

# Acquiring the meaning of free relative clauses and plural definite descriptions

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## Abstract

Plural definite descriptions (e.g. *the things on the plate*) and free relative clauses (e.g. *what is on the plate*) have been argued to share the same semantic properties, despite their syntactic differences. Specifically, both have been argued to be non-quantificational expressions referring to the maximal element of a given set (e.g. the set of things on the contextually salient plate). We provide experimental support for this semantic analysis with the first reported simultaneous investigation of children's interpretation of both constructions, highlighting how experimental methods can inform semantic theory. A Truth-Value Judgment task and an Act-Out task show that children know that the two constructions differ from quantificational nominals (e.g. *all the things on the plate*) very early on (4 years old). Children also acquire the adult interpretation of both constructions at the same time, around 6–7 years old. This happens despite major differences in the frequency of these constructions, according to our corpus study of children's linguistic input. We discuss possible causes for this late emergence. We also argue that our experimental findings contribute to the recent theoretical debate on the correct semantic analysis of free relatives.

## 1 INTRODUCTION

If there are six cookies on a plate and nothing else, adult English speakers judge both sentences (1) and (2) true. The very same sentences are judged false in a situation in which there are only marbles on the plate. If the plate holds three marbles and three cookies, (1) and (2) are judged either false or infelicitous/awkward.

- (1) [The things on the plate] are edible.
- (2) [What's on the plate] is edible.

More generally, the sentences in (1) and (2) appear to have the same felicity/truth conditions, despite their lexical and syntactic differences. In (1), the bracketed subject is a plural definite description (PDD), that is, a nominal expression introduced by *the*. In (2), however, the bracketed subject is a free relative clause (FR), that is, a clause introduced by a *wh*-word that resembles an interrogative clause but is not interpreted as conveying a question. As we discuss in section 2, PDDs and FRs have received very similar semantic analyses, though their syntactic differences require a different syntax/semantic mapping. In particular, the semantic function of the definite determiner *the* in PDDs has been assigned to a silent operator in FRs.

In this paper, we explore the idea that PDDs and FRs share a common semantic representation by investigating their emergence in language acquisition.<sup>1</sup> Previous acquisition studies have investigated how children acquiring English interpret either PDDs (Munn *et al.* 2006) or FRs (Modyanova & Wexler 2008; Modyanova 2009: 83–92). However, these studies do not establish when children acquire adult-like interpretations of these forms, or how they are related in acquisition. Also, these studies have used different methods to investigate the acquisition of PDDs and FRs, making it difficult to compare their results. Here, we assess children's understanding of both constructions using the same set of experimental tasks: a Truth-Value Judgment (TVJ) task and an Act-Out task. We also determine the frequency of both constructions in child-directed speech. Our findings show that from very early on (around 4 years old) children treat PDDs and FRs as semantically equivalent, but assign an adult-like interpretation to them relatively late (around 6–7 years old). These results are particularly interesting given our corpus analysis of child-directed speech, which finds that PDDs are significantly more frequent than FRs in children's input. Given this difference, the

<sup>1</sup> FRs are truth-conditionally equivalent to singular (rather than plural) definite descriptions when they denote a singleton set. For instance, if there's only one cookie on the plate, then the FR in (1) can be paraphrased with the singular definite description in (2).

- (1) [What's on the plate] is edible.
- (2) [The thing on the plate] is edible.

In this paper, we focus on FRs and PDDs rather than singular definite descriptions because we are interested in studying whether children treat FRs and PDDs as referential expressions or as quantificational expressions like universally quantified nominals (e.g. *every cookie on the plate* or *all the cookies on the plate*), or perhaps as existentially quantified nominals (e.g. *some cookies on the plate*), or instead as number nominals (e.g. *two cookies on the plate*). This comparison is impossible with singleton sets since quantified expressions like *pass me every/some/one thing on the plate* are unnatural when there is only a single item on the plate. For a review of past work on the acquisition of singular definite descriptions, see Wexler (forthcoming).

synchronized emergence of PDDs and FRs is most naturally explained by the hypothesis that both forms are assigned a common semantic representation, which children master relatively late in development.

The paper is structured as follows. Section 2 briefly overviews the analyses that have been suggested for the semantics of PDDs and FRs and for their syntax/semantics mapping. Section 3 reviews previous related acquisition studies. Section 4 presents and discusses the results of two experiments on the acquisition of PDDs and FRs: a TVJ task and an Act-Out task. Section 5 presents and discusses the findings of a corpus study in which we examine child-directed speech for PDDs and FRs. Section 6 contains some general remarks about the theoretical consequences of our experimental findings and some speculation on the causes of delay in children's acquisition of the adult-like interpretation of PDDs and FRs and related open issues. Section 7 concludes.

## 2 SEMANTIC AND SYNTACTIC BACKGROUND

Over the past 30 years, the semantic properties of PDDs have been carefully described and several accounts have been suggested. Though different in the details, all the accounts we are aware of agree on at least two main properties of PDDs. First, a PDD is referential rather than quantificational. In other words, a PDD like *the cookies* semantically behaves more like a proper name in referring to an object rather than quantifying over a set of objects in the way quantified nominals like *every cookie* or *all the cookies* do.<sup>2</sup> Second, a PDD does not refer to any random object in a given set, but only to the maximal element of that set. Different specific proposals may vary on the nature of the maximal object a PDD refers to: a (possibly plural) maximal individual out of a set of (atomic and plural) individuals or a maximal set of individuals out of a set of sets of individuals.<sup>3</sup> The very same semantic approach has then been extended to FRs: they have been argued to refer to a maximal element.<sup>4</sup> Thus, both PDDs and FRs have been analysed as

<sup>2</sup> See Löbner (2000: 233–34, 251–53) and references therein for a discussion of the non-quantificational nature of PDDs and definite descriptions in general.

<sup>3</sup> See Abbott (2010) for an accessible overview of the main facts and proposals about definiteness and definite descriptions in general and about PDDs in particular; Schwarzschild (1996) and Landman (2000) for more technical presentations of the issues about PDDs and for specific proposals according to which PDDs refer to maximal sets of individuals rather than maximal individuals; and Link (1983) for the fully detailed version of the specific semantic analysis of PDDs we are adopting according to which PDDs refer to maximal individuals rather than maximal sets.

<sup>4</sup> See Jacobson's (1995) seminal work and, among others, Rullmann (1995), Dayal (1996), and Caponigro (2003, 2004).

referential expressions ‘triggering maximality’ (i.e. referring to the maximal element of a given set). In this section, we focus on one specific semantic analysis of PDDs—the one offered by Link (1983)—and one specific semantic analysis of FRs—that of Jacobson (1995) and Caponigro (2003, 2004).<sup>5</sup>

Link (1983) proposes a unified semantic analysis for singular and plural definite determiner phrases (DPs), according to which they both refer to the *maximal* element of the set denoted by the NP.<sup>6</sup> The main intuition behind this proposal is that we can linguistically represent both simple objects (*atomic individuals*) and complex objects (*plural individuals*). Plural individuals result from grouping atomic individuals and/or other plural individuals and representing the result as a unit. Link formalizes this notion with an operation called *sum* ( $\oplus$ ).

On this analysis, plural individuals are ‘bigger’ than the individuals they are made of. Link (1983) formalizes these intuitions by means of the *part-of relation* ( $\leq$ ), which is reflexive, transitive and anti-symmetric. Given a set of atomic individuals and all of the possible plural individuals built by summing the atomic individuals, there will always be an individual that is bigger than all the others. This is called the *maximal element* of that set. A general definition of the maximal element of a set is given in (3).<sup>7</sup>

- (3) *Maximal element*  $\max_p$  of a set of entities P  
 $\max_p = x$  such that  $x \in P$  and  $\forall y \in P \ y \leq x$

Maximal elements are not necessarily plural individuals. For instance, the maximal element of the singleton set containing just a cookie is just the cookie itself, that is, an atomic individual.

Let us now look at how these ideas can be applied to natural language and to the semantics of PDDs in particular. If a plate holds a cookie, an onion and an egg and nothing else, then the singular NP *thing on the plate* will denote the set containing those three atomic individuals (4)a. When plural morphology is added to the NP, it has a crucial semantic effect: it closes the set denoted by the singular NP under the sum operation and excludes all the atomic individuals. Intuitively, the plural NP *things on the plate* will denote the set of all the plural individuals that can be obtained by summing the cookie, the

<sup>5</sup> It has also been suggested to us that salience may be a notion besides maximality that can account for the semantic properties of PDDs and FRs. We consider this further in Appendix, where we note why maximality is still necessary, even if salience is considered.

<sup>6</sup> See also Sharvy (1980).

<sup>7</sup> It can be proven that if there is a maximal element, it is unique, and that the maximal element is the only individual in the set that all other individuals in the set are part of.

onion and the egg in all the possible combinations (4)b. Finally, the plural definite DP *the things on the plate* will refer to the maximal element of the set denoted by the plural NP (4)c.

(4) If an egg *e*, a cookie *c* and an onion *o* are the only things in the box, then:

a. *Singular NP*:  $\llbracket \text{thing on the plate} \rrbracket = \{e, c, o\}$

b. *Plural NP*:  $\llbracket \text{thing-s on the plate} \rrbracket = \left\{ \begin{array}{c} e \oplus c \oplus o \\ \wedge \\ e \oplus c \quad e \oplus o \quad c \oplus o \end{array} \right\}$

c. *Plural DP*:  $\llbracket \text{the thing-s on the plate} \rrbracket = e \oplus c \oplus o$

Following Jacobson (1995), FRs can be given a similar analysis. Given the example described above, the FR in (5)a denotes the same individual as the PDD in (4)c, that is, the maximal element of the set of things on the plate (5)b.

(5) If an egg *e*, a cookie *c* and an onion *o* are the only things on the plate, then:

a. Cookie Monster likes  $[_{\text{FR}} \text{what's on the plate}]$ .

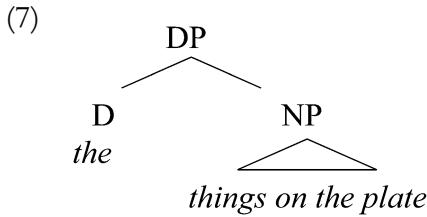
b.  $\llbracket [_{\text{FR}} \text{what's on the plate}] \rrbracket = e \oplus c \oplus o$

Therefore, FRs and PDDs are truth-conditionally equivalent, except for the fact that the former do not express any restrictions about the singular v. plural nature of the maximal element they denote, whereas definite DPs do. This is due to the fact that *wh*-words in FRs are morphologically singular in English, causing the whole FR to behave as a morphologically/syntactically singular constituent, as shown by the singular agreement on both the matrix predicate and the FR predicate in (6).

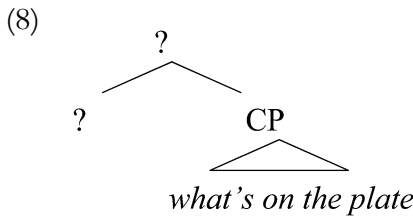
(6)  $[_{\text{FR}} \text{What smell-s/*smell good}]$  often taste-s/\*taste good too.

Although truth-conditionally equivalent, PDDs and FRs are syntactically very different, resulting in an interesting problem of

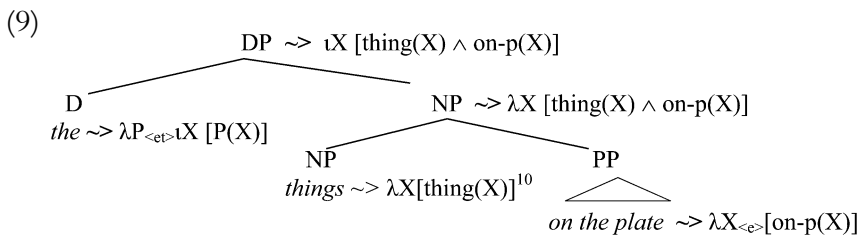
syntax/semantics mapping. As shown in (7), PDDs are DPs with the D head *the* taking an NP as its complement.<sup>8</sup>



The syntactic structure of FRs is still an open issue.<sup>9</sup> Nevertheless, it is clear that this structure is different from that of PDDs. FRs are finite clauses with a structure containing a clause-initial *wh*-word, that is, they are *wh*-CPs. Even if it turns out that FRs as a whole are DPs, their internal structure would still be different from PDDs and much more complex, without anything corresponding to the D head *the* (8).



A critical question to the current discussion is how these two constructions end up denoting the same object if they are syntactically so different. What is the nature of their syntax/semantics mapping? The crucial components of the syntax/semantics mapping for the PDD *the things on the plate* are given in (9).



<sup>8</sup> More articulated internal structures have been suggested for DPs like the PDDs in (7). See Bernstein (2003) and Longobardi (2003) for an overview of DPs, their internal structures, and the supporting evidence.

<sup>9</sup> See van Riemsdijk (2005) for a thorough survey.

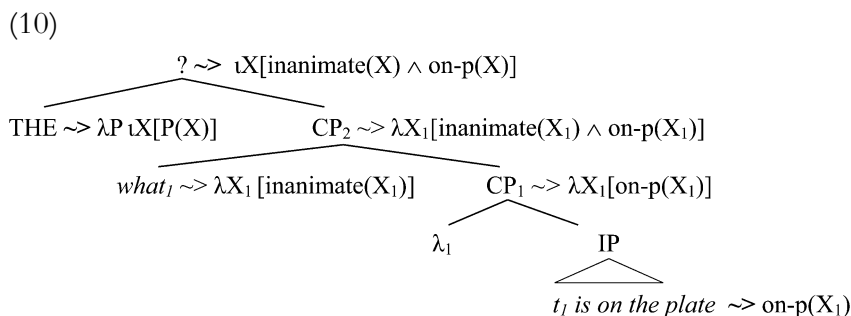
<sup>10</sup> X is a variable ranging over atomic and plural individuals. Therefore, the fully correct translation for the NP *things* would be the one in (i) below since Link (1983) assumes a plural NP to denote a set of plural individuals only, without atomic individuals.

(i)  $\lambda X[\text{thing}(X) \wedge \exists y[\text{thing}(y) \wedge [y \leq X] \wedge \sim[y = X]]]$

For the ease of exposition, we will continue using the shorter but less accurate translation given in the main text.

The plural NP *things* denotes a set of individuals: the individuals that have the property of being things. The PP *on the plate* denotes a set of individuals as well: the individuals that have the property of being on the given plate *p*. The complex NP *things on the plate* denotes the intersection of the aforementioned sets. The definite determiner *the*, which is translated as the operator *iota* ( $\iota$ ) in the formal language, denotes a function that applies to a set of individuals to return the maximal element of that set. In (9), the function denoted by *the* applies to the set of things on the plate and returns its maximal element, the plural individual made of all the things on the plate.

Next, consider the syntax/semantics mapping for the FR *what's on the plate*. The crucial steps are given in (10).



The IP in (10) denotes an open proposition, since the variable  $X_1$ —the logical translation of the *wh*-trace—is free, that is, its interpretation depends on the assignment function. Standard lambda-abstraction applies such that  $\text{CP}_1$  denotes the set of individuals on the given plate *p*. The semantic contribution of the *wh*-word *what* (and *wh*-words in general) is an open issue. Jacobson (1995) proposes that *what* denotes a function that applies to a set of individuals and returns the singleton set containing the maximal individual of the initial set. In other words, *what* is responsible for triggering maximality in FRs. We follow Caponigro (2003, 2004) instead, who provides evidence that *wh*-words in FRs cannot trigger maximality and proposes that *what* simply denotes a set of inanimate individuals. We come back to the differences between these two proposals in section 6.2, where we argue that our experimental findings may bring further support to Caponigro's (2003, 2004) approach.

The denotation of  $\text{CP}_2$  in (10) results from the intersection of the set denoted by  $\text{CP}_1$  and the set denoted by *what*, which returns the set

of inanimate things on the plate.<sup>11</sup> Notice that this is the same denotation as the NP of the PDD in (9).<sup>12</sup> Here, however, the set is the result of *wh*-movement in the syntax and the corresponding semantic operation of lambda-abstraction/set-formation over the variable associated with the trace of the moved element.

Both the CP<sub>2</sub> in the FR in (10) and the NP in the PDD in (9) denote a set of individuals, but the final denotation of both the FR and the PDD is an individual, not a set. As already discussed, the function denoted by the definite determiner *the* is responsible for the shift from a set of individuals to its maximal element in the case of the PDD. As for the FR, we follow Caponigro (2003, 2004) and assume that a covert operator THE occurs as the sister of CP<sub>2</sub> of the FR and that the semantic contribution of this operator is the same as the definite determiner *the* in the case of PDDs.

PDDs and FRs can thus be seen as two different instantiations of the same general semantic principle/rule: a shift in meaning between a set and its maximal element. According to Partee (1986), Chierchia (1998), and Dayal (2004), this shifting—by means of the *iota* operator—is part of a restricted set of type-shifting rules that are made available by the grammar to fix type mismatches. The empirical basis for this analysis comes from the cross-linguistic behavior of DPs, in particular bare plurals and bare singulars, that is, nominals occurring without a determiner (e.g. *kids* and *sweet things* in *Kids like sweet things*). A general formulation of *iota* is given in (11).

(11) ***iota* (ι)**:  $P \rightarrow \iota xP(x)$  ( $\langle e, t \rangle \rightarrow \langle e \rangle$ )

According to the analyses of PDDs and FRs we just discussed, *iota* is lexically triggered in both constructions, though the trigger is the definite determiner *the* in PDDs, while it is the covert operator THE in FRs. This analysis predicts that, all else being equal, children should exhibit a similar pattern in their acquisition of the meanings of PDDs and FRs since the underlying semantic properties are the same and, crucially, both constructions have maximality triggers. We believe our experimental findings confirm this, as discussed in section 6.2. Also, it is an open issue whether the covert operator THE is just the silent version of the same syntactic/semantic object as the determiner *the* or is

<sup>11</sup> This rule of predicate modification was originally proposed by Quine (1960) and Montague (1973) to combine a headed relative clause with its head. Cf. Heim & Kratzer (1998) for a more recent reformulation and discussion.

<sup>12</sup> Unlike the NP of the PDD, CP<sub>2</sub> of the FR does denote a set of individuals that includes atomic individuals as well, not just plural ones. This is because the *wh*-word of FRs does not carry plural morphology. See(6) above and the related discussion.



different. Although this issue may not be resolvable purely on the basis of descriptive adequacy, acquisition may bring further relevant evidence (again, see section 6 for detailed discussion).

### 3 PREVIOUS ACQUISITION STUDIES

In this section, we briefly review the previous studies that have investigated children's interpretation of PDDs and FRs. We are aware of only one study on the acquisition of PDDs in English and one study regarding the acquisition of FRs in general.<sup>13</sup> We discuss them in turn below.

Munn *et al.* (2006) investigated the acquisition of PDDs together with singular definite descriptions and indefinite DPs in English and Spanish using an Act-Out task. To evaluate the interpretation of English PDDs, they tested 15 children (aged 3;0 to 5;5, mean 4;1) and presented scenarios with toys like the one in Figure 1, where three frogs were next to a barn and three frogs were next to a house. They then uttered the following request (where the PDD is underlined): 'Give me the frogs next to the barn.'



**Figure 1** Scenario from Munn *et al.* (2006).

According to Munn *et al.*, almost all children (95%) provided adult-like responses and gave all three frogs next to the barn, that is, they gave the maximal element of the relevant set of frogs (44 adult controls selected the 3 frogs 100% of the time). Based on this, they concluded that most children interpret PDDs correctly, that is, maximally, and do so by at least the age of 3. However, this conclusion is tempered by two issues. First, the study did not include control trials to be sure that children would not select the maximal set for other requests—for example 'Give me some of the frogs next to the barn'. This is a problem since, once young children have begun collecting frogs, they may see no reason to stop at two, the minimum required by the plural noun (for evidence of this, see the pilot results from Experiment 2,

<sup>13</sup> Flynn & Lust (1981) study the acquisition of FRs that refer to an atomic rather than a plural individual (i.e. are paraphrased by a singular rather than a plural definite description). They investigate the production (rather than the interpretation) of FRs in English by means of an elicited imitation task. Flynn & Foley (2004) discuss cross-linguistic data along the same line.

below). Second, no breakdown by age was provided, making it difficult to determine whether children's knowledge changed as a function of age.

In a separate study reported by Modyanova & Wexler (2008) and Modyanova (2009), children's interpretation of FRs was tested using a TVJ task. Children were shown pictures like the one in Figure 2, in which two green apples and one red apple were under a blanket that was partially lifted so that children could see under it, while another red apple was completely outside the blanket. Children were then asked a question containing a FR, for example: 'Is what is under the blanket red?'

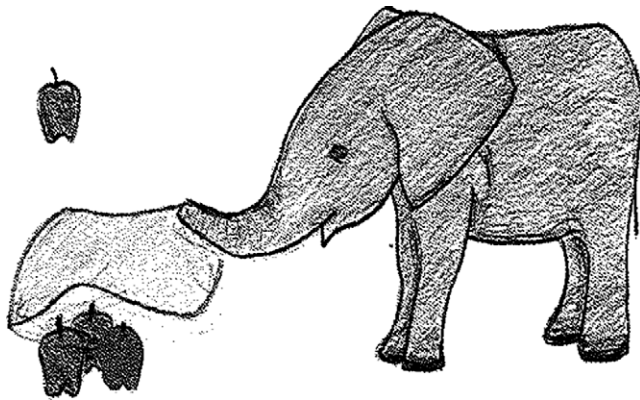


Figure 2 Example picture from Modyanova & Wexler (2008).

The authors expected the correct answer to be 'no' since the FR *what is under the blanket* refers to the plural individual made of two red apples and one green apple; the plural individual is not red, since an atomic part of it is green. Instead, children seldom answered 'no' regardless of age ('no' answers: sixteen 3- to 5-year-olds = 17%; thirteen 6- to 8-year-olds = 22%; nine 9- to 12-year-olds = 33%). Crucially, adults also rarely said 'no', contrary to what was predicted (twenty two 18- to 25-year-olds = 30%). Therefore, based on this task, neither children nor adults appear to interpret FRs as maximal.<sup>14</sup>

Although this conclusion is consistent with the data, another explanation is that the contexts used in TVJ task of Modyanova & Wexler (2008) violate what some have called the presupposition of

<sup>14</sup> Modyanova & Wexler (2008) note that adults showed a large reaction-time difference between critical trials that tested maximality (on which they were relatively slow) and control trials, whereas children showed no such difference. Based on this, they argue that adults were likely uncertain of their responses to the maximal trials, whereas children were not. However, it is difficult to interpret the reaction time data decisively due to the lack of a condition that includes adult success.

homogeneity or, equivalently, the presupposition of indivisibility (see Löbner 2000; Gajewski 2005). When a predicate like *be red*—which Löbner (2000) calls ‘summative’—applies to a PDD (or any other expression referring to a plural individual), it requires that all of the atomic individuals that comprise the plural individual be red for the sentence to be true. Similarly, it requires that none of the atomic individuals be red in order for the sentence to be false. In any other situation (e.g. some of the atomic individuals are red and some are green, as in the maximal trials of Modyanova & Wexler 2008), the sentence does not receive a truth-value. By this account, if speakers are forced to assign a truth-value anyway, they may base responses on factors that are not related to the semantics of maximality. Thus, in the Modyanova & Wexler (2008) study, participants may have been unable to generate coherent responses to the questions because the situations violated a critical presupposition.

In conclusion, although previous studies have independently examined children’s understanding of maximal expressions—PDDs and FRs—they have done so using two different methods, each of which presents difficulties of interpretation. It is therefore not known (i) precisely when the respective forms are acquired, and (ii) whether they exhibit similar patterns of acquisition. Thus, the present study had two goals. First, we conducted the first simultaneous study of both PDDs and FRs using the same set of methods in order to allow a direct comparison of results. To do so, we tested children using both a TVJ task and an Act-Out task. Second, we investigated when children first acquire maximal interpretations of PDDs and FRs. By investigating these issues, we address the larger question of how PDDs and FRs are related in development, and whether they are supported by a common semantic representation.

## 4 EXPERIMENTS

### 4.1 *Experiment 1: TVJ task*

The purpose of our first experiment was to assess children’s interpretation of PDDs and FRs using a task similar to that of Modyanova & Wexler (2008). We introduced a character (Cookie Monster) who loves cookies but strongly dislikes onions and asked children questions containing a PDD, ‘Does Cookie Monster like the things on the plate?’ or a FR, ‘Does Cookie Monster like what’s on the plate?’ We contrasted children’s interpretation of PDDs and FRs with control items, including nominals with the quantifiers *some* and *all* (‘Does Cookie Monster like some of the things on the plate?’, ‘Does

Cookie Monster like all the things on the plate?) or with the numeral *one* ('Does Cookie Monster like one of the things on the plate?').

#### 4.1.1 Methods

4.1.1.1 *Participants* We tested 69 children aged 4–7 years. There were nineteen 4-year-olds ( $m=4;7$ , range: 4;0–4;11), seventeen 5-year-olds ( $m=5;8$ , range: 5;1–5;11), twenty 6-year-olds ( $m=6;5$ , range: 6;0–6;11), and thirteen 7-year-olds ( $m=7;4$ , range: 7;1–7;8). Families were recruited by phone or through daycares in the greater San Diego area. We also tested 16 undergraduates at the University of California, San Diego, who participated for course credit.

4.1.1.2 *Materials and procedure* The experimenter first presented participants with a color picture of Sesame Street's Cookie Monster. Participants were asked, 'Do you know who this is? This is Cookie Monster! Do you know what Cookie Monster loves to eat?'. When the participant responded, 'cookies', the experimenter presented a picture of a single chocolate chip cookie and said, 'That's right! Cookie Monster loves cookies. Here is a cookie!'. The experimenter also told participants, 'Do you know what Cookie Monster really does NOT like? Cookie monster does NOT like onions', and children were shown a picture of an onion. The child was asked to label both the cookie and the onion, and to identify which food Cookie Monster liked, and which he did not like. Once the experimenter was confident that the child could identify both cookies and onions and knew Cookie Monster's preferences, she began the experimental trials.

Participants were given 15 trials. On each trial, the experimenter presented a picture of a plate with six objects (all cookies, all onions, or half cookies and half onions) in front of the child (Figure 3). Over the course of the study, participants received five different question trials for each picture: a FR trial ('Does Cookie Monster like what's on this



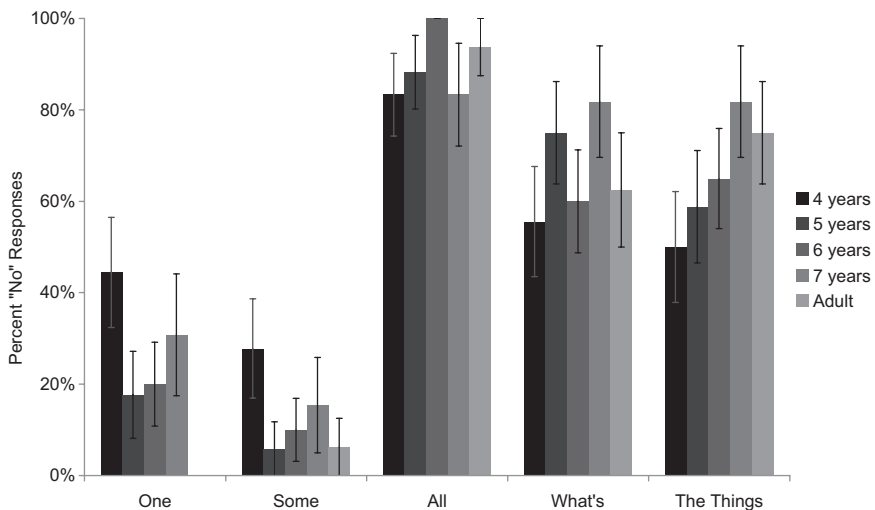
**Figure 3** Example pictures that were presented to the children in our TVJ task.

plate?’), a PDD trial (‘Does Cookie Monster like the things on this plate?’), two quantifier control trials (‘... all the things...’ and ‘... some of the things...’), and one numerical control trial (‘... one of the things...’). Trials were presented in two quasi-random orders, with no two trials occurring consecutively in which the same picture was shown or the same question was asked.

**4.1.2 Results** For control trials, children and adults responded similarly. Across questions and age groups, children correctly responded ‘no’ 97.3% of the time for the plate with six onions, while adults said ‘no’ 95% of the time. Similarly, children correctly replied ‘yes’ 86.1% of the time for the plate with six cookies, while adults said ‘yes’ 90% of the time. A binomial logistic regression showed no main effect of age ( $P = 0.68$ ) and no interaction of age and question type on these trials ( $P = 0.72$ ). The remaining analyses focus on the critical trials, which had the mixed plates.

Figure 4 shows participants’ responses to critical trials, on which mixed sets were presented (i.e. cookies and onions). A binomial logistic regression with Question Type as a within-subjects factor and child Age as a continuous between-subjects factor found a significant main effect of Question Type ( $F(4,321) = 34.81, p < 0.001$ ), but no main effect of Age ( $p = 0.714$ ). There was no significant interaction between Question Type and Age ( $p = 0.183$ ).

The model showed significant differences between responses to PDDs and ‘some’, ‘blick’, and ‘all’ trials ( $\beta_s > 0.25, t_s > 3.9$ , adjusted



**Figure 4** Percent of participants in each age group who said ‘no’ to each mixed plate question on the TVJ task. Error bars represent standard error.

$ps < 0.001$  after a Bonferroni correction, and no significant difference between responses to PDDs and FRs ( $\beta = -0.025$   $t = 0.34$ , adjusted  $p > 0.05$ ). This suggests that, overall, FRs and PDDs were interpreted maximally more frequently than DPs with the determiners ‘one’ or ‘some,’ but less frequently than those with ‘all’. However, participants’ responses to questions with FRs and PDDs were not different from chance in most cases, making it unclear whether performance reflected true knowledge or just guessing. On FR trials, only 5-year-olds and 7-year-olds were statistically better than chance (one-tailed sign tests, all  $ps > 0.05$ , except for 5-year-olds,  $p = 0.04$ ; and 7-year-olds,  $p = 0.03$ ). On PDD trials, only 7-year-olds ( $p = 0.03$ ) and adults ( $p < 0.04$ ) were statistically above chance.

The lack of interaction between age and question suggests that there was no significant age-related change in participants’ responses to the critical FR and PDD trials, despite the appearance of an age-related trend in the case of the PDD trials.

To test whether success on FR trials was related to success on PDD trials, we conducted a Spearman’s correlation (appropriate for binomial variables) and found a strong and significant correlation between responses on PDD and FR trials (Spearman’s  $\rho = 0.709$ ,  $p < 0.001$ ,  $n = 82$ ). This suggests that children who understood one form also understood the other, providing further support to our hypothesis that the adult-like maximal interpretations of PDDs and FRs develop in synchrony.

**4.1.3 Discussion** These data suggest that, beginning as young as 4 years of age, children do not treat FRs and PDDs the same as quantifiers like ‘some’. On the other hand, even adults fail to treat FRs and PDDs as equivalent to ‘all’ on this task. As with the task of Modyanova & Wexler (2008), it is difficult to assess children’s performance in light of adults’ lower-than-expected performance. Additionally, as acceptance rates hover just above 50% for the critical trials until age 7, it is difficult to determine whether younger children are interpreting these sentences maximally half the time, or whether they are simply guessing.

The imperfect performance of adults may reflect the issue discussed in section 3 regarding the TVJ task of Modyanova & Wexler (2008). As in their study, a violation of the presupposition of homogeneity may have been triggered by an interaction between a summative predicate and its plural individual denoting argument, as argued by Löbner (2000) and Gajewski (2005). If the verb *like* that we used in our experiments is summative with respect to its object argument—which was realized by a PDD or a FR in our test sentences—then the

presupposition would require Cookie Monster to like all the things on the plate or none of things in order for the answer to be question to be 'yes' or 'no', respectively. In any other circumstance, including our experimental conditions, the presupposition might be violated, such that no true or false answer can be given to the question. Thus, our results are consistent with the conclusion that a TVJ task does not offer a valid test of maximality since any critical condition that is capable of assessing maximality will necessarily involve mixed sets in which the presupposition of homogeneity/indivisibility is violated. Based on this analysis, Experiment 2 tested a similar group of children with PDDs, FRs, and control items using an Act-Out task.

## 4.2 Experiment 2: Act-Out task

Experiment 2 used an Act-Out task in which children were instructed to give a set of objects to the experimenter. This task provides a better test of interpretation as it still requires the child to interpret the sentence in order to perform the task, but it does not require violating any presuppositions. Additionally, we tested children with control trials including quantifiers (*some*, *all*) and a nonsense word (*blick*) in order to determine whether children's behaviors reflected true knowledge or merely random responding.

### 4.2.1 Methods

**4.2.1.1 Participants** We tested a total of 67 children between 4 and 7 years of age. There were thirteen 4-year-olds ( $m = 4;8$ , range: 4;1–4;11), nineteen 5-year-olds ( $m = 5;5$ , range: 5;0–5;11), eighteen 6-year-olds ( $m = 6;5$ , range: 6;2–6;11) and seventeen 7-year-olds ( $m = 7;5$ , range: 7;0–7;11). Children were recruited by phone or through daycares in the greater San Diego area. An additional 17 children were tested but excluded from analyses for failure to complete the task (two 2-year-olds), for giving the same number of items on all trials (2: one 4-year-old and one 6-year-old), and for failing to give one item when asked for 'one' on control trials (13: four 4-year-olds, six 5-year-olds, and three 6-year-olds). We also tested 16 University of California, San Diego undergraduates, who participated for course credit. Children or adults who participated in Experiment 1 were not eligible for Experiment 2.

**4.2.1.2 Materials and procedure** The experimenter placed a plastic sand bucket and a colorful paper plate in front of the participant and then placed four pieces of plastic fruit (an orange, an apple, a banana, and a strawberry) in each of the two locations (Figure 5).



**Figure 5** Experimental set-up for our Act-Out task.

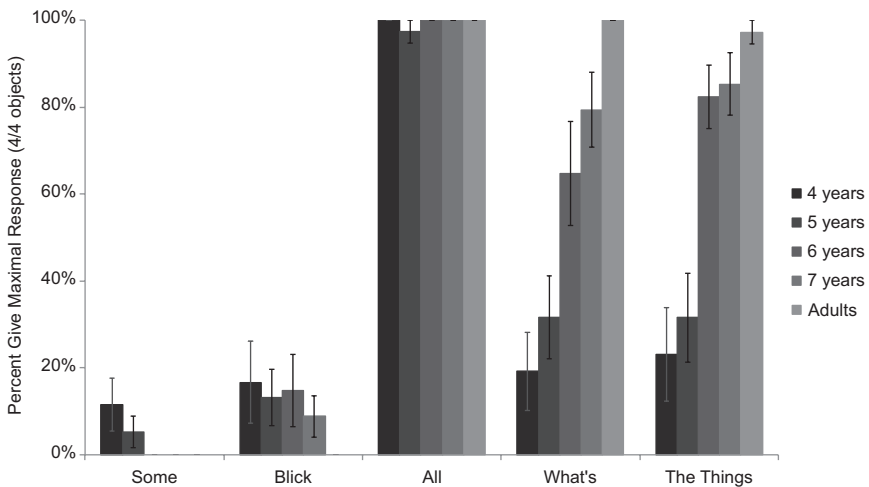
Participants were told, ‘In this game, I’m going to ask you to give me food from the plate [*experimenter points to plate*] OR from the bucket [*experimenter points to bucket*]. Listen to what I ask for, and then put the food in my hands. My eyes will be closed, so when you’re done giving me the food, and say, ‘I’m done!’’. Children were then asked to identify the plate and the bucket. After they had identified both items correctly, the experimenter began the test trials. Each of the 12 trials began with the experimenter making a request, and ended when the participant said s/he was done. There were six trial types: FR trials, in which participants were asked, ‘Can you give me what’s in the bucket/on the plate?’; PDD trials, in which participants were asked, ‘Can you give me the things in the bucket/on the plate?’; and Control trials, in which participants were asked for ‘one of the things’, ‘some of the things’, ‘blick of the things’, or ‘all the things’ from either the bucket or the plate. Each request type was performed on two trials: once for the plate and once for the bucket. Trials were presented in two quasi-random orders, with the same request never asked on consecutive trials and the same location never requested on more than two consecutive trials.

Consistent with our concerns regarding the study of Munn *et al.* (2006), pilot results showed that children who did not receive a ‘one’ trial very early in the experiment were more likely to give all fruit from



the requested location on every trial. For this reason, the first trial in both orders was ‘Can you give me one of the things on the plate?’. Children received neutral feedback throughout the experiment except after trials where they gave fruit from the wrong location. In this case, the experimenter reminded the child to give food from the location requested. Trials on which children gave fruit from the wrong location were not repeated, but were excluded from analyses.

**4.2.2 Results** Figure 6 shows the percentage of trials on which participants interpreted each request maximally, by giving all four items in the requested location. Since children who did not give one object when asked for ‘one’ were excluded from the study, data for ‘one’ trials were not included in analyses.



**Figure 6** Percent of participants who give all objects for each request on the Act-Out task, by question and age group. Error bars represent standard error.

A binomial logistic regression was conducted, with Question Type as a within-subjects factor and child Age as a continuous between-subjects factor. The analysis revealed significant main effects of Question Type ( $F(4,644) = 182.83, P < 0.001$ ) and Age ( $F(1,644) = 48.93, P < 0.001$ ), and a significant interaction between Question Type and Age ( $F(4,644) = 28.17, P < 0.001$ ). The model showed that PDD responses differed significantly from responses to ‘some’, ‘all’, and ‘blick’ ( $\beta_s > 0.40, t_s > 10$ , adjusted  $p_s < 0.001$  after a Bonferroni correction). Responses to PDDs did not differ significantly from responses to FRs ( $\beta = 0.07, t = 1.72$ , adjusted  $p > 0.05$ ). While

responses to PDDs and FRs increased significantly with age relative to responses to 'all' (PDDs:  $\beta = 0.25$ ,  $t = 6.68$ , adjusted  $p < 0.001$ ; FRs:  $\beta = 0.22$ ,  $t = 5.94$ , adjusted  $p < 0.001$ ), responses to 'blick' and 'some' did not change relative to 'all' with age (adjusted  $\beta$ s  $< 0.05$ ,  $p$ s  $> 0.05$ ). To explore children's performance in comparison with adults, we relaxed the assumption that age was linearly related to performance, and conducted a second logistic regression on FR and PDD trials with all age groups, using age as a categorical variable. This model showed that the responses of 4- and 5-year-olds were significantly different from those of adults (4 yrs:  $\beta = 0.83$ ,  $t = 5.83$ , adjusted  $p < 0.001$ ; 5 yrs:  $\beta = 0.65$ ,  $t = 5.22$ , adjusted  $p < 0.001$ ), while responses of 6- and 7-year olds were not (6 yrs:  $\beta = -0.25$ ,  $t = 1.88$ , adjusted  $p > 0.05$ ; 7 yrs:  $\beta = 0.17$ ,  $t = 1.3$ , adjusted  $p > 0.05$ ). As on the TVJ task, a strong and significant correlation was found between responses to 'what's' and 'the things' (Spearman's  $\rho = 0.723$ ,  $p < 0.001$ ,  $n = 82$ ).

**4.2.3 Discussion** Results from the Act-Out task indicate a developmental progression in which young children (4- and 5-year-olds) do not initially interpret FRs and PDDs maximally,<sup>15</sup> but begin to do so by 6 or 7 years of age, at which point their responses are similar to those of adults.<sup>16</sup> The strong correlation between responses for these two expressions suggests that children acquire maximal interpretations for both expressions around the same time.

Children and adults were much less equivocal in their interpretations of FRs and PDDs in the Act-Out task than the TVJ task. While the TVJ results suggested that even adults do not always interpret FRs and PDDs maximally, the Act-Out task clearly shows that in a situation where they are prompted to act out their interpretation, adults and older children have a strong preference for the maximal interpretation.

<sup>15</sup> In fact, young children (4-year-olds) seem to treat PDDs and FRs the same as DPs with a nonsense determiner like *blick*. This may mean they rely on a default interpretation strategy of some kind. See further discussion in section 6.3.2.

<sup>16</sup> See Karmiloff-Smith (1979) for a similar finding regarding children acquiring PDDs in French, within a larger study of the acquisition of the French determiner system. By using both production and comprehension tasks, she shows that children acquiring French do not assign a maximal interpretation to PDDs until around the age of 6, though the very same children exhibit an adult-like interpretation of the French equivalent of *all+the+NP* at a much earlier age. Thus, her results for French PDDs are consistent with the results presented here for English. It is important to note that the distribution and the semantic behavior of PDDs in French is not exactly the same as in English (e.g. some uses of PDDs in French—as generic or kind-denoting expressions—are equivalent to bare plural nouns in English, rather than PDDs).

## 5 CHILDREN'S EXPOSURE TO MAXIMALITY: A CORPUS ANALYSIS

Our experimental results suggest that children do not assign PDDs and FRs an adult-like interpretation until ages 6 or 7, when children simultaneously develop the knowledge that both expressions refer to the maximal element of a given set. Below, we explore whether this behavior can be easily explained by accounts based solely on children's input for these expressions. These accounts would view PDDs and FRs as separate linguistic phenomena with no underlying commonality, and, in fact, no particular connection at all. As such, the observed simultaneous emergence of both constructions would need to be correlated with input frequency in some way, such that both constructions have similar frequencies in children's input.

Table 1 displays the results of a corpus analysis of child-directed speech portions of several naturalistic corpora from the American English section of the CHILDES database (MacWhinney 2000): Bates, Brown, Gleason, Hall, Kuczaj, MacWhinney, Valian, VanHouten, and VanKleeck. This aggregated corpus contains 1,316,401 words and comprises speech directed at 200 children aged 2–7 years old.<sup>17</sup>

DPs	PDDs	WH-clauses	EmbWH-clauses	FRs
194562	6404 (3.3% of DPs)	32937	12352	689 (2.1% of WH-clauses) (5.6% of Emb WH-clauses)

Table 1 Analysis of children's input. DPs = all determiner phrases, either singular or plural (e.g. *the kitty*; *other people*); PDDs = all plural DPs that are a definite description; WH-clauses = all clauses headed by a wh-word [e.g. *what other tapes do you have*; *what's in there*]; Emb WH-clauses = all subordinate clauses headed by a wh-word [e.g. *do you know what a tape recorder is*; *it tells the boats where to go*]; FRs = all free relative clauses

The table shows a marked difference in overall frequency for the two relevant expressions (PDDs: 6404 v. FRs: 689), which seems to immediately rule out a simple frequency-based account for explaining the observed simultaneous acquisition. However, it is possible that children might use frequency information in a more sophisticated manner.

<sup>17</sup> The breakdown of the input by age exhibits the same trend and is therefore omitted.

For instance, another possible account is that children learn the correct interpretation for PDDs and FRs simultaneously because they track the semantic interpretations of key words associated with these expressions. The most plausible candidates seem to be *the* in initial position for PDDs and a *wh*-word like *what* in initial position for FRs. Let us assume that whenever these key words are encountered in DP-initial position or clause-initial position, children might observe whether the expression they occur in refers to the maximal element of a given set. This account predicts that *the* should occur in an expression associated with a maximal element as frequently as *wh*-words occur in an expression associated with a maximal element.

Whenever *the* occurs at the beginning of a plural DP, that is, whenever we are dealing with a PDD, *the* occurs in an expression referring to a maximal element 100% of the time (PDDs: 6404 out of 6404). In contrast, *wh*-words occur in expressions referring to the maximal element of a given set much less often—only 689<sup>18</sup> out of 32,937 *wh*-clauses (2.1%) or out of 12,352 embedded *wh*-clauses (5.6%). Clearly, the synchronized emergence of PDDs and FRs cannot be explained by an equal frequency of associated key words since these frequencies differ.

While we do not discount the possibility of some additional acquisition account based solely on input frequency that can explain the observed acquisition trajectory, the above accounts do not seem able to. These accounts viewed PDDs and FRs as separate linguistic phenomena with no real connection—both of them having a maximal interpretation was simply happenstance. As such, the only way to explain the simultaneous acquisition of the semantic interpretation was through similar input frequencies of some kind. The input frequencies for these expressions instead appear to be quite different. Given this, we believe it is more likely that something else is responsible for the synchronous emergence of the semantic representations for PDDs and FRs.

<sup>18</sup> This is an upper estimate on FRs since not all expressions matching the observable string pattern of FRs have a maximal interpretation, for example, *He went [where no one had gone before]* (cf. Caponigro 2003, 2004 for additional discussion on this point). FRs using the *wh*-word *what* usually do not allow for a non-maximal interpretation, so a conservative estimate of the FRs for this dataset would be 505.

## 6 GENERAL DISCUSSION AND OPEN ISSUES: LANGUAGE ACQUISITION, LINGUISTIC THEORY, AND CONCEPTUAL DEVELOPMENT

In this last section, we address three main issues that are related to our experimental findings. First, we ask whether our experimental findings support our main hypothesis that PDDs and FRs share the same basic semantic representation (section 6.1). Second, we suggest that our experimental findings bring further support to the specific analysis of FRs advocated in Caponigro (2003, 2004) v. the one in Jacobson (1995) (section 6.2). Third, we speculate on possible causes of the delay in the acquisition of the adult-like interpretation of PDDs and FRs (section 6.3).

### 6.1 *Experimental evidence that PDDs and FRs share the same semantic representation*

Our main hypothesis states that PDDs and FRs denote the same semantic object (the maximal element of a given set) via the same semantic mechanism (a maximality operator that is an instantiation of general type-shifting principles and is overtly realized as the definite determiner *the* in PDDs, while being covert in FRs). Our results indicate that children treat PDDs and FRs as semantically equivalent early in acquisition (by 4 years of age), despite their lexical and syntactic differences, and that they acquire adult-like interpretations of the forms at the same rate. Also, our corpus analysis shows that the frequency of the two constructions in child-directed input cannot explain why the two forms develop in synchrony since FRs are substantially less frequent than PDDs but are assigned an adult-like interpretation at around the same age. These findings are compatible with the hypothesis that PDDs and FRs share a common semantic representation, but do not support the alternative hypothesis, that there exist two separate semantic representations for PDDs and FRs.

### 6.2 *Experimental evidence in favor of an analysis of PDDs and FRs*

Our results also provide additional support for Caponigro's (2003, 2004) account of FRs over that of Jacobson (1995). As already mentioned in section 2, Jacobson posits that maximality is encoded in the meaning of *wh*-words. According to her analysis, a *wh*-word applies to the set that is denoted by the remaining part of the FR and returns a singleton set containing just the maximal element of the original set. A successive type-shifting operator turns the set into its only element. Such an analysis of FRs is different from those of PDDs in at least one important way: neither the *wh*-word nor the successive

type-shifting operator behaves semantically like the iota operator that constitutes the meaning of the definite determiner *the*. Instead, only their combination produces the same semantic effect as the iota operator. Therefore, we believe that Jacobson's account does not predict a simultaneous acquisition of the two constructions, contra our experimental findings. Instead, since different semantic mechanisms are involved (i.e. different type-shifting rules and different lexical meanings), different patterns of acquisition should be expected.

In contrast, Caponigro's analysis treats FRs like PDDs semantically, with a silent THE replacing the overt *the*. By claiming that PDDs and FRs share an identical representation, that is, the iota operator (with a silent THE in FRs replacing the overt *the* in PDDs), this account naturally predicts a simultaneous acquisition of the two forms. Thus, our results provide additional evidence that can be used to resolve this theoretical issue.

### 6.3 *On the late acquisition of the adult-like interpretation of PDDs and FRs*

In addition, our results show that children acquire an adult-like interpretation of these expressions very late, between the ages of 6 and 7 years. This is surprising, especially given the frequency of PDDs in the input. Relevant to this, Yang (2004) reports that the relative frequency of unambiguous data in the input predicts the age of acquisition for certain syntactic phenomena,<sup>19</sup> and notes that with only 1.2% of input perceived as unambiguous, children can acquire structures such as obligatory subjects and verb-second movement by age 3. In our study, we would consider PDD structures associated with maximal interpretations to be unambiguous data, and we found that 3.3% of DPs were PDDs (6404 of 194,562); similarly, we would consider FR structures associated with maximal interpretations to also be unambiguous data, and we found that 2.1% of wh-clauses were FRs (689 of 32,937). Yet, children did not acquire adult-like interpretations until age 6 or 7. Given Yang's correlation between informative input and age of acquisition, we might have expected children to acquire the maximal interpretation for PDDs and FRs much earlier than this—clearly, however, they do not.

Our hypothesis that PDDs and FRs share the same semantic representation may shed some light on this puzzling aspect of our results. Let us begin with some observations about what children seem to know.

<sup>19</sup> More specifically, Yang (2004) suggests that English children learn that there is an obligatory subject by paying special attention to expletive subject data (e.g. *It's raining*), while German and Dutch children learn that there is verb-second movement by paying special attention to data where something other than Subject appears in the first phrasal position (e.g. object-verb-subject constructions).

First, we know that by 4 years of age children acquire the compositional mechanism that maps the plural NP *things on the plate* onto a set of individuals. For example, 2- and 3-year-old children are able to correctly understand other expressions containing that same plural NP like the universally quantified DP *all the things on the plate* (for additional evidence, see Barner *et al.* 2009a). Notice that it is unclear whether children map plural NPs onto a set of plural individuals or just onto a set of atomic individuals. Mapping to atomic individuals is what children and adults do with singular NPs. This point will be relevant shortly.

Second, 4-year-olds have acquired the (possibly distinct) compositional mechanism that is responsible for mapping the CP of a FR like *what's on the plate* onto a set of (atomic) individuals. This conclusion is supported by evidence that young children understand the meaning of simple matrix or embedded constituent interrogative clauses like *What's on the plate?* or *Kermit knows what's on the plate* (Sarma 1991; Stromswold 1995; Crain & Thornton 1998: Part II). Since FRs and constituent interrogative clauses share most of their semantic derivation, at least up to the point that they both denote a set (Jacobson 1995; Caponigro 2003, 2004), we conclude that 4-year-old children can calculate the meaning of the FR as a set-denoting expression.

Based on this analysis, our study leaves open two main accounts of why children acquire maximal interpretations so late in development. The first explanation, proposed by Wexler (forthcoming), appeals to maturation, and argues that children have difficulty with definite descriptions because they have not yet acquired the iota operator. Along these same lines, it is also possible that children have not yet developed the non-linguistic ability to represent plural individuals (or collections). Alternatively, according to a second account, it is possible that children already have acquired conceptual and semantic knowledge of plural individuals, but have difficulty mapping these representations to linguistic structures like PDDs and FRs in an adult-like fashion. We briefly discuss these alternatives below. Although we cannot bring conclusive evidence in favor of one specific option, we argue that the mapping problem is the most likely source of children's delay.

**6.3.1 Maturation of Semantic or Conceptual Resources** One explanation of why children's maximal interpretation of PDDs and FRs emerges late is that they lack knowledge of the iota operator—the logical object we have argued adults assign as the meaning of *the* in PDDs and THE in FRs. Focusing on a variety of puzzling data concerning the acquisition of singular definite descriptions, Wexler (forthcoming) argues that children do not assign iota as the meaning of *the*, but instead that they treat *the* as

an existential quantifier with a presupposition that its domain be non-empty. For instance, on this account, *Pass me the cookie* would mean the same thing as *Pass me a cookie*, with the added presupposition that there is at least one cookie. Wexler's claim is that knowledge of the iota operator emerges later in acquisition as the result of maturation, at which point children could acquire the adult-like interpretation of definite descriptions by mapping *the* to iota.

By this account, to explain the simultaneous emergence of FRs and PDDs, Wexler would need to claim, as we do, that the iota operator is associated with both *the* in PDDs and THE in FRs. Also, some account of why the iota operator should emerge so late would be required.

This account would need to explain why iota was maturationally delayed, when no such delay was observed with other complex logical representations like those associated with quantifiers like *all* (which emerge much earlier in acquisition; see Barner *et al.* 2009a, 2009b). In our view, an account that appeals to maturation has difficulty explaining differences in the acquisition trajectories of different logical forms, particularly when these representations are equivalently complex, frequent in language, and fundamental to linguistic meaning. Currently, there are no good *a priori* reasons to believe that iota differs from other logical operators in these respects nor is there any direct evidence for such a proposal. As such, we believe iota should not emerge later than other similar logical resources.

For similar reasons, we see no reason to believe that children's difficulties arise from a conceptual delay. Also, several pieces of empirical evidence suggest that children have the capacity to treat sets as collections—and thus like plural objects—well before they encode maximality in language and assign an adult-like interpretation to PDDs and FRs. Bloom & Markson (1998) note three ways in which children can successfully treat sets as plural individuals earlier in development. Specifically, they describe three cues to 'object-hood' that children sometimes apply to sets of discrete individuals. First, when objects are organized into discrete groups, and each group is assigned a singular count noun (e.g. 'This is a fendle, this is a fendle, and this is a fendle'), 5-year-old children often interpret each word as referring to a collection, rather than to its atomic parts (Bloom & Kelemen 1995). Second, what they call 'intentional cues' may help children identify plural objects. For example, when an experimenter arranges objects into several groups that are divided by picture frames, and says 'These are fendles', children again treat the noun as a collective, suggesting that the explicit segregation of objects by the experimenter highlights the intended 'plural object' reading (Bloom 1996). Critically,



this result is found even when the frames are removed before the sets are named, suggesting that it is the intention of the speaker, rather than just the spatial cues, that guide children's interpretation. Finally, Bloom & Markson (1998) note that children can use Gestalt cues to objecthood, like common motion, to infer that a set of individuals form a collection. When adults are shown groups of objects moving as units on a computer screen, they perceive the groups as collections and infer that the DP *the fendles* refers to these groups, rather than to their individual members. Interestingly, this ability to use common motion to infer collections is also found in 5-month-old infants. When infants are habituated to either three or four collections of objects that move on a computer screen as units, they then dishabituate when shown a novel number of collections at test (Wynn *et al.* 2002). Based on these findings, Bloom & Markson (1998) conclude that 'a collection is like an object—both are described with singular count nouns, treated as a single entity by others, and move as bounded units' (p. 70).

These facts suggest that children's difficulty does not lie in the unavailability of logical or conceptual resources, but instead is due to the problem of mapping these representations to linguistic forms in acquisition.

*6.3.2 The development of mapping from language to meaning* The second option that we would like to consider does not rely on the maturation of linguistic or cognitive resources. It instead assumes that children already have access to the logical and conceptual elements that underlie the meaning of PDDs and FRs. The issue is that children have simply not yet developed the adult-like mapping between those linguistic structures and plural individuals, which the notion of a maximal plural individual is based on.

A growing body of evidence suggests that, at least until the age of 6, children have difficulty mapping linguistic structures onto individuals that are not defined by non-linguistic cognitive systems by means of explicit grouping and Gestalt cues. Before acquiring language, infants can represent and quantify a broad array of individuals including discrete objects, sounds, and bounded actions (Feigenson *et al.* 2004, for review). As they begin to count and use quantifiers, children appear to rely on these non-linguistic units as defaults, often ignoring the individuals that are specified by language (which differ, critically, from these default units). For example, when asked to count a fork that is cut into three pieces, children as old as six count 'three forks' (Shipley & Shepperson 1990), whereas adults count 'one'. Thus, they fail to bind the three discrete pieces into one unit, i.e. a single fork, and instead

quantify discrete physical objects that have fork properties. In contrast, adults count units (e.g. forks) that transcend the physical objects presented to them. This difference is critical, of course, to treating pluralities as objects since this also requires packaging sets of discrete atoms into single abstract units. Besides their difficulties in counting, children also label a broken fork as ‘some forks’, thereby treating a singular object as a plural set, unlike adult controls.<sup>20</sup> Also, they touch each piece in an array of broken forks when asked to touch ‘every fork’ and judge that a fork cut into three pieces is ‘more forks’ than two whole ones (Brooks *et al.* 2011).<sup>21</sup> Similar results are found for events. When asked to count how many times a rabbit has jumped into a bucket, for example, children count each jump rather than each bucket reached (Wagner & Carey 2003). Finally, and most transparently related to the present case, Huntley-Fenner (1995: chapter 4) found that 4-year-old children behave differently from adults when interpreting collective nouns without robust grouping and Gestalt cues (like in the studies reported by Bloom & Markson 1998). Like FRs and PDDs, collective nouns (*family, army, forest, class, etc.*) are mapped to plural objects—a type of abstract individual. When children were asked to count families or armies for example, they instead counted each individual member. Other studies find similar results and suggest that children have difficulty quantifying linguistically specified units until the age of 6 (Sophian & Kailihiwa 1998; Shipley & Shepperson 1990), whether these units are packaged events, things denoted by common count nouns, or collections like families. Thus, at the same age that children acquire maximality, they also become able to reliably represent abstract units when counting and interpreting other quantifiers. Crucially, these failures cannot be due to a complete inability to represent plural individuals, due to the evidence discussed in section 6.3.1 above.

Based on this previous literature, a possible answer to why children fail to assign maximal interpretations until around age 6 is that, despite being able to represent plural individuals, they struggle to spontaneously encode them in language, especially when explicit grouping and Gestalt cues are not available. As mentioned above, this is because plural individuals do not correspond to the non-linguistic units that children rely on early in acquisition. As a result, children may require significant experience with PDDs, FRs, and semantically related expressions before

<sup>20</sup> Philippe Schlenker (personal communication) suggests that plural marking may be number-neutral, and the non-singular inference could be obtained by way of implicatures, which children might fail to compute here.

<sup>21</sup> Critically, these children know that these objects are broken. When asked if something is wrong with a broken object they reply ‘yes’, and when asked what is wrong, they reply ‘it is broken’.

converging on the hypothesis that they are mapped onto plural individuals. Early in development, children may associate the NP of a PDD or the lower CP of a FR to a set containing just a plurality of atomic individuals (but no plural individuals nor a maximal individual) by default, in keeping with a more general approach to acquiring quantity expressions (and common nouns, as posited by the ‘Whole Object Constraint’; see Markman 1990). Because the meaning of *the* (or THE) cannot apply to a set lacking a maximal individual, the semantic derivation crashes, and children fail to generate a maximal interpretation.

Children may then adopt various strategies to deal with this crash, not necessarily rooted in grammatical principles. Our data show that 4-year-old children treat PDDs and FRs identically to DPs that contain a nonsense determiner like *blick*, suggesting that they have default strategies for interpreting unknown semantic operators (for discussion, see also Bale, Alan, Jessica Sullivan & David Barner. (under review), Default quantifier meanings in language acquisition: the case of “most”). This is an interesting issue that requires further investigation. Our main concern here is that the syntax/semantics mechanism in the grammar that children already master brings them to the same semantic conclusion: both PDDs and FRs denote a set of individuals and both trigger the same semantic type mismatch when they combine with the remainder of the sentence.<sup>22</sup>

Because the type-mismatch is the same, informative data about how to resolve it in an adult-like manner (e.g. by associating PDDs and FRs to plural individuals) could come from either construction. This effectively factors out different input frequencies for each structure with respect to the predicted acquisition trajectory, since acquiring the correct interpretation for both PDDs and FRs involves pooling together the data from each structure to solve the semantic type-mismatch problem.

However children acquire the linguistic capacity to refer to plural individuals (an admittedly open issue that deserves further investigation), once it is available, it can apply to all the expressions that previously denoted just sets of atomic individuals in the child’s mind/grammar. This can then lead children to new interpretations that were previously unavailable, such as the maximal interpretation.

<sup>22</sup> Note that the semantic type-mismatch does not arise for singular definite descriptions, because there is no mismatch between the function that is denoted by *the*, which takes an individual as its argument, and the atomic individual that is the denotation of the singular NP (e.g. *thing on the plate*) occurring as the complement of *the*. In contrast, this mismatch does arise for PDDs and FRs. Thus, the difficulty children have with singular definite descriptions may be different from the difficulty they have with PDDs; specifically, the PDDs have this additional issue of the semantic type mismatch. We might then expect children to get the right interpretation for singular definite descriptions before they get the right one for PDDs.

This account predicts that children should have the same intuitions about the interpretation of PDDs and FRs, at all ages—even if their intuitions are not correct—because PDDs and FRs are connected by this common semantic representation. Our experimental results support this intuition. At every age, children appear to have identical interpretations for PDDs and FRs, even if their interpretations are not adult-like. This account also predicts simultaneous acquisition of the correct interpretation for these expressions, even if the input frequencies of these expressions are very different. Unlike the acquisition accounts considered in the previous section, this accords with our experimental results and corpus analysis.

## 7. CONCLUSION

We have conducted the first experimental study comparing the acquisition of the meaning of PDDs, FRs, and quantified nominals, using the same methodologies. Our findings are both compatible with—and indeed support—the view that PDDs and FRs share a common semantic operator, despite their important syntactic differences.

Although further investigation is needed to assess why children acquire such meanings so late and how they acquire it, past research and our findings suggest that the difficulty likely lies in mapping linguistic structure to the associated concepts/objects, rather than in the maturation of either conceptual or semantic resources. More broadly, our study provides a framework for using methods from experimental psychology and corpus analysis techniques to assess the acquisition of abstract logical operators in order to inform extant debates in semantic theory.

## APPENDIX

### *Salience instead of maximality?*

Bart Geurts and an anonymous reviewer have suggested to us that salience should be considered when accounting for the semantic properties of PDDs and FRs, and that perhaps salience could take the place of maximality. However, after considering this, we conclude that salience, though perhaps relevant to domain restriction, cannot explain the semantic behavior of PDDs and FRs. One problem with the notion of salience is that, in linguistics, it is largely an informal notion, and thus is not designed to explain the formal characteristics of quantifiers and determiners that are straightforwardly accounted for by an algebraic approach like lattice theory, which readily defines maximality. Still, if

we assume an intuitive notion of salience (e.g. drawing from discussion in the social psychology and visual attention literatures; cf. Taylor & Fiske, 1978; Parkhurst *et al.* 2002, among others), it is difficult to see how it might explain the semantic behavior of PDDs and FRs, even informally. To illustrate this, let us assume that ‘being salient’ means that, out of a contextually given set P of individuals sharing the property P (e.g. being on the plate), there is a subset D of P sharing the property D (e.g. being on the plate and also being a banana or a strawberry) that has been directly or indirectly highlighted in the conversation (i.e. has been made salient). If PDDs or FRs can be used to refer to a salient individual (or set) rather than to a maximal individual, then they should be able to be used to refer to the subset D (e.g. the things on the plate that are also bananas or strawberries), even if a speaker overtly mentions the property P rather than D. Given this, let us assume the following context. There is only one plate and it contains a strawberry, a banana, an apple, two pears, three orange, some grapes, and one apricot. Johnny, who only loves strawberries and bananas, says: ‘Wow—look at that! A strawberry and a banana. They’re my favorites! I really want to eat them’. He points at them and actually eats them (so they now should be salient), leaving the other fruit untouched. Suppose his mother watches this and then describes the situation by saying this: (i) Johnny ate {what was on the plate}/{the things/stuff on the plate}. Our intuition is that Johnny’s mom’s utterance of (i) in the given context is false or at least infelicitous, although the strawberry and banana were made contextually salient by Johnny’s utterance and pointing, and his mom knows that they are the only kinds of fruit he likes. Thus, it seems like salience cannot account for the use of these constructions. Note that, even if the notion of salience played a role in the semantics of PDDs or FRs, the notion of maximality would still be needed in order to ensure that PDDs and FRs refer to the individual made of all the salient objects (e.g. the strawberry and the banana in the scenario above) and not just some of them (e.g. just the strawberry in the scenario above). Finally, salience cannot explain our experimental findings. On the view that PDDs and FRs pick out whatever individuals/sets are salient in a context, we would need to stipulate that children’s criteria for determining salient things changes gradually over development, in such a way that affects PDDs and FRs. We know of no mechanism that might explain such a change since critical aspects of visual attention that determine perceptual salience are in place well before children master maximality. Also, we would need an account of why determining a salient set is problematic for PDDs and FRs, but not for the nominals introduced by

the quantifier *all*. Note that on the salience view, *all* NPs should also depend on determining a salient set of individuals over which to quantify, in order to determine whether it is true of that set (consistent with salience playing the role of domain restriction). However, as we note, children have no difficulty interpreting *all* NPs at the youngest ages tested in our study, suggesting that they assume that the entire set of objects the NP refers to is relevant to the truth conditions of *all* NPs.

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