object in each one, as long as there is enough interest in the individual objects (Tunstall, 1998:102)."

"... *each*'s Differentiation Condition could always be trivially satisfied by having a different object in each subevent. In that case, *each* and *every* would not be making truth-conditionally distinct claims. A sentence with *each* could be truthfully asserted about exactly the same events which a sentence with *every* could be. In order to distinguish *each* and *every* something else is needed. The Differentiation Condition states that the subevents must

be differentiated in “in some way.” If there is a pragmatic condition restricting this claim to interesting or relevant ways of differentiating, the cases of trivial satisfaction will be eliminated.”

As a hypothesis, trivial satisfaction predicts that *each* can receive a distributive interpretation if the individuals in the quantifier's restrictor are interesting or relevant enough on their own to be markers of individual sub-events, whether or not a property is uniquely predicated of those individuals. This prediction, we would argue, is borne out by our proposed interpretations of (34)–(36). The fact that the interviewees in (34) are refugees, that the Chiricos in (35) are the remaining ones, and that the chefs in (36) are presumed to be responsible for their menus creates the perception that what is relevant is that each individual in the restrictor is accounted for rather than that a property is assigned to each individual. This prediction gives us a novel hypothesis regarding Musolino's findings, namely that the participants in Musolino's experiment accepted *eachNP* object sentences at such high rates because they perceived the individuals in the set denotation of the *eachNP*, rather than the property denoted by the sentence, as representing unique sub-events. One benefit of this hypothesis is that it offers a possible explanation for why children in Musolino's experiment accepted *eachNP* object sentences more often on SS distributive vignette trials (90% of the time) than on cumulative vignette trials (54% of the time), a finding Musolino left unaccounted for. The children may have accepted *eachNP* object sentences relatively more often on SS distributive vignette trials because the symmetrical distribution of object pairs to actors in the SS distributive vignettes enabled a coherent structuring of the visual space which promoted the salience of the individual objects. More specifically, the children who accepted *Three boys are holding each balloon* on these trials knew the DC but perceived the distribution of individual or pairs of balloons much more often than the holding property as an interesting basis for distinguishing subevents. This symmetrical relation was missing in Musolino's cumulative vignettes. The trivial satisfaction hypothesis predicts that both children and adults will be less prone to accept *eachNP* object sentences as descriptions of SS distributive and cumulative vignettes if the experimental trials provide more interesting ways of differentiating subevents than the individuals in the restrictor set, perhaps by using sentences with more interesting predicates. We leave further analysis and testing of these hypotheses for further research.

8. Conclusion

The main goal of our paper was to investigate why children differ from adults in the way they interpret sentences with the distributive universal quantifiers *each* and *every*. Our investigation of children's comprehension of sentences with distributive universal quantifiers leads to at least two conclusions. The first conclusion is that the Cumulative Interpretation Hypothesis presents a more realistic explanation of children's performance with distributive universal quantifiers than the Weak Quantifier account. Our study revealed no empirical support for the view that children consistently interpret *every* as an inherently relational or strong quantifier and no evidence that they are prone to assign quantifier spreading interpretations to *everyNP* sentences. However, our results do show that children are prone to assign cumulative interpretations to *everyNP* sentences. We found that both children and adults assign cumulative interpretations to sentences with *everyNP* objects but that children are more permissive in assigning cumulative interpretations to sentences with *everyNP* subjects as well. We argued that children have particular trouble with assigning distributive interpretations to sentences with *everyNP* subjects because they do not always perceive singular subject-verb agreement as a cue to distributive interpretation.

Our results and analysis raise a number of questions which go beyond the scope of this paper, including why cumulative interpretations are particularly salient for children in comparison to other possible analyses of universally quantified sentences, why singular agreement is a particularly difficult cue to distributivity for children to master, and how the acquisition of number might impact the trajectory of children's acquisition of distributive universal quantification. Unfortunately, we must leave these questions for further research.

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Appendix

Distributive contexts	Extra object contexts
Monkeys playing drums	Boys painting cupboards

Girls waving flags	Dogs biting cats
Women lighting candles	Men fixing bicycles
Girls mailing letters	Kids playing guitars
Men sitting on boxes	Men driving tractors
Pirates waving swords	Men washing cars
Men delivering pizzas	
Boys jumping over chairs	
Girls standing on horses	
Policemen blowing whistles	
Women drinking sodas	
Men ringing bells	

Cumulative contexts

Girls jumping over boys
 Girls carrying couches
 Women carrying boxes
 Women feeding giraffes
 Girls standing on tables
 Girls carrying surfboards
 Men holding watering cans
 Zookeepers petting elephants
 Men holding umbrellas
 Boys watering plants
 Cowboys pulling horses
 Men burning haybales

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