COMING TO AGREEMENT:
REPRESENTATION AND PROCESSING OF ENGLISH
SUBJECT-VERB AGREEMENT IN ACQUISITION

BY

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DISSERTATION

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Abstract

Syntactic dependencies provide a useful window on children's grammatical development. In this project, we use subject-verb agreement as a tool for investigating how young children learn and process formal linguistic relationships, considering both classic questions about the role of semantic and syntactic-distributional knowledge in acquisition, and questions about the development of online sentence processing.

One feature that makes subject-verb agreement ideal for such an investigation is the fact that the agreeing verb reflects the grammatical number of its subject. Thus, we say *she is*, but *they are*, marking the subject number both in the form of pronoun and on the verb. However, this link between number-meaning and linguistic form can easily be broken. We say *they are* even when we talk about a single pair of scissors, because *scissors* is a grammatically plural noun. Because agreement has clear notional correlates, but must ultimately be learned as a primarily syntactic dependency, we ask how this unfolds in development as a window on the role of semantic and syntactic knowledge in children's acquisition of linguistic dependencies.

Language processing is incremental: though precisely what information is accessible at different times changes with the task, both listeners and speakers put together each crumb of information as it becomes available to build a representation of the sentence at hand. Agreement involves a displacement or reflection of one word's properties onto another word in the sentence. This means that agreement can be used to investigate the incremental use of displaced information on the verb during processing, to ease integration of, or even pre-activate, features of the upcoming subject.

Experiments 1 and 2 ask what properties of the subject govern children's choice of verb form in sentence production. Experiments 3 and 4 investigate how children and adults deploy their knowledge of agreement in online comprehension. Results from these studies suggest that by the age of 3 children treat agreement as a primarily syntactic dependency. Experiments 5 and 6 follow up on this finding by asking whether notional number plays any role in the online comprehension of agreement. For adults, agreement appears to act both as a cue to the likely grammatical and the likely notional number of the upcoming subject. Experiment 6 collects similar data from children, and results suggest

that they too use agreement as a cue to the likely notional number of the upcoming subject. In the final chapter, Experiment 7 investigates 2.5-year-olds' use of agreement during online comprehension, and discusses possible learning mechanisms that might result in the observed patterns.

The findings presented here suggest that 2- and 3-year-old English-learners treat agreement as a primarily syntactic relationship, and are able to deploy their knowledge of agreement rapidly during online comprehension and in production. Remaining questions center on the balance of notional and grammatical number that agreement carries and the mechanism by which it does so, the degree to which children's knowledge, demonstrated here with the agreeing forms *is* and *are*, generalizes to the rest of the English agreement paradigm, and testing predictions of the proposed learning mechanisms.

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Chapter 1

Introduction

Proficient speakers of a language produce and comprehend sentences quickly and flexibly: they make predictions, recover from errors and misinterpretations, and can express novel ideas. By and large, conscious effort toward speaking and listening is reserved for the content of what is being expressed and perhaps the words that are being chosen, not for the form of the sentence itself. Yet even without explicit attention to structure, speakers produce grammatical utterances, and listeners unconsciously use linguistic structure to guide their interpretations and expectations.

This nearly effortless online use of linguistic structure is learned in a few short years. How do children master this intricate, highly structured system? How do children learn the structure of their native language?

1.1 Syntactic Dependencies

Languages use two primary methods to indicate the syntactic relationships among elements in a sentence: fixed word order and morphological marking. Successful acquisition of syntactic dependencies requires that learners both identify the relationships and the ways they are marked in their language, and become adept at deploying their knowledge online during language production and comprehension. Questions in the study of syntax acquisition address both parts of this process: How do children acquire syntactic dependencies, and how do children still mastering the dependencies begin to use them in language processing?

One long-standing question concerns how children represent the various linguistic dependencies they are acquiring, and how those representations shape children's use of dependencies in comprehension and production. Do they treat them as dependencies of meaning or of form? Do they store their knowledge with respect to the particular lexical items or with respect to the abstract categories that participate in the dependencies? These are not dichotomous choices to be made, but two orthogonal dimensions along which children's representation and use of dependencies may vary. These two dimensions are outlined below.

Form and Meaning

As children discover and begin to learn about the patterns syntactic dependencies create in the input, and as they begin to rely on those patterns to facilitate sentence comprehension and production, do they treat them as formal dependencies, or as dependencies of meaning?

In principle, children might do either or both. They might begin by learning about the semantic relationships among words in an utterance (e.g., AGENT of an ACTION, PROPERTY of an ENTITY), and over time develop semantically abstract syntactic representations of the relationships involved (e.g., SUBJECT, which in a passive sentence refers to the patient, not the agent of the action; Bowerman, 1973). Alternatively, children might begin by learning about the patterns in which words typically combine, and identify different syntactic categories (e.g., NOUN, VERB) and their combinatorial consequences from an early age (e.g., Valian, 1986). Children might also engage in a combination of these strategies, using both combinatorial information and meaning to learn about the relationships among words (e.g., Lany & Saffran, 2010).

Determining to what degree learners treat a dependency as form- or meaning-based can be difficult, because mappings between syntactic and semantic properties, though not perfect, are highly consistent. This means that in most cases there is a great deal of overlap in the outcomes the two strategies would produce. Distinguishing between them requires examining children's interpretation and use of structures with a non-canonical mapping between syntactic and semantic properties (e.g., syntactic and semantic role assignment in passive sentences, grammatical and notional number for pluralia tantum nouns: *my glasses **are** broken*). In these cases, the balance of form- and meaning-based representation is easier to see. For instance, if children treat grammatical role as a relatively direct indicator of meaning, they should default to the canonical mapping of syntactic position onto participant role (SUBJECT = AGENT), regardless of context. In contrast, if they recognize grammatical role as a primarily formal relationship, they may more successfully map syntactic positions onto non-canonical participant roles (for some verbs SUBJECT = EXPERIENCER, in passive sentences SUBJECT = PATIENT).

Lexical and Abstract Knowledge

Whether children treat a particular dependency as primarily form- or meaning-based, they may be storing what they know in one of two ways: with respect to abstract categories or with respect to the particular lexical items that participate in the dependency.

For instance, children might identify abstract syntactic or semantic categories (e.g., syntactic SUBJECT, or semantic AGENT), and anchor their learning and use of dependencies to those categories (Bowerman, 1973; Fisher, 2002; Pinker, 1984; Valian, 1986). On the other hand, children might first learn

about the combinations of meaning or form that particular words permit, and only over time begin to generalize those patterns across words (e.g., [kicker] KICK [kick-ee] and [hugger] HUG [hug-ee], over time become AGENT ACTION PATIENT, and/or SUBJECT VERB OBJECT; Tomasello, 2003). Again, it is possible that children engage in both types of learning, tracking both the combinatorial habits of particular lexical items, and patterns at the level of categories.

Investigating to what degree children store early knowledge of linguistic dependencies with respect to the participating lexical items or abstract categories typically requires examining their ability to generalize their knowledge to novel words. If children store knowledge primarily with respect to abstract syntactic or semantic categories, they should be able to generalize their knowledge to a new category member with relative ease. In contrast, if children store their knowledge primarily with respect to particular lexical items, and only create abstract rules after learning many instances of the same patterns, applying knowledge to a novel word should be difficult or impossible until such a rule has been created.

In the next two sections, I briefly review existing research on children's acquisition of word order and morphological marking as indicators of syntactic dependencies, with respect to the two dimensions of representation outlined above: form or meaning and abstract or lexical knowledge. I then describe the goals of the current project, and give a more extensive review of the relevant literature.

1.1.1   Word Order

English relies primarily on word order to indicate the major syntactic relationships within the sentence, though it also retains the vestiges of a more elaborate morphological system, including case-marked pronouns (e.g., *he* vs. *him*) and agreement (e.g., *I am, you are, he is*). Word order is often considered to be a stronger cue to participant role than agreement, case-marking or even animacy in English, because preschoolers and adults rely more heavily on word order cues than other types of information when they interpret a variety of grammatical and ungrammatical sentences designed to pit cues against each other (E. Bates et al., 1984; MacWhinney, Bates, & Kliegl, 1984).

A wide variety of studies have addressed, both directly and indirectly, how children acquire and represent this link between word order, syntactic position, and thematic role. Consistent with its central role in English, English word order appears to be learned quite early: 17-month-olds look longer at a matching video while hearing a reversible transitive sentence with a familiar verb (e.g., *Big Bird is tickling Cookie Monster.*, Hirsh-Pasek & Golinkoff, 1996). Twenty-one-month-olds succeed in a parallel task in which the pictured event is described with a novel verb (e.g., *The boy is gorping the girl.*, Gertner, Fisher,

& Eisengart, 2006), and 25-month-olds succeed with novel verbs even in a task that requires an explicit pointing response (Dittmar, Abbot-Smith, Lieven, & Tomasello, 2011), suggesting that toddlers' representation of word order in simple transitive sentences is abstract, rather than lexically specific, from quite early.

Because these studies of toddlers' use of word order employ transitive verbs in active sentences, and events with canonical agent and patient roles, they do not bear directly on the question of whether children's underlying representations are form- or meaning-based. Children might succeed in these studies either by using word order as a direct semantic cue to the most frequently associated participant roles (i.e., pre-verbal noun = AGENT), or as a cue to syntactic role, followed by a mapping of that syntactic role onto the participant roles displayed (i.e., pre-verbal noun = SUBJECT, and in this context SUBJECT = AGENT). Distinguishing between these possibilities would require demonstrating that a sentence subject can be mapped onto other, less canonical roles, such as PATIENT in a passive sentence, or EXPERIENCER of a mental state verb.

Unfortunately, such structures tend to be rarer than their more canonical counterparts. This makes observations that, for instance, passives appear later and less frequently in children's production and are more difficult for children to interpret than actives, inherently ambiguous (e.g., Fraser, Bellugi, & Brown, 1963; Horgan, 1978; Savage, Lieven, Theakston, & Tomasello, 2003). Children's difficulty might stem from needing to override underlying semantic representations of word order, or from the unfamiliarity of the structure itself.

Existing evidence suggests that both structure and meaning play a role in preschoolers' representation and use of word-order. Five- and 6-year-olds' production of the passive can be primed, even when there is no lexical overlap between the prime and the target sentence (Huttenlocher, Vasilyeva, & Shimpi, 2004; Messenger, Branigan, McLean, & Sorace, 2012; Savage et al., 2003). This suggests that children have access to an abstract representation of that structure. However, other evidence suggests that children also have a preference for assigning canonical semantic roles to particular syntactic positions: Despite their relatively high frequency, preschoolers find it more difficult to interpret emotion verbs whose subject is the experiencer (e.g., *like, miss, fear*) than emotion verbs whose subject is an agent (*hurt, scare, surprise*; Hartshorne, Pogue, & Snedeker, 2014).

Thus, word order, which serves as the primary cue to the major syntactic relationships in the sentence in English, appears to be learned quite early, and is represented in a lexically abstract way from an early age. Several studies suggest that both structure and meaning play some role in preschoolers' representation and use of word order, but little or no evidence is available about whether toddlers treat word order as a primarily formal syntactic relationship, which they map onto meaning as appropriate, or whether they treat it as a primarily meaning-based relationship.

1.1.2   Morphosyntactic cues

Though arguably secondary to word order in English, a variety of morphosyntactic cues also mark syntactic relationships within the sentence. Case-marking on pronouns indicates syntactic role (e.g., SUBJECT), and agreement highlights the link between subject and verb and between determiner and noun, among other relationships. How do children represent these morphosyntactic dependencies?

Case

In English, case-marking is restricted to animate pronouns: The form of the pronoun depends on the syntactic role it plays in the sentence (see examples in (1)). Because animate pronouns are a closed class, novel case-marked forms are unavailable in English, making it essentially impossible to investigate where children's knowledge falls on the continuum from abstract to lexical. Furthermore, like word order, case-marking tends to align with canonical participant roles (e.g., nominative *he* is typically an agent, accusative *him*, a patient), making it difficult to determine where case-marking falls on the continuum between syntactic and semantic representation (e.g., SUBJECT vs. AGENT).

(1) a. *He* saw *him*.

   b. *She* called *her*.

   c. *It* fell on *him*.

   d. *He* broke *it*.

However, one study does appear to differentiate between these latter possibilities. Ibbotson, Theakston, Lieven, and Tomasello (2010) showed that 2- and 3-year-old children use case-marked pronouns in English to facilitate processing of the structure of the sentence, not just to assign canonical participant roles, suggesting that their representation of case is not solely semantic. Ibbotson et al. used a pointing task to assess children's interpretation of active and passive sentences with a novel verb and one or two case-marked pronouns as arguments (e.g., active with one case-marked pronoun: *He is tamming it*; passive with two case-marked pronouns: *He is getting tammed by her*, etc.). Passive sentences are a particularly interesting test-case because they reverse the typical mapping between syntactic and semantic roles, and therefore between case-marking and participant roles: In the passive, the nominative pronoun (*he, she*) is the patient of the event described and the accusative pronoun (*him, her*) is the agent.

If children represent case-marking as a direct cue to semantic role, they should misinterpret passive sentences as active. That is, if children have learned from patterns in the input that *she* tends to be an agent rather than a patient, they may assign the nominative pronoun the agent role, and the accusative pronoun the patient role, regardless of the structure of the sentence in which they occur. Instead, Ibbotson et al. found that even children in the youngest age group tested (average age 2;10) were best able to differentiate between

active and passive sentences when both pronouns were case-marked, precisely the situation that should have been most misleading if children treated case-marked pronouns as direct markers of participant role. The authors suggest that this is the result of children's familiarity with these pronoun frames and with the active and passive constructions. Whether this knowledge is represented in terms of particular constructions and pronoun frames or in terms of syntactic categories and features, these data suggest that children do not represent case-marking as a direct indicator of semantic role.

Thus, though case-marking presents many of the same difficulties for investigating children's representations that word order does, there is some evidence that young English-learners can use case-marked pronouns to facilitate comprehension even when they do not map onto their canonical participant roles, and even with respect to a novel verb. This suggests that children as young as 2 and 3 represent case-marked pronouns as part of a system marking syntactic relationships within the sentence, not as something that indicates particular semantic interpretations directly.

Agreement

Agreement comes in many forms, but all agreement involves a *target* (e.g., verb, determiner) that reflects syntactic features (e.g., grammatical gender or number) of a *controller* (e.g., subject noun phrase, head noun; Corbett, 2006), see examples in (2). While word order and case-marking serve to indicate the major structural relationships in the sentence, agreement marks a variety of different syntactic dependencies. This variety, and the variety of features that agreement marks, make it a useful test case for investigating young children's representation and online use of linguistic relationships.

(2) Types of Agreement

    a. *He* talked to *his* friend. PRONOUN

    b. *They are* going to call tomorrow. SUBJECT-VERB

    c. *Those flowers* you sent bloomed for weeks. DETERMINER-NOUN

An agreement target reflects properties of its controller (e.g., person, grammatical number), not its own status in the sentence (e.g., SUBJECT, as a case-marked pronoun does). This makes it easier to determine whether children represent the relationship in a primarily abstract or lexically specific way: If a particular type of agreement is learned with respect to the specific lexical items that participate in the relationship, then making the agreement controller a novel word should disrupt children's ability to use agreeing forms appropriately in production and comprehension (e.g., a novel subject noun phrase *the blickets are/is...*).

Because agreement reflects properties of its controller, it is tied to different aspects of meaning than case and word order are (e.g., grammatical number, not

syntactic role). This permits investigation of the second dimension of interest, the degree to which the dependency is represented in terms of form or meaning, without resorting to infrequent structures like passives. Instead, for instance, we can manipulate the form-meaning congruence of the agreement controller (e.g., a single item named by a pluralia tantum noun: *my glasses*), and see which aspect determines children's choice of agreeing form (e.g., *it/they*, *is/are*).

Determiner-noun and subject-verb agreement have drawn the majority of the attention in research on agreement acquisition. In many languages, determiners agree with their nouns in number, as in English, and in grammatical gender. Evidence suggests that determiner-noun gender agreement is more form- than meaning-based, and is lexically specific. Three-year-olds can use gender agreement marked on a determiner to facilitate processing of the following noun (Spanish, Lew-Williams & Fernald, 2007; French, van Heugten & Shi, 2009). Children look more quickly to a target picture (e.g., *la galleta*$_{\text{FEM}}$, "the cookie") when the distractor picture is of a different grammatical gender (e.g., *el zapato*$_{\text{MASC}}$, "the shoe"), than when it is of the same grammatical gender (e.g., *la pelota*$_{\text{FEM}}$, "the ball"; Lew-Williams & Fernald, 2007). Though grammatical gender often aligns with biological gender for animate referents (e.g., *la niña*$_{\text{FEM}}$, "the girl", *el padre*$_{\text{MASC}}$, "the father"), for inanimate objects like those used in Lew-Williams and Fernald's study, there is no clear meaning associated with a word's grammatical gender category. Given this, children's use of grammatical gender to facilitate processing of a following noun suggests that they treat gender agreement as more of a syntactic than a semantic relationship during online comprehension. That is, gender-marked determiners seem to serve as a cue to which words may legally follow, not directly to likely upcoming meanings (Maratsos & Chalkley, 1980).

There is also good reason to suspect that the determiner-noun relationship in Spanish is initially learned with respect to particular lexical items rather than with respect to abstract categories of grammatical gender. Grammatical gender is a lexical property of a given noun, and it may even be the case that children initially fail to parse off the most frequent agreeing determiner, treating it as the word's first syllable for some time, before beginning to treat it as a separate morpheme (e.g., Arnon & Ramscar, 2012).

The story is less clear for subject-verb agreement, in part because research has frequently focused on different questions, especially whether a regular verb marked for tense and agreement is represented as a whole or as a combination of root and affix (he *looks* vs. *look-s*, e.g., Berko, 1958; Marcus et al., 1992; Pinker & Ullman, 2002). Subject-verb agreement is a very different dependency than determiner-noun agreement. The determiner-noun relationship is a particularly intimate context for agreement: Determiners and nouns are typically adjacent, and always occur in the same linear order. In contrast, subject-verb agreement spans two major sentence constituents, and the order of the dependent elements varies (e.g., *The apples are sweet.* vs. *Are the apples sweet?*).

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Furthermore, in English an agreeing verb reflects the grammatical number of its subject, and for most nouns, grammatical number is not a property of the word, but varies depending on the intended meaning (e.g., one *apple*, many *apples*).

Existing research suggests that preschoolers and even toddlers most likely represent agreement as primarily syntactic, rather than meaning-based, and that it is unlikely to be lexically specific. An agreeing verb does not easily convey information about subject number in offline comprehension tasks (e.g., Blossom, 2013; V. E. Johnson, de Villiers, & Seymour, 2005; Nicolaci-da Costa & Harris, 1984), as it would be expected to do if number agreement were treated as a meaning-based relationship. For instance, children do not reliably use an agreeing verb-form to infer the number of an ambiguous subject noun phrase until the age of 5 or 6 (e.g., *the ducks swim in the pond*, where the initial /s/ of *swim* hides the final /s/ of *ducks*; V. E. Johnson et al., 2005).

Even so, preliminary evidence suggests that an agreeing verb may help facilitate comprehension when the agreement controller is a novel noun, suggesting that agreement may be lexically abstract. Twenty-four-month-olds looked longer at a matching picture while hearing a sentence with multiple cues to number, but not when the sentence had only a single cue (e.g., *There are some blickets!* vs. *Look at the blickets!*, Kouider, Halberda, Wood, & Carey, 2006). This study provides important initial evidence that an agreeing verb may facilitate online comprehension of agreement: Children in the multiple-cues condition began looking at the target picture before noun onset. However, because the verb was immediately followed by a number-marked quantifier, it is difficult to pinpoint the source of this facilitation. Furthermore, other investigations of children's ability to use an agreeing verb in comprehension that have used novel noun subjects have not met with success, though there are many differences in methodology and design (Blossom, 2013; Keeney & Smith, 1971).

Thus it appears that young children treat subject-verb agreement as a primarily syntactic, and possibly as a lexically abstract dependency. The literature investigating young children's acquisition of agreement is reviewed in more detail below (see section 1.2.2).

As reviewed in Section 1.1, syntactic dependencies offer a window into the role of semantic and syntactic knowledge in language acquisition. Though syntactic dependencies are ultimately represented as primarily syntactic, they often align closely with semantic relationships. Thus, young learners might, in principle, represent them anywhere along the continuum from syntactic to meaning-based. Similarly, though syntactic dependencies are ultimately relationships among categories of words, learners may treat them as anything from lexically specific to fully abstract. Different dependencies may fall in different places on these two dimensions of representation, and further investigation of where particular dependencies fall has the potential to inform our understanding of how children acquire, represent, and process linguistic relationships.

1.2 The Current Project

The current project uses subject-verb agreement as a tool to address both long-standing questions about children's acquisition and representation of linguistic dependencies, and more recent questions about young children's use of linguistic dependencies in language processing. To do this, we investigate English-learners' use of subject-verb agreement in production and comprehension.

1.2.1 Subject-Verb Agreement

English verbs agree with their subjects in person and grammatical number, but English agreement is quite minimal (Corbett, 2006). With the sole exception of BE, English verbs have only one agreeing form that differs from the others: the third-person singular present tense (Huddleston & Pullum, 2002; see examples in Table 1.1). Grammatical number has a clear conceptual parallel in the number of objects under discussion, or notional number. Grammatical and notional number usually coincide, but do not align perfectly. For instance, though (3a) and (3b) refer to different numbers of napping felines, (4) can be used equally well to describe a single tool as to describe dozens waiting for an elementary school art class: The word *scissors* is always grammatically plural and takes plural agreement in both situations.

(3)   a. The cat is sleeping.

        b. The cats are sleeping.

(4)   The scissors are dull.

Agreement is traditionally analyzed as a primarily syntactic relationship: It is the grammatical number of the subject, not the conceptual number of the thing it describes, that governs the verb's form (Corbett, 2006). However, most object names, and therefore the majority of early vocabulary items (Samuelson & Smith, 1999), are count nouns. Because count nouns' grammatical number does vary with conceptual number (e.g., one *flower*, many *flowers*), in third-person sentences the correlation between the number of referents and the form of the agreeing verb will be high, and either semantic or syntactic strategies will provide reasonably good accounts of the observed input. How, then, is agreement represented and used during production and comprehension?

I first review the psycholinguistic evidence that subject-verb agreement is treated

Table 1.1: The English agreement paradigm for irregular verb BE and regular verb WRITE

BE	**Singular**	**Plural**	WRITE	**Singular**	**Plural**
1st p.	I am	We are	*1st p.*	I write	We write
2nd p.	You are	You (all) are	*2nd p.*	You write	You (all) write
3rd p.	She is	They are	*3rd p.*	He writes	They write

as a primarily syntactic dependency by adult English-speakers. I then review three threads of research on the acquisition of subject-verb agreement that, taken together, suggest agreement may be syntactic from the start. Finally, I conclude the introduction by describing an initial study indicating that an agreeing verb can serve as an informative cue to facilitate both adults' and children's sentence comprehension, and even supports pre-activation of the likely features of an upcoming subject.

Adult Agreement Production

Language production involves taking an intended meaning and generating an utterance to convey it. For the purposes of agreement, there are two crucial elements that must be selected: the subject noun phrase and the form of the verb (see Bock & Middleton, 2011 for review). The subject noun phrase is chosen on the basis of the intended meaning. Its grammatical number depends on the particular lexeme selected, the structure of the noun phrase, and the conceptual number of the referent. There are two primary classes of theory about how the verb-form is selected. Some theories suggest that the verb-form can to some extent be directly influenced by the conceptual number of the subject's referent (e.g., Haskell & MacDonald, 2003; Vigliocco & Hartsuiker, 2002; for an extreme example of this position, see Reid, 2011), while others suggest that the verb-form is fully governed by the grammatical number of the subject noun phrase, though the grammatical number assignment is itself influenced by the conceptual number of the referent (e.g., Bock & Middleton, 2011; Eberhard, Cutting, & Bock, 2005).

Whatever the precise mechanism, adults appear to treat agreement as primarily syntactic in production: even agreement errors are driven by the grammatical properties of interfering nouns, rather than their conceptual properties (e.g., Bock, Eberhard, & Cutting, 2004). For instance, in sentence production tasks, in which adult speakers are asked to complete preambles like the one shown in (5), participants are more likely to produce an erroneous plural-agreeing verb-form following a complex subject with an embedded grammatically plural noun than one with an embedded singular noun (e.g., *needle*). This is true regardless of whether the intervening grammatically plural noun refers to a single item or to more than one: Participants in a norming study confirmed that while regular plural nouns like *needles* are taken to refer to more than one item, pluralia tantum like *tweezers* are treated as conceptually singular (Bock et al., 2004, Exp.5). The fact that speakers make more errors in the context of a grammatically but not notionally plural local noun suggests that the mechanism by which they compute the agreement relationship is susceptible to purely grammatical interference, and therefore syntactic.

   (5)   The drawer for the needles/tweezers...

Another suggestion that subject-verb agreement is primarily syntactic comes

from studies that compare verb and pronoun agreement. Pronouns agree with their antecedents in person, gender and number, but in contrast to verb agreement, pronoun agreement is traditionally analyzed in terms of discourse or semantic reference. That is, pronouns refer back to particular referents in the discourse context, and thus are more heavily influenced by conceptual properties of their agreement controllers than verbs are. Comparisons of verb and pronoun agreement, using sentence completion tasks in which participants repeat and complete a preamble with either an agreeing verb (see (6a)), or a tag question containing a pronoun (see (6b); Bock et al., 2004), suggest that subject-verb agreement is comparatively insensitive to the notional properties of the head noun. Given a collective singular head (e.g., *team*), which is grammatically singular, but refers to multiple individuals, participants produce 44% plural pronouns, but only 12% plural verb agreement (Bock et al., 2004; Exp. 3). This suggests that, in contrast to pronoun agreement, subject-verb agreement is primarily controlled by the grammatical properties, rather than the conceptual properties of the subject.

(6) a. The team with the commercial contract was/were...

b. The team with the commercial contract won, didn't it/they?

However, when participants were given an individual singular head noun, which is both grammatically and conceptually singular (e.g., *player*, as in (7); Bock et al., 2004), they produced only 2% plural verb-forms. Thus the 12% plural verb agreement produced in response to preambles with notionally plural heads represents a substantial increase in plural agreement from baseline: an effect of conceptual number on verb agreement.

(7) The player with the commercial contract...

Other findings suggest that participants' construal of the entire noun phrase, not just its head noun can influence agreement production. When asked to complete preambles containing individual singular head nouns, whose meaning suggested that they describe a single referent distributed over multiple instances (e.g., one picture replicated across many postcards, as in (8a)), participants produced more plural agreement than when they completed preambles with individual singular head nouns, whose meanings did not suggest distributive interpretations (e.g., a single road to many mountains, as in (8b), Eberhard, 1999).

(8) a. The picture on the postcards...

b. The road to the mountains...

The source of such notional effects on subject-verb agreement production is the subject of current debate, with positions ranging from treating the choice of verb-form as a separate communicative choice (Reid, 2011), to treating the choice of verb-form as the result of the application of lexical and grammatical

constraints of varying strengths (Thornton & MacDonald, 2003), to treating agreement as fully syntactic, with occasional faulty grammatical number marking on the subject NP (Bock et al., 2004; Bock & Middleton, 2011).

The relative size of the notional and grammatical effects on adults' agreement production, and the fact that agreement appears to be susceptible to purely grammatical interference suggest that adults' use of agreement in language production is primarily syntactic, but influenced, directly or indirectly, by notional number. Does adults' use of agreement in language comprehension follow similar patterns?

Adult Agreement Comprehension

In contrast to production, which begins with meaning and ends with a linguistic utterance, the comprehender must use the incoming linguistic signal to infer the intended meaning. Comprehenders do this incrementally, making use of each crumb of linguistic information as they hear it (Allopenna, Magnuson, & Tanenhaus, 1998). For the purposes of agreement, this makes for two very different potential comprehension scenarios: one in which the listener first hears the subject of the sentence, followed later by the verb, and one in which the listener hears the agreeing verb first, followed by the subject. Though basic English word order puts the subject before the verb (as in (9a)), this order is reversed in common sentence types including questions and locative inversions. Compare the sentences in (9).

(9) a. The flowers are blooming.

  b. Are the flowers blooming?

  c. Where are the flowers?

  d. There are flowers in the garden.

In many ways, the information available to a listener hearing (9a) is parallel to the information available to the speaker. Once the subject of the sentence has been uttered, the listener has access to both its grammatical and its notional properties, and in principle could use those to determine what agreement features to expect on the verb. Indeed, studies of agreement comprehension in which the subject precedes the verb typically show patterns of processing ease and difficulty that align well with the patterns of errors speakers make (e.g., Pearlmutter, Garnsey, & Bock, 1999; Wagers, Lau, & Phillips, 2009), suggesting that like agreement production, agreement comprehension may be primarily syntactic.

Electrophysiological evidence on adult agreement processing also comes from studies using a subject-first word order, and results are consistent with the possibility that agreement is primarily syntactic. Agreement errors typically elicit a P600 (e.g., Hagoort, Brown, & Groothusen, 1993; Osterhout & Mobley, 1995), an ERP component commonly found in response to other syntactic violations

(e.g., pronoun case, Coulson, King, & Kutas, 1998; tense violations, Allen, Badecker, & Osterhout, 2003), rather than an N400 effect, which is typically associated with the ease or difficulty of accessing and integrating meaning (e.g., Federmeier & Kutas, 1999; Kutas & Hillyard, 1980). This suggests that agreement errors are treated as unlikely or ungrammatical elements in the sentence, not as anomalous meaning-bearing elements.

In principle, however, comprehenders might treat inverted sentences such as (9b) differently, and to date there is little research examining the use of agreeing forms during comprehension of inverted sentences. Because comprehension is incremental, and in these sentences the verb agreement arrives first, listeners will likely use any information it carries as best they can to infer what might be coming next. The inferences a listener draws in such situations may be quite different than the inferences drawn when the subject is known. Because of the preponderance of count nouns in the language, listeners may have a baseline expectation that number agreement signals the notional number of the upcoming subject. Relying on this baseline expectation may result in agreement operating more directly through meaning during comprehension of inverted contexts than during production or during comprehension of subject-first utterances.

Thus, existing evidence suggests that agreement is primarily syntactic in comprehension as well as in production, but questions remain about how the order of incoming information affects agreement processing, and how children initially represent and use the dependency.

1.2.2 Acquisition of Agreement

Ultimately, subject-verb agreement must be learned as a syntactic dependency. However, there are many ways learners might arrive at this eventual state: Do they begin with meaning-based representations of the dependency, and eventually arrive at semantically-abstract representations? Do they track agreement with respect to the particular word forms that participate in the dependency, or do they track agreement with respect to abstract categories such as SUBJECT and VERB? Three threads in the acquisition research suggest that agreement may be learned as a formal, abstract dependency from the start. Below, I review each of these threads of research in turn.

Distributional Learning

Artificial grammar learning studies demonstrate that infants and toddlers can successfully learn about meaning-independent patterns in stimuli in just a few minutes of exposure (Marcus, Vijayan, Rao, & Vishton, 1999; Saffran, Aslin, & Newport, 1996). This suggests that children can begin learning about syntactically relevant distributional categories (e.g., nouns, verbs) and dependencies (e.g., agreement) even before the elements they are tracking have been tied to meaning (e.g., Aslin & Newport, 2012; Mintz, 2003). For instance, 12-month-

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olds can use probabilistic distributional cues to assign novel, meaningless words to rudimentary categories (Gómez & Lakusta, 2004), and can use early exposure to adjacent dependencies to facilitate later discrimination of the same dependencies in non-adjacent positions (Lany & Gómez, 2008). Such abilities may play an important role in infants' acquisition of natural language categories and dependencies. However, it is not clear that these abilities scale up to the problem of natural language learning. When Gómez and Lakusta (2004) gave 12-month-olds probabilistic distributional cues with variability approaching that of natural language (67% consistent marking), they failed to learn and generalize the category assignment after a brief training period. Similarly, 12-month-olds do not successfully learn non-adjacent dependencies when they are not supported by earlier adjacent learning (Gómez & Maye, 2005).

Though toddlers fail to discover artificial categories and non-adjacent dependencies over short exposures when the input has relatively high variability or weak early support for the pattern of interest, other evidence suggests that children's early distributional learning may play a role in natural language learning. First, contexts with greater variability are not always problematic for children. When the intervening element in a non-adjacent dependency is more variable, it appears to highlight the invariance of the surrounding dependency and facilitate learning (Gómez, 2002). Second, there is modeling evidence that distributional cues alone can be used quite effectively to pick out natural language categories in corpora of child-directed speech (Mintz, 2003). It is also important to note that in comparison to the amount of exposure children get to the artificial grammars in these studies, their natural language input is vast. Thus, children's distributional learning abilities may be better suited to the task of natural language learning than they first appear.

Indeed, other studies demonstrate that children show sensitivity to a variety of distributional patterns in natural language. In a listening-preference task, English-learning 18- but not 15-month-olds listen longer to passages containing the grammatical sequence *is* VERB-*ing* than to passages containing the ungrammatical sequence *can* VERB-*ing*, suggesting that they have learned this common pattern across the verb root (Santelmann & Jusczyk, 1998; for similar results in German, see Hohle, Schmitz, Santelmann, & Weissenborn, 2006). English-learning 16-month-olds also listen longer to passages with legal sequences of function and inflected content words (e.g., *they used to sing in these chairs on the porch*) than to passages with illegal sequences (**they used to sings in these chair on the porch*; Soderstrom, White, Conwell, & Morgan, 2007). These findings suggest that infants track non-adjacent dependencies between function words, such as auxiliaries, modals and determiners, and noun and verb affixes.

There is also evidence that infants are sensitive specifically to the distributional patterns that agreement creates in the input. Nineteen-month-old English-learners listened longer to sentences with legal rather than illegal combinations of affixes (*the team bakes bread* vs. **the team bake bread*; Soderstrom,

Wexler, & Jusczyk, 2002). This is not due to a general preference for the /s/ affix, since 19-month-olds listened no longer to sentences that are ungrammatical because they are over-inflected (e.g., *the boy does bakes bread*) than to sentences that are appropriately inflected (e.g., *the boy does bake bread*; Soderstrom, 2002). Similar findings in French demonstrate that 17-month-old Canadian French-learners are sensitive to the dependency between a number-marked determiner and the form of the verb, even across an intervening novel noun (e.g., *la fotiste*[1] *est parfois...* vs. **les fotiste(s) est parfois...*, van Heugten & Shi, 2010). These findings suggest that by the middle of their second year, children have already discovered and begun learning about the dependency between the form of the subject and the form of the verb.

Of course, demonstrating sensitivity to the distributional patterns that agreement creates in the input does not imply full knowledge of the agreement system. Even so, these and similar findings have led to a broad consensus that distributional learning might create categories and dependencies at least partly independent of meaning (e.g., Aslin & Newport, 2012; Connor, Fisher, & Roth, 2013; Mintz, 2003; Naigles, 2002; Soderstrom, 2008). If so, young learners' knowledge of the agreement dependency might begin as familiarity with particular patterns of word forms or affixes, and number morphology might only later be tied to number-meaning.

Production

There is a great deal of research on young children's production that is relevant to the acquisition of agreement. One well-known pattern in studies of early sentence production is that young children frequently omit function words and function morphemes from their early utterances (e.g., Brown, 1973; Wexler, 1994). A wide variety of explanations have been proposed for such omissions, ranging from differences between the child and adult grammars (e.g., Rizzi, 1993; Wexler, 1994, 2011), to the difficulty of producing unstressed function morphemes in consonant clusters or in certain positions in the prosodic structure of the sentence (e.g., Gerken & McIntosh, 1993; Song & Demuth, 2008; Song, Sundara, & Demuth, 2009), to patterns of familiarity and lexical co-occurrence (e.g., Pine & Lieven, 1997; Rubino & Pine, 1998; Theakston, Lieven, & Tomasello, 2003).

Children's patterns of agreement omission are particularly interesting. From the time they begin producing verbs until they are 3 or 4 years old, children frequently produce non-finite verb-forms in place of adult-like inflected forms (Rizzi, 1993; Wexler, 1994, 2011). During this Optional Infinitive stage, English-learners tend to produce bare forms of regular verbs (e.g., *he go*) and omit the copula and auxiliaries (e.g., *that pretty*), but learners of languages with a marked infinitive form appear to identify the infinitive as the default and

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[1]*fotiste* is a phonotactically legal, but unattested word of French.

produce it in place of an inflected form (e.g., *pas manger la poupee*, "not eat_{INF} the doll": Pierce, 1992, cited in Wexler, 2011). The Optional Infinitive stage can make asking questions about children's knowledge of the agreement system difficult, but evidence suggests that when children do produce agreeing forms, they are almost invariably correct (Keeney & Wolfe, 1972; Wexler, 2011). This pattern suggests that children may have a strong grasp of the agreement system, but that their knowledge is being cloaked by other properties of an immature grammar, or by production difficulties unrelated to the agreement dependency itself.

One important consideration, however, is that most subjects in casual speech are singular. Thus, studies of spontaneous production, such as the majority of those cited above, do not permit many opportunities for observing agreement with plural subjects. When sentences with singular and plural subjects were examined separately in a corpus of one Brazilian 3-year-old's spontaneous Portuguese, average accuracy was much lower across the few plural subjects than across singular subjects (Rubino & Pine, 1998). A similar contrast was found in an elicited production task in English in which 3-year-olds produced auxiliary *is* and *are* in yes-no and wh-questions. Children were much more likely to produce agreement errors in questions with plural subjects than in questions with singular subjects (Theakston & Rowland, 2009). This suggests that the overall high accuracy of agreeing forms observed in other studies may be at least partially an artifact of children's facility with one frequent agreeing form, and not an indication of mastery of the system.

Several studies have attempted to address the question of how and when children master agreement as a system. Does their production of agreeing forms indicate that they treat the forms as part of a paradigm, or do different forms appear to develop and operate separately? In one such study, Rissman, Legendre, and Landau (2013) primed 32-month-olds to include auxiliary verbs in their descriptions of simple scenes (e.g., *the bees **are** flying*). Thirty-two-month-olds are squarely in the Optional Infinitive stage, and therefore frequently omit auxiliaries in their spontaneous utterances. Rissman et al. found evidence of both same- and cross-form priming, suggesting that 32-month-olds treat *is* and *are* as related forms of the same verb, not as separate, unrelated words. Similarly, Rispoli, Hadley, Holt, Smith, and Loeb (2012) found evidence that 33-month-olds' production of forms that express the same tense, person and number combination, *is, -s,* and *does*, are correlated with each other more strongly than with forms that express other combinations (e.g., past tense *-ed*). These findings suggest that despite evidence that some forms may be harder for children to produce, especially in questions, which introduce the added difficulty of subject-verb inversion, in production even young learners treat agreeing forms as part of a single, interrelated system of morphemes.

Young children's high accuracy in choosing the appropriate form when they produce a finite verb and evidence that they treat agreeing forms as part of a

paradigm are both consistent with the possibility that children begin to acquire agreement by learning about the distributional patterns in the input, at least partly independently of number-meaning. Such distributional learning is, in principle, sufficient to support accurate agreement production. This possibility is further supported by children's marked difficulty using an agreeing verb-form as a direct cue to number-meaning, discussed next.

Offline Comprehension Tasks

Studies of children's use of agreement in offline comprehension tasks suggest that, unlike markers of linguistic number in the noun phrase, agreement does not easily carry number-meaning on its own. In one such study, children were shown two pictures that differed only in number (e.g., one vs. two ducks swimming in a pond) paired with a sentence in which the verb-form was the only audible cue to subject number (e.g., *the ducks swim in the pond*, the initial /s/ of *swim* hides the final /s/ of *ducks*; V. E. Johnson et al., 2005), and were asked to point to the picture that matches the sentence. Five- and 6-year-old children showed some sensitivity to the form of the verb in their picture selections, but 3- and 4-year-olds did not. Even in similar tasks using other strategies for disguising the plurality of the subject noun phrase, and other verbs (e.g., *the sheep are eating*; Leonard, Miller, & Owen, 2000; see also de Villiers & Johnson, 2007; Miller, 2012; Miller & Schmitt, 2013), sensitivity to verb agreement as a cue to subject number does not appear before age 4.

By contrast, when children hear multiple cues to linguistic number, or when the only cue to number-meaning is on the noun, they show much greater sensitivity to the number information being conveyed. In one task, 24-month-olds heard a description of the contents of a box and were permitted to search the box (e.g., *"Here **are** my **frogs** in the box! Can you reach?"*, Blossom, 2013; see also, Wood, Kouider, & Carey, 2009). After they withdrew one toy, the second having been surreptitiously removed by the experimenter, their search time was measured. Toddlers searched for another toy longer after hearing a description containing a plural-marked noun, or both a plural-marked noun and verb, but not after hearing a description in which the only cue to number was the form of the verb. This is also true of older children in explicit tasks. Leonard et al. (2000) found typically developing 4- and 5-year-olds were more accurate at choosing the appropriate picture when the only cue to number-meaning was on the noun (e.g., *the hats*) than when it was on the copula (e.g., *the sheep are eating*) or the third person singular (e.g., *the deer jumps*). Children were even more accurate when more than one cue was available in the sentence (e.g., *the cat jumps*). Similarly, even the 3- and 4-year-old participants in V. E. Johnson et al.'s 2005 study showed perfect accuracy in the foil trials, where number was redundantly marked on the noun and the auxiliary (e.g., *the lady is talking on the phone*).

Preschoolers do show some sensitivity to verb agreement in comprehension in a context where they are given no explicit task: German 3-year-olds looked longer to a matching picture (e.g., one vs. two girls feeding a dog) when they heard a sentence in which verb-marking was the sole cue to subject number (Brandt-Kobele & Höhle, 2010). Because the pronouns for *she* and *they* are homophonous in German, children hearing sentences like those in (10) must use the verbal affix to infer subject number and determine the intended referent. When a second set of children were shown the same stimuli, but were asked to point to the matching picture, they showed no sensitivity to verb agreement in either eye-gaze or pointing. This suggests that one reason children fail to show sensitivity to verb agreement in picture choice tasks may simply be task difficulty. However, the success of younger children in picture-pointing tasks when number is marked redundantly on both the noun and an auxiliary (e.g., Leonard et al., 2000; Nicolaci-da Costa & Harris, 1984, foil trials in V. E. Johnson et al., 2005) suggests that task difficulty is not the only barrier to children's success. Rather, using an agreeing verb as the sole cue to subject number appears to be an especially difficult task.

(10) a. Sie   fütter-t einen Hund. (Brandt-Kobele & Höhle, 2010)
         (she) feed-3SG a   dog.

      b. Sie   fütter-n einen Hund.
         (they) feed-3PL a   dog.

The one apparent exception to this pattern is the finding that French-learning 30-month-olds can use a number cue affixed to the verb as an indicator of subject number (Legendre, Barriere, Goyet, & Nazzi, 2010). In French, plural pronouns and determiners end in an *-s* that typically goes unpronounced. This final consonant is only audible when the following word begins with a vowel. In such contexts the final *-s* gets resyllabified, and pronounced as though it were the initial consonant of the following word. Though this liaison consonant is traditionally analyzed as part of the pronoun in which it originated, Legendre et al. (2010) argue that in modern spoken French, when the liaison consonant is pronounced as the initial phoneme of a verb, it is better analyzed as an agreement morpheme. Children saw pairs of videos accompanied by a sentence in which the only cue to subject number was the liaison consonant (see examples in (11)). Children in both preferential-looking and pointing versions of the task were more likely to choose the video of two boys kissing a novel object when hearing (11a) than when hearing (11b).

(11) a. Ils   embrassent le   tak. /izɛ̃bʁaslətak/
         They kiss   the "tak"

      b. Il embrasse le   gef. /ilɛ̃bʁasləgef/
         He kisses   the "gef"

The transition from pronoun to agreement is a common diachronic change for a morpheme to undergo (Givón, 1976). If French liaison has completed the

transition from clitic pronoun to agreement, 30-month-olds' successful use of liaison as an indicator of number-meaning is the earliest evidence that children can use an agreement morpheme in comprehension. However, this is not the only possible interpretation of the result: Other groups have used similar tasks as a diagnostic to determine whether a morpheme has completed this transition (e.g., Smouse, Gxilishe, de Villiers, & de Villiers, 2012). They argue that if the morpheme still readily carries number information, it has not yet completed the transition, and is better analyzed as a clitic. Thus, French-learners' ability to use liaison, a relatively rare, perceptually small cue, in comprehension is impressive, but may not be an example of early use of agreement in comprehension.

With the possible exception of French-learning 30-month-olds, there is little evidence that children can use an agreeing verb in comprehension before age 3 or 4. This forms a striking contrast to 2.5-year-olds' remarkably accurate production of agreement when they produce finite forms (e.g., Rissman et al., 2013), and is consistent with the possibility that young children learn agreement as a primarily formal dependency, not as a dependency based in meaning.

Production before comprehension?

Production before comprehension is a very unusual pattern to observe in acquisition. For most linguistic phenomena, children show evidence of comprehension well before they begin to competently produce the pattern. Indeed, in most cases children must understand how others are using a word or structure before they can begin using it to express their own thoughts. The earliest evidence that children are attaching meaning to particular word forms appears between the ages of 6 and 9 months (Bergelson & Swingley, 2012), but the median age for children to begin producing their first words is closer to 14 months (Fenson et al., 2000). Similarly, the earliest evidence for multiword sentence comprehension appears around 15 months (Hirsh-Pasek & Golinkoff, 1996), and 21-month-olds can even interpret word order with respect to a novel verb in comprehension (Gertner et al., 2006), despite the fact that they typically do not yet combine words in their own sentences. Why, then, do children begin to produce agreeing forms before they can demonstrate sensitivity to those same forms in comprehension?

One possible explanation is that children are insensitive to all linguistic cues to number, but this is not the case. As noted earlier, 2-year-olds look longer to a display showing multiple novel objects than to a display showing a single novel object when they hear a sentence with multiple linguistic cues to number (e.g., *There **are some** blicke**ts***!; Kouider et al., 2006). This effect even begins shortly after verb onset, providing an initial suggestion that verb agreement may be a useful cue for children. Two-and-a-half-year-olds can also accurately answer many questions about quantity (e.g., *Are all the bananas in the red circle?*, Barner, Chow, & Yang, 2009), and can use number-marking on

a novel noun to identify its referent (Jolly & Plunkett, 2008). In the latter task, children were shown a pair of similar novel animals on one screen, and a single different novel animal on the other screen. They heard one picture or the other labeled (e.g., *Look! Find the goom!* or *Look! Find the jeels!*). Across a series of trials, which type of animal was named, the number of each animal pictured and the presence of plural morphology on the novel word varied together. The novel words had not been previously introduced. Therefore, across trials, the only information available to children for determining their meaning was the inflectional morphology. Thirty- but not 24-month-olds were able to successfully track the information carried by the inflectional morphology and map the novel nouns onto the appropriate novel animals. Thus, young children are capable of using linguistic cues to number in a variety of comprehension tasks, which suggests that their difficulty using verb agreement in comprehension does not arise from a general insensitivity to linguistic number.

Rather, children seem to be specifically insensitive to number agreement as a cue to notional number. In one of the few studies that attempts to directly compare children's use of different cues to notional number, Nicolaci-da Costa and Harris (1983, 1984) found that 3- and 4-year-olds were best able to use number marking on a determiner or noun (*this/these sheep jumped*, *the girl/girls jumped*) as a cue to number-meaning, followed by forms of the auxiliary (*the sheep is/are jumping*), and then by regular verb agreement (*the sheep jumps/jump*; see also Leonard et al., 2000). Three- and 4-year-olds were asked first to complete a picture choice task, and then, using the same sentences, to complete an act-out task. The sentence was considered to be understood only if children produced the appropriate response in both tasks. Children showed an overall bias to respond with the singular, but for both singulars and plurals they responded more accurately to number-marked determiners and nouns than to number agreement on the auxiliary alone or to number agreement on a regular verb. This, in combination with findings that young children are sensitive to a variety of linguistic cues to number, suggests that children are specifically insensitive to number agreement as a cue to the notional number of the subject.

This suggests a different explanation: Children treat agreement as a primarily syntactic relationship from the beginning. If agreement serves as a pointer to the grammatical features of the subject, and not as a direct indicator of number-meaning, using agreement to determine subject number is a multi-step, potentially meta-linguistic undertaking. Furthermore, the sentences tested thus far typically employ canonical English declarative subject-first word order, with a clever trick to hide the subject number: either using an invariant plural noun as the subject (e.g., *sheep*), or disguising the noun morphology with an /s/-initial verb (e.g., *ducks swim*). If children do their best to fix reference upon hearing the subject regardless of number ambiguity, using an agreeing verb-form to determine subject number will often require revising their initial assumptions. Syntactic revision is difficult for young children (Trueswell, Sekerina, Hill, & Lo-

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grip, 1999), making children's use of agreement to determine subject number in these contexts even less likely.

Children's accurate use of agreement in production before comprehension, and the asymmetries between their use of agreeing verb-forms and noun morphology in comprehension suggest that they are treating agreement as a primarily syntactic relationship. That is, children appear to treat agreement as a rule about the way words may legally combine in sentences, and thus potentially as an indicator of abstract properties of the subject, not as an element that carries number-meaning on its own.

1.2.3   Using Agreement in Online Comprehension

Though treating agreement as primarily syntactic provides a neat explanation for children's difficulty using agreement as a direct cue to the subject's notional number properties in explicit agreement tasks, treating agreement as syntactic does not preclude its use in comprehension. If agreement is permitted to play its typical role in language, by predicting or checking the grammatical features of the subject noun phrase rather than having to carry number-meaning on its own, it may prove a more useful cue, even to young children.

Below I first review the literature on the development of incremental language processing and prediction, including studies that use morphosyntactic cues. I then describe a recent study demonstrating that both adults and 3-year-olds can use an agreeing verb as a cue to the properties of an upcoming subject during online comprehension.

Online Comprehension

Comprehension is an incremental process: Both adults and children use information from multiple sources as soon as it becomes available to interpret the sentence as revealed so far, and to predict likely continuations (Allopenna et al., 1998; Altmann & Steedman, 1988; Federmeier, 2007; Kamide, 2008; Kukona, Fang, Aicher, Chen, & Magnuson, 2011; Marslen-Wilson, 1987; van Berkum, 2008). This incremental use of multiple information-sources is an early-developing property of the comprehension system. For example, 2-year-olds use phonological evidence incrementally to identify words, and thus in a looking-while-listening task were quicker to look at a named picture (e.g., *doll*) if the distractor picture's name began with different phonemes (*ball* rather than *dog*; Swingley, Pinto, & Fernald, 1999).

Like adults, toddlers and preschoolers use word meanings and world knowledge to anticipate plausible nouns. For example, children use a semantically restrictive verb to drive looks to a plausible object referent (e.g., *drink* vs. *take the juice*), and they unite the semantic constraints of the subject and verb (*The dog hides...*) to anticipate a plausible object referent (the *bone* rather than independent associates of either hiding or dogs; Borovsky, Elman, & Fernald, 2012;

Borovsky, Sweeney, Elman, & Fernald, 2014). These effects can be measured before the onset of the target noun, yielding strong evidence for the pre-activation of words or their semantic features, given strong semantic constraints (see also Friedrich & Friederici, 2005). Such evidence suggests that young children, like adults, make implicit predictions about likely upcoming words as sentences unfold. These predictions speed computation of the speaker's meaning, making rapid language comprehension possible.

Children also use morphosyntactic cues in comprehension (e.g., Gerken & McIntosh, 1993; Kedar, Casasola, & Lust, 2006; van Heugten & Johnson, 2011; Zangl & Fernald, 2007). For example, 3-year-old Spanish speakers were quicker to look at a named target picture (e.g., *encuentra la pelota*$_{\text{FEM}}$, "Find the ball") when the distractor picture's name differed in grammatical gender (*el zapato*$_{\text{MASC}}$, "the shoe") than when it matched in gender (*la galleta*$_{\text{FEM}}$, "the cookie"; Lew-Williams & Fernald, 2007). Similarly, French-learning 2-year-olds used the gender (van Heugten & Shi, 2009) and number features of determiners during online processing (Robertson, Shi, & Melançon, 2012).

However, in all the studies mentioned above, effects of the determiner were measured in a window that included the target noun. Indeed, the only study that, to my knowledge, has tested for predictive use of functional morphology failed to find it: Robertson et al. (2012) found effects of French number-marked determiners (*les* vs. *le*) on 2-year-olds' comprehension in an analysis interval after target-noun onset, but not in an earlier interval between determiner and noun onset. Interestingly, adults showed the same pattern in a similar task (Dahan, Swingley, Tanenhaus, & Magnuson, 2000): Adult French speakers used gender-marked determiners to constrain the set of phonological competitors they considered upon hearing the target word's onset (avoiding looks to *la bouteille*$_{\text{FEM}}$ when hearing *le bouton*$_{\text{MASC}}$), but showed no tendency to look toward objects with gender-matching names in response to the determiner itself.

Given these findings, one might conclude that neither children nor adults pre-activate possible upcoming words on the basis of function word cues alone. Instead, they use the determiner to facilitate the identification of the target word only after encountering its initial phonemes. Another possibility, however, is that the short intervals tested did not provide sufficient time to generate an observable prediction (for discussion, see Dahan et al., 2000).

Two sets of findings support this possibility. First, several studies demonstrate that adults use function words to shape predictions derived from content words (e.g., Altmann & Kamide, 2007; Kamide, Scheepers, & Altmann, 2003; Kukona et al., 2011). For instance, when hearing the verb in a passive sentence (e.g., *The rabbit will be eaten by the fox*), adults directed anticipatory looks to a plausible agent (the fox), not a plausible patient (a cabbage), as required by the verb's passive morphology (Kamide et al., 2003). These effects appeared before target-noun onset, revealing pre-activation based in part on function morphology. Similar effects have been found for 5-year-old Mandarin speakers (Huang,

Table 1.2: Example stimuli from Lukyanenko and Fisher (in prep.)

Informative	Where are the good cookies?	*plural*
	Where is the good apple?	*singular*
Uninformative	Can you find the good cookies?	*plural*
	Can you find the good apple?	*singular*

Zheng, Meng, & Snedeker, 2013).

Second, another study demonstrates that adults use function words to predict upcoming referents (Tsang & Chambers, 2011). Cantonese speakers used shape classifiers to pre-activate compatible object names: They looked more at objects whose names could legally follow the classifier they heard, and did so before target-noun onset. This effect held even for objects that lacked the canonical shape associated with the classifier (e.g., one classifier typically occurs with names of long, thin, flexible objects, but is also used for keys), suggesting that these predictions are driven primarily by the classifiers' grammatical properties (predicting a set of co-occurring nouns), not their semantic content.

These findings suggest that previous failures to detect strong predictive effects based on function-word cues might be the result of the brief observation intervals function words typically afford, not something fundamental about language processing. Because subject-verb agreement is a longer-distance dependency, it is an ideal tool for investigating this possibility.

Using a Verb-form as a Cue to Subject Properties

By using subject-verb agreement, we were able to create a context in which an agreeing verb-form could be used to predict an upcoming noun phrase across a relatively long observation interval (Lukyanenko & Fisher, in prep., see also Lukyanenko, 2011). In a simple two-choice version of the visual world paradigm, 38-month-old and college-age participants heard sentences of two types: *informative* sentences were simple questions and locative inversions (e.g., *There are the good cookies!*, see Table 1.2) in which a number-marked verb preceded its subject noun phrase, while in *uninformative* sentences the target noun was not the subject of the sentence, and thus the verb gave no advance information about the target (e.g., *Look at the good cookies!*). Each sentence accompanied a pair of pictures that differed in number and object-type (e.g., one apple, two cookies). In this constrained context, the agreeing verb in informative trials predicts the upcoming noun: Upon hearing *"Where are..."*, a listener can reject a single item (one apple) as a referent for an anticipated plural subject. Such rejections should lead to faster, more frequent switches to the target in trials

Figure 1.1: Proportion looks to target from verb onset. Error bars represent standard error of the mean.
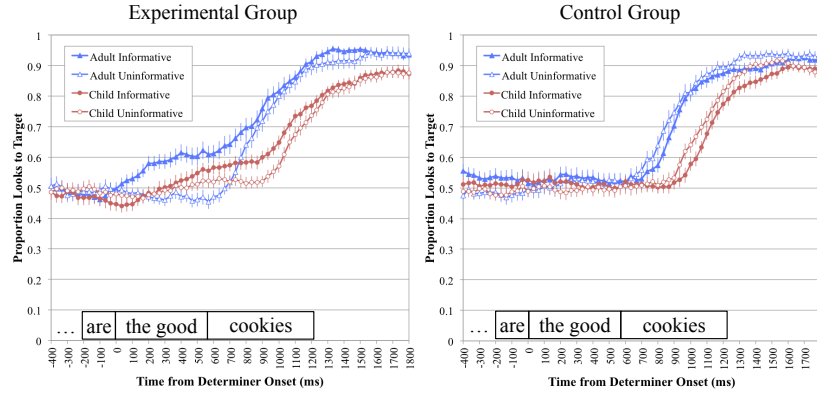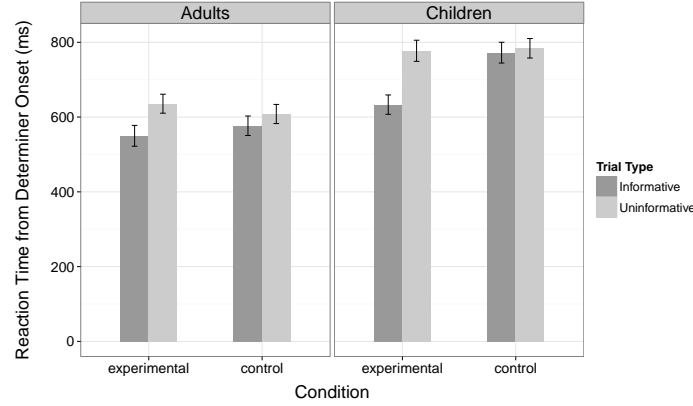

Figure 1.2: Latency of distractor-to-target saccades, measured from verb onset by trial type and age group. Error bars represent standard error of the mean.

where participants happen to be looking at the distractor at verb onset.

Figure 1.1 shows the proportion of looks directed to the target picture in the experimental condition described above and in a control condition in which the distractor picture always matched the target in number, rendering the agreeing verb in "informative" trials unhelpful in context. Adults and children in both conditions looked about equally to the target and distractor before the onset of the verb. In the experimental but not in the control condition, both adults and children made more fixations to the target in informative than in uninformative trials. This suggests that participants were able to use the informative agreeing verb to facilitate online comprehension.

To better quantify this increased tendency to look at the target, we examined two dynamic measures of looking behavior: the latency of participants' first shift from the distractor to the target in distractor-initial trials, and the proportion of distractor-initial trials that included a switch to the target before the onset of the noun.

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Figure 1.3: Pre-noun Switch Proportion: The proportion of distractor-initial trials that included a shift to target in the pre-noun window, by trial type and age group. Error bars represent standard error of the mean.
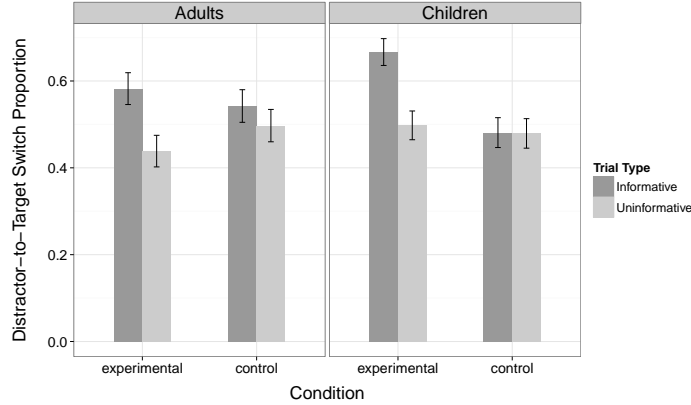

Figure 1.2 shows the average latency of participants' first shift from distractor to target. Adults were faster overall to shift than children were, and participants in both age groups were reliably faster to switch to the target in informative trials than in uninformative trials in the experimental condition, but not in the control condition. This informative advantage suggests that the presence of an agreeing verb in an informative context facilitates sentence processing, but because the window over which latency was calculated includes the noun itself, it is unclear whether the advantage is the result of pre-activation of likely features of the upcoming noun, or of facilitated integration of the noun into an informative preceding context.

Figure 1.3 shows the proportion of distractor-initial trials that included a shift to the target in a pre-noun window encompassing the verb, determiner and adjective (e.g., *...are the good...*), but ending before switches could be driven by information from the noun itself. Participants were reliably more likely to switch away from a number-mismatching distractor in informative trials than in uninformative trials in the experimental condition, but not in the control condition. Thus, the informative advantage appears even before the onset of the target noun itself, suggesting that both 3-year-olds and adults use the information carried by the agreeing verb to pre-activate features of the upcoming noun.

Participants' greater tendency to switch away from a mismatching distractor to the target in informative trials suggests that both adults and young children use agreement in online comprehension. The fact that facilitation appears before the onset of the target noun suggests that participants are using agreement to anticipate likely upcoming features of the subject (i.e., PLURAL vs. SINGULAR), not just to facilitate processing of the target noun once it arrives.

Interestingly, though not confined to plural trials, both of these effects were stronger in trials with a plural target than trials with a singular target: In

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follow-up comparisons the effect of trial type appeared consistently in the plural trials in the experimental group, but less consistently in singular trials, and never in the control group. There are a number of potential sources for this asymmetry. First, the plural-marked verb is simply more informative in context: A question that begins *"Where is..."* could easily continue by asking about one of the two cookies pictured (e.g., *"...the yummiest cookie?"*), whereas a sentence beginning with *"Where are..."* is unlikely to continue by referring to the picture of a single apple. Psycholinguistic evidence also suggests that in many languages PLURAL is the marked value in subject-verb agreement, while SINGULAR serves as the default (e.g., Eberhard, 1997)[2]. For example, for adults, plural but not singular local nouns attract agreement errors (e.g., *the drawer for the needles was/*were...*, Bock et al., 2004). This asymmetry in our data, along with children's greater difficulty producing plural forms than singular forms (Rubino & Pine, 1998; Theakston & Rowland, 2009), raises the possibility that children also treat the singular as a default. A third possibility is that participants are familiar with one of the many dialects of English in which *is* can occur with plural subjects, especially in inverted sentences such as the locative inversions and wh-questions used here. Such patterns tend to be asymmetrical: The singular form is more likely to be used with plural subjects (e.g., *There's three cookies*) than vice versa (**?There are a cookie*; Hay & Schreier, 2004)

Whatever the source of the singular-plural asymmetry, the current results are consistent with existing evidence that adults and children can use morphosyntactic cues to facilitate online comprehension (Dahan et al., 2000; Huang et al., 2013; Kamide et al., 2003; Lew-Williams & Fernald, 2007; Robertson et al., 2012), and demonstrated for the first time that children can *pre-activate* features of likely upcoming nouns on the basis of morphosyntactic cues. This finding also provided the second demonstration (after Tsang & Chambers, 2011) that adults can use morphosyntactic cues to pre-activate likely upcoming words.

Furthermore, this result demonstrates that despite children's difficulty using agreement as a direct cue to subject number (Brandt-Kobele & Höhle, 2010; V. E. Johnson et al., 2005; Leonard et al., 2000; Miller, 2012; Nicolaci-da Costa & Harris, 1984), they are sensitive to agreement during comprehension, provided it is permitted to play its syntactic role. This provides additional support for the possibility that learners treat agreement as a primarily syntactic dependency.

1.2.4 Outline of the Document

In the following chapters, I follow up on this initial finding, taking subject-verb agreement as a case-study in children's representation and processing of

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[2]In contrast, the plural has been proposed to be the semantic default (Bale, Gagnon, & Khanjian, 2011; Sauerland, Anderssen, & Yatsushiro, 2005). To the extent that both these arguments are valid, the observed asymmetry may constitute further evidence that agreement is treated as a syntactic dependency.

syntactic dependencies.

As discussed in section 1.2.2, a common observation about young children's production of agreement is that when children include an agreeing verb it is nearly always correct. However, children's spontaneous speech includes primarily count noun and pronoun subjects, for which notional and grammatical number coincide. Chapter 2 reports on two elicited production tasks, one that assessed 3-year-olds' agreement production with non-count subject noun phrases (e.g., *toast, glasses*), and one that assessed 3-year-olds' agreement production with complex subject noun phrases (e.g., *the cat and the dog, the bear with the flower*), in which we asked how good children's production actually is. Findings from these studies indicate that 3-year-olds do typically provide the appropriate agreeing forms, even with non-canonical subject NPs: Participants relied primarily on the grammatical number of the subject for producing agreement, not its notional properties or shallow distributional facts.

Chapter 3 reports on two experiments that investigate the source of the online processing advantage reported by Lukyanenko and Fisher (in prep.), and described above. In two looking-while-listening studies, children demonstrated that they are capable of using agreement as a cue to grammatical number in online comprehension even when notional number is held constant (e.g., one pair of glasses, one phone), and that they can use an agreeing verb to anticipate a novel subject noun phrase (e.g., *Where are the new luns?*. This suggests that the processing advantage children and adults show in informative sentences stems neither from a fully notional nor from a fully lexical representation of agreement.

Even if agreement is not fully notional, notional number may still play a role in the representation and processing of the agreement dependency. Chapter 4 investigates the role of notional number in online comprehension of verb agreement. Results suggest that agreement carries information both about the likely notional and likely grammatical number of the upcoming subject for both adult and 3-year-old listeners.

Chapter 5 extends the original finding reported by Lukyanenko and Fisher (in prep.) to 30-month-olds, suggesting that the ability to use morphosyntactic cues predictively in online comprehension begins early. The chapter then further explores the account of the acquisition of subject-verb agreement described above, discussing how the priority of distributional learning in the acquisition of agreement might result in the observed patterns of use and representation.

In Chapter 6 the results of all 7 experiments are summarized and discussed, and the implications are considered.

Chapter 2

Agreement Production

2.1 Introduction

One of the most striking patterns in young children's production of verbal morphology is that they leave it out. Young children frequently produce bare or infinitival verb-forms in place of adult-like finite forms, and often omit agreeing copula or auxiliary verbs (Wexler, 1994, 2011; Wexler, Schaeffer, & Bol, 2004), see (12) and (13). Because children go through an extended period in which they produce finite (shown in (12b) and (13b)) and non-finite forms ((12a) and (13a)) more or less interchangeably, this period has been dubbed the Optional Infinitive stage. Children's use of non-finite forms begins as soon as they begin producing verbs in multi-word sequences for which the relevant statistics can be computed, typically between 1.5 and 2 years. Finite forms gradually replace the non-finite forms in children's production, until children reach roughly adult levels of finite verb provision between the ages of 3 and 4.

(12) English, Eve (Wexler & Harris, 1996)

    a. it only write on the pad

    b. my finger hurts

(13) Dutch (Weverink, 1989)

    a. pappa schoenen wassen
       daddy shoes   wash.INF

    b. ik pak 't op
       I pick it up

The primary concern in the literature examining the Optional Infinitive stage is the reason for children's production of non-finite forms. One set of theories suggests that the cause is fundamentally syntactic: Children have an immature grammar that permits main verbs to appear in the infinitive (e.g., Hoekstra & Hyams, 1998; Rizzi, 1993; Schütze, 2004; Wexler, 1994, 2011). These approaches propose that either a maturational or parameter-setting process, children eventually approach the adult grammar and correctly produce finite forms where appropriate. Other theories suggest a statistical-distributional or construction-based source. The bare form is the most frequent form in English, and children do hear sequences of subjects and infinitival forms, for instance in

questions (e.g., *Did **she cry**?, Where will **he go** next?*, e.g., Freudenthal, Pine, Aguado-Orea, & Gobet, 2007; Freudenthal, Pine, & Gobet, 2006; Räsänen, Ambridge, & Pine, 2013). Children would be expected to make errors in the Optional Infinitive pattern if they are sensitive to the occurrence of these strings in the input, but have not yet determined that they are permissible only in certain syntactic contexts and are ungrammatical on their own. A third set of explanations suggest that children leave out unstressed syllables in certain prosodic contexts, and only gradually become more adept at including all the appropriate syllables in their sentences (Gerken & McIntosh, 1993; Song & Demuth, 2008; Song et al., 2009).

For our purposes, two observations from this literature are crucial. First, rather than appearing in their infinitival forms, in English the auxiliaries BE and HAVE and copula BE tend to be omitted (Schütze, 2004; Wexler, 2011). Second, when children do produce finite agreeing forms, they are typically the appropriate ones (Hoekstra & Hyams, 1998; Keeney & Wolfe, 1972; Wexler, 2011; Wexler & Harris, 1996). Thus, as the Optional Infinitive stage fades across the third and fourth years, children's spontaneous productions begin to include the appropriate agreeing forms with high accuracy (Brown, 1973; de Villiers & de Villiers, 1973).

Does this high degree of accuracy in children's productions of finite verb-forms indicate an adult-like underlying representation of agreement? Adult agreement production depends on the grammatical features of the subject noun phrase to govern the form of the verb (Bock et al., 2004; Corbett, 2006). When children accurately produce agreeing forms, is it because they too are using the subject's grammatical features to determine the appropriate verb-form? Unfortunately, the types of subjects that reveal adults' reliance on grammatical number rather than number-meaning, namely non-count nouns and complex noun phrases, are poorly represented in children's spontaneous speech. Thus children's high levels of agreement accuracy in studies of spontaneous production do not necessarily stem from an adult-like representation of the agreement system.

On one hand, evidence suggests that it may not. Subjects in casual speech are overwhelmingly singular, and several studies suggest that children have more difficulty producing plural forms (Rubino & Pine, 1998; Theakston & Rowland, 2009). For instance, Theakston and Rowland elicited agreeing auxiliaries from children in declarative sentences, yes-no and wh questions. In yes-no and wh-questions, which require inversion of the subject and verb (e.g., *What is the zebra eating?*), 3-year-olds produced *is* with high accuracy, but were much less consistent with *are*. This suggests that while children's overall accuracy in producing agreement is high, their choices do not always pattern with adults'. On the other hand, children in Theakston and Rowland's study were highly accurate with both *is* and *are* in the simpler declarative structures tested, and other studies suggest that children treat related agreeing forms as part of a

paradigm: Different forms of BE prime each other (Rissman et al., 2013), and agreeing forms expressing the same combination of features tend to correlate in children's production (Rispoli et al., 2012). These patterns suggest more adult-like representations.

To our knowledge, no study has yet tested children's use of subject-verb agreement with non-count nouns. Non-count nouns are an ideal test case, because they are one of the few places where notional number and grammatical number can be in direct conflict. When this occurs, which do children use to govern their choice of agreeing form? Do they rely primarily on the notional number of the referent they are describing, or do they use the lexical-syntactic properties of the subject noun phrase? Investigating children's use of agreement in contexts where grammatical and notional number conflict will allow us to determine whether children represent agreement in terms of number-meaning, or in terms of the legal combinations of word forms.

2.1.1 Non-Count Nouns

Though children's production of subject-verb agreement with non-count subjects has not yet been tested, previous findings suggest that children as young as 2 are sensitive to the differences between different noun subcategories (e.g., the mass-count distinction).

In spontaneous speech there is evidence that 2-year-olds avoid pluralizing mass nouns, and tend to use them with different determiners (e.g., avoiding *a milk*, but producing *the milk*, Gordon, 1988; Valian, 1986). However, one reason for this might be that mass nouns frequently describe substances (e.g., *flour, sand, juice, jelly*), rather than the sort of discrete entities that lend themselves to plural descriptions (typically described by count nouns: e.g., *car, dog, chair, block*). In a clever elicitation task Gordon (1985a) addressed this concern by testing 2- to 5-year-olds' tendency to pluralize superordinate mass nouns (e.g., *furniture, fruit*), which do describe sets of discrete entities and thus might be more readily pluralized. Children were shown a series of small "stores" and asked questions about what they each sold (e.g., *"What do you get at the furniture/toy store?" "furniture/toys", "What do they sell in the fruit/vegetable section?" "fruit/vegetables"*). Children in all age ranges tested overwhelmingly avoided pluralizing superordinate mass nouns (7% plurals, all from 4-year-olds), but readily pluralized corresponding superordinate count nouns (96% plurals). Especially in light of evidence that children base quantity judgments for superordinate mass nouns on the number of items present, not the the total amount of "stuff" (Barner & Snedeker, 2005), children's avoidance of plural markers on mass nouns in this study suggests that they have already learned some of the unusual grammatical properties of these nouns, and their consequences within the noun phrase.

Evidence concerning children's treatment of pluralia tantum nouns is less

readily available. One suggestion that children treat pluralia tantum nouns differently from count nouns is that 3- to 5-year-olds are more likely to include the -*s* of a plurale tantum in a compound than they are the -*s* of a regular count plural (e.g., *clothes-eater*, but not *rats-eater, Gordon, 1985b).

These patterns indicate that young children have learned that there are different subcategories of nouns, and that they behave differently: appearing in different forms in different contexts, and taking different sets of determiners. However, children's avoidance of plural mass nouns, and their use of pluralia tantum inside compounds do not convincingly demonstrate that children know the grammatical number properties of these noun subcategories, and their consequences for verb agreement. It could be that children have observed that certain words always occur in a one form in the input, and are accurately reproducing this pattern in their speech, never stripping the -*s* from pluralia tantum nouns and never adding one to mass nouns. That is, children may have learned, for example, that the word-form *pant does not exist, not that the word *pants* is grammatically plural. This might lead to correct production of the noun-forms, but inconsistent or incorrect production of verb agreement.

Thus, children's accurate production of agreeing forms, when the provide them, may or may not arise from using grammatical plurality to drive verb agreement. To determine whether this is the case, we must examine children's production of agreement with non-count and complex subject noun phrases.

2.1.2 The Current Studies

The studies in this chapter seek to answer the question of how children represent the agreement relationship in production: What features of the subject noun phrase do children use to govern their choice of agreeing verb-form? To do this, we use a pair of elicited production tasks with 2- and 3-year-olds. Children in this age range have typically begun to produce agreeing forms with enough regularity to make them a useful source of agreement data, but are not yet at adult-like levels of finite verb provision, suggesting that they are still in the process of mastering agreement production. At this stage, how do they represent the agreement relationship? What drives their agreement choices?

In the first task, children were asked to produce simple sentences describing the locations of familiar objects, which varied in the number of items pictured (one vs. two) and the class of the target noun (count, mass, pluralia tantum; e.g., *the scissors are/go on the star*). If 2- and 3-year-olds rely primarily on the notional number of the subject noun phrase, they should produce more plural agreement in the two-object trials, regardless of noun class. In contrast, if they rely on the grammatical properties of the subject noun, they should produce more plural agreement with pluralia tantum (*scissors*), than with mass nouns (*corn*), and should rely on the number of items pictured for determining the plurality of count noun targets.

In a second study, we ask how the structure of the noun phrase influences children's agreement decisions. By asking 2- and 3-year-olds to produce sentences with conjoined singular and complex subject noun phrases (e.g., *the cat and the dog are on the square*, *the bear with the flower is on the circle*), we can determine whether children's choice of agreeing verb is driven by lexical-distributional patterns or by properties of the entire subject noun phrase. If children rely on observed patterns of co-occurrence of noun- and verb-forms, the singular nouns that make up the complex subjects should occur more frequently with singular agreement, and children should produce singular agreement with both complex and conjoined noun phrase subjects. In contrast, if children use the structure of the subject to influence their agreement choices, we would expect children to use plural agreement with conjoined singular subjects, and singular agreement with complex singular subjects.

By eliciting production of agreeing verb-forms from 2- and 3-year-old participants, we can explore what properties of the subject noun phrase children use to determine their production of an agreeing verb, and therefore how they represent the agreement relationship for the purposes of production.

2.2 Experiment 1

The goal of Experiment 1 was to determine what features of the subject noun phrase children use to govern their choice of agreeing verb-form. By asking 2- and 3-year-olds to produce simple sentences describing the location of familiar objects while varying the number of objects pictured and the class of the target noun (e.g., *The scissors are/go on the star*; pictured: one or two pairs of scissors), we can see whether children rely more strongly on the number of objects displayed or on the grammatical category of the item's name in their choice of noun plural marking (e.g., *scissors* vs. *scissor*) and verb agreement (e.g., *is/are*, *go/goes*). Do they produce more plurals in response to two-object trials regardless of the target noun class, or does their pattern of plural responding change for the different subcategories of subject nouns?

We included both the copula (BE) and a regular verb (GO) as target verbs. By doing so, we can examine the patterns of omission and plural production in two verbs that have previously been found to behave differently: When young children omit agreement markers, they tend to produce the bare form of regular verbs, and to omit the copula and auxiliary verbs entirely (e.g., Schütze, 2004; Wexler, 1994. If children in the current study follow this pattern, we should see more omitted verbs in the BE condition than in the GO condition, and more (apparently) plural forms in the GO condition than in the BE condition.

Despite these predicted differences in the base rate of plural responding, it is still possible to compare rates of plural responding in 1- and 2-item trials with different subject noun types. Production of the bare form as the result of tense/agreement omission should occur at approximately the same rates in 1-

Table 2.1: Target and location nouns used in Experiment 1.

Target Nouns			Locations
Count	*Mass*	*Pluralia Tantum*	
apple	bread	glasses	circle
banana	cheese	pajamas	square
phone	corn	pants	star
shirt	toast	scissors	triangle

and 2-item trials. Therefore, differential production of plural verb-forms across trial types in the GO condition is likely to be the product of children's actual agreement choices, not an artifact of agreement omission. Similar patterns of differential production of plural forms across the two target verbs would suggest that, despite the fact that these verb types pattern differently with respect to function morpheme omission, children treat both types of verbs similarly for the purposes of producing agreement.

2.2.1 Method

Participants

Fifty-four 2- and 3-year-old children participated (33 - 43 months, $M = 38$; 26 girls), 28 in the BE condition, and 26 in the GO condition. All were native English speakers. An additional 11 children were excluded due to parent-reported language delay (6) or refusal to participate (5; i.e., asking to leave, having completed fewer than half the critical trials). Participants' productive vocabularies were measured using the MacArthur Bates CDI (Level III; Fenson et al., 2007) and ranged from 12 to 100 (median = 80).

Stimuli and Procedure

Stimuli consisted of clip-art pictures of 12 familiar items, four each named by count, mass and pluralia tantum nouns (see Table 2.1). On each trial a picture of one item, or two identical items would appear in the center of the screen and then move to a shape destination. Children described this scenario (e.g., *The shirt is/goes on the star*).

Children sat on a parent's lap in front of a desk holding a laptop computer. Stimuli were presented on the laptop screen using Microsoft Power Point. Children were awarded a sticker for each trial they completed. The task took approximately 15 minutes to complete.

Children took turns with an experimenter, who described similar displays (though her items were different from those the children saw, and were always named by count nouns). The experimenter's trials served to demonstrate to children how the game was played, and to model the production of complete sentences on each trial. Each child received 12 test trials, one for each target noun listed in Table 2.1. For each noun-type, children saw two one-item trials

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and two two-item trials. The assignment of object number to noun was counterbalanced across children, as was the plurality of the experimenter's preceding sentence. Thus, while one child saw a single pair of scissors and two pairs of pants, another child saw two pairs of scissors and a single pair of pants.

The 12 test trials were preceded by 4 count-noun practice trials in which children received feedback if they did not provide complete sentences, and by a naming phase in which children were encouraged to produce each of the target nouns individually. During the naming phase, the experimenter provided the target form on the few occasions when the child refused to produce a name for the picture, or used a different root (e.g., *remote* for *phone*). During the practice trials, children were encouraged to include verbs if they did not spontaneously do so (e.g., "Can you say the whole thing?"), but their agreement choices were never corrected.

Trials were presented in one of two pseudo-random orders, restricted such that children never encountered more than two trials in a row with the same noun class, or more than three trials in a row with the same target plurality, number of items, or plurality of the experimenter's sentence. Verb type was manipulated between subjects: Using the practice trials and the experimenter's model sentences, one group of children was encouraged to produce copula BE (n=28), and another group was encouraged to produce the regular verb GO (n=26).

Transcription and Coding

Each session was transcribed in standard English orthography by two trained transcribers who were native speakers of English. Both transcriptions were coded independently, and the coding was compared. Where there were disagreements in the coding that resulted from differences in transcription, a third transcriber transcribed the trial. Any element on which all three transcribers disagreed was considered unintelligible and therefore excluded. Elements on which two of the three transcribers agreed were included.

In the event that the child produced more than one sentence for a trial, the most complete sentence was coded. As shown in Table 2.2, we coded properties of the subject noun phrase, including use of the target noun or an acceptable variant (e.g., *jammies* for *pajamas*) and presence or absence of plural -*s*. We also coded the verb-form. When a verb was present, it was classified as singular, plural or "other". When there was no verb, the structure of the sentence was used to determine whether this was the result of an omission, such as might be expected from children in the optional infinitive stage (Wexler, 2011), or whether it was simply missing data. If relevant clause was a main clause, and included both a subject and a preposition, a missing verb was coded as an omission, otherwise the sentence was excluded from verb analyses (e.g., omitted verb: *the shirt ∅ on the star*, *shirt ∅ on...*; excluded from verb analyses: *I see*

Table 2.2: Coding examples from Experiment 1.

Child's production	Subject Noun Phrase		
	Noun	*Morphology*	**Verb**
Included for all analyses			
The phone goes on the star.	target	-∅	singular
Jammies are on the circle.	target	-s	plural
Pants on the star.	target	-s	omitted
Included for noun analyses			
The shirt.	target	-∅	NA
Star and pants.	target	-s	NA
I see glasses on the circle.	target	-s	NA
The apples land on the star.	target	-s	other
Excluded			
The clothes are on the circle.	other	-s	plural
They're on the square.	pronoun	NA	plural
On the star	NA	NA	NA

*the shirt on the star, shirt star, the shirt, on the star*, see Table 2.2).

2.2.2 Results and Discussion

To briefly preview our findings, with count noun subjects children relied primarily on the number of items pictured for determining both noun and verb plural marking, whereas item number mattered less for mass noun subjects and not at all for pluralia tantum subjects. Overall, agreement was high: Whether the noun- and verb-forms were adult-like or not, they tended to match.

We begin by examining children's noun responses, then consider verb omissions, and finally patterns of plural verb marking and agreement. Unfortunately, children's productions were not suited to parametric analysis, because, as shown in Figures 2.1 and 2.2, some cells of the design contained little or no variability in key measures (e.g., no child produced a plural form of BE following a count noun in the 1-item condition). The presence of true zeroes in the dataset as a whole, and the large proportion of zeroes and ones in the by-participant means for many conditions made analysis strategies using linear mixed-effects models or ANOVAs impractical and unreliable. Instead, in what follows we conduct a series of non-parametric tests of our key comparisons.

Note that each comparison contains all the participants who contributed a sufficient number of the relevant trial types, and this number varies from analysis to analysis. For each test, the number of contributing participants is noted in parentheses along with the medians, test statistic and p-values. One child who completed the task in the BE condition and produced several included noun phrase responses, produced no included sentences (primarily due to production of incomplete sentences, and pronoun rather than the target noun subjects), leaving a maximum of 53 participants' data available for verb analyses.

Figure 2.1: Plurality of included noun phrases. Bars represent the proportion of target nouns in that cell of the design produced with the plural *-s*. Error bars represent the standard error of the mean.
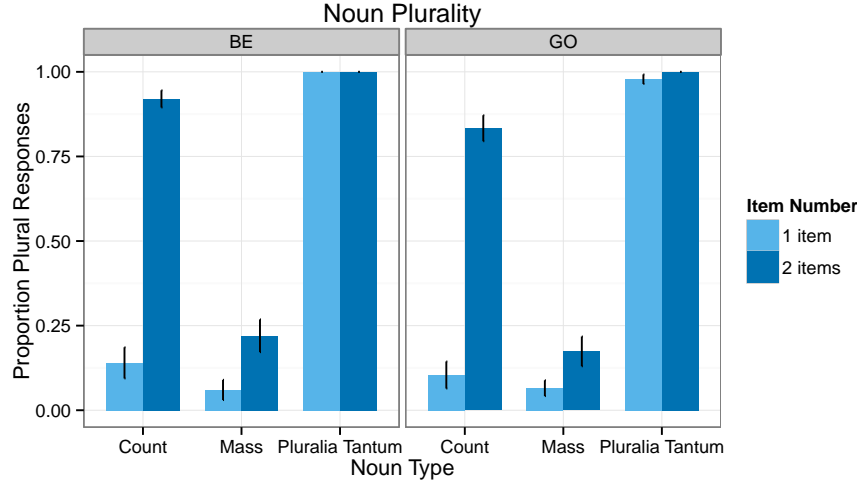
Noun plurality

In order to investigate the determinants of children's production of verb agreement, we chose three noun types with different patterns of grammatical number. However, these noun classes are only useful to the extent that children are familiar with them and their associated grammatical number. The patterns shown in Figure 2.1 suggest that the children in this study do treat count, mass and pluralia tantum nouns differently. The presence of the plural *-s* on count nouns appears to be driven primarily by the number of items in the display, while mass nouns are rarely pluralized, and the *-s* is hardly ever stripped from pluralia tantum nouns.

We analyzed these patterns in two steps. We first compared the proportion of plural-marked responses in 1- and 2-item trials. To do this, we calculated proportion of nouns with the plural *-s* for 1- and 2-item trials separately within each noun class. Children who contributed at least one 1-item and at least one 2-item trial within a particular noun class were included in a within-participants comparison: The proportion of plural nouns in 1-item trials was significantly different from the proportion in 2-item trials for count (1-item Mdn $= 0$, 2-item Mdn $= 1$, $V = 0, p < .0001, N = 45$; Wilcoxon signed-rank) and mass nouns (1-item Mdn $= 0$, 2-item Mdn $= 0$, $V = 13.5, p = .04, N = 43$), but not for pluralia tantum nouns (1-item Mdn $= 1$, 2-item Mdn $= 1$, $V = 0, p = 1, N = 45$). This demonstrates that children do not rely on the number of items pictured for determining the appropriate form of pluralia tantum nouns, and that the number of items pictured does influence their noun-form choices for count and mass nouns.

Second, we compared the size of the item-number influence on plural-marking

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of count and mass nouns. Children who contributed at least one 1-item trial and at least one 2-item trial for mass noun targets, count noun targets, or both were included in the analysis. For each noun type, a difference score was calculated by subtracting each participant's plural proportion in 1-item trials from their plural proportion in 2-item trials. These difference scores were significantly larger in count noun trials than in mass noun trials (count $Mdn = 1$, mass $Mdn = 0$; $W = 1660.5, p < .0001, N = 50$; Wilcoxon rank-sum), suggesting that while the number of items pictured influences children's tendency to pluralize both count and mass nouns, it is a primary determinant of plural marking for count nouns, but has less influence on the marking of mass nouns.

Thus, the 2- and 3-year-olds in the current study appear to have treated count, mass and pluralia tantum nouns differently: pluralizing count nouns on the basis of the number of items being described, and relying primarily on the noun itself for mass and pluralia tantum nouns. This replicates previous findings that children treat these noun types differently (e.g., Gordon, 1985a, 1985b, 1988; Valian, 1986).

There are two possible sources for this pattern. First, children might have learned something about the grammatical number of these nouns: Only count nouns have a grammatical number feature that depends on the number of items described. Alternatively, children may have learned something more lexically concrete: *shirt* has two forms, and which you choose depends on the number of items being described, while *pants* and *corn* have one form apiece, and there is no decision to be made. By examining patterns of plural verb provision and verb agreement in this study and in Experiment 2, we can begin to determine which of these is the case.

Patterns of verb omission

Given that children are treating our three noun classes differently, we move to analyses of children's verb production. Because children between the ages of 2 and 4 frequently omit markers of tense and agreement, and because this tendency may interfere with our ability to examine the determinants of 2- and 3-year-olds' agreement choices, we began by analyzing patterns of omission in the children's verb productions.

When young children omit agreement markers, they tend to produce bare forms of regular verbs (such as GO in the current study), and to omit copular and auxiliary verbs (e.g., BE; Schütze, 2004; Wexler, 1994). Thus we predicted more omitted verbs in the BE condition than in the GO condition, and more (apparently) plural forms in the GO condition than in the BE condition.

To determine if the predicted patterns of verb omission were present in the current dataset, we first compared children's tendency to omit verbs in the BE and the GO conditions. The proportion of sentences with included verbs can be calculated for all 53 participants who produced an included sentence. Seventeen

Figure 2.2: Verb responses in included sentences. Bars represent the proportion of each response type out of all included sentences in the category, thus each triplet of bars adds to 1. Error bars represent the standard error of the mean.
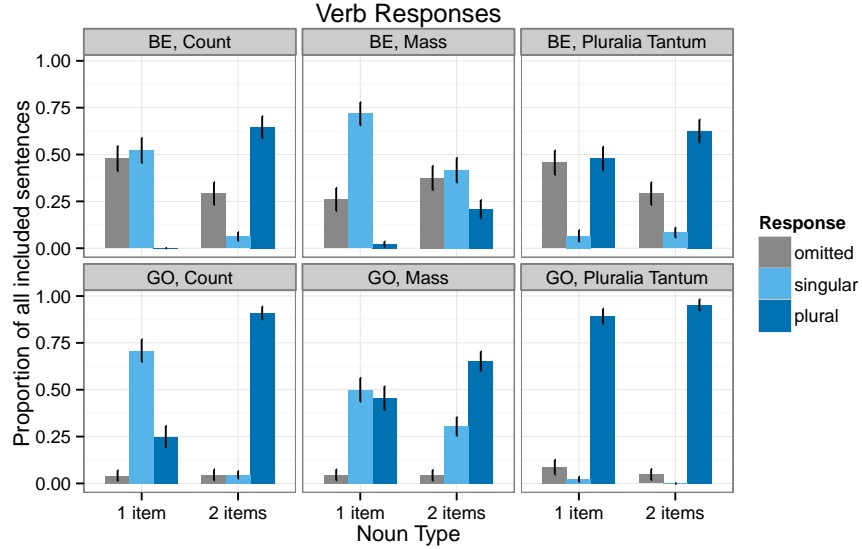

of the 27 children in the BE condition produced at least one sentence with an omitted verb (Mdn inclusion proportion = .75). In contrast, only 2 of the 26 children in the GO condition omitted a verb (Mdn inclusion = 1). Proportion verb inclusion differed significantly across the two groups ($W = 162.5, p < .0001$, Wilcoxon rank-sum).

We then compared the rate of plural verb-form production in the two target verb conditions. This proportion was calculated for all participants who produced an overt verb in at least one expected-singular (count 1-item, mass 1- and 2-item) and one expected-plural trial (count 2-item, pluralia tantum 1- and 2-item; N = 32), and was weighted such that expected-singular and expected-plural trials contributed equally to the result: Perfectly adult-like performance would result in a plural proportion of .5. Of the 19 children in the BE condition who contributed overt verbs in both expected-singular and expected-plural trials, 5 produced more plural than singular forms (Mdn proportion plural = .5). In the GO condition, 19 of the 23 children who contributed to the analyses produced more plural than singular forms (Mdn = .667). The proportion plural verb responses differed significantly across the two groups ($W = 86, p = .0007$, Wilcoxon rank-sum).

This pattern of more omission of BE and more bare-form production for GO is consistent with previous observations for children of this age (Schütze, 2004; Wexler, 1994). Unfortunately, it also interferes with our ability to ask questions about children's agreement choices: The overproduction of plural (bare) verb-forms in the GO condition makes the absolute level of agreement in that condition uninformative at best. However the overproduction of the

Figure 2.3: Plurality of overt verb responses in included sentences. Bars represent the proportion of target verbs in that cell of the design that were produced in the plural form. Error bars represent the standard error of the mean.
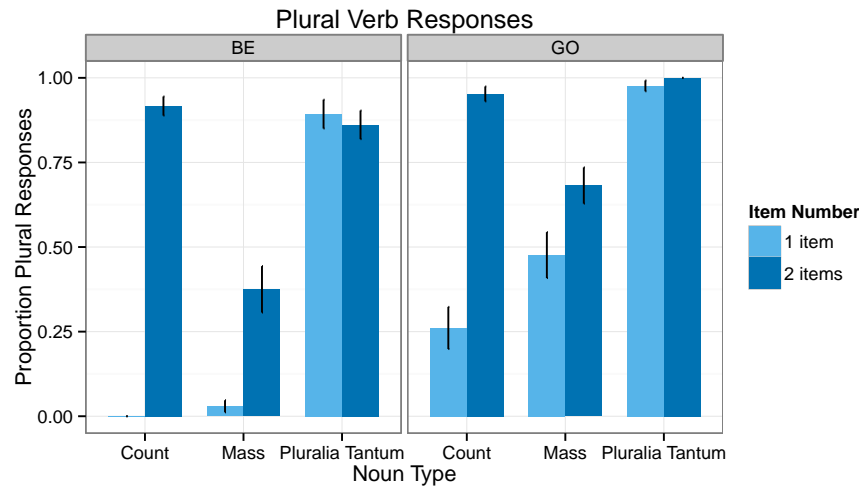
plural should occur at similar levels in one- and two-item trials, meaning that differential production of plural verb-forms across trial types is likely to be the product of children's actual agreement choices. For this reason, in analyses of the absolute level of agreement, we rely on the BE condition only, while in analyses comparing rates of plural verb production across cells of the design, we use data from both conditions.

We conducted one final check on our data: Some studies have shown children to have more difficulty with plural-marked verbs than with singulars (e.g., Theakston & Rowland, 2009), so we compared participants' tendency to omit verbs across expected-singular and expected-plural trials. We calculated the proportion of overt verbs in expected-plural (Mdn = 1) and expected-singular trials (Mdn = 1) for participants who contributed at least one trial of each type. These proportions did not differ significantly ($V = 23, p = .40, N = 51$, Wilcoxon signed-rank). In our task, children were no more likely to omit plural than singular forms.

Patterns of plural verb-form provision

The primary aim of this study was to investigate what governs children's agreement choices: the grammatical number of the subject noun phrase, or the number of items depicted. We first compared the proportion plural verb responses in 1- and 2-item trials. We calculated the proportion plural verb-forms separately for 1- and 2-item trials in each noun class, collapsing across the BE and GO conditions. The proportion plural verb responses in 1-item trials was significantly different from the proportion in 2-item trials for count (1-item Mdn = 0, 2-item Mdn = 1,$V = 0, p < .0001, N = 32$, Wilcoxon signed-rank) and mass nouns (1-

item Mdn $= 0$, 2-item Mdn $= .5, V = 11, p = .004, N = 34$), but not for pluralia tantum nouns (1-item Mdn $= 1$, 2-item Mdn $= 1$, $V = 6, p = .77, N = 31$). Thus, children did not rely on the number of items pictured for determining the appropriate form of the verb with pluralia tantum subjects, but the number of items picture did influence their verb-form choices with count and mass noun subjects.

We then compared the size of the item-number influence on plural verb-form production with count and mass noun subjects. Children who contributed at least one 1-item trial and at least one 2-item trial with mass noun subjects, count noun subjects, or both were included in the analysis. For each subject type, difference scores were calculated by subtracting each participant's plural verb proportion in 1-item trials from their plural verb proportion in 2-item trials. These difference scores were significantly larger for count noun subjects than for mass noun subjects (count Mdn $= 1$, mass Mdn $= 0$; $W = 889, p < .0001, N = 38$; Wilcoxon rank-sum), suggesting that though the number of items pictured does influence children's tendency to produce plural verb-forms with mass noun subjects, item-number is a primary determinant of verb-form selection with count noun subjects, but has less influence when the subject is a mass noun.

These patterns demonstrate that, as with plural markers on the nouns themselves, the 2- and 3-year-olds in the current study produced plural-marked verbs at different rates following nouns with different grammatical properties. Children clearly relied on the number of items pictured in determining noun- and verb-forms for count nouns, and clearly did not for pluralia tantum nouns. Interestingly, children showed a tendency to produce more plural noun and verb responses in 2-item mass noun trials than in 1-item mass noun trials, though their overall tendency was to produce singular responses, the median response was all-singular, and the size of this tendency was significantly smaller than the corresponding difference in count noun trials..

This pattern makes it clear that children do not determine their noun- and verb-form choices based solely on the number of items being described.

Agreement

In the preceding analyses, we examined children's provision of plural noun- and verb-forms separately, concluding that children do not drive their choice of verb-form based entirely on the number of items pictured. However, agreement is crucially a dependency between forms, not the independent likelihood of each plural form appearing in a particular context. In most cells of the design, children produce at least a few unexpected noun- and verb-forms. Do these errors come from the same sentences, suggesting maintenance of the agreement relationship despite the non-adult-like noun-form? Figure 2.4 shows the proportion of sentences with matching noun- and verb-forms (both singular or both plural), out of included sentences with an overt verb in the BE condition. The GO con-

Figure 2.4: Proportion Agreement: The proportion of sentences in which the noun and verb matched, out of included sentences with an overt verb in the BE condition.
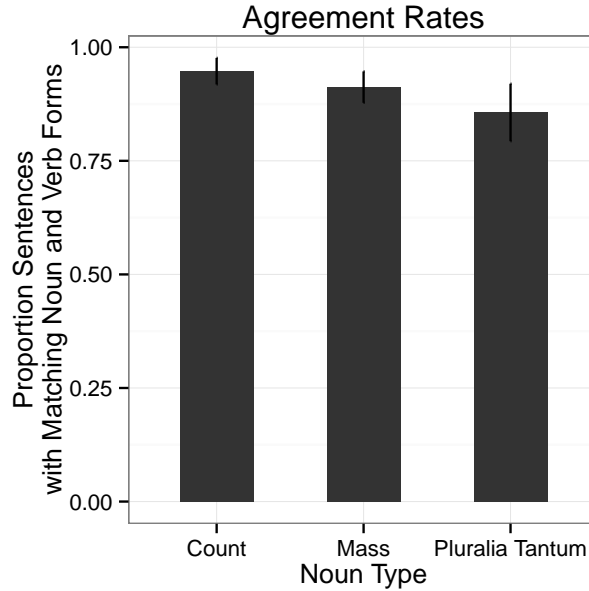
dition was not included for this analysis because the overproduction of the bare form will differentially influence apparent agreement rates in expected-singular and expected-plural trials. Agreement rates were high in all three noun classes, but were numerically highest in the count noun trials.

Were children less consistent in their responses for non-count nouns? That is the pattern that would be expected if children have learned that some nouns only have one available form (e.g., *pants, corn*), but use the number of items being described to help drive their choice of verb-form. The median agreement proportion for all three noun classes was 1, and proportion agreement did not differ significantly among the three noun classes ($\chi^2(2) = 1.05, p = .59$; Kruskal-Wallis rank-sum). This suggests that children were not less consistent in producing agreement following non-count nouns: Even when children produce forms that are inappropriate in context or ungrammatical in the adult language, they seem to honor the agreement dependency.

This pattern suggests that one potential explantation for the increase in plural forms in the 2-item mass noun trials is that some children have misanalyzed some mass nouns as count nouns. However, the design of the current study makes this difficult to determine: Because each child received only one trial with each target noun, we cannot make the within-participant comparisons across 1- and 2-item trials with the same target noun that would clarify how particular children analyzed particular nouns. Furthermore, among the 14 sentences in the

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BE condition[1] with a mass noun subject and some form of plural marking, no consistent pattern emerged. Noun plural marking (e.g., *"corns"*; 10 trials) was approximately as likely as verb plural marking (*"are"*; 9 trials), and each of the target mass nouns (*corn, bread, cheese, toast*) participated in the pattern. Ten of the 14 trials included both a noun and a verb, and of these, 5 had matching forms (e.g., *"the breads are on the circle"*) and 5 had mismatching forms (e.g., *"the toast are on the rectangle"*, *"cheeses is on the triangle"*).

2.2.3 Conclusion

The 2- and 3-year-olds who participated in Experiment 1 used a combination of information about the noun class and the number of items pictured to govern their production of noun plurals and plural agreeing verbs. The predominant patterns were adult-like: with count nouns, children used the number of items pictured to determine the appropriate noun-form, but they primarily treated mass nouns as singular and pluralia tantum nouns as plural. Patterns of plural verb production were very similar, and this is not coincidental: The rate of agreement was high across all three noun classes.

Two patterns in the current data echo findings in the extensive literature on the Optional Infinitive stage. First, we observed that copular BE was more likely to be omitted than the regular verb GO was, and that GO was more likely to appear in its plural (bare) form (e.g., Schütze, 2004; Wexler, 2011). Second, we found that when participants did include a finite form (overt *is* and *are*, shown in Figure 2.4), agreement accuracy was very high (e.g., Keeney & Wolfe, 1972; Wexler, 2011).

We add to these previous findings by showing that 2- and 3-year-olds produce appropriately agreeing forms even when notional and grammatical number are in conflict: Children's production of plural or singular verb-forms was only strongly influenced by the number of items shown when the subject was a count noun, and levels of agreement did not differ statistically among the noun types. Furthermore, the pattern of notional influence was similar across the two target verbs. This suggests that children's choice of verb-form is not primarily based on number-meaning, and thus that children do not represent agreement in terms of number-meaning alone.

This answers one of the two orthogonal questions about the representation of syntactic dependencies that we raised in the introduction, but leaves the other open. Children appear to treat agreement as a primarily formal dependency in production, not one based primarily in meaning. Do children also represent agreement in terms of abstract morphosyntactic properties, or do they use lexical-distributional knowledge about the patterns in which particular word forms appear to determine the appropriate agreeing form? In Experiment 2 we

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[1]Because the omission of tense/agreement morphemes in the GO condition leads to an overproduction of apparently plural verb-forms, here we examine only the plural-marked forms in the BE condition.

present children with complex and conjoined subject noun phrases as a way of answering this question.

2.3 Experiment 2

In Experiment 2, we sought to determine whether children rely primarily on familiar patterns of lexical co-occurrence in determining their agreement choices, or whether they compute agreement based on abstract properties of the subject noun phrase. We again asked children to produce sentences describing the location of familiar items. In contrast to Experiment 1, items in Experiment 2 were described by four types of subject noun phrases: simple singulars, simple plurals, conjoined singulars or complex singulars (see Table 2.3 in section 2.3.1). All nouns were regular count nouns.

For English count nouns, grammatical plurality is consistently marked by the morphological form of the word: singular nouns are bare, and plural nouns have the *-s* affix. One way children might have succeeded in Experiment 1 is by learning an association between the affixed forms of nouns (e.g., *phones, scissors*) and plural-agreeing verb-forms (e.g., *are, go*), and between bare forms (e.g., *phone, corn*) and singular-agreeing verb-forms (e.g., *is, goes*). If children use this lexical-distributional strategy in producing agreement, they should rely heavily on the morphological form of the noun(s) in the subject NP for determining their choice of agreeing verb-form.

To investigate this possibility, we examine children's choice of agreement with conjoined singular count nouns (e.g., *the boy and the girl*). In this case, the nouns in the subject NP are morphologically singular, but conjoined count nouns typically elicit plural agreement from adults. Specifically, when adults are asked to produce agreement with conjoined noun phrases, their agreement choices appear to be governed by the notional plurality of the entity or entities described. For instance, with a conjoined noun phrase like the one in (14), agreement depends on whether the two descriptions refer to the same item or to different ones (Lorimor, 2007).

(14)   The most expensive item and the last one sold was/were...

This also holds true experimentally. Lorimor (2007) presented participants with conjoined noun phrases with conjuncts of different types, intended to encourage singular or plural construals of their referents. For instance, conjoined deverbal mass nouns (e.g., *the singing and dancing*) should be highly susceptible to coalescence, or interpretation as referring to a single event, while conjoined count nouns should be less susceptible to this type of interpretation (*the name and address*). Across two experiments the probability of singular or plural construal predicted agreement patterns. Speakers produced most plural agreement with conjoined count nouns (78%), and the least with conjoined deverbal mass nouns (31%).

If, unlike adults, children rely primarily on the association between particular noun- and verb-forms to determine their agreement choices, they should predominantly use singular agreement with conjoined singular count nouns, as each of the singular nouns is more closely associated with the form *is* than the form *are*. Alternatively (though unlikely, given the results of Experiment 1), children might rely primarily on the number of items described, without regard for the structure of the NP, in which case they would produce plural agreeing forms with conjoined singular NPs, complex singular NPs and with simple count plurals. However, if, like adults, children use a combination of information about the syntactic structure of the subject noun phrase and the notional number of its referent(s) to help determine its grammatical number and thus the appropriate agreeing form, we would expect them to use plural agreement with conjoined singular count nouns and singular agreement with complex singulars.

2.3.1 Method

Participants

Forty-three 3-year-old children participated (34-42 months, $M = 39$; 20 girls). All were native English speakers. An additional 9 children completed part or all of the task, but were excluded for reported language delay (3), refusal to participate before completing at least half of the task (5), or experimenter error (1). Participants' productive vocabularies measured using the MacArthur Bates CDI (Level III; Fenson et al., 2007) ranged from 20 to 100 (median = 78).

Stimuli and Procedure

As in Experiment 1, participants sat on a parent's lap in front of desk that held a laptop computer, on which the stimuli were presented. The study was set up as a game in which the participant and the experimenter took turns describing simple displays. The experimenter also manipulated a puppet who "sat" beside the computer and led the game. Children were awarded a sticker for each completed trial. The task took approximately 20 minutes.

Stimuli were clip-art pictures of familiar items. On each trial children saw one or two items pictured in the center of a computer screen, and were prompted by the puppet to repeat a target noun phrase describing them (e.g., *Can you say "the cat and the dog"?*). The pictured items then moved to one of two shape destinations, and the puppet prompted children to describe the scene (e.g., *Now what do you see?*, target response: *"The cat and the dog are on the square"*). Target noun phrases were of four types: simple singular, simple plural, complex singular and conjoined singular (see Table 2.3).

Children alternated turns with an experimenter, who, prompted by the puppet, described similar displays containing different items. The experimenter's items were described using simple count noun singulars, conjoined plurals (e.g.,

Table 2.3: Subject noun phrases used in Experiment 2.

Singular	Plural	Complex Singular	Conjoined Singular
bike	airplanes	the bear with the flower	the apple and the orange
cookie	elephants	the bunny with the carrot	the boy and the girl
cow	phones	the doll with the ice cream	the car and the truck
present	shirts	the pig with the balloon	the cat and the dog

the books and the balls), or complex noun phrases, both of whose members were plural (e.g., *the ducks with the pretzels*). Thus, half of the experimenter's sentences took singular agreement, and half took plural agreement, and she was able to model repetition and sentence completion using complete conjoined and complex noun phrases. Crucially, because her conjoined and complex noun phrases were composed of plural nouns, her trials never demonstrated to children that agreement can mismatch the morphologically marked number of the nouns composing the subject. Furthermore, if children rely on the experimenter's trials as models for their agreement production with particular structures, without regard to the plurality of the component nouns, they should consistently use plural agreement with both their complex singulars and their conjoined singulars.

The task consisted of 16 test trials, four with each subject type. These test trials were preceded by 4 simple count noun practice trials, with two singular and two plural targets. During the practice trials, children received feedback if they did not provide complete sentences and were encouraged to provide verbs if they did not spontaneously do so, but their agreement choices were never corrected.

The plurality of the experimenter's preceding sentence was counterbalanced across children for each target noun phrase. Trials were presented in one of two pseudo-random orders, constrained such that target noun phrases of each type were roughly evenly distributed between halves of the study for both participants and the experimenter, and such that children never received more than two trials in a row with the same subject type. All children were encouraged to produce copula BE.

Transcription and Coding

As in Experiment 1, each session was transcribed separately into standard English orthography by two trained transcribers. The two transcriptions were coded separately, and the coding compared. Where there were differences in the coding that resulted from disagreements in transcription, a third transcriber transcribed the trial. Any element on which all three transcribers disagreed was considered unintelligible and therefore excluded. Elements on which two of the three transcribers agreed were included.

In the rare event that the child produced more than one sentence for a trial, the most complete sentence was coded. As shown in Table 2.4, we coded whether the noun phrase was an exact repetition (for complex and conjoined

Table 2.4: Coding examples from Experiment 2.

Child's production	Subject	Verb
Included		
The cat and the dog are on the square.	accurate	are
The bear with the flower is on the circle.	accurate	is
Trains on the square.	accurate	omitted
Excluded: Inaccurate subject NP		
Cat and the dogs on the square.	number	omitted
The bear and the flower are on the circle.	structure	are
Excluded: No verb data		
Bear with a flower.	accurate	NA
Cookie with a star.	accurate	NA

NPs, this required repeating both nouns in the appropriate forms, and the intended connector, *and* or *with*), contained a number error, or preserved the target nouns but not other structural features. We also coded their verb choice. As before, the structure of the sentence was used to determine if a missing verb was the result of verb omission, as might be expected during the Optional Infinitive stage, or if it was simply missing data. If the relevant clause was a main clause, included both a subject and a preposition and did not take the form of the complex noun phrases children were being prompted to provide (i.e., did not use the preposition *with*), the missing verb was coded as an omission, otherwise the sentence was excluded from analyses.

2.3.2 Results and Discussion

Figure 2.5 shows the proportion singular, plural or omitted verbs out of all included sentences by subject noun phrase type. Levels of omission were similar across all four subject types, but proportions of singular- and plural-marked verbs varied. As in Experiment 1, the true zero in the singular condition (no plural verbs were produced following a simple singular subject in the entire experiment) and the large proportion of 1s and 0s in the by-participant means made these data ill-suited for parametric analyses. Instead we conduct a series of non-parametric tests on key comparisons.

Omissions

Experiment 2 elicited production of the copula. Because children in this age range often omit markers of tense and agreement, we first analyzed children's patterns of verb omission. Based on previous studies, we might expect omission to be more likely in certain prosodic contexts (Song et al., 2009), or with certain target forms (Theakston & Rowland, 2009). However, in Figure 2.5 levels of omission appear to be similar across all four subject types.

The subject noun phrases in this study varied widely in length: simple singulars and plurals were short, while complex singulars and conjoined singulars were

Figure 2.5: The proportion of singular, plural or omitted verbs out of all included sentences by subject noun phrase type. Each triplet of pars adds to 1. Error bars represent standard error of the mean.
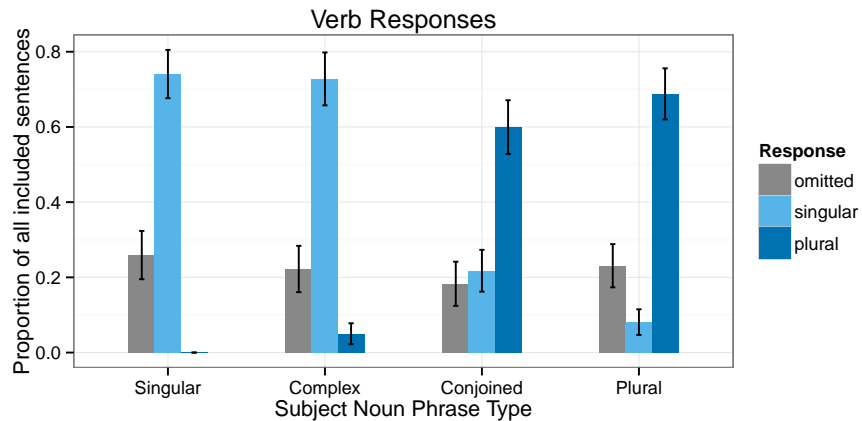
longer, multi-word phrases. This difference in the amount of material preceding the production of the verb might influence children's probability of producing an overt verb-form. To assess this possibility, we calculated the proportion of included sentences with an overt verb for long (complex singular and conjoined singular) and short (simple singular and plural) subject noun phrases. The 34 children who contributed proportions to both categories were included in the analysis. Inclusion of an overt verb was slightly more likely following a long subject NP (Mdn inclusion rate $= 1$) than following short one (Mdn $= .94$), but these proportions did not differ significantly ($V = 144.5, p = .15$; Wilcoxon signed-rank).

Another possibility is that children might omit plural target forms more often than singular target forms. To evaluate whether this were the case in the current dataset, we calculated verb inclusion rate for expected-singular (simple singular and complex singular) and for expected-plural (simple plural and conjoined singular) trials. Verb inclusion was slightly more likely in plural (Mdn $= 1$) than in singular contexts (Mdn $= .86$), but these proportions did not differ significantly ($V = 131, p = .34$, N $= 37$)

These patterns suggest that in the current materials, children show no tendency to omit verbs more often following certain subject types than others.

Patterns of plural verb-form provision

In contrast to children's tendency to omit verbs, which remained relatively stable, their rate of plural responses varied widely across subject types. This is clearly visible in Figure 2.6, which shows the proportion plural-marked verbs out of all overt verbs in included sentences by subject type. Singular responses predominate for simple singular and complex singular trials, while plural responses predominate for simple plural and conjoined singular trials. There appears to be

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Figure 2.6: The proportion plural verb-forms out of included sentences with overt verbs, by subject noun phrase type. Error bars show standard error of the mean.
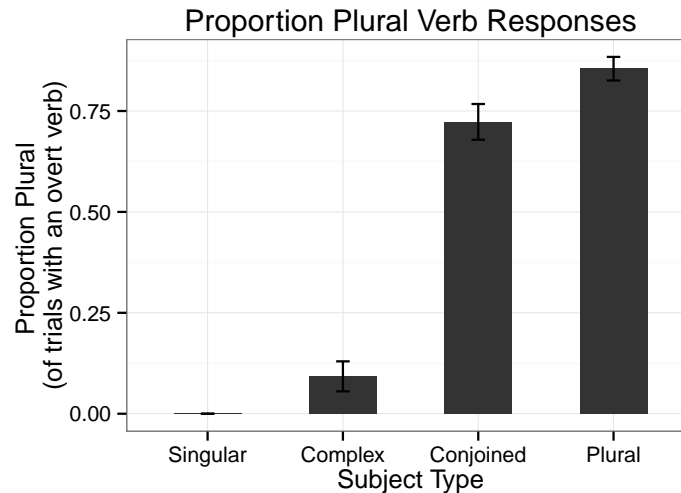
a trend toward more plural responses following the morphologically marked simple plurals than following conjoined singulars. This suggests that, like adults, children take both structure and notional number of the subject noun phrase into account in producing agreeing forms. In simple count noun trials, noun plurality determines children's choice of agreeing form, but in complex and conjoined singular trials, the structure of the noun phrase is crucial.

To explore these patterns we first compared the rate of plural verb provision (proportion plural out of included sentences with overt verbs) in simple singular and complex singular trials. There were 22 participants[2] who contributed proportions in both categories, and therefore were included in the analysis. Two participants provided at least one plural response in the complex singular trials, and no participants did so in the simple singular trials (both medians were 0). These proportions were not statistically different ($V = 0, p = .37$), suggesting that having two pictures on the screen and producing a subject NP with two component nouns is not sufficient to increase the proportion of plural responses.

We next compared responses in complex singular and conjoined singular trials. For adults, complex singular subjects (e.g., *the bear with the flower*) are unambiguously grammatically singular, whereas conjoined singular count nouns (e.g., *the boy and the girl*) are typically construed as MORE THAN ONE and therefore grammatically plural (Lorimor, 2007). Children also appear to

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[2]Consistent with their structure, children frequently reduced complex singular noun phrases to simple singular forms (e.g., producing *"the pig is on the star"* in place of *"the pig with the balloon is on the star"*. Because of our interest in whether the production of a subject NP containing two count nouns might drive an increase in plural verb production, we excluded sentences with these reduced subject NPs, resulting in fewer included trials in the complex singular condition than in other conditions, and therefore fewer included participants in within-participant comparisons that involve complex singular trials.

treat these subject types differently. The proportion of plural verb responses was much higher for conjoined singulars (Mdn = 1) than for complex singulars (Mdn = 0), and these proportions differed significantly ($V = 0, p < .0001$, N = 24). This suggests that children are sensitive to the influence of the structure of the subject NP on the subject's grammatical number.

Finally, we compared the proportion plural responses in conjoined singular and simple plural trials. Overall there was more plural agreement following simple plural subjects than following conjoined singular subjects (see Figure 2.6), though the median rate of plural provision was 1 in both conditions. The conditions differed marginally ($V = 26, p = .06$, N = 30), suggesting that for children, as for adults, morphologically marked plurals are the strongest controllers of plural agreement.

2.3.3 Conclusions

In Experiment 2, 2- and 3-year-olds used a combination of information about the structure and the notional number of the subject noun phrase to govern their choice of agreeing form. Children preferred plural agreement with conjoined singulars, despite the fact that each component noun (e.g., *cat, dog*) was singular and should therefore be independently more likely to occur with *is* than with *are*. This suggests that children do not rely primarily on their lexical-distributional knowledge of the co-occurrences of the words in question, but compute something more abstract about the properties of the subject noun phrase.

2.4 General Discussion

The studies in this chapter set out to determine what representations support young children's production of subject-verb agreement. Despite children's relatively frequent omission of tense and agreement morphemes, results from Experiments 1 and 2 revealed that the representations children rely on for determining agreement are remarkably adult-like. In Experiment 1, 2- and 3-year-olds largely ignored the number of items pictured when making their agreement choices for mass noun and pluralia tantum subjects, but relied on it heavily for determining agreement with count noun subjects, indicating that they treat agreement as a dependency between forms, not meanings. In Experiment 2, 2- and 3-year-olds used the structure of the subject NP to determine the appropriate agreeing form, producing plurals with conjoined singular subjects. Their lack of reliance on the component nouns themselves indicated that they do not represent agreement as a dependency between particular lexical forms, but between abstract properties of the subject NP and a matching verb-form.

These findings reveal subject-verb agreement's place on the two orthogonal dimensions of representation discussed in the introduction: Children do not

treat subject-verb agreement as a meaning-based dependency, nor do they rely primarily on the lexical co-occurrence of component nouns and verb-forms. Instead, like adults, children seem to treat agreement as an abstract, form-based dependency, that is, as primarily syntactic (Bock & Middleton, 2011; Corbett, 2006; Lorimor, 2007).

This fits well with previous observations that when children produce agreeing forms, they tend to produce the appropriate ones (Hoekstra & Hyams, 1998; Keeney & Wolfe, 1972; Wexler, 2011; Wexler & Harris, 1996), and adds to our understanding of the development of agreement by suggesting continuity in the representations that underlie agreement production. This continuity can be seen not just at the coarse-grained level of whether we have reason to label the representations "abstract" and "form-based", but also at a fine-grained level. For instance, children in Experiment 2 produced mostly plural verb agreement with conjoined singular subjects, but, like adults (e.g., Lorimor, 2007), were less consistent about producing the plural with conjoined singulars than they were with morphologically-marked plurals. This suggests that there may be continuity, not just in the way the agreement dependency is represented, but also in the way grammatical number is computed for complex subject NPs.

If we consider the two experiments separately, there are several alternative explanations for the pattern of results observed in each, but by considering the two studies together most alternative explanations are ruled out. For instance, children might have produced the pattern of agreement found in Experiment 1 using co-occurrence at either the level of the word form (*scissors...are*), or at the level of the morpheme (*-s...are*) to drive their choice of verb-form. However, contrary to the observed pattern in Experiment 2, this tactic would have led to predominately singular agreement following conjoined singular subjects: Conjoined singulars contained no plural morphology. Similarly, children might have succeeded in producing plural agreement with conjoined singulars by relying on notional number alone, disregarding the structure of the subject NP. The results of Experiment 1, however, make it clear that children do not rely on notional number alone in determining the appropriate agreeing form.

There is one alternative possibility that is not immediately ruled out. Children might have relied on the lexical co-occurrence of particular noun and verb-forms in Experiment 1, and in Experiment 2 relied on the co-occurrence of *and* with particular verb-forms. However, *and* occurs only very rarely in subject position. It is much more common for sentences to contain conjoined verbs or objects (e.g., *he sings and dances a lot, I am talking to my brother and sister*; Hakuta, de Villiers, & Tager-Flusberg, 1982; Tager-Flusberg, de Villiers, & Hakuta, 1982), in which the conjunction has no influence on the verb. At best, this should render any learned dependency between *and* and plural agreement very noisy. Furthermore, even when conjoined singulars do occur in subject position, adults' agreement production depends on the notional number of the subject referent: Conjoined count nouns typically get plural agreement, but

conjoined deverbal mass nouns hardly ever do (e.g., *singing and dancing is fun*; Lorimor, 2007). Together, these facts make children's use of *and* to drive agreement choices in Experiment 2 unlikely.

Thus, the studies presented in this chapter demonstrate that children, like adults, treat agreement as formal and abstract, that is, as primarily syntactic.

Chapter 3

Representing Agreement

3.1 Introduction

How is agreement represented and used during online comprehension? As we have seen, 3-year-olds appear to use a combination of information including the noun class, structure and notional number of a subject noun phrase to govern their agreement production. Agreement may play a rather different role in comprehension.

Despite agreement's minimal appearance in English, agreeing verbs facilitate sentence comprehension, and are even used to anticipate the properties of an upcoming subject noun phrase (Lukyanenko, 2011): Three-year-olds and adults switched more quickly from a distractor picture (e.g., one cookie) to a target picture (e.g., two cookies) when they heard a sentence with an informative agreeing verb than when they heard one without (e.g., *Where are the good cookies?* vs. *Can you find the good cookies?*). They were also more likely to make such a switch in a window that ended before the noun could have influenced eye-movements. How did agreeing verbs facilitate comprehension in this study? In contrast to speakers, listeners may encounter a verb without information about its subject. In such contexts, the verb may provide the only information about the properties of the upcoming subject. What features do listeners infer from the form of the verb and how do they use them?

The studies in this chapter address the two orthogonal questions raised in the introduction with respect to agreement comprehension: Experiment 3 addresses whether listeners treat an agreeing verb solely as a cue to the notional number of likely upcoming elements, or whether it can also be used as a cue to the grammatical number of the upcoming subject noun phrase. Experiment 4 asks whether agreement is represented in terms of particular learned combinations of noun- and verb-forms, or whether it is represented at the level of abstract categories.

By answering these two questions, we determine whether the same underlying representations support both production and comprehension of verb agreement. Is agreement comprehension also primarily syntactic?

Table 3.1: Example stimuli from Experiment 3.

Trial Type

	Informative	*Uninformative*
Pl. Tant.		
	Where is the pretty phone? Where are the pretty glasses?	Where are the pretty phones? Where are the pretty glasses?
Mass		
	Where is the good corn? Where are the good apples?	Where is the good corn? Where is the good apple?

3.2 Experiment 3

When listeners hear an agreeing verb in an inverted sentence (e.g., *Where **are** the...*), what information can they glean about the properties of the upcoming subject? One possibility is that listeners primarily use agreement as a direct cue to notional number. Because most nouns are count nouns, whose grammatical number varies with notional number, plural agreeing forms are most typically associated with notionally plural subjects. This frequent association may be sufficient to drive predictions during online comprehension. Another possibility is that listeners primarily use agreement as a cue to the grammatical number of the upcoming subject, and that in constrained contexts this permits them to draw appropriate inferences about the notional number of the upcoming subject, leading them to reject a mismatching distractor and look more quickly to the target. Because previous studies use count noun targets, existing data is insufficient to tease these possibilities apart (Lukyanenko & Fisher, in prep.).

In the current study, we address this question by asking whether an agreeing verb can be used to facilitate processing in online comprehension, even when notional number is held constant in the visual context. As shown in Table 3.1, participants saw pairs of pictures accompanied by sentences directing their attention to one picture or the other (e.g., *Where are the pretty glasses?*). Trials were of two types: *informative*, in which the names of the two pictures differed in grammatical number (e.g., one pair of glasses, one phone), and *uninformative*, in which they did not (e.g., two pairs of glasses, two phones). In order to manipulate the grammatical number match of the picture pairs while holding the notional number constant, picture pairs always included one picture named by a count noun and one named by a non-count noun, either mass (*corn, toast*), or pluralia tantum (*glasses, pants*).

If participants can use an agreeing verb to anticipate the grammatical number of the upcoming subject noun phrase, they should look at the target earlier and longer in informative than in uninformative trials. If listeners use agree-

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ing verbs only as a direct cue to the notional number of the upcoming subject, however, there should be no difference in looking behavior between the two trial types.

3.2.1 Method

Participants

Thirty-two 3-year-old children (34.5-41.1 months, $M = 37.1$, 16 girls) and 32 college students (18 women) participated. All were native English speakers. One additional child was excluded because he left the room less than halfway through the study session. Three additional adults were excluded due to experimenter error (1), inattentiveness (1; see Coding below) and glare on glasses that made coding impossible (1). Three-year-olds' productive vocabularies were measured using the MacArthur Bates CDI (Level III; Fenson et al., 2007) and ranged from 10 to 100 (median = 80.5).

Stimuli

Stimuli consisted of sentences, each containing one of 8 familiar object-names, accompanied by photographs of the named object and of a distractor, as shown in Table 3.1. Sentences were recorded by a female native speaker of English. All sentences employed an inverted word order, in which the verb preceded its subject, the target noun phrase (e.g., *Where are the pretty glasses?*). Trials were of two types: In *informative* trials, the grammatical number of the target and distractor differed (e.g., 1 pair of glasses, 1 phone), while in *uninformative* trials, the grammatical number of target and distractor matched (e.g., 2 pairs of glasses, 2 phones).

Pictures appeared in yoked pairs (glasses-phone, pants-shirt, corn-apple, toast-banana). Each pictured object served 4 times as the target and 4 times as the distractor, with target side counterbalanced. Participants saw 16 trials of each type (informative, uninformative), each with 8 singular and 8 plural targets. Three filler trials involving a single, centrally-presented picture were interspersed among the 32 critical trials.

Apparatus and Procedure

Participants sat about 4 feet from a 50-inch television. Children sat on a parent's lap and parents wore opaque glasses that blocked their view of the screen. A camera beneath the screen recorded participants' eye-movements. To be sure they stayed attentive, adult participants were asked to point to the named target picture in each trial.

In each trial, pictures were visible for 7 seconds. The onset of the verb in the critical sentence occurred 2.5 seconds after the pictures appeared; thus

speech began approximately 2 seconds into the trial. Trials were separated by a 1 second blank-screen interval.

Coding

We coded where participants looked (left, right, away) during each 7-second trial, frame-by-frame from silent video. Reliability was calculated for 25% of the data. Coders agreed on 94.9% of all video frames for children, and 93.8% for adults. For children, individual trials were eliminated (137 of 1024 possible trials, 13%) if more than 50% of the trial was spent looking away or was uncodeable (124 trials), or if the child's or parent's speech obscured the critical sentence (13 trials; Fernald, Zangl, Portillo, & Marchman, 2008). For adults, trials were eliminated (20 of 1024, 2%) if more than 50% of the 7s trial was spent looking away or was uncodeable. One adult participant's data were excluded because more than 4 of the 8 possible trials in several of the trial type-plurality combinations (informative singular, informative plural, uninformative singular, uninformative plural) were eliminated.

Measures

To examine participants' use of agreeing verbs in online processing, we analyzed three measures of fixation patterns over time. First, we measured the latency of participants' first saccade to the target picture in trials where participants happened to be looking at the distractor at verb onset. If the verb provides useful information when the grammatical number of the pictured items differs, we would expect participants to shift their gaze more quickly to the target in informative trials than in uninformative trials. We also asked whether there was evidence of anticipatory use of an informative agreeing verb by examining two measures of looking behavior during a pre-noun window encompassing the verb, determiner and adjective. If participants are making rapid use of the information carried by the agreeing verb to pre-activate the properties of the upcoming subject noun phrase, in this early window we would expect them to be more likely to shift from distractor to target, and to spend more time overall looking at the target in this early window in informative than in uninformative trials.

3.2.2 Results

Figure 3.1 shows the proportion of all fixations that were directed to the target picture in 33 ms time intervals measured from verb onset by trial type and age group. As the Figure shows, both adults and children looked about equally to the target picture at verb onset, but looks to the target increased earlier in informative than in uninformative trials. This informative trial advantage began before noun onset. The informative trial advantage was noticeably smaller among children than among adults, and children's eventual accuracy was also

Figure 3.1: Proportion looks to target in the informative trials (blue) and uninformative trials (red), for adults (panel a) and children (panel b).
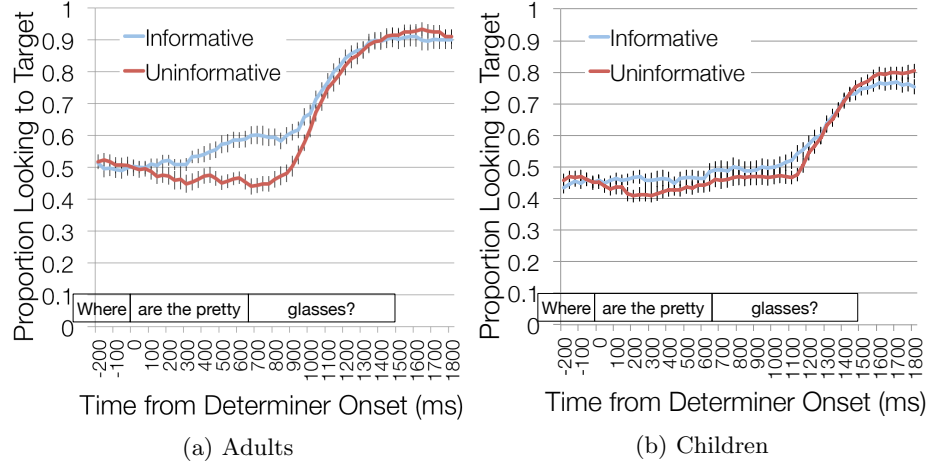
lower. These patterns suggest that when the number-marked verb was informative in the visual context, even in the absence of a notional number contrast between the pictured items; both 3-year-olds and adults used this information to speed sentence comprehension.

Latency of First Distractor to Target Shift

To assess the effect of the critical number-marked verbs, we measured the latency of participants' first shift to the target picture in trials where participants happened to be looking at the distractor at verb onset. Analyses of eye-movements typically exclude shifts launched less than 200 ms after the stimulus of interest for adults, and 300 ms (or more) for young children (e.g., Fernald et al., 2008). For 3-year-olds, we therefore calculated the latency of the first shift to the target within a 300 to 1800 ms window from verb onset. For adults, we calculated latencies within a window of equal length, extending from 200 to 1700 ms from verb onset. As shown in Figure 3.2, latencies were shorter in informative than in uninformative trials for both children and adults. This suggests that both children and adults used an informative agreeing verb to facilitate sentence processing.

To test this pattern, we fit a mixed effects model of children's and adults' shift latencies in R (R Core Team, 2013) using the *lmer()* function of the *lme4* package (D. Bates, Maechler, & Bolker, 2013). Predictor variables were the between-participants factor age group (child, adult) and the within-participants factor trial type (informative, uninformative). Both variables were coded using mean centered contrast codes. The model included the maximal random effects structure justified by the design (Barr, Levy, Scheepers, & Tily, 2013). Model syntax and results can be found in Table 3.2. The χ^2 statistics and associated p-values shown were obtained using model comparison. This analysis revealed

Figure 3.2: Latency of distractor-to-target saccades, measured from verb onset by trial type and age group. Error bars represent standard error of the mean.
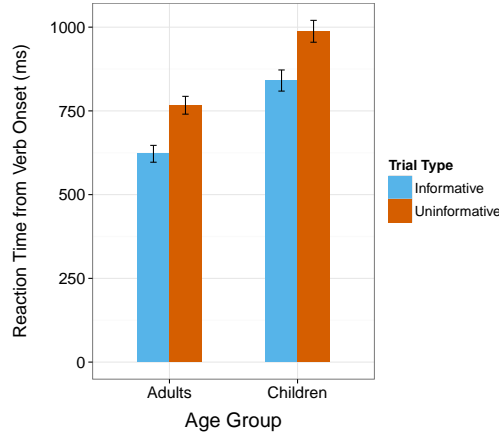

Table 3.2: Fixed effects estimates for the mixed-effects model of shift latency, with age group and trial type as predictor variables. Model was fit using the following formula: `latency ~ agegroup * trialtype + (1 + trialtype | participant) + (1 + agegroup * trialtype | target)` (N=614)

	Estimate	Std. Error	t value	χ^2	p value
(Intercept)	793.39	26.92	29.48	41.94	<.0001
age group	−222.17	42.97	−5.17	16.42	<.0001
trial type	−122.18	31.37	−3.90	9.88	0.0017
age group × trial type	−5.89	64.50	−0.09	0.01	0.92

a significant main effect of trial type and a significant main effect of age group, but no interaction between the two factors.

Follow up comparisons were conducted by using treatment coding to extract the simple main effect of trial type for each age group. The simple main effect of trial type was significant for both children ($\chi^2(1) = 4.45, p = .035$) and adults ($\chi^2(1) = 8.40, p = .004$). Thus, both children and adults used the information carried by the agreeing verb in informative contexts to speed sentence processing. However, because the window in which latency was measured included the noun, this measure may reflect either predictive use of the agreeing verb or the ease of integrating noun information with the informative context. Stronger evidence for predictive processing, and therefore for the agreeing verb's influence independent of the noun, would come from effects measured before information from the noun is available.

Pre-noun Window Switch Probability

To determine whether there was evidence for anticipatory use of an agreeing verb in informative trials, we examined participants' tendency to switch from the distractor to the target picture in the pre-noun window (Thorpe & Fernald,

Figure 3.3: Pre-noun Switch Probability: the proportion of trials that included a distractor-to-target shift in the pre-noun window, by trial type and age group. Error bars represent standard error of the mean.
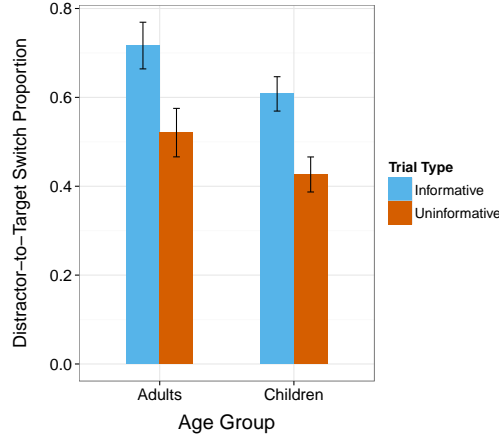

Table 3.3: Fixed effects estimates for the binomial mixed-effects model of switch probability, with age group and trial type as predictor variables. Model was fit using the following formula: `glmer( dtswitch ~ agegroup * trialtype + (1 + trialtype | participant) + (1 + agegroup * trialtype | target), family = "binomial")` (N=482)

	Estimate	Std. Error	z value	χ^2	p value
(Intercept)	0.19	0.13	1.45	1.86	.17
age group	0.37	0.24	1.54	1.96	.16
trial type	0.81	0.24	3.40	10.27	.001
age group × trial type	0.17	0.50	0.35	0.11	.73

2006). The pre-noun window was a 667 ms window that encompassed the verb, determiner and adjective portions of the sentence, but ended before shifts could be driven by the onset of the noun itself. For children, the window began 300 ms after verb onset and ended 300 ms after the earliest noun onset. For adults, the window began 200 ms after verb onset and ended 200 ms after earliest noun onset. If participants use an agreeing verb to pre-activate the grammatical number of the upcoming subject, they should be more likely to switch away from a mismatching picture in this early window in informative trials, even before noun information becomes available.

Figure 3.3 shows the mean switch probabilities during informative an uninformative trials for adults and children. Both children and adults made more distractor-to-target shifts in informative than in uninformative trials.

This pattern was supported by a binomial mixed-effects model of switch probabilities, fit using the *glmer()* function of the *lme4* package (D. Bates et al., 2013). As before, the model included the between-participants factor age group (child, adult) and the within-participants factor trial type (informative, uninformative) as predictor variables. Both predictors were coded using mean-

centered contrast codes. The model again included the maximal random effects structure. Model syntax and results can be found in Table 3.3. The χ^2 and p values shown were obtained using model comparison. This analysis revealed a significant main effect of trial type.

Follow-up comparisons were conducted using treatment coding to extract simple main effects of trial type for children and adults. The simple main effect of trial type was significant for both children ($\chi^2(1) = 5.92, p = .01$), and adults ($\chi^2(1) = 6.14, p = .01$). This indicates that both children and adults use the information carried by the agreeing verb to pre-activate properties of the upcoming noun in informative contexts.

Pre-noun Window Match Proportion

Another measure of anticipatory use of the agreeing verb is participants' overall tendency to look at the target during the pre-noun window. If participants use the agreeing verb in informative trials quickly and reliably, they might spend more time looking at the target in informative than in uninformative trials, even before noun information becomes available.

Figure 3.4 shows the mean proportion of target looking during the pre-noun window for adults and children in informative and uninformative trials. Adults but not children appear to look more to the target in informative than in uninformative trials. This pattern was supported by mixed-effects model of the empirical logit transformed match proportions over this early window. Model syntax and results can be found in Table 3.4. This analysis revealed a significant main effect of trial type.

As before, follow-up comparisons were conducted using treatment coding to extract the simple main effect of trial type for both children and adults. The simple main effect of trial type on match proportion was significant for adults ($\chi^2(1) = 4.62, p = .03$), but not for children ($\chi^2(1) = 1.46, p = .22$). This suggests that, while both adults and children use the information carried by an agreeing verb to anticipate properties of the upcoming subject, only adults reliably do so early enough to influence the overall proportion of time they spend looking at the target before the onset of the noun.

Table 3.4: Fixed effects estimates for the mixed-effects model of empirical logit transformed match proportion, with age group and trial type as predictor variables. Model was fit using the following formula: `lmer( el.matchprop ~ agegroup * trialtype + (1 + trialtype | participant) + (1 + agegroup * trialtype | target))` (N=1757)

	Estimate	Std. Error	t value	χ^2	p value
(Intercept)	0.10	0.13	0.74	1.84	0.18
age group	0.19	0.16	1.16	1.37	0.24
trial type	0.47	0.20	2.32	6.24	0.01
age group × trial type	0.31	0.32	0.32	2.27	0.13

Figure 3.4: Pre-noun Match Proportion: Proportion of time participants spent looking at the target in the pre-noun window, by trial type and age group. Error bars represent standard error of the mean.
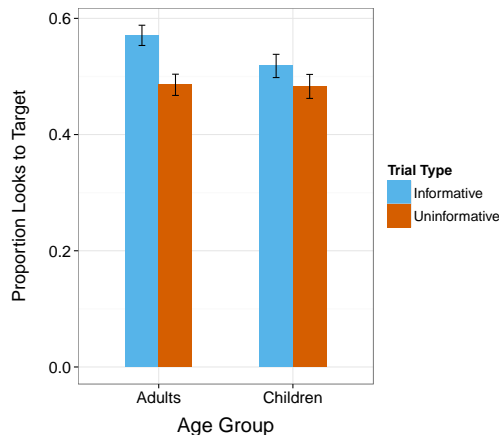
3.2.3   Discussion

Both children and adults used an informative agreeing verb to facilitate processing of the subject noun phrase in online comprehension, even when notional number was held constant across the distractor and target pictures. This facilitation appeared in an early window that ended before the noun could have influenced eye-movements. Thus, even in the absence of its canonical notional correlate, participants used number marking on the verb to pre-activate the grammatical number of the subject noun phrase. Participants' ability to predict grammatical number in this context suggests that both 3-year-olds and adults treat agreement as about the legal combinations of words in the language, not about legal combinations of meaning.

As with Experiment 1, however, participants' success with simple, familiar subject nouns might be the result of lexical-distributional knowledge about the relationships among the particular word forms used. That is, just as listeners must have learned that *glasses* is an unusual English noun in that it always plural, they may have learned about the combinations of other particular familiar forms in the input (e.g., *apples* typically appears with *are*, but *apple* typically appears with *is*). If this is the case, facilitation in Experiment 3 might be the result of predicting common co-occurring forms, not of predicting grammatical number as an abstract feature. To examine this possibility, we conducted a second comprehension experiment.

3.3   Experiment 4

Listeners appear to represent agreement in terms of how words in the language may legally combine, not in terms of how meanings in the language may

combine: In Experiment 3 listeners were able to use agreement to facilitate comprehension even in contexts where notional number was held constant. Is the underlying representation that supports this ability abstract or lexically specific?

Agreement creates distinctive lexical-distributional patterns in the input, and even very young children are sensitive to these patterns (Soderstrom, 2002; Soderstrom et al., 2002). Furthermore, children and adults are sensitive to fine-grained differences in word co-occurrence frequencies. For instance, children produce words more accurately when they occur as part of a frequent 4-gram, than when they occur in a different 4-word sequence matched for individual word, bigram, and trigram frequency (Bannard & Matthews, 2008). Children are also more likely to produce the correct irregular plural form in a frame that strongly predicts that particular form, as compared to in a frame that strongly predicts a plural (*three blind **mice*** vs. *so many **mice***; Arnon & Clark, 2011). These findings suggest that even relatively abstract, variable patterns like agreement might be represented in terms of the particular word forms that make them up.

If listeners represent agreement in terms of abstract grammatical categories, then agreeing verbs allow prediction and facilitate processing by permitting pre-activation of the grammatical number features of the upcoming subject noun phrase. In contrast, if listeners represent agreement primarily in terms of learned pairings of noun- and verb-forms, number-marked verbs (*is* and *are*) facilitate the processing of particular word-forms with which they frequently co-occur. To what degree can listeners use agreeing verbs to cue a grammatical property, as opposed to a likely co-occurring word? To investigate this question we tested listeners' ability to use an agreeing verb-form to facilitate processing of a novel noun (e.g., *Where are the pretty keppins?*). If facilitation occurs with novel nouns, it will suggest that prior experience with the particular word combinations is not a necessary component of the facilitation that occurs, and therefore that listeners represent agreement in terms of abstract grammatical categories.

3.3.1   Method

Participants

Ninety-six 3-year-old children (2;10-3;6, $M = 3;0$, 48 girls) and 48 college students (27 women) participated. As in Experiment 3, all were native English speakers. Twelve additional children were excluded because of reported language delay (2), refusal to participate (2), or inattentiveness and parental interference (8; see Coding, below). One additional adult was excluded because glare on his glasses made coding impossible. Children's productive vocabularies measured using the MacArthur-Bates CDI (Level III) ranged from 11 to 100 (median = 79). Vocabulary data were missing for one child.

Table 3.5: Example stimuli from Experiment 4.

	Novel		Familiar		
Inf.	There are the pretty keppins!		There are the nice puppies!		*pl.*
	There is the pretty lun!		There is the nice butterfly!		*sing.*
Uninf.	Look at the pretty keppins!		Look at the nice puppies!		*pl.*
	Look at the pretty lun!		Look at the nice butterfly!		*sing.*

Stimuli

As in Experiment 3, stimuli in Experiment 4 consisted of sentences, each containing the name of a target object, accompanied by photographs of the named object and of a distractor, see Table 3.5. However, in Experiment 4, 4 of the object names were familiar (*butterfly, puppy, doll, teddybear*) and 4 were novel (*keppin, lun, fendle, cham*). Novel names were associated with brightly-colored unfamiliar objects (a citrus reamer, a silicone trivet, a field-marking cone, and a miniature speaker, respectively). *Informative* sentences employed an inverted word order, as in Experiment 3, in which the verb preceded its subject, the target noun (e.g., *There are the pretty keppins!*). In *uninformative* sentences, in contrast, the target noun was not the subject of the sentence (e.g., *Look at the pretty keppins!*), and thus the verb could provide no advance information about the upcoming target NP.

The test phase was preceded by a brief introduction phase, in which all 8 objects were labeled by phrases that identified them as singular count nouns, but provided no direct information about verb agreement (e.g., *Look, a keppin!*; compare *a glasses, *a sand). This provided children with an opportunity to hear and become familiar with the novel words, and their associated referents.

During the test phase, pictures appeared in yoked pairs (puppy-butterfly, doll-teddybear, keppin-lun, cham-fendle). Each pictured object served 4 times as the target and 4 times as the distractor, with target side counterbalanced. Participants saw 16 novel-noun trials and 16 familiar-noun trials, each evenly divided among the four possible trial type-plurality combinations: informative singular, informative plural, uninformative singular and uninformative plural. Thus, each specific combination of verb- and noun-form appeared only once. Seven filler trials showing a single, centrally presented picture were interspersed among the 32 critical trials.

The experimental condition was compared to a control condition in which the distractor always matched the target in number, rendering the agreeing verb uninformative in context.

Apparatus and Procedure

The apparatus and arrangement were identical to Experiment 3. Children sat on their parent's lap, and parents wore opaque glasses to block their view of the screen.

In each trial, pictures were visible for 7 seconds. The onset of the determiner in critical sentences occurred 2.5 seconds after the pictures appeared; thus speech began approximately 2 seconds into the trial. Trials were separated by a 1 second blank-screen interval.

Coding

We coded where participants looked (left, right, away) during each 7-second trial, frame-by-frame from silent video. Reliability was calculated for 25% of the data. Coders agreed on 93.4% of all video frames for children, and 92.8% for adults. For children, individual trials were eliminated (346 of 3072 possible trials, 11%) if more than 50% of the trial was spent looking away or was uncodeable (265 trials), or if the child's or parent's speech obscured the critical sentence (81 trials). For adults, trials were eliminated (33 of 1536, 2%) if more than 50% of the 7s trial was spent looking away or was uncodeable. Eight children's data were excluded because more than 4 of the 8 possible trials of each trial type-plurality combination (informative singular, informative plural, uninformative singular, uninformative plural) were eliminated. No adults met this exclusion criterion.

Measures

Because Experiment 4 divides 32 trials across an additional variable of interest, noun type, there are half as many trials in each key cell of the design as there are in Experiment 3. This made it impractical to look at the same dynamic measures of eye-movements used in Experiment 3. These dynamic measures require selecting only those trials in which participants happen to be looking at the distractor at determiner onset, effectively reducing the number of trials by half again. Therefore, to determine whether participants used the information carried by the agreeing verbs to facilitate processing of both familiar and novel nouns, we examined two measures that can be calculated for every trial: the proportion of time participants spent looking at the target in two equal-sized windows aligned with determiner and noun onset.

If participants look longer to the target in informative trials than in uninformative trials in either window in the experimental condition, but not in the control condition, it will suggest that the agreeing verb facilitates processing in contexts that render it informative. If this effect appears in the early window, which ends before the noun itself could plausibly influence processing, we will have evidence that this effect is anticipatory, just as in Experiment 3.

Figure 3.5: Proportion looks to target in the experimental condition for adults (light lines) and children (dark lines). Informative trials are shown in blue and uninformative trials in red. Familiar noun trials are shown in panel (a), and novel noun trials in panel (b). Error bars represent standard error of the mean at each timepoint.

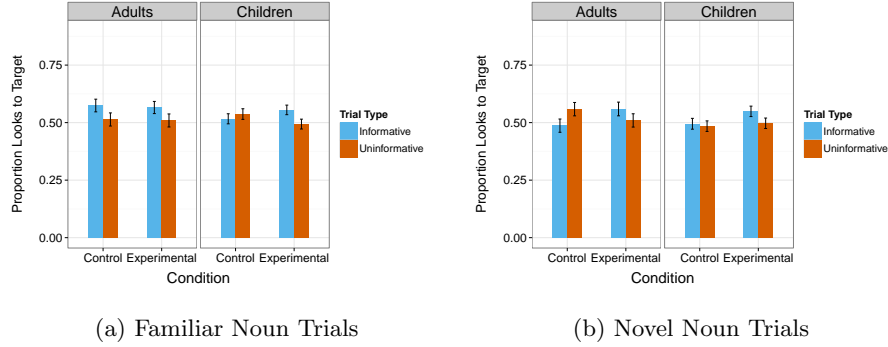(a) Familiar Noun Trials

(b) Novel Noun Trials
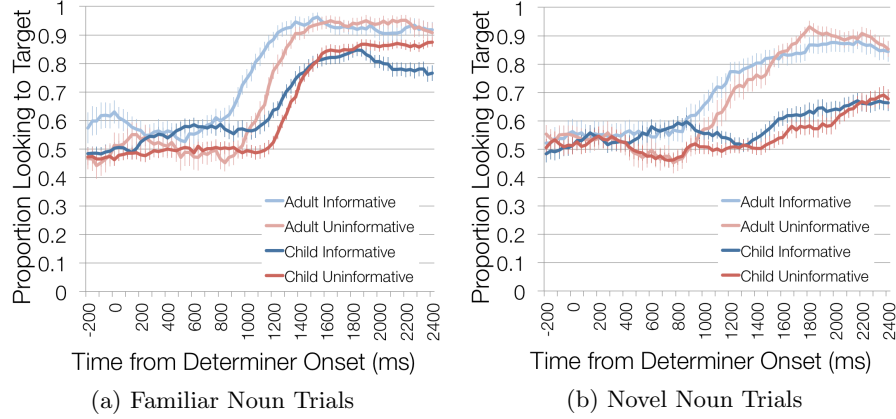
3.3.2 Results

Visual fixations during the sentences suggest that the processing advantage conferred by an agreeing verb extends to novel nouns. As can be seen in Figure 3.5, both adults and children looked more to the target in informative than in uninformative trials for both familiar and novel noun targets.

Pre-noun Window Match Proportion

To assess this pattern we measured the proportion of time participants spent looking at the target during a pre-noun window. The pre-noun window was a 767 ms window that encompassed the determiner and the adjective portions of the sentence. The beginning of the window was aligned with the onset of the determiner. We chose the determiner as our starting point because it was present in both informative (e.g., *Where are **the** pretty keppins?*) and uninformative sentences (e.g., *Can you find **the** pretty keppins?*), and in informative sentences occurred immediately after the number-marked verb. The average duration of the agreeing verb in informative trials was 200 ms. To allow time for the planning and execution of eye-movements, for children, the pre-noun window began 100 ms after determiner onset, and thus approximately 300 ms after verb onset in informative trials. The window ended 300 ms after the earliest noun onset, 767 ms later. For adults, the window extended from determiner onset, and therefore approximately 200 ms after verb onset, to 200 ms after the earliest noun onset. Thus, this is an early window in which the only information about which picture is the target comes from the agreeing verb.

As shown in Figure 3.6, children look longer to the target in informative than in uninformative trials in the experimental condition for both familiar

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Figure 3.6: Pre-noun Window Match Proportion: Proportion looks to target averaged over the pre-noun window for adults and children in the experimental and control conditions. Informative trials are in blue and uninformative trials in red. Familiar noun trials are shown in (a), and novel noun trials in (b).

(a) Familiar Noun Trials   (b) Novel Noun Trials

and novel noun targets, but there is little difference between informative and uninformative trials in the control condition. Adult also show an informative advantage in the experimental condition for both familiar and novel targets. Unlike the children, however, they also show moderate differences in the control condition: an informative advantage in the familiar trials and an uninformative advantage in the novel trials. While a consistent informative or uninformative advantage in the control condition might indicate a crucial difference between the different sentence types in clarity or ease of processing, this inconsistent pattern is likely a fluke. This possibility is supported by the fact that there is no such difference in the children's control condition, which consisted of precisely the same recorded sentences and picture pairs.

To assess the effects of the critical number-marked verbs across age groups and trial types, we fit a mixed-effects model of the empirical logit transformed pre-noun window match proportion using the *lmer()* function of the *lme4* package. Predictor variables were the between-participants factors condition (experimental, control) and age group (child, adult), and the within-participants factors trial type (informative, uninformative) and noun type (familiar, novel). All factors were coded using mean-centered contrast codes. A model with the maximal random effects structure justified by the design was attempted, but did not converge. Using a forward best path algorithm, we found that the random slopes of noun type and age group by target added to the model ($\alpha = .2$). The final model therefore included these slopes, and random intercepts for participant and target noun. Model syntax and results are shown Table 3.6.

This analysis revealed a significant main effect of trial type and the crucial significant interaction of trial type and condition. None of the interactions involving noun type or age group were significant. This suggests that as a whole, the group shows the interaction of interest: an informative advantage in the experimental condition, but not in the control condition, and that this

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Table 3.6: Fixed effects estimates for the mixed-effects model of empirical logit transformed pre-noun window match proportion, with age group, condition, noun type and trial type as predictor variables. Model was fit using the following formula: `lmer( el.prenoun.matchprop ~ agegroup * condition * trialtype * nountype + (1 | participant) + (1 + nountype + agegroup | target))` (N=3965)

	Estimate	Std. Err.	t value	χ^2	p value
(Intercept)	0.158	0.225	0.70	0.65	.42
age group	0.152	0.138	1.11	1.36	.24
condition	0.090	0.088	1.02	1.05	.30
trial type	0.225	0.088	2.55	6.50	.01
noun type	0.069	0.459	0.15	0.03	.86
age group × condition	−0.060	0.185	−0.32	0.11	.74
age group × trial type	0.003	0.185	0.02	0.00	.99
condition × trial type	0.459	0.177	2.60	6.75	.01
age group × noun type	−0.095	0.275	−0.35	0.14	.71
condition × noun type	−0.203	0.177	−1.15	1.31	.25
trial type × noun type	0.143	0.177	0.81	0.65	.42
age group × condition × t. type	−0.020	0.370	−0.05	0.32	.57
age group × condition × n. type	0.230	0.370	0.62	0.39	.53
age group × t. type × n. type	0.565	0.370	1.53	2.34	.13
condition × t. type × n. type	−0.058	0.354	−0.16	0.34	.56
age × cond. × t. type × n. type	−1.172	0.740	−1.58	2.51	.11

pattern does not differ strongly across noun types or age groups.

To follow up, we used treatment coding to examine the simple main effect of trial type within each key cell of the design. Among children in the experimental condition, the simple main effect of trial type was significant in familiar noun trials ($\chi^2(1) = 5.72, p = .017$), and marginal in novel noun trials ($\chi^2(1) = 3.14, p = .076$). For adults in the experimental condition, the effect of trial type was marginal in familiar noun trials ($\chi^2(1) = 2.90, p = .09$), but non-significant in novel noun trials ($\chi^2(1) = 1.74, p = .19$). The simple main effect of trial type did not reach significance for any of the comparisons within the control group (adult-familiar, $\chi^2(1) = 2.33, p = .13$; adult-novel, $\chi^2(1) = 2.12, p = .16$; children, both noun types $\chi^2 < 1$).

Thus, both children and adults appear to be able to use information carried by the agreeing verb to pre-activate properties of an upcoming noun, provided that the noun is familiar. Children also show some evidence of being able to pre-activate properties of an upcoming novel noun.

Noun Window Match Proportion

To examine the patterns of facilitation over time, we also examined participants' looking preferences during a window aligned with the onset of the noun in each trial. For children it began 300 ms after noun onset, and for adults it began 200 ms after noun onset. To match the pre-noun window, it lasted 767 ms. This encompassed most of the noun, which was 850 ms long on average.

Figure 3.7 shows the average proportion of time participants spent looking

Figure 3.7: Noun Window Match Proportion: Proportion looks to target averaged over the noun window for adults and children in the experimental and control conditions. Informative trials are in blue and uninformative trials in red. Familiar noun trials are shown in (a), and novel noun trials in (b).

(a) Familiar Noun Trials

(b) Novel Noun Trials
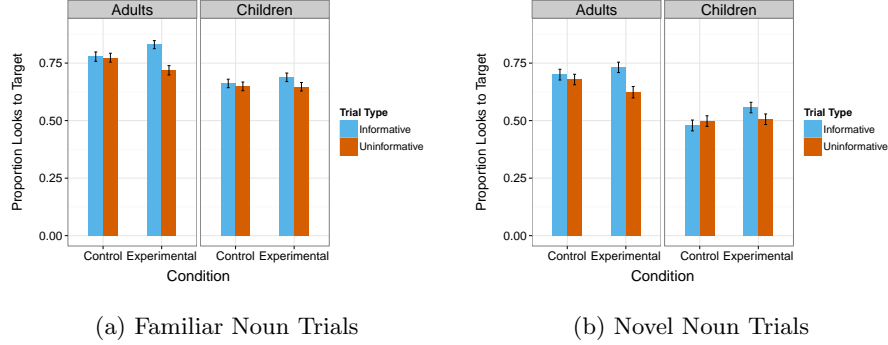
at the target during this window. Both children and adults spent longer looking at the target in informative than in uninformative trials in the experimental condition, but showed little or no difference in looking time in the control condition. Unsurprisingly, children's overall performance in the novel noun trials is markedly lower than their performance in familiar noun trials, reflecting their as-yet incomplete learning of the novel words.

To test this pattern, we fit a mixed-effects model of the empirical logit transformed noun window match proportion. Predictor variables were the same as in the previous model, and as before, the model with the maximal random effects structure did not converge. Using a forward best path algorithm, we found that the random slope of age group by target added to the model ($\alpha = .2$). The final model included this random slope, and random intercepts for participant and target noun. Model syntax and results are shown in Table 3.7.

This analysis revealed significant main effects of age group, trial type and noun type, as well as a marginal interaction between age group and trial type and the crucial, significant interaction between condition and trial type.

Follow up comparisons were conducted by using treatment coding to examine the simple main effect of trial type within each cell of the design. For children in the experimental condition the effect of trial type was significant in the novel noun trials ($\chi^2(1) = 4.91, p = .03$), but not in the familiar noun trials ($\chi^2(1) = 1.34, p = .24$). For adults in the experimental condition, the effect of trial type was significant in both familiar ($\chi^2(1) = 9.45, p = .002$), and novel noun trials ($\chi^2(1) = 8.73, p = .003$). The simple main effect of trial type was non-significant for all comparisons in the control condition (all $\chi^2(1) < 1$)

Thus it appears that both children and adults use the information carried by an agreeing verb to facilitate processing of both novel and familiar nouns.

Table 3.7: Fixed effects estimates for the mixed-effects model of empirical logit transformed noun window match proportion, with age group, condition, noun type and trial type as predictor variables. Model was fit using the following formula: `lmer( el.noun.matchprop` $\sim$ `agegroup * condition * trialtype * nountype + (1 | participant) + (1 + agegroup | target))` (N=4062)

	Estimate	Std. Err.	t	χ^2	p value
(Intercept)	1.01	0.20	5.07	13.36	.0003
age group	0.91	0.14	6.33	16.54	<.0001
condition	0.14	0.09	1.62	2.66	.10
trial type	0.27	0.08	3.55	12.64	.0004
noun type	0.90	0.40	2.26	4.91	.03
age group × condition	−0.27	0.18	−1.48	2.21	.14
age group × trial type	0.28	0.16	1.73	3.02	.08
condition × trial type	0.43	0.15	2.77	7.65	.006
age group × noun type	−0.43	0.28	−1.55	2.52	.11
condition × noun type	−0.15	0.15	−0.99	0.98	.32
trial type × noun type	−0.02	0.15	−0.16	0.03	.87
age group × condition × t. type	0.35	0.32	1.09	1.52	.21
age group × condition × n. type	0.41	0.32	1.28	1.65	.20
age group × t. type × n. type	−0.03	0.32	−0.10	0.01	.92
condition × t. type × n. type	−0.21	0.31	−0.67	0.77	.38
age × cond. × t. type × n. type	0.54	0.64	0.84	0.70	.40

3.3.3 Discussion

Both children and adults seem to readily extend their use of agreement in online processing to novel nouns. An informative agreeing verb facilitates novel and familiar subject noun processing to similar degrees, and does so for both children and adults. There is even a suggestion that this effect appears before the onset of the noun in children.

The ease with which children and adults extend their use of agreement in comprehension to novel nouns suggests that they have a pre-existing count noun category to which they are easily able to add new members. Adding the novel nouns to such a category would permit quick generalization of previously learned agreement patterns to the new category members, and would result in patterns like those observed. Thus, these results indicate that agreement not represented as a large set of dependencies between pairs of particular word forms, but as a dependency between categories with abstract features.

3.4 General Discussion

Experiments 3 and 4 examined the representations that underlie children's use of agreement during online comprehension, with respect to the two orthogonal dimensions of representation outlined in the introduction. Results demonstrate that 3-year-olds and adults neither treat agreement as a fully meaning-based nor as a fully lexical dependency in comprehension: An agreeing verb facilitated comprehension in both age groups even when notional number was held constant in the visual context, and even when the agreement controller was a novel noun.

The studies reported in this chapter provide additional evidence (following Lukyanenko & Fisher, in prep.) that children and adults use an informative agreeing verb as a cue to subject properties in online comprehension. These findings expand our understanding of this ability by indicating that the representation underlying this ability is primarily syntactic.

These findings also suggest that by the age of 3, children may have an abstract representation of the syntactic subject. In Experiments 3 and 4 and in Lukyanenko and Fisher's study (in prep., described in the introduction, section 1.2.3), 3-year-olds used an agreeing verb to infer properties of the subject. This was true despite the non-canonical, sentence-final position in which the subject occurred, and despite the fact that the subjects in locative inversions and location questions have few of the canonical properties associated with subject position (e.g., agent, movement; Dowty, 1991). Indeed, the fact that both canonical and non-canonical subjects control agreement on the verb may be one of the cues that helps children group them together.

One of the intriguing patterns described by Lukyanenko and Fisher (in prep.) was an asymmetry between singular and plural trials. The advantage of informative over uninformative trials tended to be stronger in plural trials than it was in singular trials both for measures of distractor-to-target shift latency over a longer window, and distractor-to-target shift probability in a pre-noun window. Unfortunately the designs of the current studies make it difficult to determine whether such an asymmetry also appears here. In Experiment 3, the non-count nouns were specifically selected to occur only in the plural (e.g., *glasses*), or only in the singular (e.g., *corn*). This means that dividing the trials by plurality interferes with the counterbalancing. If participants are more familiar with some of the non-count nouns than others, for instance, or if the pictures displaying some of the associated items are more visually attractive, item differences might either exacerbate or cloak any true asymmetry. Indeed, if we split trials by plurality, inspection of the resulting means suggests that there is no consistent tendency for the informative advantage to be larger in either singular or plural trials.

Similarly, examining singular and plural trials separately in Experiment 4 requires further subdividing the already limited number of trials in each cell, making results difficult to interpret. As in Experiment 3, inspection of means suggests that the relative sizes of the informative advantage in singular and plural trials varies across measures and age groups. One suggestive pattern is that asymmetries favoring the plural are more common among children than adults and in novel noun trials than in familiar trials. If this pattern is replicable, it might suggest that a plural-marked verb carries more weight particularly when other factors, such as age or unfamiliarity, make processing slow. However, for the reasons just listed, all of these patterns must be interpreted with caution. Minimally, the inconsistency in the patterns of asymmetry in these studies suggests that the previously observed plural advantage is not so robust

as to overwhelm item differences, or the noise inherent in further subdividing the data in Experiment 4. We revisit the singular-plural asymmetry in Chapter 5.

Another important observation about the current studies is that their results closely parallel those in Experiments 1 and 2, despite differences in the sentence structures used, the tasks, and whether children were asked to engage in production or comprehension. In both studies, young children demonstrated that they treat agreement as a primarily syntactic dependency, neither relying heavily on meaning, nor on lexical dependencies. This suggests that the representations children consult during production and comprehension are minimally based on the same features, and may be shared.

Note that because the two orthogonal dimensions of representation we are investigating (meaning–form, lexical–abstract) are indeed dimensions along which representations may vary, not dichotomous choices between potential styles of representation, there is a further question to address: Does notional number play any role in agreement at all? If children represent both agreement's syntactic properties and its notional correlates, they might well succeed at using grammatical number alone in comprehension, but still show some influence of the notional properties in other tasks. This question is addressed in the next chapter.

Chapter 4

Notional Number

4.1 Introduction

Both 3-year-old and adult listeners use an informative agreeing verb to pre-activate grammatical number features of an upcoming subject noun phrase (Experiment 3), and to facilitate processing of both novel and familiar subject nouns (Experiment 4). These patterns suggest that both children and adults treat agreement as a primarily syntactic dependency in comprehension. What role, if any, does notional number play in comprehension?

Notional number undeniably has an influence on agreement; its effect on agreement production is well-documented (e.g., Bock et al., 2004; Eberhard, 1999; Humphreys & Bock, 2005). Speakers are more likely to produce plural agreement when the subject has a notionally plural interpretation, as in (15a), as opposed to a singular one, as in (15b).

(15)   a. The gang on the motorcycles...

          b. The gang by the motorcycles...

However, because of the processes involved, this particular pattern of notional influence may be specific to production. Producers are creating an utterance to express a meaning, and therefore have access to the notional number information in the message (i.e., whether they are describing one or more than one item) as they plan both the subject and the verb. This knowledge may influence their assignment of grammatical number to the subject noun phrase (e.g., Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001; Eberhard et al., 2005), or influence verb-marking directly (e.g., Reid, 2011; Vigliocco & Hartsuiker, 2002). In either case, comprehenders are engaged in a different task, that of reconstructing unknown message information from incoming linguistic information.

In principle, there are two places notional number might play a role in comprehension. First, in contexts in which the subject precedes the verb, listeners may use the properties of the subject to predict the agreement features that should appear on the verb. In such a situation, the listener is likely to quickly access the meaning of the subject noun phrase, making both its grammatical and notional properties available to influence verb prediction, and creating

a process parallel to that in production. In such a situation, notional number might exert a small influence on the ease with which a subsequently-encountered verb-form is integrated with the preceding material. For example, *are* might be easier to read and integrate following a notionally plural subject (e.g., *the label on the bottles*), than following a notionally singular one (e.g., *the road to the mountains*).

However, some evidence suggests that listers do not typically predict the agreement features that the verb is likely to reflect, but instead use the agreement features of the verb, once encountered, as a cue to retrieve a matching noun from their representation of the unfolding sentence (e.g., Nevins, Dillon, Malhotra, & Phillips, 2007; Wagers et al., 2009). Specifically, listeners do not show a reduced P600 to verb endings that share features with the expected endings, as might be expected if a pre-activated set of agreement features were priming related sets (Nevins et al., 2007). Similarly, readers do not slow down when reading grammatically agreeing verbs in a context that frequently elicits attraction errors in speakers and their parallel in comprehenders, facilitated reading of an ungrammatical verb-form (e.g., *The key to the cabinets was/*were...*; Wagers et al., 2009). In principle, prediction during comprehension should be subject to the same difficulties production is, and the same contexts that make speakers more likely to produce the wrong agreeing form, should make readers more likely predict the wrong form. If incorrect predictions are the source of agreement attraction in comprehension, they would be expected to occasionally interfere with the comprehension of appropriately agreeing forms. The fact that there is little evidence for this suggests that upon encountering the noun, comprehenders are not pre-activating particular agreement features or forms before encountering the verb itself. If little or no prediction is occurring on the basis of the subject NP, it is unlikely that notional number plays a parallel role in comprehension and in production.

The other place notional number may play a role in comprehension is in inverted contexts, in which the agreeing verb precedes its subject (e.g., questions, locative inversions). In these contexts, information about the grammatical number of the subject noun phrase arrives before the noun itself. On one hand, this makes it less likely that notional number would influence comprehension, because the notional number is not yet apparent. On the other hand, if listeners are sensitive to the frequent overlap between notional and grammatical number, they may treat cues to grammatical number as probabilistic indicators of notional number, even while representing agreement as a primarily syntactic dependency.

Listeners are known to take a wide variety of information into account during comprehension, from both linguistic and non-linguistic sources (e.g., a word's initial phonemes, Allopenna et al., 1998; agreement marked on a determiner, Lew-Williams & Fernald, 2007; world-knowledge, Federmeier & Kutas, 1999; speaker preferences, Creel, 2012; and speaker accent, Trude & Brown-Schmidt,

2012). More specifically, listeners use the semantics of open-class words to retrieve helpful search features in visual tasks (Dahan & Tanenhaus, 2005; Huettig & Altmann, 2007; E. K. Johnson & Huettig, 2011). For instance, listeners who are asked to find a missing object with a canonical color (e.g., *strawberry*) will look more to a color-matching than to a color-mismatching distractor (e.g., red vs. yellow airplane). Thus, it seems likely that if listeners are sensitive to the typical congruence between notional and grammatical number, they might use an agreeing verb-form to drive similar predictions about the likely number of objects being described. To the extent that listeners can reasonably assume that an unknown noun (e.g., the as-yet unheard subject of an inverted sentence) is a count noun, they may infer notional number on the basis of verb-form, and look more quickly to pictures of single or multiple objects, accordingly.

To explore this potential role of notional number in agreement comprehension, and its relationship to listeners' use of agreement as a cue to grammatical number, we conducted two experiments. The first investigated adults' use of agreement as a cue to both notional and grammatical number during comprehension, and the second investigated children's use of the same cues.

4.2 Experiment 5

When adults hear an agreeing verb they are able to use it as a cue to the likely grammatical properties of its upcoming subject (Experiment 3). Do they also treat an agreeing verb as a likely cue to the subject's notional number?

In Experiment 5, we manipulate both notional and grammatical number, pitting the two cues against each other. As in previous studies, listeners heard sentences with an early agreeing verb (e.g., *Where are the nice glasses?*). These sentences were accompanied by pairs of pictures that either matched (*uninformative*) or differed (*informative*) in their grammatical number. The target picture on each trial either displayed *congruent* notional and grammatical number (e.g., two pairs of glasses, one slice of toast) or *incongruent* notional and grammatical number (e.g., one pair of glasses, two slices of toast). If listeners use agreement as a cue to grammatical number, as they did in Experiment 3, we should see facilitation in informative over uninformative trials, and if they use agreement as a cue to notional number, we should see facilitation in congruent over incongruent trials. It is also possible that these cues might interact, such that one operates only when the other is absent (e.g., notional congruence might matter only in grammatically uninformative trials).

4.2.1 Method

Participants

Forty college students (22 women) participated for course credit. All were native speakers of English. One additional participant was excluded from the

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Table 4.1: Example stimuli from Experiment 5.

Grammatical Number

	Informative		*Uninformative*	
Congruent				
Incongruent				

"Where are the nice glasses?"

sample because he frequently pointed to the wrong picture (see Apparatus and Procedure, below).

Stimuli

Like Experiments 3 and 4, Experiment 5 used a two-choice version of the visual-world paradigm. Participants saw pairs of pictures accompanied by a sentence directing their attention to one picture or the other. In Experiment 5, all pictured items were named with non-count nouns, eight mass nouns (*bread, cheese, corn, icecream, milk, pizza, soap, toast*) and eight pluralia tantum nouns (*binoculars, glasses, overalls, pajamas, pants, pliers, scissors, shorts*).

Using non-count nouns permitted the control of two independent dimensions of the stimuli: the congruence of the target's notional and grammatical number, and the informativeness of an agreeing verb given the visual context. In *congruent* trials, the target's notional and grammatical number aligned (e.g., 1 piece of toast, 2 pairs of glasses), while in *incongruent* trials, they did not (e.g., 2 pieces of toast, 1 pair of glasses). In *informative* trials, the grammatical number of the target and distractor differed (e.g., *glasses, toast*), and in *uninformative* trials they did not (e.g., *glasses, pants*). These two factors were fully crossed.

Note that in all trials, the number of items pictured in the target and distractor pictures differed. Thus, congruent trials had a distractor that was notionally incongruent with the grammatical number of the verb, and incongruent trials had a distractor that was notionally congruent with the grammatical number of the verb. This means that in each trial, the notional number of the two pictures either pointed listeners in the right direction or pointed them in the wrong direction. Notional number was never a neutral cue, as it was in Experiment 3.

Because this design required different pairings of nouns (*glasses - pants, glasses - toast*, etc.), pictures did not appear in yoked pairs, but instead in counterbalanced sets of 4. Adult participants are better at sitting through a repetitive video than 3-year-olds are. Therefore, in Experiment 5 we presented participants with 64 5-second trials. Each pictured object served 8 times as the target and 8 times as the distractor, with target side and the number of items pictured counterbalanced. Participants saw 16 trials in each congruence-

informativeness combination: congruent-informative, congruent-uninformative, incongruent-informative, incongruent-uninformative.

Because none of the nouns are count nouns, the actual number of items pictured is irrelevant to the grammatical number of the picture's name. If participants are sensitive only to the grammatical implications of an agreeing verb, they should show a processing advantage in informative over uninformative trials. If, however, they also interpret agreeing verbs as carrying information about the likely notional number of the upcoming referent, they should also show processing advantages in congruent over incongruent trials.

Apparatus and Procedure

The apparatus and procedure were identical to Experiments 3 and 4. Participants were asked to point to the named target picture on each trial, to be sure that they remained attentive for the duration of the study.

On each trial, pictures were visible for 5 seconds. The onset of the verb occurred 2 seconds after the pictures appeared. Thus, speech began approximately 1.5 seconds into the trial. Trials were separated by a 1 second blank-screen interval. There were 7 single-picture filler trials interspersed among the test trials.

Coding

We coded where participants looked (left, right, away) during each 5-second trial, frame-by-frame from silent video, as well as the direction participants pointed on each trial. Reliability was calculated for 25% of the data (10 participants). Coders agreed on 94.7% of all video frames. Individual trials were eliminated (103 of 2560, 4%) if more than 50% of the trial was spent looking away or was uncodeable (84 trials), or if the participant pointed to the distractor instead of the target (19 trials).

One participant's data were excluded because he pointed to the wrong picture on 19 of 64 trials, resulting in the elimination of more than half the trials in the incongruent-uninformative condition. The only other participant who pointed to the wrong picture on a notable number of trials pointed to the incorrect picture on 10 trials, clustered at the beginning of his session, due to a brief misunderstanding of the instructions. This did not result in the elimination of more than half the trials in any of the four congruence-informative combinations, and the participant's data were retained.

Measures

To examine participants' use of agreeing verbs in this task, we analyzed four measures of fixation patterns over time. First, we measured the latency of participants' first saccade to the target picture in trials where they happened to be looking to the distractor at verb onset. We also asked whether there was

Figure 4.1: Proportion looks to target from verb onset. Grammatically informative trials are in blue, and uninformative trials are in red. Pale lines represent notionally incongruent trials, and dark lines represent notionally congruent trials. Error bars represent standard error of the mean.
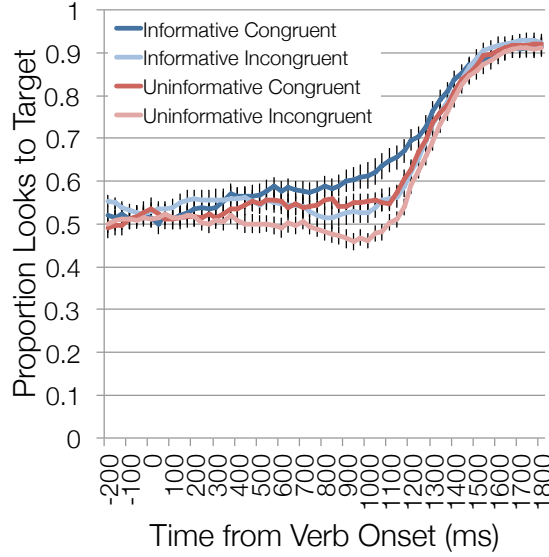
evidence of anticipatory use of the agreeing verb as a cue to notional or grammatical properties of the upcoming subject by examining participants' propensity to shift from the distractor to target in an pre-noun window encompassing the verb, determiner and adjective. We also examined the proportion of time participants spent looking to the target in the pre-noun window and in a window of equal length anchored to the onset of the noun.

If participants use the agreeing verb as a cue to the likely notional properties of the upcoming subject, we expect to see shorter shift latencies, more distractor-to-target shifts and more target looks in the congruent than in the incongruent trials. Similarly, if participants use agreement as a cue to grammatical number as they did in Experiment 3, we would expect shorter shift latencies, more distractor to target shifts and more target looks in grammatically informative than grammatically uninformative trials, despite the added notional number contrast.

4.2.2 Results

Figure 4.1 shows the proportion of all fixations that were directed to the target picture in 33 ms time intervals measured from verb onset, by grammatical informativeness and notional congruence. Adults looked about equally to the target at verb onset, but looks to the target increased earlier in informative than in uninformative trials, and earlier in congruent than in incongruent trials. Both the informative and the congruent advantage began before noun onset, which occurred an average of 890 ms after verb onset. The grammatical advantage

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Figure 4.2: Latency of distractor-to-target saccades, measured from verb onset by grammatical informativeness and notional congruence. Error bars represent standard error of the mean.
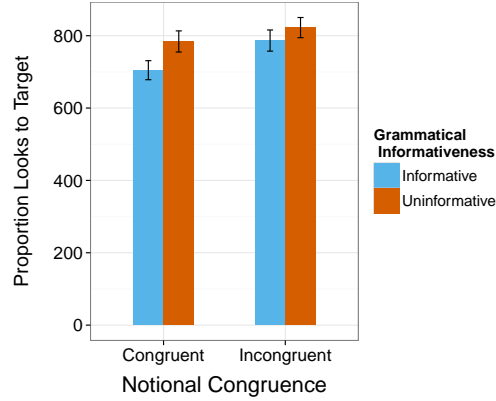

Table 4.2: Fixed effects estimates for the mixed-effects model of shift latency, with grammatical informativeness and notional congruence as within-participants predictor variables. Model was fit using the following formula: `lmer( latency ~ grammatical * notional + (1 + grammatical * notional | participant) + (1 + grammatical * notional | target))` (N=847)

	Estimate	*Std. Error*	*t*	χ^2	*p value*
(Intercept)	776.0	24.5	31.7	81.45	<.0001
grammatical	−42.0	38.7	−1.08	1.20	.27
notional	−73.0	33.6	−2.17	4.39	.036
grammatical × notional	−44.6	70.2	−0.64	0.43	.51

replicates our findings in Experiment 3, and the congruent advantage suggests that even in the absence of count noun targets, participants use an agreeing verb as a cue to the likely notional properties of the upcoming subject.

Latency of First Distractor to Target Shift

To assess the effect of the critical agreeing verbs, we measured the latency of participants' first shift to the target picture in trials where participants happened to be looking at the distractor picture at verb onset. Analyses of eye-movements typically exclude shifts launched less than 200 ms after the stimulus of interest for adults. Thus, we calculated latencies within a window extending from 200 to 1700 ms from verb onset. As shown in Figure 4.2, latencies were shorter in informative than in uninformative trials, and in congruent than incongruent trials. This suggests that agreement serves both as a cue to the grammatical and the likely notional properties of the upcoming subject.

To test this pattern we fit a mixed-effects model of adults' shift latencies in R, using the *lmer()* function of the *lme4* package. The predictor variables

were the within participants factors of grammatical informativeness (informative, uninformative), and notional congruence (congruent, incongruent), coded using mean-centered effects coding. The model included the maximal random effects structure justified by the design. Thus, random intercepts and random slopes of informativeness, congruence and their interaction by participant and by target noun were included. Model syntax and results are shown in Table 4.2. This analysis revealed a significant main effect of notional congruence, but no effect of grammatical informativeness, nor an interaction between the factors.

This suggests that participants show a processing advantage in notionally congruent over incongruent trials, but that the numerical advantage for informative over uninformative trials visible in the graph is not statistically reliable. Upon hearing an agreeing verb, participants are faster to shift away from a picture whose notional number is incongruent with the verb's features, than to shift away from a picture whose notional number is congruent with the verb's features. That is, hearing *Where are...*, listeners shift their gaze more quickly from a picture of a single item to a picture of two items, than from a picture of two items to a picture of one item, regardless of the grammatical number of the items' names.

Pre-noun Window Shift Probability

To determine whether there was evidence for anticipatory use of an agreeing verb to facilitate processing on the basis of grammatical or notional cues, we examined participants' tendency to switch from the distractor to the target in a pre-noun window (Thorpe & Fernald, 2006). The pre-noun window was a 700 ms window extending from 200 ms after verb onset to 200 ms after earliest noun onset. Thus, it began as soon as the agreeing verb might influence looking behavior, and ended before shifts could be driven by the onset of the noun itself. If participants use an agreeing verb to pre-activate likely notional features of the upcoming subject, they should be more likely to shift to the target in congruent than in incongruent trials. Similarly, if they use the agreeing verb to pre-activate grammatical features of the upcoming subject, as they did in Experiment 3, they should be more likely to switch away from a grammatically mismatching picture, and should therefore shift more in informative than in uninformative trials.

Figure 4.3 shows the mean shift probabilities during all trial types. The probability of shifting from distractor to target was highest in the informative congruent trials. This pattern was tested using a binomial mixed-effects model of shifts, fit using the *glmer()* function of the *lme4* package. As before, the predictor variables were grammatical informativeness and notional congruence, and random intercepts were included for participant and target noun. A model with the maximal random effects structure did not converge, so a forward best path algorithm was used to determine which random slopes to include. Only the random slope of grammatical informativeness by target noun met the inclusion

Figure 4.3: Pre-noun Shift Probability: The proportion of distractor-initial trials that included a shift to target in the pre-noun window, by grammatical informativeness and notional congruence. Error bars represent standard error of the mean.

Table 4.3: Fixed effects estimates for the mixed-effects model of distractor-to-target shift probability in the pre-noun window, with grammatical informativeness and notional congruence as within-participants predictor variables. Model was fit using the following formula: `glmer(dtswitch ~ grammatical * notional + (1 | participant) + (1 + grammatical | target), family = ``binomial")` (N=918)

	Estimate	Std. Error	z	χ^2	p value
(Intercept)	0.267	0.134	1.99	3.79	.052
grammatical	0.045	0.180	0.25	0.06	.80
notional	0.293	0.139	2.11	4.29	.038
grammatical × notional	−0.288	0.279	1.03	1.03	.31

Figure 4.4: Pre-noun Match Proportion: Proportion of the time participants spent looking to the target during the pre-noun window, plotted by grammatical informativeness and notional congruence. Error bars represent standard error of the mean.
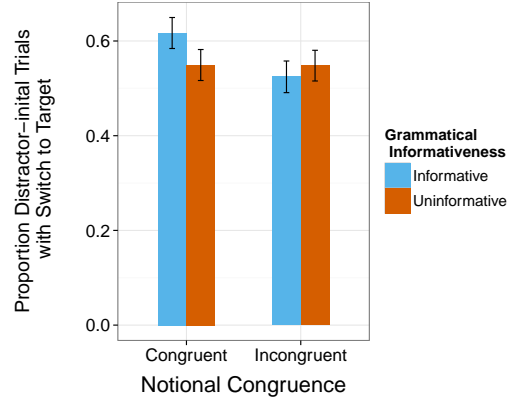

Table 4.4: Fixed effects estimates for the mixed-effects model of empirical logit transformed pre-noun window match proportion, with grammatical informativeness and notional congruence as within-participants predictor variables. Model was fit using the following formula: `lmer(emplogit.prenoun ~ grammatical * notional + (1 + grammatical | participant) + (1 + notional | target))` (N=2364)

	Estimate	Std. Error	t	χ^2	p value
(Intercept)	0.275	0.094	2.94	7.38	.0066
grammatical	0.292	0.126	2.32	5.15	.023
notional	0.287	0.171	1.68	2.72	.099
grammatical × notional	−0.110	0.219	−0.50	0.25	.61

criterion ($\alpha = .2$). Model syntax and results can be found in Table 4.3. This analysis revealed a significant main effect of notional congruence, but no effect of grammatical informativeness, nor an interaction

This suggests that in visual contexts with a notional number contrast, participants used agreement to pre-activate the likely notional number features of an upcoming subject, despite the fact that all target nouns were non-count nouns and that notional number was therefore irrelevant to grammatical number within the task.

Pre-noun Window Match Proportion

Another measure of anticipatory use of the agreeing verb is participants' overall tendency to look at the target during the pre-noun window. If participants use the agreeing verb as a cue to notional and grammatical number quickly, they should look longer to the target in congruent than in incongruent trials, and in informative than in uninformative trials, even before noun information becomes available.
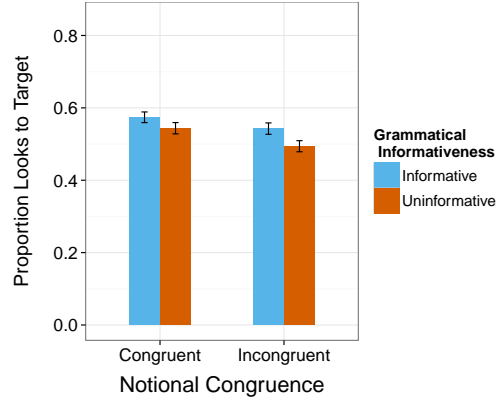
80

Table 4.5: Fixed effects estimates for the mixed-effects model of empirical logit transformed noun window match proportion, with grammatical informativeness and notional congruence as within-participants predictor variables. Model was fit using the following formula: `lmer(emplogit.noun ~ grammatical * notional + (1 + grammatical | participant) + (1 + notional | target))` (N=2426)

	Estimate	Std. Error	t	χ^2	p value
(Intercept)	2.179	0.107	20.37	74.24	<.0001
grammatical	0.205	0.083	2.46	5.81	.016
notional	0.192	0.115	1.66	2.68	.10
grammatical × notional	−0.024	0.145	−0.16	0.02	.87

Figure 4.4 shows the mean target looking during the pre-noun window for all trial types. Participants look more to the target in informative than in uninformative trials, and in congruent than in incongruent trials. This pattern was supported by a mixed-effects model of the empirical logit transformed match proportions over this early window. The predictor variables, as before, were the within participants factors of informativeness and congruence. The model included random intercepts for participant and target noun, but the maximal model resulted in convergence issues. Therefore a forward best path model ($\alpha = .2$) was used to determine which random sloes to include. The random slopes of informativeness by participant and congruence by target noun met this criterion. Model syntax and results are shown in Table 4.4. This analysis revealed a significant main effect of grammatical informativeness, and a marginal main effect of notional congruence.

This suggests that, while grammatical informativeness did not seem to influence participants' tendency to shift from distractor to target in this early window, they do use the agreeing verb to pre-activate the grammatical features of the upcoming subject. Participants look longer to the target in informative than in uninformative trials, even before information from the noun itself becomes available. Note that the different patterns of results in this and the previous analysis do not constitute a worrisome discrepancy. One important consideration, for instance, is that many more trials can be included in the current analysis than can be included in the analysis of shift probability, and furthermore, that the proportion of looks at the target over a particular window is driven not only by participants' tendency to switch to a particular picture, but also by their tendency to continue looking once they fixate it.

Noun Window Match Proportion

Figure 4.4 shows the mean target looking during the noun window for all trial types. Participants look more to the target in informative than in uninformative trials, and in congruent than in incongruent trials, but the differences were numerically very small. This pattern was supported by a mixed-effects model of the empirical logit transformed match proportions over the noun window.

Figure 4.5: Noun Match Proportion: Proportion of the time participants spent looking to the target during the noun window, by grammatical informativeness and notional congruence. Error bars represent standard error of the mean.
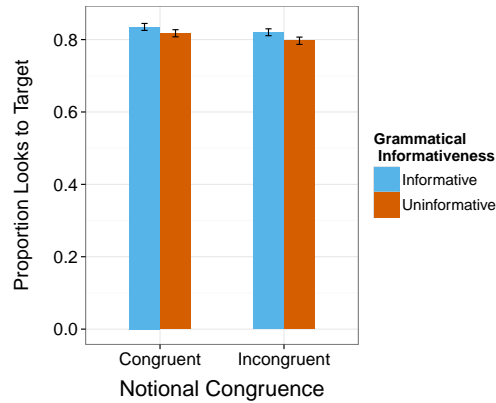
The predictor variables, as before, were the within participants factors of informativeness and congruence, coded using mean-centered effects coding. The model included random intercepts for participant and target noun, and because the maximal model failed to converge, a forward best path model was used to determine which random slopes should be included ($\alpha = .2$). This resulted in the inclusion of the random slope of informativeness by participant and of congruence by target noun. Model syntax and results are shown in Table 4.5. The analysis revealed a significant main effect of grammatical informativeness and a marginal main effect of notional congruence.

Thus, though differences were small, participants showed a reliable pattern of facilitation based on the presence of an agreeing verb in a grammatically informative context. Participants looked more at targets that differed from the distractor in grammatical number than at targets that did not, even once information from the noun was available.

4.2.3 Discussion

Experiment 5 asked what properties of the subject adults infer on the basis of an early agreeing verb. Participants showed evidence of facilitation and prediction in both notionally congruent and grammatically informative trials, suggesting that they treated an agreeing verb as a cue both to the likely notional properties and the likely grammatical properties of the upcoming subject.

Interestingly, evidence for the use of the agreeing verb as a cue to notional features came primarily from the dynamic measures of eye-movements (latency and proportion of distractor-to-target shifts), while evidence for use of the verb as a cue to grammatical features came from looking patterns averaged across longer windows (pre-noun and noun match proportions). This may suggest that though agreement carries information about the likely notional number of the

upcoming subject, it plays more of an automatic role: Upon hearing an agreeing verb-form, participants are able to generate a perceptual prediction based on the notional properties frequently associated with the observed grammatical number, and their eyes are drawn to pictures that fit that perceptual prediction first. They may then quickly activate the name of the item and assess its grammatical fit with the preceding agreeing verb. Such a process would result in more, faster shifts to a notionally congruent picture, but continuing fixations only on pictures that fit grammatically. So for instance, a participant might quickly look toward a picture of two items upon hearing *are*, but then activate the name of the pictured items, *corn*, discover that this word's properties do not match those of the agreeing verb, and quickly switch again. Such a pattern would result in an advantage on dynamic measures in congruent trials, and an advantage on measures of overall preference in grammatically informative trials.

4.3 Experiment 6

Adults in Experiment 5 used an agreeing verb as a cue to both the likely notional and grammatical properties of an upcoming subject. What properties of the subject do children infer from the form of the agreeing verb during online comprehension? Children, like adults, use an agreeing verb as a cue to the grammatical properties of an upcoming subject when notional number is held constant (Experiment 3), and use an agreeing verb to facilitate processing of both familiar and novel nouns (Experiment 4), suggesting that they treat agreement as primarily syntactic.

Do children, like adults, also use agreement as a cue to the likely notional number of the subject noun phrase? On one hand children might have a stronger tendency to infer notional number on the basis of the agreeing verb. After all, children have less experience with the types of subject noun phrases that distinguish between notional and grammatical number (e.g., non-count nouns, complex NPs), and this might make the typical congruence between notional and grammatical number a stronger influence on their interpretation. On the other hand, Experiments 1 and 2 demonstrated that by the age of 3, children choose the appropriate agreeing forms for both non-count noun and complex subjects. Furthermore, children process incoming linguistic information more slowly than adults do, making adults' apparent tendency to look quickly to a notionally congruent picture and then assess grammatical fit, potentially less helpful for children than for adults.

4.3.1 Method

Participants

Sixty-four 2- and 3-year-olds (2;6-3;5, $M = 2;10$, 32 girls) participated in a shortened version of Experiment 5. All were native English speakers. Twelve

additional children were excluded because of reported language delay (5), refusal to participate (1), or inattentiveness and parental interference (6; see Coding). Children's productive vocabularies, measured using the MacArthur-Bates CDI (Level III) ranged from 5 to 97 (median = 78.5).

This study included a larger age range than Experiments 3 and 4 partly for practical reasons and also in hopes of gathering preliminary data about the trends of these effects across the third year.

Stimuli

Experiment 6 used a two-choice version of the visual-world paradigm. Trials were a subset of those presented to adults in Experiment 5. Experiment 6 used only those trials with the mass nouns *corn, toast, cheese* and *bread*, and the pluralia tantum nouns *pants, scissors, pajamas* and *glasses*. These 32 trials represented a counterbalanced half of the Experiment 5 design. Thus, each pictured object served as the target 4 times and as the distractor 4 times, with target side counterbalanced. Thus, participants saw 16 trials with a mass noun target, and 16 with a pluralia tantum target. There were 8 trials in each of the informativeness-congruence combinations: congruent-informative, congruent-uninformative, incongruent-informative, and incongruent-uninformative. Seven filler trials showing a single picture were interspersed among the critical trials.

Apparatus and Procedure

The apparatus and procedure were identical to Experiments 3 and 4. Children sat on their parent's lap for the video, which lasted approximately 5 minutes. Parents wore opaque glasses to block their view of the screen.

Trials in Experiment 6 were 7 seconds long. Thus trials were the same length as in Experiments 3 and 4, but were longer than in Experiment 5. The onset of the verb in critical sentences occurred 2.5 seconds after the pictures appeared on the screen: Thus, speech began approximately 2 seconds into the trial. Trials were separated by a 1 second blank-screen interval.

Coding

We coded where participants looked (left, right, away) during each 7 s trial, frame-by-frame from silent video. Reliability was calculated for 25% of the data. Coders agreed on 95.7% of all video frames. Individual trials were eliminated (228 of 2048, 11.1%) if more than 50% of the trial was spent looking away or was uncodeable (172 trials) or if the child's or parent's speech obscured the critical sentence (56 trials). Six children's data were excluded because more than 2 of the 4 possible trials were eliminated in one or more of the combinations of informativeness, congruence and plurality.

Figure 4.6: Proportion looks to target from verb onset. Grammatically informative trials are in blue and uninformative trials are in red. Notionally congruent trials are plotted with dark lines, and incongruent trials are plotted with light lines. Error bars represent standard error of the mean.
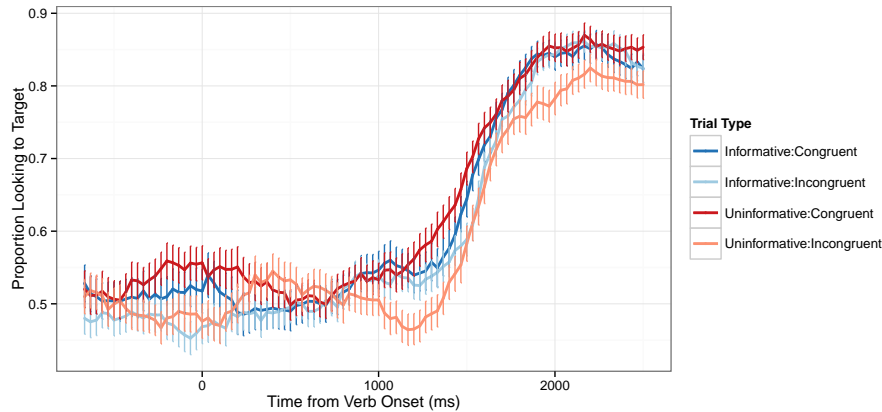
Measures

This study includes half as many trials per condition as Experiment 5 did, making it less likely that dynamic measures of eye-movements will be revealing. However, given that the adults showed effects of notional number on dynamic measures and effects of grammatical number on averaged measures, it seemed prudent to analyze both types of measure for the children. We therefore report the latency of the first shift from distractor to target, the probability of a distractor to target shift in the pre-noun window, and match proportions across both the pre-noun and noun windows.

Note that while the recorded sentences are the same as those used in the adult study, the pre-noun window in Experiment 6 (867 ms) is longer than that in Experiment 5 (700 ms). This is because the sentence with the earliest noun onset in Experiment 5 was not in the half of the design used for Experiment 6, conveniently permitting a little more time to observe potential anticipatory effects.

4.3.2 Results

Figure 4.6 shows the proportion of all fixations that were directed to the target picture in 33 ms time intervals from verb onset, by grammatical informativeness and notional congruence. Children's looking patterns were noisier than adults: There is substantially more variability among the conditions, for instance, in where children were looking at verb onset than there was in Experiment 5 (compare Figure 4.1, and Figure 4.6). Children also show a rather different pattern than adults did. Analyses of adults' responses in Experiment 5 showed two main effects of similar size: Both informative trial types showed an advantage over their uninformative counterparts, and both congruent trial types showed

Figure 4.7: Latency of the first distractor-to-target saccade, measured from verb onset and plotted by grammatical informativeness and notional congruence. Error bars represent standard error of the mean.
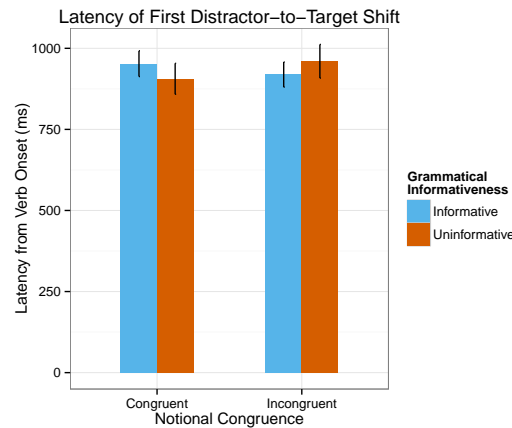
an advantage over their incongruent counterparts. This resulted in an overall advantage for congruent-informative trials, and an overall disadvantage for incongruent-uninformative trials. Children show a similar overall disadvantage in the incongruent-uninformative trials, but no overall advantage in congruent informative trials. Instead, the other three trial types seem to pattern together.

This pattern suggests that children may treat agreement as an indicator of both grammatical and notional number, but that the cues are not additive. That is, a context in which either cue proves helpful facilitates processing, but having a context that supports both is not additionally helpful. If this pattern is statistically reliable, it should appear as an interaction of grammatical informativeness and notional congruence. However, given children's noisier looking patterns, it may be difficult to pin down.

With this in mind, we examine the same four measures of looking behavior that we used with adults: the latency of the first distractor to target shift, the probability of such a shift in the pre-noun window, and the proportion of time spent looking to the target in the pre-noun and noun windows.

Latency of First Distractor to Target Shift

Figure 4.7 shows the average latency of the first shift from distractor to target, measured from verb onset for trials in which the child happened to be looking at the distractor picture at verb onset. For children, latencies were measured in a 1500 ms window extending from 300 ms following verb onset to 1800ms after verb onset. Latencies under 300 ms were excluded as too early to have been driven by the verb itself. As shown in the Figure, latencies were quite similar across all four trial types.

This relatively flat pattern was supported by the results of a mixed-effects model of latency, fit in R, using the *lmer()* function of the *lme4* package. Pre-

Figure 4.8: Pre-noun Shift Probability: The proportion of distractor-initial trials that included a shift to target in the pre-noun window, plotted by grammatical informativeness and notional congruence. Error bars represent standard error of the mean.
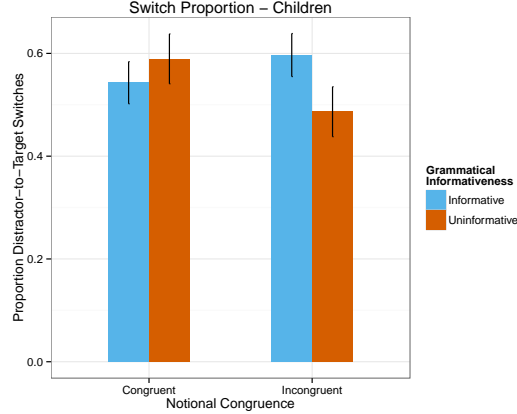
Table 4.6: Fixed effects estimates for the mixed-effects model of children's distractor-to-target shift probability in the pre-noun window, with grammatical informativeness and notional congruence as within-participants predictor variables. The model was fit using the following formula: `glmer( dtswitch ~ grammatical * notional + (1 | participant) + (1 + notional | target), family = ''binomial")` (N=627)

	Estimate	Std. Error	z	χ^2	p value
(Intercept)	0.270	0.142	1.90	3.21	.073
grammatical	0.261	0.172	1.52	2.20	.14
notional	−0.101	0.316	−0.32	0.10	.75
grammatical × notional	−0.629	0.344	−1.83	3.16	.075

dictor variables were the within participants factors notional congruence (congruent, incongruent) and grammatical informativeness (informative, uninformative). Both variables were coded using mean-centered contrast codes. The model included the maximal random effects structure. This analysis revealed no significant main effects, nor a significant interaction: all $\chi^2(1) < 1$, all $p > .8$.

To determine whether the latency varied across the wider age range tested in this study, we compared the model described above was compared to a model identical except for the inclusion z-scored age. The addition of age as a fixed-effect did not contribute significantly to model fit ($\chi^2(1) = 1.24, p = .27$), suggesting that latency of the first distractor to target shift did not vary dramatically across this age range.

Pre-noun Shift Probability

To determine whether there was any evidence of anticipatory processing in children's eye-movements, we examined the proportion of distractor-initial trials in which children switched to the target picture during the pre-noun window. The

Figure 4.9: Pre-noun Match Proportion: Proportion of the time children spent looking to the target during the pre-noun window, plotted by grammatical informativeness and notional congruence. Error bars represent standard error of the mean.
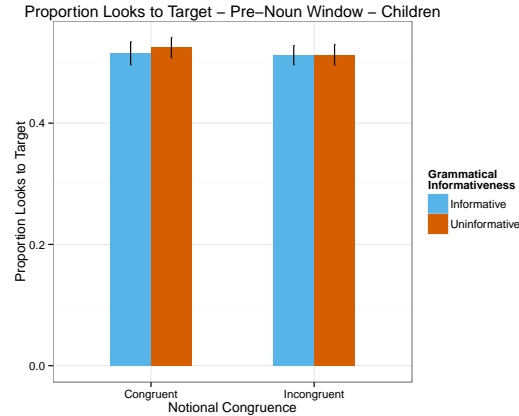

pre-noun window extended from 300 ms after verb onset to 300 ms after the earliest noun onset, and was 867 ms long. Because the window ends shortly after noun onset, looking behavior in this window should not be influenced by information from the noun itself. Average shift proportions are shown in Figure 4.8. Here we see something that echoes the patterns in the line graph more closely: Children make fewer shifts from distractor to target in the uninformative incongruent trials, while the other three trial types generally pattern together.

A binomial mixed-effects model of shift proportion supported this pattern. As before, predictor variables were grammatical informativeness and notional congruence, and random intercepts were included for participant and target noun. A model with the maximal random effects structure resulted in convergence difficulty, so a forward best path algorithm was used to determine which random slopes to include. Only the random slope of notional congruence by target noun met the inclusion criterion ($\alpha = .2$). Model results and syntax can be found in Table 4.6. This analysis revealed a marginal interaction of grammatical informativeness and notional congruence.

We also compared this model to one that included z-scored age as a fixed effect. Adding age into the model did not significantly improve model fit ($\chi^2(1) = 0.81, p = .37$), suggesting that children's tendency to shift in this early window does not change substantially over the age range measured.

These patterns suggest that children are marginally less likely to make anticipatory distractor-to-target shifts when neither notional congruence nor grammatical informativeness point them in the right direction.

Pre-noun Window Match Proportion

Figure 4.9 shows the proportion of time children spent looking to the target during the pre-noun window. If participants quickly use an agreeing verb as a cue to notional or grammatical number, they might look longer to the target in informative or in congruent trials in this early window. Adults in Experiment 5 showed a significant effect of grammatical number and a marginal effect of notional number in this window. Children in Experiment 6, in contrast, showed little or no difference in their tendency to look at the target during the pre-noun across conditions.

This lack of difference was supported by a mixed-effects model of empirical logit transformed pre-noun window match proportion. Predictor variables were grammatical informativeness and notional congruence, and the model included random intercepts by participant and target noun. The random slopes of grammatical informativeness and notional congruence by target noun met the inclusion criterion ($\alpha = .2$), and were added to the model. This analysis revealed no significant effects: all $\chi^2(1) < 1$, all $p > .8$.

A parallel model with the inclusion of age did not converge, but inspection of the partially converged model suggested that age did not add substantially to model fit.

Thus, though children show a marginal tendency to shift more from distractor to target in the pre-noun window when they have either notional congruence or grammatical informativeness pointing them in the right direction, this does not translate into an overall tendency to look more to the target in the early window.

Noun Window Match Proportion

Figure 4.10 shows the proportion of time children spent looking at the target during the noun window. The noun window was chosen to be the same length as the pre-noun window (867 ms), and began 300 ms after the onset of the noun in each trial. Children looked longer to the target in congruent trials than in incongruent trials, and within the incongruent trials, looked more to the target in informative than in uninformative trials.

This pattern was supported by a mixed-effects model of empirical logit transformed noun-window match proportion. Predictor variables, as before, were grammatical informativeness and notional congruence. They were coded using mean-centered effects coding. The model included the maximal random effects structure. Model syntax and results are shown in table 4.7. This analysis revealed both a significant main effect of notional congruence and a marginal interaction between grammatical informativeness and notional congruence.

This indicates that, like adults, children use agreement as a cue to the likely notional properties of the upcoming subject. The marginal interaction of notional and grammatical number suggests that grammatical informativeness may

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Figure 4.10: Noun Match Proportion: Proportion of the time children spent looking to the target during the noun window, plotted by grammatical informativeness and notional congruence. Error bars represent standard error of the mean.
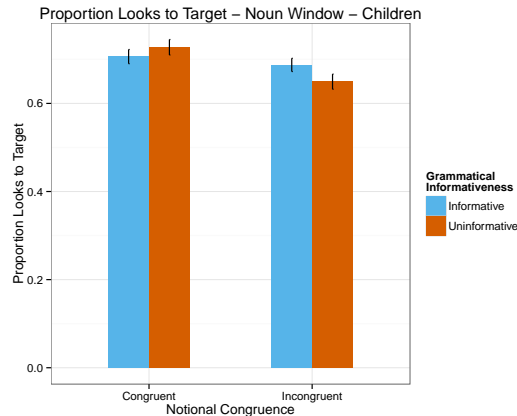
Table 4.7: Fixed effects estimates for the mixed-effects model of empirical logit transformed noun window match proportion, with grammatical informativeness and notional congruence as within-participants predictor variables. Model was fit using the following formula: `lmer( emplogit.noun ~ grammatical * notional + (1 + grammatical * notional | participant) + (1 + grammatical * notional | target))` (N=1737)

	Estimate	Std. Error	t	χ^2	p value
(Intercept)	1.422	0.129	11.01	24.12	<.0001
grammatical	0.130	0.154	0.85	0.71	.39
notional	0.366	0.167	2.19	4.25	.039
grammatical × notional	−0.557	0.289	−1.92	3.39	.066

be especially helpful when notional number points children in the wrong direction. When children hear an agreeing verb in a context that makes these cues useful, the agreeing verb facilitates processing.

4.3.3 Discussion

Experiment 6 asked what properties of the subject children infer upon hearing an agreeing verb. Two- and 3-year-olds showed evidence of facilitated processing on notionally congruent trials in the proportion of target looks during the noun window, and marginal interactions of grammatical informativeness and notional plurality on the proportion of trials with a distractor-to-target shift in the pre-noun window and on the proportion of target looks in the noun window. These patterns indicate that 2- and 3-year-olds use an agreeing verb as a cue to the likely notional number of the subject, and suggest that agreement as a cue to notional number may interact with whether agreement is grammatically informative in context.

For children, grammatical informativeness and notional congruence do not

seem to be additive cues: There is no additional advantage in trials in which both sources of information are helpful. We return to how this pattern differs between children and adults in the General Discussion, below.

4.4 General Discussion

Experiments 5 and 6 set out to determine whether adults and children used an agreeing verb to infer the likely notional number of an upcoming subject. Results clearly showed that both adults and 2- to 3-year-old children use agreement as a cue to the likely notional properties of the subject: Both adults and children showed evidence of facilitation in notionally congruent trials as compared to incongruent ones. This is consistent with the fact that grammatical number and notional number frequently align, and the fact that listeners rapidly integrate information from many sources into their interpretations of preceding material and predictions about upcoming material. Given this, it would be surprising if listeners discarded potentially useful information during comprehension.

Evidence that both adults and children use agreement as a cue to the number of items being described is also consistent with prior findings that adult and child listeners use the semantics of open-class words to generate perceptual predictions, and that these predictions influence visual attention (e.g., adults: Dahan & Tanenhaus, 2005; Huettig & Altmann, 2007, 2011; children: E. K. Johnson & Huettig, 2011; E. K. Johnson, McQueen, & Huettig, 2011). For instance, listeners who are instructed to find a missing canonically-colored target item (e.g., *strawberry*) generate a color prediction, and look more at a color-matching distractor (a red airplane) than at a color-mismatching one (a yellow airplane; E. K. Johnson & Huettig, 2011). The current findings add to this literature by demonstrating that such perceptual predictions can not only be driven by meaning-rich open-class words, but also by meaning-poor function words.

One interesting question is what mediates this perceptual prediction in the current studies. There are two possibilities: First, the agreeing verb may activate the associated grammatical number feature (e.g., PLURAL), and the frequent association between grammatical and notional plurality might support the perceptual prediction of more than one item. Second, the agreeing verb might itself be more frequently associated with ONE or MORE-THAN-ONE, and a direct association might support a perceptual prediction. The current results do not permit us to distinguish between these two possibilities, but the different patterns in adults' and children's looking behavior raise the possibility that they may be engaging in different processes.

Adults showed a pattern of two similarly-sized main effects: Informative trials showed an advantage over uninformative trials, and congruent trials showed an advantage over incongruent ones. Furthermore, evidence for use of agreement as a cue to notional number appeared primarily on measures of adults' dynamic eye-movements, while evidence for the use of agreement as a cue to gram-

matical number appeared primarily on longer averages of looking preference. Children instead showed a marginal interaction of grammatical informativeness and notional congruence, such that performance was worst in uninformative-incongruent trials, and similar in the other three trial types. They also showed some evidence of this pattern in both dynamic (distractor-to-target shift probability) and preference measures (noun window match proportion).

One potential explanation for the pattern of results that adults show is that the perceptual prediction they make draws their eyes to perceptually congruent pictures first. Thus, they use agreement as a cue to look toward a notionally congruent picture, but then quickly access the picture's name and assess its grammatical fit with the preceding context. This results in advantages for notionally congruent trials on measures of dynamic eye-movements, but a tendency to look longer overall at the target in grammatically informative trials. Children's pattern, on the other hand, suggests that they treat agreement's grammatical and notional consequences differently. One possibility is that when the visual context makes an agreeing verb grammatically informative, children use this information to drive looks to the target. In grammatically uninformative contexts, in contrast, they fall back to notional number, resulting in good performance in notionally congruent uninformative trials, but poor performance in incongruent uninformative trials. This would predict the observed (though marginal) interaction of notional and grammatical factors, and a main effect of grammatical informativeness that was not observed in Experiment 6. This lack of a grammatical effect is likely due to the reduced power of the design, compared to Experiment 5, and the difficulty of detecting main effects in the presence of interactions. Thus, pinning down the details of the role notional number plays in children's and adults' online comprehension will involve substantial further experimentation.

One potential complication of the current results is that they may require a reassessment of our interpretation of Experiment 4. If children use agreement as a cue to notional number, this, rather than abstract grammatical number, might have driven the patterns of facilitation we found with novel noun targets. I return to this point in the General Discussion.

Overall, the results of Experiments 5 and 6, taken together with the studies in Chapter 3, make it clear that listeners use agreement in a variety of ways during online comprehension. Though a grammatically informative agreeing verb can act as a cue to properties of the upcoming subject even in the absence of a notional number contrast (Experiment 3), both adults and children used agreement as a cue to the likely notional properties of the upcoming subject in the current studies, even in a task that involved no count noun targets.

Chapter 5

Learning Mechanisms

5.1 Introduction

Despite effects of notional number on agreement in both production (e.g., Eberhard, 1999; Humphreys & Bock, 2005), and comprehension (Experiments 5 and 6), evidence suggests that subject-verb agreement is fundamentally syntactic (e.g., Bock et al., 2004, Experiments 1-4 of the current document). What learning process results in underlying representations that permit the dependency to remain primarily syntactic, while still allowing small influences of notional number?

Taken together, the threads of existing research reviewed in section 1.2.2 of the Introduction, and the studies presented in the preceding chapters suggest a learning story in which the temporal priority of distributional learning creates a push toward syntactic abstraction. The current chapter outlines this learning story, and presents a study with 28- to 32-month-old children, substantially younger than those previously tested, whose results are consistent with its predictions.

A Learning Story

As reviewed in Section 1.2.2 of the Introduction, infants have begun learning about agreement-relevant distributional patterns early in their second year (Gómez, 2002; Lany & Gómez, 2008; Soderstrom, 2002; Soderstrom et al., 2002). For instance, 12-month-olds can use early exposure to adjacent dependencies to facilitate later discrimination of the same dependencies in nonadjacent configurations (Lany & Gómez, 2008), and 16-month-olds listen longer to passages with legal sequences of function and inflected content words (e.g., *to sing, these chairs*) than to passages with illegal sequences (**to sings, *these chair*; Soderstrom et al., 2007).

These abilities are developing well before children show clear evidence of having access to a conceptual distinction between ONE and MORE-THAN-ONE (Li, Ogura, Barner, Yang, & Carey, 2009). Infants and toddlers can represent small numbers veridically, tracking up to about 3 objects at a time. Thus, when toddlers see 3 objects hidden in a box, and are permitted to withdraw one, they continue to search for the remaining objects. However, when toddlers younger

than 22 months see 4 objects hidden in the box and withdraw one, they search no longer than if they had seen a single object hidden to begin with. This suggests that, faced with a quantity that exceeds their representational capacity, they cannot resort to MORE-THAN-ONE as a conceptual short-hand. Thus, infants are in the process of acquiring number-relevant distributional categories and dependencies, before they have access to conceptual distinctions that are crucial to those dependencies' mature representation (see Naigles, 2002; Soderstrom, 2008).

In principle, once a conceptual distinction between ONE and MORE-THAN-ONE becomes available, children might link it to the morphological elements surrounding nouns (quantifiers, the plural affix), elements surrounding verbs (agreement), or both. Two considerations suggest that children might be led to link conceptual number distinctions to elements surrounding nouns, more strongly than to verb morphology. First, noun number marking in the input will tend to correlate better with number-meaning than verb agreement will. When a speaker says *"My sisters are flying to Tucson"*, there are multiple sisters, but there may be either one or two flights: Verbs marked for plural agreement do not indicate a plural event in any straightforward way, whereas nouns with the plural affix typically indicate a plural referent. Furthermore, count nouns are marked as singular or plural wherever they appear in a sentence, but a verb only shows plural agreement when its subject is plural. The linguistic data should therefore support just the pattern of behavior that appears in the early comprehension literature: The best carriers of number-meaning will be linguistic elements that are marked for plurality wherever they occur in the sentence, that is, the nouns, not the verbs (Leonard et al., 2000; Nicolaci-da Costa & Harris, 1983, 1984).

Second, prior distributional learning of the dependency between the form of the subject and the verb-form may block the binding of number-meaning to verb morphology. One influential proposal is that children engage in error-based learning as part of syntax acquisition (e.g., Chang, Dell, & Bock, 2006; Dell & Chang, 2014). Error-based learning is a proposed process in which children predict a likely continuation of a current utterance, and then compare their prediction with reality. The error-signal generated by a mismatch between the predicted and actual outcomes drives learning of additional predictive cues. If children engage in such a process, a previously learned predictive relationship between noun and verb morphology would largely prevent the errors that are necessary to drive further learning, and therefore prevent verb morphology from being tied to number-meaning directly (e.g., Arnon & Ramscar, 2012; Ramscar, 2013)[1]. Thus, to the extent that that the agreement dependency is already well-

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[1]One suggestive piece of evidence for this blocking story is the pattern of notional agreement across languages: Adult agreement production is more strongly influenced by notional number in languages with poor as opposed to rich morphology (Foote & Bock, 2012; Lorimor, Bock, Zalkind, Sheyman, & Beard, 2008). This pattern is predicted by a blocking account, because languages with richer morphology should support better distributional learning of the

established based on prior distributional learning, the form of the noun should predict the form of the verb, and there will be little or no push to attribute verb-form choices to notional number directly.

This learning story is highly consistent with observed patterns in the existing literature and in the current studies. In principle, early distributional learning about the dependency between the noun- and the verb-form could be sufficient to support young children's accurate production of agreement with count and non-count nouns (e.g., Experiment 1; Keeney & Wolfe, 1972; Wexler, 1994). If these dependencies are learned at least partly independent of meaning, it becomes unremarkable that evidence for accurate production of agreement appears at an earlier age than evidence for use of agreement to determine subject number (Naigles, 2002; Soderstrom, 2008). Additionally, the proposal that learners should more quickly and reliably associate number-meaning with noun morphology than with verb morphology is consistent with the appearance of evidence for sensitivity to noun morphology as an indicator of number-meaning shortly after evidence that children have access to the conceptual distinction between ONE and MORE-THAN-ONE: Toddlers begin to demonstrate sensitivity to the connection between number-meaning and noun morphology between 24 and 30 months (e.g., Jolly & Plunkett, 2008; Zapf & Smith, 2007), shortly after they begin to show evidence of access to the relevant conceptual distinction at 22 months. Finally, the fact that children treat grammatical number agreement as an abstract rather than a lexical dependency, choosing the appropriate agreeing forms to follow conjoined NPs and using an agreeing verb to facilitate novel noun processing (Experiments 2 and 4), suggests that the early distributional learning creates not solely word-to-word dependencies, but categories and category-level dependencies (e.g., Connor et al., 2013; Mintz, 2003).

In principle, an agreeing verb could begin facilitating comprehension of a following subject as soon as children have begun to learn the distributional dependency between the two. For children to use agreement to facilitate comprehension in the type of studies reported here, however, the connection between noun morphology and number-meaning likely plays an important role. When children look at a picture of a single apple and hear *"Where are..."*, they must quickly assess the match between the picture's name (*apple*) and the form of the verb. If they do not yet consistently connect the form of a count noun with the number of items pictured, the dependency between the noun- and the verb-form is not sufficient to support anticipatory looks, only to ease integration of the noun once it is heard. That is, if they cannot predict whether the speaker will call the picture of a single apple *"apple"* or *"apples"*, the form of the agreeing verb tells them nothing about whether the incoming sentence matches the current picture. However, if the conceptual distinction between ONE and MORE-THAN-ONE becomes available to children at the end of their second year

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agreement dependency, which in turn more efficiently blocks the binding of number agreement to verb morphology.

(Li et al., 2009), and if children's knowledge of the agreement dependency itself is well-established through distributional learning by that time, children should rapidly become able to use agreement as a cue to subject properties in visual-world comprehension studies. In the current study, we test this prediction by investigating whether 30-month-old toddlers use an agreeing verb to facilitate comprehension of a following subject noun phrase.

5.2   Experiment 7

Experiment 7 investigates whether 30-month-olds use an agreeing verb in comprehension by presenting them with a design like that in Lukyanenko and Fisher (in prep.). Children saw pairs of pictures that differed in kind and number (e.g., one apple, two cookies) and sentences with (e.g., *There are...*) or without (e.g., *Look at...*) an early, informative agreeing verb. As before, if children are faster to look toward the target or more accurate in trials with an agreeing verb than in trials without, it will suggest that an agreeing verb facilitates processing of subject noun phrase and that even very young children are able to take advantage of the information it carries during online comprehension. It is worth noting that in the version of this task with 3-year-olds and adults, we found a consistent tendency for anticipatory effects of verb agreement to be carried by plural trials (e.g., Lukyanenko & Fisher, in prep.). We anticipated that the same would be true of younger children, and also that younger children would be slower to use linguistic information as it became available (Fernald, Perfors, & Marchman, 2006). Thus, we sought evidence of facilitation both before and after participants heard the target noun, and included plurality as a predictor.

5.2.1   Method

Participants

Sixty-four 2-year-olds participated (28.1-32.3 months, $M = 29.8$; 28 girls). All were learning English as their first language. Nine additional children were excluded because of reported language delay (5), refusal to participate (1) or inattentiveness or parental interference (3; see Coding below). Children's productive vocabularies, measured using the short form of the MacArthur-Bates CDI (Level III; Fenson et al., 2007), ranged from 0-92 (median = 55.5).

Stimuli

Stimulus pictures were identical to those used by Lukyanenko and Fisher (in prep.), and the accompanying sentences were new recordings of the same script, read at a slower rate.

In *informative* trials, sentences used an inverted word order in which the verb preceded its subject, the target noun phrase. See Figure 1.2. In *uninfor-*

mative trials, the target noun was not the subject of the sentence, and thus the verb provided no advance information abut the target. Because informative and uninformative trials involved different recorded sentences, we compared the experimental condition depicted in Figure 1.2 to a control condition in which participants heard the same recorded sentences, but saw target and distractor pictures that matched in number. This rendered the number-marked verb unhelpful, and thus in this referential context children should show no facilitation in 'informative' sentence with number-marked verbs relative to those without.

Pictures appeared in yoked pairs, with each pictured object serving as the target 4 times and as the distractor 4 times. Target side, trial type and target plurality were counterbalanced. Seven filler trials with a single picture were interspersed among the 32 critical trials.

Apparatus and Procedure

As in previous studies, children sat on a parent's lap, about 4 feet from a 50-inch television screen. Parents wore opaque glasses that blocked their view of the screen. On each trial, two pictures appeared, aligned with the left and right edges of the screen. A camera beneath the screen recorded children's eye-movements.

In each trial, the pictures were visible for 7 seconds. The onset of the determiner in the critical sentence occurred 3 s after the pictures appeared; thus speech began approximately 2 s into the trial. Trials were separated by a 1 s blank-screen interval.

Coding

We coded where participants looked during each 7 s trial, frame-by-frame from silent video. Reliability was calculated for 25% of the data. Coders agreed on 96% of all video frames. Individual trials were eliminated (174 of 2048 possible trials, 8.5%) if more than 50% of the trial was spent looking away or was uncodeable (123 trials), or if the child's or parent's speech obscured the critical sentence (51 trials; Fernald et al., 2008). Three children's data were excluded because such eliminations left fewer than 4 of the 8 possible trials in one or more trial type-plurality combination (informative singular, informative plural, uninformative singular, uninformative plural).

Measures

Because 2-year-olds are likely to process and react to incoming information more slowly than 3-year-olds and adults (Fernald et al., 2008; Zangl & Fernald, 2007), we used a slightly different set of measures to investigate 2-year-olds' use of agreement in online comprehension. We evaluated the latency of the first shift from distractor to target, measured from noun onset, rather than from determiner onset. We also evaluated the fixations directed to the target picture

Figure 5.1: Proportion target fixations over time by trial type and condition.
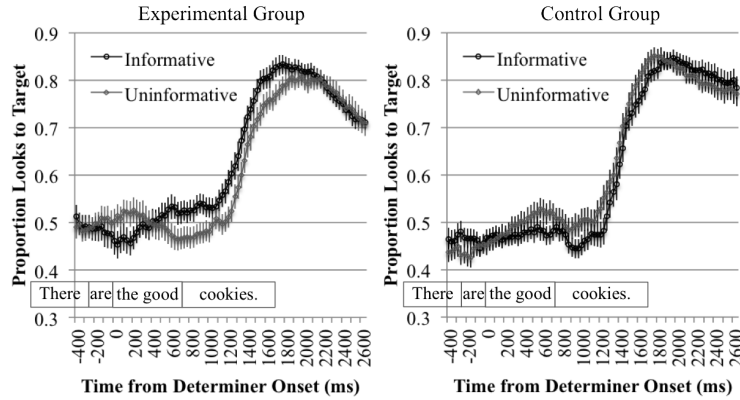
at noun onset and, as before, we looked for evidence of anticipatory processing in the likelihood of distractor-to-target shifts in the pre-noun window.

5.2.2 Results

Figure 5.1 shows looks to the target as a proportion of looks to either picture in informative and uninformative trials, separately for the experimental and control conditions. Fixations to the target picture increased earlier in informative than in uninformative trials in the experimental condition, but not in the control condition.

Latency of First Distractor-to-Target Shift from Noun Onset

We measured the latency of the first shift in fixation from distractor to target, after the onset of the noun. If children use agreeing verbs to facilitate noun processing, they should need less information to identify the noun in informative trials in the experimental condition, leading to shorter latencies. As in previous experiments, we selected trials in the which children happened to be looking at the distractor at the key frame, in this case, the onset of the noun. We then measured the latency of their first shift to the target in a 1500 ms window extending from 300 ms after noun onset to 1800 ms after noun onset. Latencies shorter than 300 ms were excluded because they were deemed to be too early to be driven by the noun (Fernald et al., 2008).

As shown in Figure 5.2, children were quicker to shift to the target picture in informative than in uninformative trials, and this was true only in the experimental condition. This suggests that the presence of an agreeing verb in an informative context facilitates 2-year-olds' processing of the noun.

This pattern was supported by a mixed-effects model of latency, fit in R using the *lmer()* function of the *lme4* package. Predictor variables were the between-participants factor condition (control, experimental), and the within participants factors trial type (informative, uninformative) and target plurality

Figure 5.2: Latency of first distractor-to-target shift in gaze, measured from noun onset, by condition, trial type and plurality. Error bars indicate standard error of the mean.
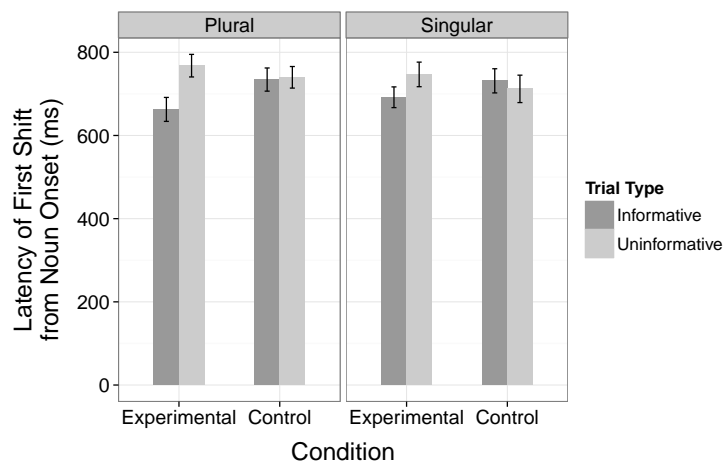
Table 5.1: Fixed effects estimates for the mixed-effects model of distractor-to-target shift latency from noun onset, with condition, trial type and plurality as predictor variables. Model was fit using the following formula: `lmer( latency ~ condition * trialtype * plurality + (1 | participant) + (1 | target))` (N=701)

	Estimate	Std. Err.	t value	$\chi^2(1)$	p value
(Intercept)	726.1	17.9	40.46	48.70	<.0001
condition	−20.0	31.4	−0.64	0.40	.53
trial type	−32.7	27.9	−1.17	1.36	.24
plurality	0.8	18.8	0.04	0.00	.95
condition × trial type	−115.4	37.7	−3.06	9.28	.002
condition × plurality	−22.9	37.7	−0.61	0.37	.54
trial type × plurality	−22.7	37.7	−0.60	0.36	.55
condition × t. type × plurality	−32.4	75.6	−0.43	0.17	.68

Figure 5.3: Proportion target fixations at noun onset, by condition, trial type and plurality. Error bars indicate standard error of the mean.
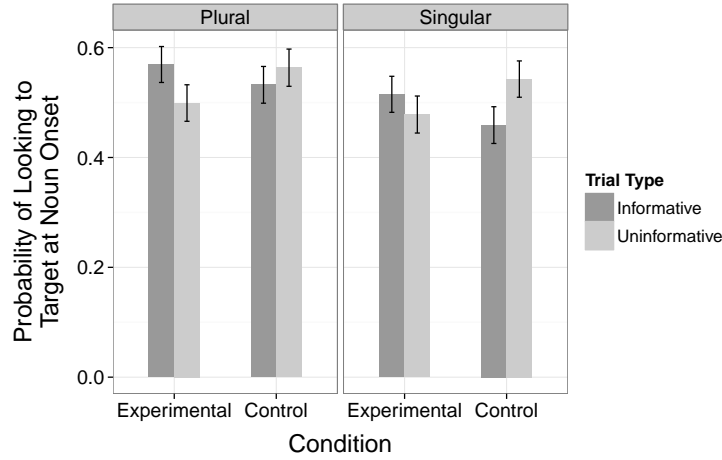

(singular, plural). All factors were coded using mean-centered contrast codes. A model with the maximal random effects structure justified by the design failed to converge. Using a forward best-path algorithm, we found that only the random slope of trial type by target added to the model ($\alpha = .2$). The final model therefore included this slope and random intercepts for participant and target noun. Model syntax and results can be found in Table 5.1. This analysis revealed the crucial significant interaction between condition and trial type. No other main effects or interactions reached significance, all other $\chi^2 < 1.5$.

Follow-up comparisons were conducted using treatment coding to examine the simple main effect of trial type within each cell of the design. For children in the experimental group, this revealed a marginal effect of trial type in singular trials ($\chi^2(1) = 2.89, p = .09$) and a significant effect of trial type in plural trials ($\chi^2(1) = 6.05, p = .01$). In the control group, the simple main effect of trial type was not significant for either singular or plural trials ($\chi^2(1) < 1, p > .5$).

Thus, informative agreeing verbs facilitated 30-month-olds' online sentence comprehension: Children needed less information from the noun itself if it was heralded by informative verb agreement. However, this measure investigates only effects occurring after the onset of the noun. Clearer evidence for anticipatory processing, as found with older children (Lukyanenko, 2011; Lukyanenko & Fisher, in prep.) requires looking in earlier time windows. If participants used the information carried by the agreeing verb to *pre-activate* the number features of the upcoming subject, we should find effects of the agreeing verb at or before noun onset.

Table 5.2: Fixed effects estimates for the binomial mixed-effects model of fixations at noun onset, with condition, trial type and plurality as predictor variables. Model was fit using the following formula: `glmer( nonsetlook ~ condition * trialtype * plurality + (1 | participant) + (1 | target), family = "binomial")` (N=1800)

|	Estimate	Std. Err.	z value	$\chi^2(1)$	p value
(Intercept)	0.08	0.10	0.82	0.64	.42
condition	−0.02	0.10	−0.26	0.07	.79
trial type	−0.02	0.10	−0.23	0.05	.82
plurality	−0.15	0.10	−1.53	2.35	.13
condition × trial type	−0.44	0.19	−2.33	5.43	.02
condition × plurality	0.06	0.19	0.33	0.11	.74
trial type × plurality	0.28	0.19	1.45	2.10	.15
condition × t. type × plurality	−0.00	0.38	−0.01	0	.99

Noun-onset Looks

Because we suspected that younger listeners would be slower to process and respond to the incoming linguistic stimuli, we first looked for evidence of anticipatory processing at the last possible moment, by asking whether children were already more likely to be fixating the target as opposed to the distractor at noun onset. This is the same point from which we measured shift latencies above. At this point, children have received no information about the noun, but in informative trials have already heard a potentially useful agreeing verb.

Figure 5.3 shows the proportion of fixations to the target at noun onset out of fixations to either picture. By noun onset, children were already more likely to be looking at the target in informative than in uninformative trials in the experimental condition. In the control condition there is no such difference, and even a trend in the other direction in singular trials. Though this reversal is likely a fluke, it may also be the result of small differences in the intelligibility or degree of coarticulation between the sentence recordings used in the informative and uninformative trials. The control condition is designed to control for precisely this sort of variation.

This pattern was supported by a binomial mixed-effects model of looks to the target or distractor at noun onset, fit using the *glmer()* function of the *lme4* package in R. Predictor variables were condition, trial type and plurality and a forward best-path algorithm was used to determine the inclusion of random slopes. No random slopes met the inclusion criterion ($\alpha = .2$). Model syntax and results can be found in Table 5.2. The analysis revealed a significant interaction of condition and trial type. Though the reversal noted above did result in the main effect of plurality and a non-significant trend toward an interaction of trial type and plurality ($p < .15$), none of the other effects, these included, were reliable.

Follow-up comparisons were conducted by using treatment coding to extract the simple main effect of trial type within each cell of the design. For children in the experimental condition, there was a significant effect of trial type in plural

Figure 5.4: Probability of shifting from distractor to target in pre-noun window, by condition, trial type and plurality. Error bars indicate standard error of the mean
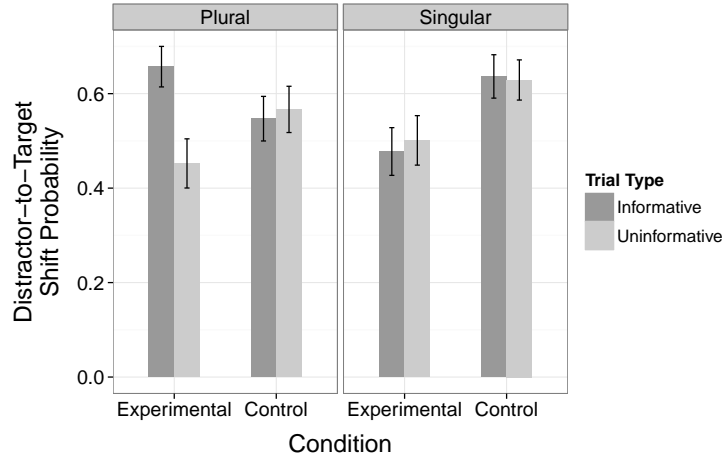
trials ($\chi^2(1) = 4.02, p = .04$), but not in singular trials ($\chi^2(1) = 0.31, p = .58$). In contrast, among children in the control condition the informative disadvantage in singular trials was marginal ($\chi^2(1) = 3.20, p = .07$), and the effect of trial type in plural trials was non-significant ($\chi^2(1) = 0.11, p = .75$).

The significant interaction of trial type by condition supports the observation that at noun onset, children in the experimental condition were already more likely to be fixating the target than children in the control condition. Thus, at noun onset, the last moment at which we could expect to observe evidence of anticipatory processing untainted by information from the noun itself, we see an advantage for informative trials in the experimental but not the control condition. Thus, the presence of an informative agreeing verb directed children's attention to the target picture even before information from the noun was available.

Distractor-to-Target Shifts

To get another view of 30-month-olds' anticipatory processing, we assessed children's likelihood of making a shift from distractor to target in the 900 ms pre-noun window. The window began 67 ms after determiner onset (and thus 300 ms after the average onset of *is* or *are* in the informative trials), and ended 300 ms after the earliest noun onset. Figure 5.4 shows the proportion of distractor-initial trials that included a shift from distractor to target in this early window. Such shifts were more likely in informative than in uninformative trials in the experimental condition, but only in trials with a plural target, suggesting that an informative agreeing verb drove anticipatory eye-movements in those trials.

This pattern was analyzed using a binomial mixed-effects model, with pre-

Table 5.3: Fixed effects estimates for the binomial mixed-effects model of switch probability, with condition, trial type and plurality as predictor variables. Model was fit using the following formula: `glmer( dtswitch ~ condition * trialtype * plurality + (1 | participant) + (1 | target), family = "binomial")` (N=858)

	Estimate	Std. Err.	z value	$\chi^2(1)$	p value
(Intercept)	0.34	0.17	2.02	3.50	.06
condition	−0.30	0.21	−1.43	2.01	.16
trial type	0.22	0.15	1.48	2.10	.15
plurality	0.02	0.15	0.11	0.01	.92
condition × trial type	0.52	0.29	1.79	3.09	.08
condition × plurality	0.69	0.29	2.36	5.35	.02
trial type × plurality	0.46	0.29	1.56	2.32	.13
condition × t. type × plurality	1.07	0.58	1.83	3.22	.07

dictors and coding as described above. No random slopes met the inclusion criterion. Model syntax and results are shown in Table 5.3. This analysis revealed a marginal overall interaction of condition and trial type, a significant interaction of trial type and plurality and a marginal three-way interaction of condition, trial type and plurality.

Follow-up analyses using treatment coding to extract the simple main effect of trial type in each cell of the design revealed that the effect of trial type was significant for plural trials in the experimental condition ($\chi^2(1) = 11.21, p = .0008$), and non-significant elsewhere ($\chi^2(1) < 1, p > .8$).

This analysis suggests that any effect of informative verb agreement on anticipatory shifts was carried by plural trials. Upon hearing the verb-form *are*, 30-month-olds tended to look away from a picture showing a single item. This confirms that younger children use agreement to anticipate features of the upcoming subject, and echoes the patterns we have found with older children and adults: The anticipatory effects of agreeing verbs tend to be stronger in plural than in singular trials.

5.2.3 Discussion

In this study we asked whether 30-month-olds, like older children and adults, could use an informative agreeing verb to facilitate processing of the upcoming subject. When the subject noun was preceded by an informative agreeing verb, 30-month-olds were faster to look toward the target. and this effect began to emerge before looking could be influenced by the noun itself: In plural trials, toddlers were already more likely to shift gaze from the distractor to the target in the pre-noun window, and by noun onset they were more likely to be fixating the target. These data demonstrate early use of agreement in comprehension, and provide new evidence of anticipatory processing in early language comprehension.

The present data add to previous findings showing anticipation of an upcoming noun based on constraining verb semantics (e.g., *you can **drink** the **juice***,

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Fernald et al., 2008), and facilitation of processing at the noun based on morphosyntactic cues that were informative in the referential context (e.g., la$_{FEM}$ pelota$_{FEM}$, shown: ball$_{FEM}$, shoe$_{MASC}$; Lew-Williams & Fernald, 2007; les$_{PL}$ chiens, shown: one cat, two dogs; Robertson et al., 2012). The current study represents the earliest evidence that young children can use a morphosyntactic cue to *pre-activate* linguistic features.

5.3 General Discussion

This chapter sets out a potential learning account of how agreement might come to be primarily syntactic. This learning story suggests that the foundation of the agreement relationship is an early-learned distributional dependency, which is later partly tied to conceptual number via number-marking on the noun. If this is true, an agreeing verb should begin facilitating comprehension of a matching subject noun phrase (and vice versa) as soon as children have become familiar with the distributional patterns agreement creates in the input: Minimally, frequently associated forms should prime each other. The dependency should acquire its subject-mediated connection to notional number relatively rapidly once children have access to the conceptual distinction between ONE and MORE-THAN-ONE, shortly before age 2 (Li et al., 2009).

Thus, in comprehension studies of the sort presented here, children should begin showing an advantage in trials with an informative agreeing verb early in their third year. Experiment 7 tested this prediction by examining 28- to 32-month-old toddlers' use of agreement in comprehension. Results indicated that toddlers use an agreeing verb in online comprehension, both to facilitate processing of the following noun, and to pre-activate its likely properties. This is true despite the fact that children at this age are quite inconsistent about providing agreeing forms in their own speech (Theakston & Rowland, 2009; Wexler, 1994, 2011).

Several features of this learning story bear further discussion, especially the argument that blocking plays a key role in where number-meaning gets assigned during the acquisition of morphology. The blocking argument creates interesting cross-linguistic predictions, discussed below.

Cross-linguistic Patterns in Acquisition of Morphology

The learning story laid out in section 5.1 suggests some interesting potential cross-linguistic differences. First, because distributional learning is proposed to set the stage in crucial ways for the later construction of the morphological system, cross-linguistic differences in early distributional learning may have far-reaching consequences. In particular, cross-linguistic differences in agreement patterns that create disparities in the ease of identifying and learning the associated distributional dependencies may result in differences in how strongly

notional number is tied to verb morphology. That is, to the extent that cross-linguistic differences in morphological style create differences in early learning, the early-learned distributional dependency may be more or less able to block the binding of notional number to verb agreement.

Languages vary in morphological style: Some languages have rich morphology with many distinct morphemes marking a variety of dependencies (e.g., Italian, Russian), while others have many fewer morphemes per dependency marked, and fewer dependencies that are morphologically marked at all (e.g., English, Mandarin). Though, a priori, it might seem that a greater number of morphemes indicating a particular relationship would make the dependency difficult to learn, evidence suggests the reverse. For instance, young Italian-learners learning a rich-morphology language are consistently ahead of young English-learners in mastering a variety of aspects of the verb system in spontaneous production (e.g., Pizzuto & Caselli, 1992; Slobin, 1982). It may be that the additional data a rich morphological system provides to children out-weighs the added burden of the additional morphemes that must be identified: A rich morphological system presents learners with many more overt, correlated markers of the dependencies they need to acquire.

This suggests that particular variations among morphologically rich languages in, for instance, patterns of syncretism or whether case-marking is common, might be especially helpful or challenging to learners acquiring the agreement dependency. For instance, case-marking might make agreement an easier distributional dependency to learn by highlighting the subject, the agreement controller, with a distinctive nominative marker. If so, agreement might be better-learned as a distributional dependency in languages with case-marking than in similarly morphologically rich languages without case-marking. Identifying which patterns make the dependency more salient or more opaque, and comparing acquisition across languages with those particular combinations of features should help to clarify our understanding of how and to what extent cross-linguistic differences in morphological style create differences in the ease of distributional learning of morphosyntactic dependencies.

If the preceding proposals turn out to be true, this account additionally predicts that speakers of rich-morphology languages should show less influence of notional number on the agreement relationship than speakers of poor-morphology languages do. There is some evidence that this is the case (Foote & Bock, 2012; Lorimor et al., 2008), contrary to accounts that predict the frequent marking of number agreement that is required by rich morphology languages to cause a greater influence of notional number on production (Vigliocco, Hartsuiker, Jarema, & Kolk, 1996). At this stage, however, no strong conclusions can be drawn.

In conclusion, the results of Experiment 7 indicate that 2-year-olds use agreement to facilitate online comprehension. Patterns of results are similar enough

to those observed with older children and adults to make assumptions about shared underlying representations tempting. However, because the nouns used in this study were count nouns, it remains possible that younger children's anticipatory processing is based on representations or processes that differ from those of older participants: Both primarily meaning-based and primarily syntactic strategies would result in similar patterns in this case, as would abstract and lexically specific knowledge. Further research will be necessary to ascertain the precise mechanisms by which agreement facilitates younger children's comprehension.

Similarly, the learning story presented here fits the existing evidence well, but remains largely hypothetical. Substantial further research will be necessary to pin down the processes by which infants go from their initial sensitivity to agreement-relevant distributional patterns to an adult-like, primarily syntactic representation of subject-verb agreement by age 3.

Chapter 6

General Discussion

In this project, we set out to use subject-verb agreement as a tool for investigating how children represent and use linguistic dependencies. Because subject-verb agreement is determined by the grammatical number of the subject, and because grammatical number is often, but not always aligned with the notional number of the subject's referent, it is an ideal tool for exploring where children's use of a syntactic dependency falls along two orthogonal dimensions of representation: form- or meaning-based representations, and abstract or lexically specific representations.

Experiments 1 and 2 demonstrated that children use the grammatical plurality of the subject noun phrase, not solely on the notional plurality of its referent or the lexical properties of the subject noun, to govern their choice of verb-form in sentence production. In Experiment 1, children correctly relied on the number of items pictured to determine the grammatical number of the subject and the form of the agreeing verb in count noun trials. In pluralia tantum trials, 2- and 3-year-olds overwhelmingly produced plural noun- and verb-forms. In mass noun trials, children typically produced singular forms, though they had a small tendency to produce more plural forms in 2-item contexts than in 1-item contexts. In Experiment 2, we asked whether children's success with mass nouns and pluralia tantum was the result of lexically specific distributional learning, or whether they were learning about agreement as an abstract relationship. Three-year-olds primarily used plural-agreeing forms after conjoined singular count nouns (e.g., *the dog and the cat are on the square*), suggesting that they are not representing agreement as a predictive dependency between specific word forms (e.g., *glasses* and *are*, *dog* and *is*). If they were representing agreement in a lexically specific way, we would have expected primarily singular agreement following conjoined singulars. Together, Experiments 1 and 2 demonstrate that 2- and 3-year-olds relied on the grammatical number of the subject noun phrase for determining verb agreement, and that they, like adults, determined the grammatical number of the subject on the basis of information about the subject noun's lexical properties, the subject's structural properties, and the notional plurality of the referent.

Experiments 3 and 4 showed similar patterns in comprehension. In a pair of two-choice visual world studies, children and adults used an agreeing verb

to facilitate processing of an upcoming subject (e.g., *Where **are** the pretty **glasses?***). In Experiment 3, this facilitation occurred when the target and distractor pictures differed in grammatical but not in notional number (e.g., one pair of glasses, one phone), indicating that neither 3-year-olds nor adults treat agreement as an entirely meaning-based relationship in comprehension. In Experiment 4, agreeing verbs facilitated processing similarly for novel and familiar count nouns, even though the novel nouns were taught to children immediately before the comprehension task in a short introduction phase which included the novel nouns in count-noun frames (e.g., *Wow! A keppin!*, compare **a sand*), but no evidence about what agreeing verb-forms they should co-occur with, or even that they could occur in the plural. This indicates that in comprehension, as in production, children treat agreement as a relationship between abstract categories, not a relationship between particular word-forms. Children know something about how subject-verb agreement depends on notional plurality for count nouns, and appear to easily add a recently-learned count noun to this category, even without direct evidence about which agreeing forms it should co-occur with. Taken together, Experiments 3 and 4 show that both 3-year-olds and adults treat agreement as an abstract, primarily syntactic dependency, not a relationship between word meanings or a lexically specific pattern.

Experiment 5 showed that adults use agreement both as a cue to the likely grammatical properties of an upcoming subject, and as a cue to its likely notional properties. An agreeing verb conferred a processing advantage in situations in which the target and distractor differed in grammatical number (e.g., *glasses, corn*) over situations in which they did not (e.g., *glasses, pants*), and in situations in which the target had congruent notional and grammatical number features (e.g., two pairs of glasses), over situations in which it did not (e.g., one pair of glasses). Intriguingly, the effects of notional number in Experiment 5 appeared primarily on the dynamic measures of visual attention (latency, probability of shifts), while effects of grammatical number appeared on measures of target-looking averaged over a window. This hints at the processes behind each of these effects, but will require further experimentation to clarify.

Experiment 6 demonstrated that 2- and 3-year-olds also use an agreeing verb as a cue to the likely notional properties of an upcoming subject. An agreeing verb conferred a processing advantage in trials in which the target had congruent notional and grammatical properties (e.g., two pairs of glasses), suggesting that young children hearing an agreeing verb make inferences about the likely notional number of the agreement controller. Experiment 6 did not replicate the grammatical informativeness effect found for 3-year-olds in Experiment 3. However, this does not call the results of Experiment 3 into question. In Experiment 6, the number contrast between the pictures on each trial (e.g., one pair of glasses, two pairs of pants; compare with Experiment 3's matching number of items: one pair of pants, one shirt) may have made the task more difficult for children by adding a feature to their assessment of the currently-

fixated picture, and therefore may have reduced the sensitivity of the task to the influence of grammatical informativeness. Furthermore, Experiment 3 included a mix of count and non-count nouns, while Experiment 6 included only non-count nouns. Though the non-count nouns in both studies were chosen from among early-learned words on the MacArthur-Bates Communicative Development Inventory (Fenson et al., 2007), they are slightly less-frequent and later-appearing than the selected count nouns. This reduction in familiarity may also have complicated the the task for children, and reduced our ability to measure an influence of grammatical informativeness. Finally, though there was no hint of a main effect of grammatical informativeness, there was a marginal interaction of grammatical informativeness and notional congruence, such that the uninformative-incongruent trials were at a disadvantage compared to the other three trial types. This suggests that by making the task easier for participants and increasing the power of the design, we might be able to find grammatical and notional effects in the same study with children, just as we did in Experiment 5 with adults.

The results of Experiments 5 and 6 fit well with other evidence that adults and children use linguistic information to make perceptual predictions (e.g., Huettig & Altmann, 2011; E. K. Johnson & Huettig, 2011), but complicate the interpretation of the novel-noun results in Experiment 4. In Experiment 4 an agreeing verb facilitated online comprehension of novel count nouns for both children and adults. Our initial interpretation of this result was that it indicated that agreement was not represented solely in terms of particular lexical combinations, but in terms of abstract categories. That is, we argued that participants in Experiment 4 were able to add a newly-learned noun to an existing count-noun category, and use their knowledge about that category to make the link between the form of the agreeing verb and the grammatical properties of the upcoming noun. However, the effects of notional congruence in Experiments 5 and 6 raise the possibility that the facilitation in Experiment 4 might have been the result of listeners using the agreeing verb an indicator of notional number, either directly or via an assumption that an as-yet-unheard noun will be a count noun, without regard for the actual category of the recently-introduced novel noun. If this is the case, the results of Experiment 4 do not demonstrate the use of abstract categories. One way to test this possibility would be to introduce novel non-count nouns to children, without demonstrating their consequences for verb agreement (e.g., pluralia tantum: *"Look at those! A pair of dags!"*, mass: *"Do you see that? Some kabe"*). If children subsequently use an agreeing verb to facilitate the processing of the novel non-count nouns in a visual context where notional number is held constant, it would demonstrate more convincingly that they are able to add novel nouns to existing abstract categories, and that they do not rely on lexically specific representations of agreement.

Finally, Chapter 5 proposes a potential learning story for how agreement

might come to be primarily syntactic, and tests the simplest prediction of that story: that even younger children should be able to use an agreeing verb to facilitate comprehension. Experiment 7 demonstrates that even 30-month-olds can use an agreeing verb to facilitate processing and to pre-activate likely properties of an upcoming subject during online comprehension. This fits in well with an account of agreement acquisition that begins with early distributional learning about the categories and patterns involved in the agreement relationship, followed by a process of connecting those categories and patterns to meaning. Because count nouns' morphology is better aligned with differences in notional number in the scene than verb morphology is, it is the noun morphology that gets most strongly tied to notional number. After all, count nouns reflect the notional number of their referent in any syntactic position[1], but the verb reflects the notional number of count noun subjects only. For instance, in a sentence such as "*a bird is singing in the bushes*", *bushes* is grammatically and notionally plural, but has no influence on the form of the verb. Another reason for verb morphology not to carry number meaning is that thorough prior learning of the predictive distributional dependency between the subject and verb may block the learning of additional predictors of verb form. Thus, when the conceptual distinction between ONE and MORE-THAN-ONE becomes available, children may find no reason to bind that distinction to the verb form: It is more clearly associated with noun morphology, and noun morphology predicts the form of the verb already.

This proposed learning story predicts that subject-verb agreement should be treated as primarily syntactic from the very beginning. However, the results of Experiment 7 are ambiguous: Because Experiment 7 used count nouns, both meaning- and form-based representations would result in similar patterns, as would lexically specific and abstract representations. The predictions of this learning story could be further tested by examining younger children's ability to use agreement as a cue to grammatical number, even when notional number is held constant (as in Experiment 3), and by comparing the amount of number-meaning carried by different cues. According to this learning story, markers in the noun phrase should be better carriers of number-meaning than markers in the verb phrase. Thus, comparing the degree to which a grammatically informative number-marked determiner facilitates processing (e.g., *"Look at **those** good cookies!"*) to the degree to which a grammatically informative number-marked verb does so (e.g., *"There **are** the good cookies"*, vs. grammatically uninformative *"Look at the good cookies"*), would help to clarify the relationship between number-meaning and various forms of grammatical number-marking.

Note that, despite predicting that agreement should be primarily syntactic, the proposed learning story does not preclude the association of an agreeing verb-form with likely notional properties of the subject noun phrase. First, in a

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[1]Though not always in quantified phrases: *every student* likely refers to more than one person, but the noun has singular morphology.

morphologically poor language like English, the the distributional dependency between the form of the noun and the form of the verb may be incompletely learned when children begin to tie number-meaning to linguistic distinctions. If so, the distributional dependency may incompletely block the association of number-meaning with verb-form, and children may, to some degree, learn this as a direct association. Alternatively, the association might come from a fully syntactic representation of the agreement dependency, accompanied by a default assumption that an as-yet-unheard noun is likely to be a count noun, for which grammatical and notional number properties coincide. Finally, the association between particular verb-forms and number-meaning might not be a function of the agreement dependency at all. Listeners might be sensitive to the frequent co-occurrence of, for instance, *are* with discussions of more than one thing, such that *are* primes the concept of MORE-THAN-ONE, even without particular predictions about the identity or properties of the grammatical subject.

Together, the findings in these seven experiments indicate that agreement is treated as an abstract, primarily syntactic relationship from quite early in development. This suggests that the temporal priority of distributional learning may create an environment that pushes children toward syntactic abstraction. That is, agreement may never be formulated as a meaning-based relationship, but be abstract and form-based from the beginning. Children's early distributional learning supports acquisition of the statistical patterns agreement creates in the input, before any of the dependent elements are connected to number-meaning. This, in turn may support the early construction of syntax-like representations, and pave the way for the mature system, in which the dependency operates in terms of formal properties, and is not directly reflective of number meaning.

Chapter 7

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