The Acquisition of Recursive Modification in NPs

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1 Introduction

The growth of linguistic competence from telegraphic speech to full adult competence involves the production of longer, increasingly complex utterances. It seems natural to assume that the complexity of a given structure is the same whether it is generated by the grammar of a child or an adult. However, it is not clear whether sentences containing more elaborated structure are more difficult for speakers, and whether difficulties arise to the same degree in children and adult speakers. Making clear predictions is hindered in part because the field lacks a coherent understanding or consensus of what constitutes complexity in grammar (Culicover 2013; Roeper & Speas 2014; Trotzke & Bayer 2015; Newmeyer & Preston 2014; McWhorter 2011). Despite the heterogeneity of perspectives, most discussions of grammatical complexity assume that structural elaboration in general, and embedding specifically, introduces complexity (Culicover & Jackendoff 2006; Givón 2009). In this paper we seek to better understand the effects of structural elaboration in grammar by isolating degree of embedding and studying how it affects the performance of children and adults.

Our focus is the production of complex noun phrases (NPs) containing recursive prepositional phrase (PP) modifiers.[1] Modification is one of the most basic forms of NP elaboration. Under one view, its use in natural language is regulated

by the Gricean Maxim of Quantity: speakers provide just enough information to identify a referent, but no more than is needed. Speakers make choices about the quantity of descriptive content to be expressed when labeling a referent, and these choices are conditioned by discourse and context (Heller & Chambers 2014; Sedivy 2003; Davies & Katsos 2013; Tanenhaus et al. 1995). Our understanding of how children make choices to elaborate an NP, however, is less clear. The acquisition literature contains two seemingly conflicting observations about the referential skills of children. On one hand, experimental results show that five-year-olds are highly sensitive to context in their production of modified NPs. They use adjectives (the *small* glass) only when a competing referent is present in the context (e.g. a *large* glass), and only when this competing referent is accessible to their interlocutor (Nadig & Sedivy 2002). On the other hand, there appears to be a productivity gap in children's production of complex NPs, as most of the nouns they produce spontaneously are unmodified nominals. Children's use of modification seems more limited for embedded PP modifiers than for adjectives. Recursively modified NPs are particularly challenging (Roeper 2011; Pérez-Leroux et al. 2012b). This opens up the possibility that deployment of children's referential abilities is constrained by properties of the structures themselves. The goal of this study is to explore the source of children's difficulty with recursive modification, and to investigate whether such difficulties remain to a certain extent in adults. We seek to tease apart the basis for the difficulty arising from this type of embedding, in order to ascertain whether it is best described in syntactic or semantic terms, and in derivational or representational terms.

To do so, we investigate the production of two types of doubly-modified definite descriptions. The two cases differ minimally with respect to the attachment of the second modifier. Consider the scenarios in Figures 1 and 2, which serve as visual context for a question requiring the identification of a unique referent.

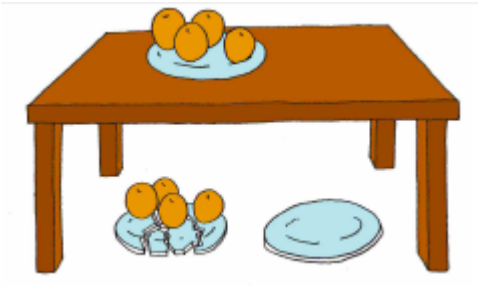


Figure 1: Which plate got broken?

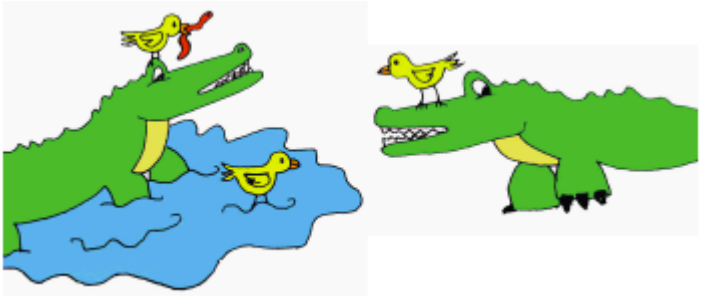


Figure 2: Which bird got the worm?

The correct answer to the question in Figure 1 involves simple modification: the highest NP is sequentially modified by two independent restrictive PPs, as shown in the bracketing analysis in 1. The response to the prompt in Figure 2 also involves two restrictive modifiers, but they are recursive: the second modifier restricts the referent contained in the first PP modifier, as shown in 2:

(1) The plate [under the table] [with oranges]

(2) The bird [on the alligator [in the water]]

These two NP types, Sequential Double Modification (SDM) and Recursive Double Modification (RDM), constitute a minimal pair distinguished only by level of embedding. Comparing the two allows us to tease apart quantity of descriptive content (e.g. number of modifiers) from level of embedding.

This article presents an elicited production study of children's and adults' production of the two types of complex NPs described above. Section 2 discusses the basic semantic and syntactic properties of modification, leading to the formulation

of a null hypothesis: that SDM and RDM should pattern alike. This null hypothesis is then considered in light of a recent proposal about the consequences of embedding for semantic interpretation, and an alternative hypothesis is formulated. Section 3 summarizes the literature on children's difficulties with modification in general, and specifically with recursive structures. Section 4 presents our study and the results, pointing to the need to reject the null hypothesis. Section 5 explores the limitations of a purely syntactic or semantic approach to characterizing our results and proposes some alternative ways of analyzing the contrasts revealed therein.

2 Syntax and semantics of nominal modification

In this section we examine specific differences in the syntactic and semantic representations of the two types of complex nominals (SDM and RDM). We first examine some basic formal assumptions about the internal structure and interpretation of modified DPs. Then we consider their derivational properties in light of phase theory.

2.1 The formal ingredients of modification

Our first observation is that SDM and RDM structures are syntactically identical with respect to the inventory of individual syntactic elements and steps or operations involved in combining them. If we take each step in their syntactic derivation to be an instance of the Merge operation, the two kinds of expressions contain the same number of iterations of Merge.[2] In terms of Merge, the only difference between the structures is whether the second PP modifier is merged higher (SDM) or lower (RDM). There is no a priori reason to think that any given instance of Merge, higher or lower, is somehow more difficult than another. Nor is there any a priori reason to think that merging a more complex PP (as in RDM) should be more difficult than merging a simpler one (as in SDM). This is particularly so in a phase-based model (Chomsky 2001), where at each cycle the lower structure becomes impenetrable and inaccessible to subsequent computations. In sum, from a syntactic point of view, in principle, there should be no difference in complexity between SDM and RDM.[3]

A similar conclusion can be reached regarding the semantics of SDM and RDM structures. Nominal expressions map onto entities or set-denoting predicates, depending on the type of noun (*Lily*, *dog*), and the presence or absence

of determiners (*the dog*, *dog*). Languages vary as to the presence of determiners, with consequences for the semantic mapping of NPs (Chierchia 1998; Partee 2002). The semantic type of a nominal expression is also partially determined by its syntactic position, as shown in the contrast between referential and predicative uses of DPs (*a dog barked* vs. *Lily is a dog*). The type of a constituent shifts as the constituent is subsequently merged with additional constituents to build higher extended projections. In textbook analyses of simple phrases such as 3, the NP denotes a predicate, and the determiner phrase (DP) denotes an entity (cf. Heim & Kratzer 1998):

(3) $[_{\text{DP}}$ the $[_{\text{NP}}$ table]]

Prepositions generally express a two-place relation between entities. When combined with a nominal constituent, the preposition shifts the type of the constituent from entity to predicate. This is evidenced by their use in copular constructions, as in 4, or in restrictive NP modification, as in 5:

(4) The vase is $[_{\text{PP}}$ on $[_{\text{DP}}$ the table]]

(5) $[_{\text{DP}}$ The vase $[_{\text{PP}}$ on $[_{\text{DP}}$ the table]]]

One consequence of embedding is that the embedded nominal expression no longer functions as a referring expression, but as a descriptor (e.g. a predicate) of the nominal it modifies (Arsenijevic & Hinzen 2012). In 5, The lowest DP expression (*the table*), now a constituent of the PP modifier, provides additional descriptive content to *the vase*. The complex DP denotes an entity that is both a vase and is located on the table.

We can now consider what happens with DPs with sequential modification, as in 1, and compare them to those that have recursive modification, as in 2. The logical representations help us to precisely pinpoint what is different between these two types of complex nominals. The DPs given in 1 and 2 are the corresponding fragments that can be given in response to the scenarios in Figures 1 and 2 (e.g. *the plate with oranges under the table ~~got broken~~*, and *the bird on the alligator in the water ~~got the worm~~*). Taking these visual scenarios as models, we can provide truth conditions for the corresponding propositions. The truth conditions for 1 are given in 6.[4] Here we have two PP predicates that simultaneously restrict the iota operator that picks out the (unique) plate x such that x has oranges and x is under the table.

(6) TRUE:
$broken(\iota x(plate(x) \wedge \iota y(table(y) \wedge under(xy)) \wedge \iota z(oranges(z) \wedge with(xz))))$

In 7 we describe the truth conditions for 2:

(7) a. FALSE:
$got.worm(\iota x(bird(x) \wedge \iota y(alligator(y) \wedge on(xy)) \wedge \iota z(water(z) \wedge in(xz))))$

b. TRUE:
$got.worm(\iota x(bird(x) \wedge \iota y((alligator(y) \wedge on(xy)) \wedge \iota z(water(z) \wedge in(yz)))))$

Whereas in 6 the two PP predicates are commutative, in 7 they are not. This is what 7a shows: the bird x that got the worm is the x such that x is both on the alligator and in the water. Rather, in 7b the PP modifiers of *the bird* are recursively embedded and contain their own definite descriptions, whose references determine the identification of the bird that got the worm. Crucially, the iota operator binding the alligator variable (y) must take scope over its occurrence of being in the water $(in(yz))$. To put this in plain English, only the alligator is in the water, not the bird.

These truth conditions can be straightforwardly derived with nothing but the standard semantic types. Nouns and prepositional phrases are predicates (type $\langle e, t\rangle$). By extension we assume that prepositions are of type $\langle e, \langle et\rangle\rangle$: essentially a transitive relation between entities. The definite article picks a unique individual that fits the descriptive content of the predicate it takes as argument. As such, we adopt the standard lexical entry for the definite article *the* in 8, which takes a predicate and returns an entity.[5]

(8) $[\![\text{the}]\!] = \lambda P_{\langle e,t\rangle} \,.\, \iota x[P(x)]$
$[\![\text{the plate}]\!] = \iota x[plate(x)]$

The next step is to characterize the combinations of PP modification of the nominal predicates found in the doubly-modified DPs, and their resulting definite descriptions. To begin with, modification of the kind relevant here is achieved through the rule of *predicate modification* (e.g. Heim & Kratzer 1998, p.63-73), shown in 9.

(9) *Predicate Modification*
If α is a branching node, where $\{\beta, \gamma\}$ is the set of α's daughters, and $[\![\beta]\!]$ and $[\![\gamma]\!]$ are both $D_{\langle e,t\rangle}$, then $[\![\alpha]\!] = \lambda x \in D_e \,.\, [\![\beta]\!](x) = [\![\gamma]\!](x) = 1$

Predicate modification forms a complex predicate that defines the intersection of the things that have the property set by the head noun and the property or

properties defined by the PPs. The expression in 10 represents the first level of embedding, and the one in 11, two instances of first level embedding (SDM).

(10) Simple modification
$[\![\text{plate under the table}]\!] = \lambda x\,.\,[\![\text{plate}]\!](x) = [\![\text{under the table}]\!](x) = 1$

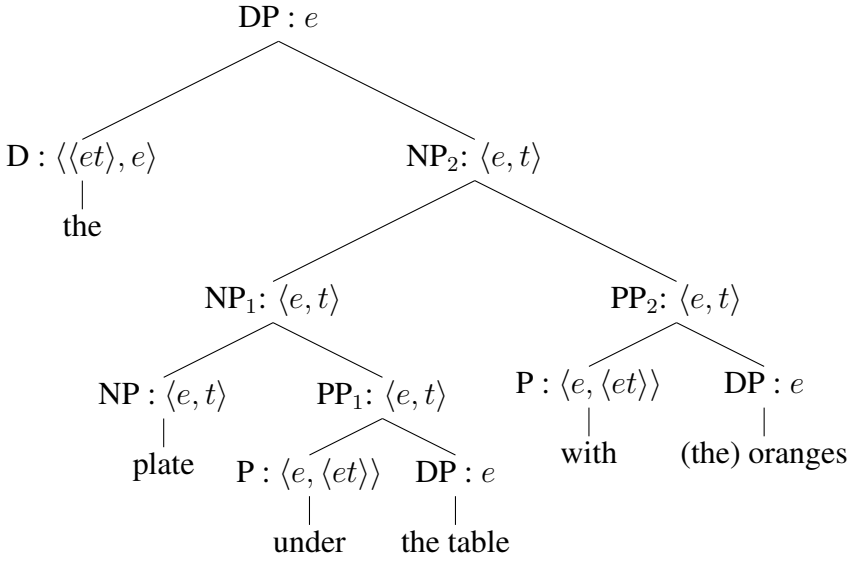
(11) Sequential (non-recursive) double modification

a. $\lambda x\,.\,[\![\text{plate under the table}]\!](x) = [\![\text{with oranges}]\!](x) = 1$

b. $\lambda x\,.\,x$ is a plate and x is under the table and x is with (the) oranges

The resulting complex predicate is argument to the definite determiner. The semantic derivation is shown in 12.

(12) Semantic derivation for sequential (non-recursive) double modification



Since sequential PP modification is commutative, the two PP modifiers of *plate*, can be freely reordered as in 13, with no effect on the truth conditions.

(13) a. the plate under the table with oranges

b. the plate with oranges under the table

The recursive DP *the bird on the alligator in the water* has similar components, but combined in a way that yields crucially different expressions. This becomes evident when we compare the two sets of truth conditions in 14, against the set-up in Figure 2:

(14) Recursive Modification

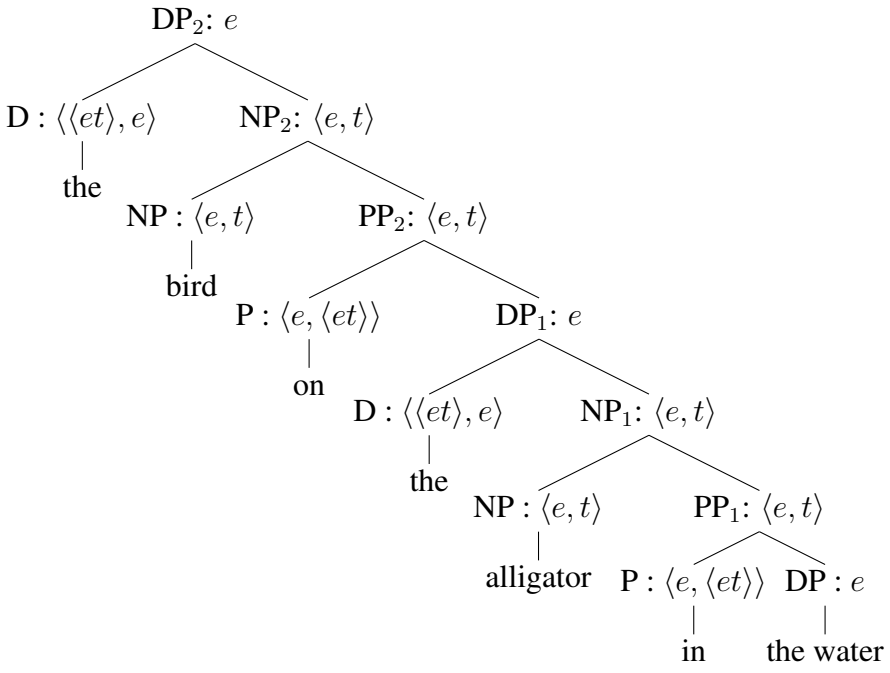
a. $[\![$bird on the alligator in the water$]\!] \in D_{\langle e,t\rangle}$

b. FALSE (two iterations of level 1 sequential modification):
$\lambda x\,.\,x$ is a bird and x is on the alligator and x is in the water

c. TRUE (level 2 recursive embedding):
$\lambda x\,.\,x$ is a bird and x is on the unique y such that y is an alligator and y is in the water

The logical form in 14b, with the three predicates directly combined via predicate modification, incorrectly predicts that this expression can apply to a context where the bird was both in the water and on the alligator. The expression in 14c provides the right conditions, by establishing reference to an intermediate definite description 'the unique y such that y is an alligator and y is in the water'. This definite description is opaque, in the sense that the predicative content inside it (the property of 'being in the water') is no longer accessible to the referent described by the higher NP. This is the relevant difference between the sequential and recursive structure. The complete derivation is provided in 15.

(15) Semantic derivation for RDM in 2



To summarize, DPs with double modification, in both the recursive and the sequential cases, are derived by the same number of iterations of predicate modification. This means that they are identical with respect to the individual steps or operations involved in building the semantic structure. We saw above that the same was true for the syntactic derivation of these structures. Although SDM structures contain additional depth and a more elaborate form, there is no difference between SDM and RDM in terms of the length of the derivational process in either syntax or semantics. Consequently, we can expect recursively modified and sequentially modified NPs to behave the same during the acquisition process. This is thus the null hypothesis: no differences between structures.

If however, acquisitional differences exist between SDM and RDM, those cannot be described in terms of derivational steps (in either the syntactic or the semantic derivations), but rather in terms of the resulting structural representation, which for RDM yields additional structural depth and a more elaborate logical form. Some possibilities along these lines are laid out in the next section.

2.2 Beyond narrow syntax

The minimalist framework distinguishes between narrow syntax (which simply consists of a sequence of applications of merge) and interfaces, where the syntactic objects generated by merge are cyclically spelled out for phonetic and logical interpretation (Chomsky 2007; Sauerland & Gärtner 2007). Sentences thus correspond to a layered system of phases or subderivations, each layer being quite simple (Trotzke & Zwart 2014). This distinction leads to a paradoxical insight: that while embedded structures obviously result from the structure building process, any difficulty they may introduce might not form part of narrow syntax. One consequence of the cyclic organization of phases is that embedded constituents exhibit dual referential behaviors. This is the point behind Arsenijevic and Hinzen's (2012) claim that syntactic embedding induces intensionality effects. For instance, regarding clauses we know that propositional complements of belief predicates are not asserted by the speaker of the sentence; they are opaque. There is one exception to this opacity effect, namely, when the proposition itself is not syntactically embedded to the epistemic verb, as witnessed by the contrast in 16.

(16) a. Bob believes Mary is wrong.

b. Mary is wrong, and Bob believes so.

This shows that referential opacity arises from a structural, rather than a merely lexical property. Arsenijevic and Hinzen argue that a comparable effect is present

also in the case of DPs: an embedded nominal expression cannot be directly predicated of, as shown in 17a. In contrast, a similar nominal coordinated or paratactically adjoined is accessible to modification by the copular predicate 17b (Arsenijevic and Hinzen 2012, p. 430):

(17) The vase on the table (was/*were) green.
The vase, the table, (were/*was) green.

The lower nominal expression in 17a is interpreted first to determine a discourse referent (e.g. the unique, familiar table). As we discussed in the previous section, the DP is rendered predicative again by the preposition, and it is no longer referential. While occurring embedded in the matrix D, *the table* merely functions as a descriptive condition used to identify the referent of the higher nominal head (the vase on the table).

This cyclic property of phases may lead us to conclude (prematurely) that the internal hierarchical structure of modified constituents is immaterial, since at the point of computation of a higher head, all the content from lower phases has already become inaccessible in the syntax, and is non-referential in interpretation. However, combining a phasal analysis with the logical form at the interface highlights one property of embedded structures: that they force speakers to keep multiple cycles of reference simultaneously active. Applying this insight concretely to example 2, the right alligator must be chosen at the same time as the right bird. This is the essence of what is formalized in the representation in 14b.

Under this view, the derivation of RDM adds additional structural depth, and results in a more elaborate logical form. This is despite our observation that doubly modified DPs are derived by the same number of iterations of semantic steps (predicate modification) and syntactic steps (Merge) in both the recursive and the sequential cases. In light of this, we see an alternative to the null hypothesis articulated in the previous. Whereas the null hypothesis takes the two structures to be equally difficult, the alternative is that RDMs are more complex than SDMs, in which case children (and possibly adults too) will have difficulties with RDMs but not with SDMs. In sum, if children exhibit the same level of difficulty with RDMs and SDMs, then we can take the two structure types to be equally challenging. Otherwise, we must consider the alternative hypothesis, that RDMs result in a more challenging representation than SDMs.

We emphasize that even if our results support the alternative hypothesis and indicate added difficulty in RDMs, under our view the difficulty cannot arise from any individual component or step in acquiring the syntax or the semantics of RDMs for the reasons just established. The alternative hypothesis posits that the

added difficulty of RDMs would have to be attributed to other factors, and the explanation built on the insight that RDM requires keeping multiple constituents open, and multiple referents active. The alternative hypothesis switches the explanatory burden to the interface of structure and interpretation and/or the processes involved in sentence production and comprehension of complex NPs.

Other possible accounts of the difference between SDMs and RDMs include non-domain-specific issues such as information processing failure relating to the various sources of information present in the referential context that must be assembled to properly point to the appropriate referent. It is not outside the realm of possibilities that this is the type of ability that develops over time in children. Other processing considerations might also be at play, hindering the deployment in real time of the target structures. Finally, it is even conceivable that a contrast in the level of difficulty between RDMs and SDMs arises from the different descriptive conditions involved.

We return to this in Section 5 using the results of our experiment, which is presented in Section 4. Next however, we consider previous literature on how children learn to use complex NPs.

3 NP modification in child language

Traditional explanations for the timing of acquisition of grammatical structures in children include frequency of the required input (Yang 2004), maturational factors (Chien & Wexler 1990), or the timing of associated conceptual developments (Johnston 1985; Pérez-Leroux 1998). In other cases, researchers explain difficulties in the acquisition of a form by appealing to certain structural properties. Complexity in these cases is articulated in configurational terms (Jakubowicz & Nash 2002; Jakubowicz & Strik 2008; Friedmann et al. 2009; Friedmann & Costa 2010).

In the case of noun modification, children seem to exhibit difficulties that go beyond the properties of the basic grammatical ingredients involved. The functional elements and relations needed to build complex nominal structures enter children's language quite early. According to Bloom et al. (1975), possession, modification and location are among the first semantic primitives identifiable in children's speech. These uses are evident even at the onset of grammatical combinations. Two-word utterances frequently include combinations such as adjective-noun, noun-noun and noun-location. The following examples from the CHILDES database clearly illustrates how these are employed to identify or restrict a referent

(MacWhinney 2000):

(18) Adjective + Noun
CHILD: Green cup. (Allison 1;10)
CHILD: Big drum. (Adam 2;03)

Noun + Noun
CHILD: Puppy dog. (Adam 2;04)
CHILD: Baby doll. (Allison 1;08)

Noun + Locatives
CHILD: Diaper out. (Allison 1;10)
CHILD: Adam a [?] home (Adam 2;03)
CHILD: Bear dere [: there] right in here. (Adam 2;03) (Brown 1973; Bloom 1973)

Despite the early appearance of these functions, for the first few years, children produce primarily simple NPs. PPs and adjectives are common in predicative contexts, but are used much less frequently in NP-internal position. Eisenberg et al. (2008) found that the narrative samples of five-year-olds contain mostly unmodified nouns. About 20% of the five-year-olds in their study used no prenominal adjectives at all (e.g. the *yellow* ball). Twice as many children produced no instances of PP or relative clause modification (e.g. *aliens with legs*, *a girl named Amanda*). Double adjectival modification (e.g. *big yellow* thing) is even rarer: only 25% of the five-year-olds produced them. No instances of double PP or relative clauses were reported. In contrast, most of the narratives from eleven-year-olds include some use of PP modification, and about half of the children are shown to use double adjectival modifiers in their narratives. NP elaboration in narrative samples increases drastically during the school years.

Complex NPs thus might seem less frequent in children than one might expect on the basis of other language abilities. What determines this apparent modification gap? Three obvious possibilities come to mind: 1) performance constraints that set limits on children's production of more difficult structures, 2) pragmatic deficits that make the children less aware of the contextual demands for modification, and 3) incomplete competence of the syntax/semantics of nominal modification. Starting with the problem of performance, we can see that the initial low productivity of complex NPs cannot be fully accounted for in terms of simple output constraints. Most five-year-olds have mean lengths of utterance (MLU) that approximate the adult range (Brown 1973). However, they do not produce

the same range of nominal structures as older children or adults.[6] The literature on the acquisition of relative clauses has long established that children tend to underproduce complex NPs. Processing of relative clauses and the specific challenges of the various relative clause constructions are themes that figure in this literature (Friedmann et al. 2009; Friedmann & Costa 2010; Guasti et al. 2012; Kidd et al. 2009). One general observation from these studies is that the same factors that present difficulties in the acquisition of relative clauses play a role in the adult processing of relative clauses (Moscati & Rizzi 2014). For instance, the McDaniel et al. (2010) study of production fluency noted a strong correspondence between how children and adults responded depending on extraction site (object/subject) and depth of embedding of the relative clause (simple relative vs. recursive relative). Children often pause or restart around the onset of the most embedded clause, and frequently fail to prosodically or discursively integrate the second relative clause within the initial utterance. McDaniel and colleagues concluded that while children conduct sentence planning more often and over shorter spans than adults, they rely on the same processes and sentence formulation systems as adults. Despite the disparities in planning resources, children and adults react similarly to the same types of structural elaboration.

The second possibility is that children's pragmatic limitations simply mask extant syntactic abilities.[7] Children may avoid complex NPs because they are simply not aware that they are supposed to use modification in a given context. In the referential pragmatics literature, children's avoidance of complex nominals, is described as under-informativeness (Matthews et al. 2007; Davies & Katsos 2010). The experimental evidence on children's referential behavior does not provide general support for a pragmatic deficit. In the Nadig & Sedivy (2002) study, five-year-olds show early sensitivity to common ground in sentence processing.[8] Children in their study carefully adjusted their use of modifications according to both visual context and interlocutor perspective. When asked to identify an object for a listener, five-year-olds produced adjectives (e.g. *the small glass*) only when a related object (e.g. *a large glass*) was present in the context. Adjectives were produced less when the object of the same kind was absent from the visual field of their interlocutor. The authors conclude that by the age of 5, children are not egocentric, and they know they have to adjust their use of adjectives according to the referential perspective of their conversation partner.[9] Nonetheless, this study identified one systematic pattern of referential failure: children in their study consistently failed to provide descriptions in terms of locative PPs even when required by the context and perspective. These authors conclude that children understand the contextual requirements of modification, but at times fail

to incorporate "common-ground information (or any potentially constraining information) [...] BECAUSE OF ITS COMPLEXITY" (Nadig and Sedivy 2002, p. 335, emphasis ours).

Subsequent work on children's referential behavior further confirms both sensitivity to informativeness, and a lag in production. According to Davies and Katsos (2010), children between the ages of four and six often produce under-informative descriptions in the presence of a contrastive set, but never over-specify in their production of referential expressions. In comprehension, however, children at that same age react like adults to under-informative descriptions, judging them as inappropriate. The same children also judge over-informative descriptions (e.g. labeling a star as *the big star*, when only one star is present in the context) as degraded, provided that the experimental task gives them an opportunity to express graded acceptability (Davies and Katsos 2010).

Online studies contribute with compatible results. Sensitivity to quantity would predict that when confronted with over-informative descriptions, such as "Find the cat with a tail" in contexts where only one cat is present, comprehension will slow down because the listener would assume that the speaker is implying the presence of a contrastive element. Analyzing reaction times and gaze direction, Morisseau et al. (2013) find that five-year-olds, but not three-year-olds are delayed in over-informative scenarios, in comparison to appropriate uses.

An independent line of experimentation investigating children's sensitivity to the semantics of definite modified NPs also suggest a great degree of semantic and pragmatic competence in young children. Children understand how definite descriptions can be used to restrict the domain of quantifiers, demonstrating awareness of the maximality restriction on plural definites and free relatives (*the things on this plate/what is on this plate*) (Munn et al. 2006; Caponigro et al. 2012). Children also possess sophisticated intuitions about the interactions between definite descriptions and the semantics of adjectival modification. Syrett et al. (2010) tested children's intuitions of the felicitousness of various descriptions (*Give me the full one/the tall one*), given contexts that either met, or failed to meet the conditions of existence and uniqueness. Three-year-olds rejected definite phrases in violation of these presuppositions (Syrett et al. 2010, p. 27), and also demonstrated sensitivity to adjective type. With relative adjectives, which are used for establishing comparisons among elements in a context, children were able to shift the standard of comparison, without over-extending context-sensitivity to absolute adjectives. In other words, children know that *a full jar* is full no matter what else is there, but *a long stick* can describe a short stick, as long as an even shorter stick is present in the context. This shows that children can already make sophis-

ticated distinctions between types of modifiers, and are simultaneously able to detect presupposition failure as well as accommodate other presuppositions when appropriate.

It seems then that the modification gap cannot be explained in terms of lack of sensitivity to pragmatics. Performance effects are likely implicated but cannot constitute the whole explanation. In fact, performance accounts make direct reference to some not fully defined notion of complexity. Let us now turn our attention to the question of structure itself. Adjectives appear to be used more freely in child language data than PP modifiers. Their formal properties also differ: AP modifiers are not considered phasal, but the DPs that provide the content for PP modifiers are; see see Hinzen and Sheehan (2013: 102). We thus propose to leave aside adjectival modification in order to concentrate on what is special about the property of self-embedding of phrases. A few studies have examined the acquisition of recursive embedding within DPs, inspired in part by the claim in Hauser et al. (2002) that recursion is the fundamental property of the human language faculty, and the subsequent debates on the universality of recursion in natural language and its psycholinguistic nature (Evans & Levinson 2009; Nevins et al. 2009; Maia et al. to appear; Pallier et al. 2011). Roeper & Snyder (2005) examined recursive possessives and PPs across the CHILDES database, and concluded that these structures are exceptionally rare in the spontaneous speech of children. They found parental use of recursive DPs, and observed that children have difficulties understanding (Roeper and Snyder 2005). The following dialogue, taken from Roeper (2011), shows that the child is unable to repeat a complex NP consisting of recursively embedded PP locatives.

(19) Father: Very good. Up in the shelf in the closet in the kitchen, can you say that? Child: yeah. Up in the # up in the # what

(Gu 2008, cited in Roeper 2011)

Other studies have tested children's comprehension of NPs. Limbach & Adone (2010) found that preschool-aged children gave non-target interpretations to recursive possessives (*Mary's father's bike*), frequently choosing reduced ('Mary's bike') or coordinated interpretations ('the bike jointly owned by Mary and her father').

Speakers informally judge a coordinated NP, such as *a boy and a dog*, as less difficult than a comparable modified NP *the boy with a dog* containing the same constituent NPs. Elicited production data from children confirm this intuition. Pérez-Leroux et al. (2012a) compared English-speaking preschoolers' ability to

produce coordinated and recursive DPs. Children were able to produce three coordinated nouns (*a bicycle*, *a ball*, *and a doll*) almost as frequently as adults. In contrast, few children managed to produce recursive possessives (as in 20) or recursive PP modifiers (as in 21):

(20) Elmo's sister's ball

(21) The girl with the dog with the hat.

Approximately two thirds of the children between the ages of three and four were limited to producing simple, unmodified NPs. The remaining children managed to produce a single level of possessive or prepositional embedding, but structures such as 20 or 21 were virtually absent. Only 2 of the 32 younger children produced any instances of either recursive possessives or recursive PPs. It is only after the age of five that these complex NPs enter production. Two-fifths of the five-year-olds produced recursive structures, with recursive PPs being more prevalent than possessives. This pattern of development, compared to the ease with which all children produce coordinated NPs, shows that there is no limitation in producing prosodically integrated multiple constituent NPs. The challenge lies with integrating these various NPs into complex descriptions linked by embedding.[10]

Interestingly, some of the non-target answers given by children in Pérez-Leroux et al. (2012a) provide a complete characterization of the target referent syntactically integrating the three NPs:

(22) Question: Which girl is eating ice cream?
Response: She looks like, um, the dog has the hat ... (TRB 4;06)
Target: The girl with the dog with the hat.

These examples suggest that some children can manage to make reference to the target expression, while showing specific difficulties with embedded syntax. This is congruous with the traditional view that children start with parataxis and eventually shift to embedded representations (Lebeaux 2000; Givón 2009). Nonetheless, if the developmental problem is described in purely syntactic terms we quickly run into explanatory problems. Embedding is simply one of the applications of merge: If children have the basic constituents, and the ability to merge syntactic elements, why should they not be able to apply it successively or recursively? All evidence from child language indicates that asymmetric hierarchical structure is a property of children's earliest productions (Hunsicker & Goldin-Meadow 2013; Takahashi 2009). Then, there is the question of recursion. If

children can produce complex NPs using a rule for embedding constituents once, why is there such a gap between this initial step (acquiring simple, first level of possession or PP modification), and the second step, of applying the modification rule recursively. In other words, assuming embedding through merge is one of the fundamental operations in language (Hauser et al. 2002; Moro 2011), why is recursive embedding such a challenge in acquisition?

To summarize, studies on semantic and pragmatic development provide clear evidence that children can navigate meaning, context and perspective in their interpretation and use of nominal modification. Despite these abilities, there is a clear productivity gap in children's use of complex nominals. Attributing this gap to the syntactic capacities raises many questions in a generative framework. Even in usage-based models, which posit that complex structures are acquired in a piecemeal fashion by analogy to what children know about matrix clauses (Diessel & Tomasello 2001, 2005), the question of recursive embedding is left unanswered: how does an embedding strategy learned for one level embedding generalize to additional levels of embedding?[11] Are these structures late because they are rare, or rare and late because they are complex? And beyond the developmental question, there is the structural question: What makes embedding more complex than other forms of structure?

We have hinted above at the path we plan to follow, which is to use what we can learn from children's acquisition patterns to tease apart the various dimensions of the problem of determining the level of difficulty emerging from structural elaboration. The most promising line of inquiry starts from the observation that the modification gap in children is uneven. From previous work, we note that some forms of nominal modification, namely adjectives, appear to be less constrained than PP or relative clause (RC) embedding (Nadig and Sedivy 2002, p. 330, footnote 1; Eisenberg et al 2008). This categorial distinction aligns with the formal notion of phases as CPs and DPs (Hinzen and Sheehan 2013). Adjectival modification extends the nominal projection but under the assumption that phasal status is linked to reference, adjectives do not introduce an additional phase.[12] In other words, we assume a distinction between adding a phase (as in PP and RC modification) and not adding a phase (adjectival modification). Treating embedding of lower phases separately from the function of modification may lead to a better understanding of children's modification gap.

4 Study

In order to test our null hypothesis and to understand how embedding may introduce complexity in grammar we need to determine how degree of embedding affects the performance of children and adults. Our purpose is to examine, at the age in which children acquire recursive modification: i) whether they are sensitive to the distinction between RDM and SDM DPs, and ii) whether they differ from adults in this regard.

4.1 Method

4.1.1 Participants

Participants were seventy-one monolingual English-speaking children recruited in preschools in upstate New York and Toronto. Ages ranged between 4;00 and 6;11. These children included 25 four-year-olds (Mean age = 4;06.3, Median 4;06, SD = 2.4 Months), 25 five-year-olds (Mean age = 5;04.3, Median = 5;04, SD = 3.3 months) and 21 six-year-olds (Mean age = 6;05.2, Median 6;04, SD = 3.2 months). All children were developing typically, with language scores within normal limits in the Clinical Evaluation of Language Fundamentals Preschool 2 (CELF-P2, Wiig et al. 2004) and typical scores for the Non-Verbal Scale of the Kaufman Assessment Battery for Children Second Edition (KABC- II, Kaufman & Kaufman 2004). Thirteen monolingual English-speaking adults from the same area served as control participants.

4.1.2 Materials

We designed a referential elicitation task to target descriptions of complex noun phrases, following the elicitation strategy in Pérez-Leroux et al. (2012a). Each trial started with a brief narrative accompanied by pictures. The short story served to draw attention to the target referent and various competing referents, and to introduce the relevant vocabulary items. The target referent was similar enough to the competing referents so that a speaker would need to use two different modifier PPs in order to uniquely identify the target. For example, the recursive conditions required that the head noun be modified by a PP that had to be itself modified by another PP. In 2 *the bird on the crocodile in the water*, the context shows two birds standing on different crocodiles, and a third standing in the water. In the non-recursive conditions, as in 1 *the plate under the table with oranges*, there are three

plates; the target can be distinguished with two independent modifiers. After the story, participants were prompted by means of simple referential questions (*which x...?*). 23 and 24 are examples of the narratives:

(23) *Sequential Modification Narrative:* Mary had many oranges (POINT TO ALL ORANGES), so, she puts them on different plates (POINT TO PLATES). Somebody threw a rock in the kitchen and broke one of the plates. Look! (POINT TO BROKEN PLATE) Which plate got broken?

(24) *Recursive Modification Narrative:* This little worm is afraid of the birds. The birds (POINT TO EACH) are afraid of the two crocodiles (POINT TO CROCODILES). One of the crocodiles is in the water, one is on land. But look, somebody caught the worm! (POINT TO WORM) Which bird caught the worm?

These materials included six stories per condition. For the non-recursive trials, half of the trials contained two locative modifiers (e.g. *the books in the box under the table*), while the other half combined locative and comitative (*with*) modifiers (as in *the plate with oranges under the table*). While both types of trials could in principle be ambiguous, the ambiguity becomes more salient in the two-locative contexts: a recursive interpretation is possible but not necessary because both the box and the books are under the table. For the recursive trials, there is no optionality and the context sets a requirement for low attachment of the second modifier.

4.1.3 Procedures

All participants were tested individually, in a school setting. Graduate students experienced in language assessment administered the tasks. In addition to the referential tasks, children received three standardized tests: CELF-P2, KABC-II, Peabody Picture Vocabulary 4 (Dunn & Dunn 2007), and a standard non-word repetition task (Dollaghan & Campbell 1998). The referential elicitation task contained a total of 42 test items, which included the SDM and RDM conditions, three additional referential conditions investigating other structures, not reported here, and 12 distractor items. To mitigate potential ordering effects the referential task was presented with three different semi-randomized orders, which were evenly distributed across participants. The entire battery of tests was administered in two or three sessions.

In the referential task, if a participant did not offer a response to a given trial, the experimenter followed up with two additional attempts. Incomplete responses (e.g. "the bird") were followed up with an additional prompt ("but which one?"). Experimenters encouraged verbal responses; the children who pointed at the referent were asked "Can you tell me with words?".

4.1.4 Coding

In this type of open ended elicitation task, it is possible for speakers to be accurate in uniquely identifying the referent without using the complex NPs that are the focus of the study. For that reason, we analyzed the data according to two independent coding systems, the first aimed to describe the syntactic structure of the responses, the other their referential properties. In the syntactic coding, we coded both level of embedding, and type of linking strategy. Children often produce simpler responses, consisting of either single NPs 25a, or a head noun and a single PP modifier 25b. In our coding system, shown in 25, recursive modification is classified as second level of embedding 25d, whereas, for sequential modification, the target was two instances of Level 1 embedding, as in 25c.

(25) Syntactic coding: Levels of Embedding

a.	Single NP:	[$_{NP}$ the bird]		
b.	Level 1:	[$_{NP}$ the bird	[$_{PP}$ on the alligator]]	
c.	2 Level 1:	[$_{NP}$ the plate	[$_{PP}$ with oranges]	[$_{PP}$ under the table]]
d.	Level 2:	[$_{NP}$ the bird	[$_{PP}$ on the alligator	[$_{PP}$ in the water]]]

Linking strategies that result in embedding included prepositional modification (PP), relative clauses (RC), and possessor genitives (POSS), given in 26. There were also linking strategies that do not entail embedding, as in the case of coordination, apposition, and linking via the predicate-argument relationships of a clause. These are illustrated in 27.

(26) Linking strategies that increase the level of embedding of the NP

[$_{NP}$ the bird [$_{PP}$ on the alligator]]	(PP)
[$_{NP}$ the bird [$_{CP}$ that is sitting [$_{PP}$ on the alligator]]]	(RC)
[$_{NP}$ [$_{GENP}$ the alligator's] bird]	(POSS)

(27) Non-embedding linking strategies

Coordination: *the bird* ***and*** *it's sitting on the crocodile in the water*. (C309, 6;06)
Apposition: *the birds that's on top of the crocodiles, the crocodiles that's in water*. (C54, 4;06)
Clausal: *The green* ***worm is in the*** *apple that is on the plate*. (Adult)

The data was independently coded in a system that integrated an evaluation of the descriptive content and referential behavior with degree of embedding. This system made reference to whether the target referential expressions (e.g. *plate*, *oranges* and *table*, and *bird*, *alligator* and *water*, for 1 and 2, respectively) were included in the response, and how they were used. This referential coding had five categories:

(28) Referential coding

a. Incomplete: These consisted of simpler or level 1 NPs responses that made reference to one or two but not all three of the target referents.
Examples: *The bird.* (C04, 5;04)

b. Sequential: These were sequences of incomplete responses that combined together provided a full description, but were not integrated into a single utterance. They either resulted from the speaker pausing and then starting a new utterance incorporating new information, or from the use of a second or third prompt.
Example: *That one with the orange. That... right there under the table.* (C025, 5;02)

c. Alternative: These consisted of simple descriptions, often stated on spatial terms (on the left, the highest one), which identified the referent correctly but not on the basis of the target PPs. Using these alternative descriptions allowed speakers to attain referential success without articulating NPs at the level of structural elaboration investigated in this study.
Example: *The dog in the middle.* (C311, 6;04)

d. Non-embedded. These were semantically complete descriptions, where the three referent were made mention in a single utterance, but were not integrated syntactically by means of embedding strategies. In the case of the recursive condition, this might include reordering of the referents.

Example: *the worm that's on the plate, in the apple* (C318, 6;03) (target: The worm in the apple on the plate) (reordering)

Example: the one on the ground had the oranges on them (C310, 6;03) (target: the plate on the ground with oranges) (clausal strategy)

e. Target: Only responses that were i) coded as descriptively complete, and ii) had the relevant syntax of embedding (Level 2 for recursive modification, 2 Level 1 for non-recursive double modification) were classified as target.

Data was coded by one investigator and independently verified by a second coder. Concordance was high, and all discrepancies were collectively discussed and reconciled.

4.2 Results

4.2.1 Overall distributions of responses

Table 1 reports the frequencies of response type across age groups, for SDM and RDM respectively. Starting from the first column, we see that the most common response by younger children is to produce incomplete NPs. In both conditions, four- and five-year-olds produce around 60% incomplete responses. By the age of six, this percentage drops sharply, with both adults and six-year-olds producing between 22% and 32% incomplete responses. Sequential responses, where a cumulative aggregation of independent simpler NPs complete the relevant description, are found primarily in the data of younger children. For four- and five-year-olds, these constitute 20% in the responses to the SDM condition, and 11%-15% in the RDM condition. Alternative responses represent a small proportion of the data, but they increase slightly in the six-year-old group, perhaps reflecting greater mastery of the spatial vocabulary used in these responses (e.g. *the one in the middle*). We also note that alternative responses represent a higher proportion of children's responses in the RDM condition. Non-embedded responses are low in the SDM condition for all groups, and higher in the RDM condition, particularly for the six-year-old group. Finally, target responses are very low initially, and particularly so in the RDM condition. Target responses in both conditions increase drastically by the six-year-old group to adult levels.

For the adult participants in our study, the most common non-target responses to both conditions are incomplete and alternative descriptions. Alternative responses are correct but uninformative about speakers' abilities. We were surprised

Table 1: Frequency of responses (with % in parenthesis) classified according to the semantic coding, by condition and age groups.

Condition	Age	Incomplete		Sequential		Alternative		Non-Embed.		Target	
Sequential	4	86	(57%)	32	(21%)	11	(7%)	4	(3%)	17	(11%)
(SDM)	5	85	(58%)	27	(18%)	3	(2%)	3	(2%)	30	(20%)
	6	34	(27%)	3	(2%)	10	(8%)	8	(6%)	71	(56%)
	Adults	17	(22%)	4	(5%)	9	(12%)	2	(3%)	46	(59%)
Recursive	4	97	(66%)	16	(11%)	18	(12%)	7	(5%)	10	(7%)
(RDM)	5	88	(60%)	23	(15%)	16	(11%)	10	(7%)	11	(7%)
	6	29	(23%)	5	(4%)	36	(29%)	27	(21%)	29	(23%)
	Adults	25	(32%)	3	(4%)	11	(14%)	8	(10%)	31	(40%)

to find that adults too produced incomplete responses, such as in 29:

(29) Descriptively incomplete responses given by adults

a. The crocodile in the water

b. The alligator with the bird on his head

c. The plate under the table

In informal conversations after the task, some adult speakers explained they had not noticed or forgotten about one of the competing referents (e.g. "Oh. I didn't see the other plate").

In what follows we set aside all response types but the target responses and explore first the distribution of those target responses across age group and conditions. We then return to the other responses to examine the specific syntactic strategies employed by speakers in response to these tasks.

4.2.2 Analysis of target responses

Children vs. Adults. We first analyzed the differences in the distribution of target responses between all children taken as a group and adults, across conditions.

To compare overall frequencies of target responses in children and adults, we fitted a generalized linear mixed-effect model using the maximum likelihood method in R (Laplace Approximation), using the binominal distribution. Following an incremental approach, we initially fitted the data with a minimal model, containing only the random effects (Participants and Items). This basic model was subsequently augmented by including group and condition as fixed effects. The result of this analysis revealed a highly significant difference between the

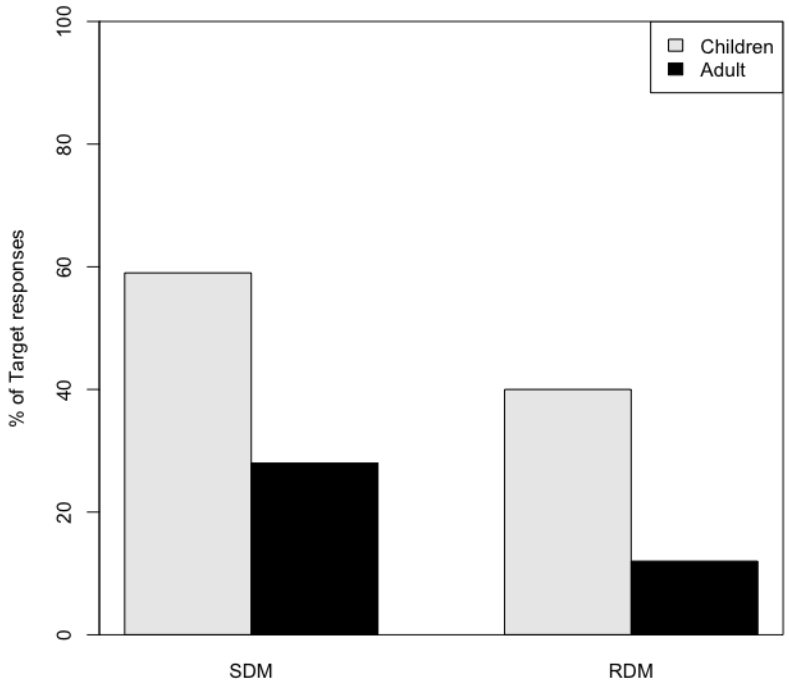


Figure 3: Percentage of Target responses given by children and adults to the SDM and RDM trials.

groups as well as a significant effect of condition. These results are reported in Table 2.

Table 2: Results of the model testing the effect of Group and Condition in the production of Target Responses (Formula: Target ~ Group + Condition + (1 | Participant) + (1 | Item))

	Estimate	Standard Error	z	p
(Intercept)	-0.72	0.59	-1.24	0.217
Group:Child	-2.12	0.51	-4.19	<.001 ***
Condition:SDM	1.29	0.54	2.39	0.017 *

A GLMER model (logit) was fit using maximum-likelihood estimation (Laplace) and included the random effects of Participant (Variance = 2.18) and Item (Variance = 0.76). This model was based on 1008 observations from 84 participants and 12 items. The fit of this augmented model was better than that of the minimal model according to the Akaike Information Criteria (AIC) (911.9 vs. 895.1). This difference was statistically significant (χ^2 = 20.729, p <.001).

A third model was generated to test for the interaction between Group and Condition. As shown in Table 3, This interaction was not significant.

Table 3: Results of the model including Group and Condition and the interaction of Group by Condition as predictor variables. Formula: Target ~ Group * Condition + (1 | Participant) + (1 | Item)

	Estimate	Standard Error	z	p
(Intercept)	-0.60	0.61	-0.99	0.322
Group:Child	-2.30	0.56	-4.13	<.001 ***
Condition:SDM	1.03	0.63	1.637	0.102 *
Group:Child x Condition:SDM	0.34	0.43	0.78	0.432 *

A GLMER model (logit) was fit using maximum-likelihood estimation (Laplace) and included the random effects of Participant (Variance = 2.20) and Item (Variance = .76). This model was based on 1008 observations from 84 participants and 12 items.

Including the interaction did not improve the fit of the model when compared to the previous model with no interaction (AIC = 896.5), and there was no statistical difference between the fit of these two model (χ^2 = 0.597, p = 0.439). This further confirms that target responses are best predicted by age status (children vs. adults) and condition (SDM vs. RDM), and that the effect of condition appears comparable for children and adults.

The effect of age in children's target responses. Our second analysis focused on examining developmental effects within the child participants. For that purpose, we entered children's responses (whether target or not) to a generalized mixed effects model, using the binomial distribution. As before, this model had participants and items as random effects, condition as a categorical predictor and age in months was entered as a continuous predictor. This analysis revealed a highly significant effect of age, and a highly significant effect of condition. A subsequent model which included the interaction between the two fixed effects

was found to provide a better fit for the data (AIC = 664.1 for the no-interaction model, and AIC = 660.9 for the model with the interaction. This difference was statistically significant. (χ^2 = 5.226, p = 0.022). As shown in Table 4, there is a highly significant effect of both Age of the children and Condition, and a significant interaction between these factors.

Table 4: Results of the model testing the effect of age as a continuous predictor, and condition as a fixed effects. Formula: Target ~ AgeinMonths * Condition + (1 | Participant) + (1 | Item)

	Estimate	Standard Error	z	p
(Intercept)	-8.57	1.63	-5.27	<.001 ***
AgeinMonths	0.09	0.02	3.95	<.001 ***
Condition:SDM	-2.34	1.71	-1.36	0.1720
AgeinMonths:ConditionSDM	0.05	0.02	2.29	0.0217 *

A GLMER model (logit) was fit using maximum-likelihood estimation (Laplace) and included the random effects of Participant (Variance = 1.06) and Item (Variance = .74). This model was based on 852 observations from 71 participants and 12 items. The differential effect of age on the two conditions is illustrated in Figure 4. The trendline indicates the line of best fit between age and number of targets.

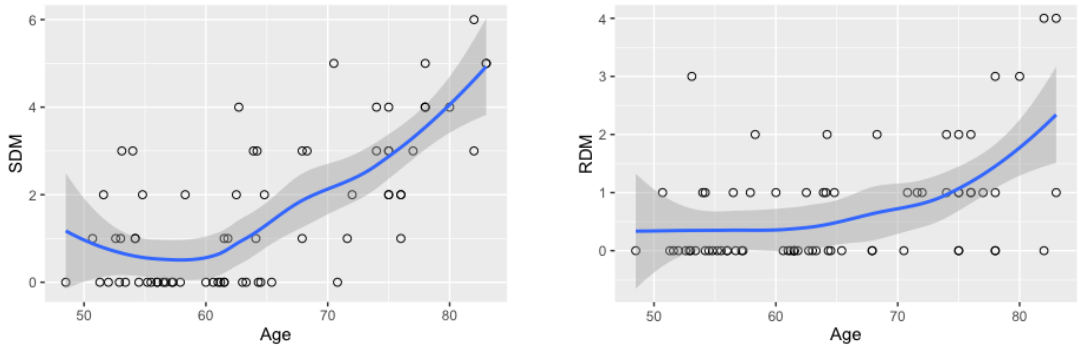


Figure 4: Number of target responses produced by individual children for the SDM (left) and RDM (right) conditions plotted as a function of children's age in months.

The plots in Figure 4 show the different learning curves of the SDM and RDM.

For SDM, production shifts around the age of five (60 months), and raises quickly. For RDM, the shift occurs five months later, and productivity remains low.

Individual analyses of target responses. The last step in the analysis of target responses was to examine the response patterns of individual participants. Participants were classified according to whether they produced at least one target response for each type (RDM, SDM). There were thus potentially four classes of participants: those who produced no targets in either type, those who produced targets for both types, and those who produced targets only in the SDM condition or only in the RDM condition. This classification, based on target performance across the conditions, was cross-tabulated against age groups in Table 5.

Table 5: Number of participants per group classified according to conditions for which they were able to produce at least one target response.

	4-year-olds	5-year-olds	6-year-olds	All children	Adults
None	13	10	0	23	1
Only SDM	5	6	5	16	0
Only RDM	2	2	0	4	0
Both	5	7	16	28	12
$N =$	25	25	21	71	13

Table 5 shows that half of the four- and five-year-old children produced targets in neither condition. This suggests that it is during this period that complex (doubly) modified NPs emerge. All of the six-year-olds produced one target type or the other; and the majority of six-year-olds managed to produce targets in both conditions. All adults except one speaker produced both types of targets. This exceptional individual produced only incomplete and alternative responses. When all the children are pooled together, the data indicate that the majority of the children were in the "Neither" or "Both" classes. For the substantial number of children who produced targets in one condition (20/71), the odds of producing an SDM before an RDM (in contrast to the opposite pattern) are 4:1.

4.2.3 Analysis of linking strategies

Our last analysis sought to explore the differences in the response patterns in the two conditions by considering how speakers performed when they did not produce targets. For that purpose, we focused on the referential coding and the various

types of linking strategies employed by speakers. Two observations are worth a brief mention.

First, we further examine the asymmetry in the distribution of non-embedded responses noted in the discussion of Table 2. Recall that in the RDM (but not in the SDM) condition, six-year-olds produced non-embedded responses as much as two to four times the rates of other groups. These responses resulted from either the use of a non-embedding linking strategy such as apposition or some other clausal relation. Additionally, for the recursive structures, responses are considered nonembedded if the two modifiers are reordered, as in (30), or coordinated, as in (31) (cf. 1 and 2).

(30) the one on the orange shelf in the bowl (C316, 6;05)
Target: The one in the cup on the shelf
(in contrast to other cups, not on the shelf)

(31) the one on the crocodile on the head and in the water (C301, 6;00)

About four-fifths of the non-embedded responses were instances of 2 Level 1 structures such as in 30 and 31, where the speaker used embedding linking strategies (RC or PP) but failed to structure these into a recursive configuration. This allows us to precisely identify the recursive embedding step as the locus of the six-year-olds' delay with RDMs.

The second observation concerns the unexpected use of RC responses. These were frequent for all groups, making up almost one quarter of the first links in the RDM responses, and about one-seventh of all the first linking strategies in the SDM responses, for both children and adult controls. These responses were particularly surprising in the case of the children because both length and structural complexity of the response NPs are increased without further informational gain.

To explore the use of RCs in doubly modified NPs, we extracted and classified responses according to whether they were linked by PPs alone 32a, by RCs 32b or by a combination of both 32c.

(32) a. The one on the plate with the apple.
(LAR,5;10) [= in the apple on the plate] (PP)

b. The bird. [Which one?] The bird that's on the crocodile that's in the water. IR, 5,08 (RC)

c. The one on the one on the crocodile's eyes that was in the water (AG, 5;03) (MIX)

Comparing the distribution of these responses across conditions yields an interesting observation: while mixed and relative clause responses were common in the SDM condition (33% and 30% of all target response for children and adults, respectively), these rates are higher for the recursive condition in both groups (42% and 45%, respectively).

5 Summary and discussion

During the period under study we are able to document children's acquisition of double modification. Our data shows that these structures are rarely produced initially, and only by a few children, and that children's abilities rapidly grow to approximate adult patterns. Our results also show continuity in many aspects of the production of complex NPs. The data of both children and adults reveals a clear contrast between our two conditions, with higher numbers of target responses in the sequential condition than in the recursive one. Our results place the emergence of recursive ability in the late preschool years, and confirm the observation in Pérez-Leroux et al. (2012b) that over a third of children aged four and five can produce recursive NPs.

Our results can be summarized as follows:

- All groups produce significantly more target responses in the SDM than in the RDM condition, but children produce them much less frequently than adults.
- The ability to produce complex NPs undergoes significant growth in the period between the ages of four and six, with six-year-olds approaching adult performance.
- Children initially respond by producing simpler descriptions; adults do so but only occasionally.
- Both children and adults frequently rely on a structurally elaborate relative clause strategy to express the modification relation. Surprisingly, both groups produce more of these responses in the recursive condition.

Children and adults differ in how often they produce incomplete responses. We gave anecdotal evidence (at the end of section 4.2.1) that adult incomplete responses can result from the challenge of attending to multiple referential contrasts simultaneously; it is reasonable to consider this as a possibility for children

as well. As the adult we quoted earlier suggested to us, it is easy to forget the other plate. The point is that we cannot properly tell when a child's incomplete description results from a grammatical limitation or from a failure to attend to all the relevant elements in the referential context. However, we must consider that for the younger children, the primary response is to produce simpler NPs, in the form of either incomplete or sequential responses. Close to half of the four- and five-year-olds fail to produce any instance of NP embedding. For those children, it is reasonable to infer that they have not acquired this grammatical operation.

Our results also point at significant changes around the age of six. Six-year-olds' data show a reduction in the structurally simpler responses, and an increase in the production of targets. One pattern specific to this age group is the higher proportion of alternative responses in the recursive condition. It is not possible to determine from the current data whether this difference lies in item-level properties, or whether it represents another structurally simpler avoidance strategy. Most importantly, six-year-old children were also different from other groups in producing many more complete but non-embedded responses, and producing them more frequently as responses to the recursive condition. Further analysis revealed that most of these non-target responses were, in fact, equivalent to sequential double modification, where two different modifiers restricted the head noun of the complex NP. Such responses in the recursive condition were sufficient to account for the contrast in targets between the two conditions for this group of children. This clearly endorses the intuition that recursive embedding is a distinct step in acquisition, while at the same time supporting the possibility that this is not because of the syntactic structures or the semantic derivations, but because children are unable to deploy their knowledge of the syntax and semantics of complex noun phrases in real time. If, as suggested by McDaniel and colleagues (2010), the sentence planning capacities of children are limited, and if RDMs require more planning resources than SDMs, this is precisely the picture we expect to see.

Our data suggest that producing complex NPs is challenging for all speakers. Notably, children and adults appear sensitive to the same types of structural conditions: the structures that are harder to produce for adults are harder to produce for children, and emerge later as a consequence. By comparing two types of complex NPs, recursive locative modifiers and doubly modified NPs with either two locatives, or a locative and a modifier combined, we sought to find out whether depth of embedding introduced an additional challenge for children. To the extent that the present findings generalize beyond our materials, we conclude that it does. This leads us to reject the null hypothesis and conclude that RDMs and SDMs are not comparable, acquisitionally speaking.

We therefore need to determine the nature of the challenge posed by RDM structures. What is clear is that degree of embedding, and not just quantity of embedded structures is a distinct developmental feature. However, the source of the differential patterns observed in our results remains unclear. Given the syntactic and semantic analyses provided in section 2, articulating the locus of the difference between RDM and SDM is far from straightforward. Both types of doubly modified DPs are built from the same number/kind of syntactic atoms and structure-building steps (iterations of Merge). There is no a priori reason to think that more deeply embedded instances of Merge are more complicated to apply than less embedded ones. Semantically, both types of complex DPs are derived by iterations of predicate modification; they are identical with respect to the individual steps or semantic operations involved in composing the semantic structure. Utterance length of the RDM cannot be the issue given previous work by Pérez-Leroux et al. (2012b) showing that while children avoid embedded NPs they produce coordinated NPs of comparable length without difficulty.

From an input perspective, it could be that multiple modification is rare overall (either type) but Perfors et al. (2010) shows that a Bayesian learning system can establish recursive rules on the basis of minimal input. From our perspective, the acquisition of recursive modification in children should not be exclusively dependent on the input frequency of level 2 embedding, but could crucially involve some learning step generalizing from level 1 to level 2. To argue otherwise would make the emergence of recursive modification in language a complete mystery to begin with.

This reasoning, along with the evidence presented in this paper, leaves us with two logical possibilities to interpret the difficulty arising from recursive modification. One possibility is that the difficulty of recursive embedding represents a measure of the challenge of integrating complex structures (beyond narrow syntax). Children's (incomplete) extra-linguistic capacity to coordinate complex sources of information may be just enough to allow them to produce the doubly-modified structures but not to embed them recursively. Under this view, changes in general capacities give rise to the ability to produce recursive configuration. While this is a reasonable interpretation, it is not the only one available. The contrast, suggested in Yang (2016), between learning a rule, and learning that a rule is productive leads to an alternative view, namely that the shift observed by the age of six reflects an actual change in grammatical competence resulting in the learning of the recursive step. This does not actually imply learning a new syntactic operation, but simply realizing that the embedding rule is unrestricted, or productive (see also Roeper & Pérez-Leroux 2011).

Interestingly, whatever the challenge involved in the production of RDM DPs, when children actually manage to articulate them, they frequently end up producing more structure rather than less. Instead of the simpler stacked NP/PP sequences, English-speaking children favor the production of forms that introduce additional structural material. Consider again that children preferred to produce relative clauses over the superficially 'simpler' double PP target structures in both conditions, and even adults produced more mixed PP/RC structures than double PP structures in the recursive condition. RC alternatives are systematically longer than their PP counterparts and yet preferred. Importantly, the availability of modification by RC demonstrates that modification, per se, is not the source of difficulty.

The favouring of RC structures over double PP structures belies attempts to account for production difficulties within the confines of narrow syntax. Indeed, the propensity for relative clauses in the experimental results for the children can be seen as a curious result when considering their syntactic and semantic complexity compared to the recursive PP targets. On the syntactic side, it is standardly assumed that relativization involves the displacement of an NP (or alternatively an operator) to a position higher in the clause, thus creating a dependency in the syntax along with the insertion of a relative pronoun such as *that*:

(33) The bird$_i$ [$_{\text{CP}}$ that t_i is on the alligator$_j$ [$_{\text{CP}}$ that t_j is in the water]] ...

On the semantic side there is also added complexity: a number of extra semantic rules are needed to not only account for the displaced structure, but also to calculate the semantic values of the trace left behind by the movement and the insertion of the relative pronoun. This is typically achieved through the application of three additional rules, none of which are needed in the recursive PP structures. [13] We reiterate that these rules are in addition to the semantic and syntactic rules given in section 2.1 (for example, predicate modification and the derivations in note 13) that derive the PP recursive structures: they do not replace them. Even a cursory assessment of the semantic and syntactic ingredients involved in relative clauses reveals that they are overall more elaborate than the recursive PP structures, in the sense that additional steps and operations are needed to derive the meaning and structure.[14] This brings us to a speculation about recursion. The parataxis and relative clause effects observed in our results suggest that the faculty of language (as revealed through the process of acquisition) may aim to maximize the structural distance existing between a higher referential expression and lower expressions embedded under its domain. Hinzen and Sheehan (2013) use a "phasal template" comprising a lexical concept and an edge containing the

functional elements that allow the concept to be used referentially. In cases of embedding there is only one referent established at the edge. Accordingly, a DP embedded in a higher DP must act as a descriptor predicate related to the higher DP via the expression of a relation (e.g. location). It is possible that the extra structure in a complex NP with RC modifier may supply a more robust buffer for reference-tracking and is therefore favoured over the RDM structure.

In closing, let us take another look at phase theory and consider its potential to illuminate our results. Arsenijevic and Hinzen (2012) propose that the forms of recursion arise from the way in which narrow syntax and interpretation interlock in phase theory, rather than from narrow syntax itself. As discussed in section 2.2, they differentiate embedding and embedded nominal categories on the basis of the two potential denotations of a DP (referential and predicative). The cases examined here fall into a lacuna in the existing discussion on the syntax/semantics of embedding and of recursion. This two-way split does not clarify the contrast between recursive and non-recursive modification. In either type, at the highest point of the derivation, all PP modifiers have become part of predicative content. While all the descriptive content in lower phases remains relevant at interface, the scopal possibilities (particularly, that of the intermediate iota operator) are fixed by the derivational history. Thus, each step in embedding introduces a new layer of descriptive complexity. The reasons why are not evident within a framework in which earlier phases are rendered fully inert. Therefore, it becomes apparent that the inertness of the content of a phase refers exclusively to the syntactic computation, and does not refer to the interfaces.

In sum, elaborated structures such as the ones examined in this study point to the limitations of syntax-only or semantics-only approaches to complexity. Structurally, these NPs involve identical parts, containing the same types (and number) of lexical-level categories, and the same types (and number) of maximal projections, and the same type of adjunction involved in integrating the parts. In compositional terms, we discussed how these structures involve the same semantic types and two applications of predicate modification. The components that enter the derivation (whether syntactic or semantic) stepwise do not help us articulate why there should be a difference in level of difficulty. However, a difference does exist, as indicated by the magnitude of the observed asymmetry in productivity, for both adults and children. Standard assumptions about how phrases are generated by the syntax, and about how they are interpreted in a compositional semantic system, do not lead to a characterization of this difference. What we do know is that the descriptive conditions associated with the recursive case are more difficult. The referent identified by non-recursive double modification can be simply described

as a Boolean intersection of three sets (denoted by the relevant predicates, *plates*, *things with oranges on*, *things under the table*). The relation between the three set-denoting predicates in the recursive case (*bird*, *things on alligators*, *things standing on water*) cannot be described by any simple set intersection. Instead, in the task of contrastively describing the referent of a recursive description, speakers must represent an intermediate domain of reference within which the intermediate iota operator (which binds the *alligator* variable in the cases considered) must bind the first variable of the lowest relational predicate (e.g. the lowest preposition). Applying these operations recursively/cyclically isolates independent scopal domains. The application of ordered operations (modification, in semantic terms, or, embedding in syntactic terms), yields increasingly elaborate and descriptively rich expressions.

6 Conclusion

What have we learned about the difficulty embedding presents to children? The results of our study support previous claims that what is difficult for adults is also difficult for children, just more so. Enough, we would argue, to account for the general modification gap found in production studies, and in spontaneous speech studies. The present study shows that recursive embedding introduces a level of difficulty that goes beyond the elements and operations used during the semantic composition of the structure, or the cyclic syntax that generates it. The exact nature of the particular complexity that emerges from recursive doubly modified structures remains a mystery to be explored in future research but it is very tempting at this early stage to see a parallel between what we observe here and Chomsky and Miller's (1963) conclusions with respect to the complexity of recursive self-embedding which, they argue, stems from performance processes not formal grammar. In other words, as stated in Trotzke & Zwart (2014, p.131-132), "the performance limitations on recursive self-embedding are captured by factors extrinsic to the competence grammar" but crucially "the generative approach postulates a competence grammar allowing unbounded recursion". This is clearly the case here as our results reveal the difficulty associated with RDM, not their impossibility. As pointed out by a reviewer, our results also lead to the overall conclusion that recursive embedding is hard for humans to perform, in spite of the fact that it appears to be a central characteristic of human language.

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Notes

[1]In this paper the term 'complex NP' is used to refer to a modified NP, not necessarily to an NP whose head N is modified by a clause as in traditional grammar or early generative grammar work (e.g. Ross 1967). Under various generative analyses, the distinction is superficial since NP internal modifiers are thought to derive by ellipsis from relative clauses (although Ross does not specifically claim this).

[2]Merge, in contemporary generative grammar, is the basic structure building operation that combines two syntactic objects to form a new constituent. For the sake of completeness, the syntactic derivation corresponding to 12 proceeds as follows: *the* merges with *oranges* [merge 1], then the result merges with *with* [merge 2]. This is then adjoined to *plate under the table* [adjoin 1]. *Plate under the table* is itself formed by merge of *the* with *table* [merge 3], followed by merge of *under* [merge 4], the result of which then adjoins to *plate* [adjoin 2]. Then the structure *plate under the table with oranges* merges with *the* [merge 5]. In the derivation in 15 *the* merges with *water* [merge 1], then the result merges with *in* [merge 2]. This is then adjoined to *alligator* [adjoin 1] and then *alligator in the water* merges with *the* [merge 3]. Then *on* merges [merge 4] and the resulting PP *on the alligator in the water* adjoins with *bird* [adjoin 2]. Then *the* merges to form *the bird on the alligator in the water* [merge 5].

[3]Throughout this paper we use the term 'complexity' in a pre-theoretical sense. We do not elaborate on the potential connection between what is difficult and what is complex. What interests us here is to determine whether SDMs and RDMs are difficult for speakers, to the same degree, and in similar way for children and adults. Whether an observed difficulty with a structure means that this structure is more complex is left for further research; see Béjar et al. (2017) for discussion.

[4]For brevity we are using the iota operator for definite descriptions in 1 and 2. As such, we adopt the standard assumption that the iota operator, alongside the predicate variable it binds, is a singular term, such that $Q(\iota x Px) \Leftrightarrow \exists x(Px \wedge \forall y(Py \rightarrow x = y) \wedge Qx)$. Also, we are not concerned with the definite description in the nuclear scope of the sentence (e.g. *the worm*). Thus, *got the worm* is simply treated as an intransitive predicate.

[5]In the given scenarios, the presupposition of existence of the various definite descriptions is satisfied (cf. Russell 1905; Strawson 1950, etc.).

[6]Although MLU continues to be used as a standard measure of complexity in the developmental field, utterance length clearly fails to capture some fundamental dimensions of the development of grammatical complexity. Some argue that MLU is more reflective of talkativeness or lexical development than of syntactic development (Dethorne et al. 2005; Pérez-Leroux et al. 2012a; Dixon & Marchman 2007).

[7]McDaniel & McKee (2004) present an interesting critique of the overuse of pragmatic deficit accounts in the child literature.

[8]Nadig and Sedivy's (2002) treatment of the common ground, which is the norm within this experimental literature, rests on the assumption that propositions can be added to the common ground through extralinguistic means, such as gesturing or drawing attention towards an object in the physical context, or the act of showing a picture.

[9]Interestingly, Nadig and Sedivy (2002) also report that children used color adjectives in the absence of a competing referent, but scalar adjectives only when required by the situation. This can be interpreted as further evidence of pragmatic ability; adults also produce descriptions that point to perceptually salient characteristics of objects even in the absence of contrasting referents. Such non-contrastive descriptive material is thought to be helpful rather than redundant.

[10]Standard current analyses of coordination attribute endocentric structure to coordinate clauses, making coordination analogous to other forms of phrase structure building (Munn 1993; Progovac 1998; but see Cowart & McDaniel 2012 for a dissenting view). This makes it difficult to state the contrast between coordination and embedding in purely structural terms. The contrast between coordination and subordination then must be defined in terms of the semantic interface: the individual referents of coordinated DPs do not interact, but in NP modification, the most embedded DP contributes to the description of the referent described by the higher DP, in the manner described in section 2.

[11]It seems unclear that piecemeal analyses such as provided in Diessel and Tomasello (2001) can contribute to the discussion here. For example, these authors explain the acquisitional difficulties of the various types of relatives by appealing to the numbers of referents expressed. Such metrics will not shed light on the contrast between coordination and embedding.

[12]What should count as a phase is an important point of theoretical discussion. Initial formalizations counted CP and vP as phasal (Chomsky 2001). We follow the ontological approach to phases, as articulated in Hinzen and Sheehan (2013), where phases are defined in terms of reference: clauses are mapped to propositions, verbal phrases to events, and nominal expressions to objects. Modifying adjectives are entered directly as properties, and do not introduce new referents. While Bošković (2014) considers APs to be phases, his arguments extend only to APs in predicative position, not to modifiers.

[13]To sketch this out: firstly, a standard analysis of relative pronouns (for example Heim and Kratzer 1998) treats them as an *identity function* of the semantic type ($\langle e, t\rangle$). This function simply insures that the semantic type of the complement the relative pronoun takes is 'transferred up' to the next dominating node: $[\![\text{that}]\!] = [\lambda f : f \in D_{\langle e,t\rangle}.f]$. Secondly, *Predicate abstraction* is the semantic rule responsible for the actual relativization: if we reconstruct *bird* to its base-generated position, we have the sentence *the bird is on the alligator*. The relativization of *bird* leaves a trace; however, this is still a sentence, t_i *is on the alligator*, the semantic value of which is a truth value. In order for a semantic derivation to proceed after relativization, the rule of predicate abstraction 're-predicates' the sentence relative to *a variable assignment*. Thirdly, the application of the *traces and pronouns rule* ensures that the trace in the relative clause shares a referent with a main clause

element, and on which the subordinate clause is grammatically dependent.

[14]The possibility that the relevant PP structures might in fact be reduced RCs cannot be discounted. This would add yet another dimension to the challenge of assessing the relative complexity of PP and RC structures, perhaps turning the tables yet again.

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