CHAPTER 5

BEHAVIORAL ACQUISITION METHODS WITH INFANTS

LAUREL PERKINS AND JEFFREY LIDZ

5.1 Introduction

The study of children's syntax was long dominated by studies of the sentences they produced (L. Bloom 1970; Braine 1963; Brown and Bellugi 1964; Hyams 1986; Poeppel and Wexler 1993; Snyder 2001; Stromswold 1990). The assumption behind this kind of research was that children's productions provided straightforward evidence of their grammars. Much of the early research on children's syntax could thus be described as a kind of corpus linguistics.

However, children's utterances represent an imperfect subset of their grammatical potential. First, a corpus is just a sampling of utterances and hence is unlikely to fully realize the range of structures compatible with a child's grammar at any one time. Second, independent factors, such as working memory and executive function, can impact children's abilities to plan and execute an utterance, hence masking aspects of their grammars (P. Bloom 1990; Phillips 1995; Shipley et al. 1969). Third, to the extent that comprehension precedes production, production measures run the risk of underestimating children's grammatical abilities. Finally, production measures are limited to studying children's grammars once they have started talking. But surely children attain some grammatical knowledge prior to being able to express it in their utterances. Indeed, the lower bound imposed by production makes it impossible to see the very earliest stages of syntactic development and the processes that precede children's first multi-word utterances (Hirsh-Pasek and Golinkoff 1996).

In this chapter, we face this lower bound by describing how developmental linguists have probed the growth of grammar in infancy. Such probes typically involve measures of comprehension and attention, measured by eye movements, looking time, or listening time. Of course, just as production studies are limited by performance factors affecting planning and execution, comprehension measures face related challenges from immature sentence processing mechanisms that can hide adult-like grammatical knowledge. Moreover, as in all behavioral studies, correct performance may derive from erroneous knowledge masquerading as adult-like knowledge. To face these challenges, infant researchers rely on short and simple designs that take into account potential interference from extralinguistic factors. To the extent that such factors can be minimized, simple comprehension measures may give us the tools to investigate the very earliest steps children take in acquiring a syntactic system.

We review three areas in which progress in understanding infants' syntactic development has been made. These areas represent a natural starting place for children's early syntax because they illustrate the most basic properties of any syntactic system: grammatical categories, hierarchical structure, and grammatical dependencies.

First, we explore children's initial steps in acquiring the syntactic categories of their language. To what extent can infants distinguish lexical and functional categories distributionally, and use these distributional properties to make inferences about the syntactic and semantic properties of novel words? How do infants use their knowledge of grammatical categories to constrain online lexical access and comprehension? A good deal of work has probed infants' sensitivity to subcategories of verbs and how these subcategories relate to verb meaning.

Second, we examine children's early phrase structure representations, especially in the clausal domain. Are children's earliest syntactic representations hierarchically structured? We further explore when and how children learn the canonical order of subjects, verbs, and objects in their language. Relatedly, we examine whether infants' early clause representations are complete, and when infants become sensitive to language-specific properties of clauses, such as whether null subjects are licensed.

Finally, we turn to infants' acquisition of grammatical dependencies. We explore when and how infants detect dependencies that hold across non-adjacent morphemes in particular syntactic environments, and we ask how richly they represent these dependencies. We also examine movement dependencies in infancy. We ask whether infants know that only constituents can move and how they go about detecting movement dependencies in the sentences that contain them. Furthermore, we explore infants' knowledge of binding dependencies, specifically the constraint that a pronoun cannot be referentially dependent on an NP that it c-commands. We examine how online processing can provide insight into the nature of the hierarchical relations that underlie binding dependencies.

We hope that this review provides a clear summary of both the prospects and the challenges for examining syntax in infancy. While infant research must face the challenge that infants are limited in their behavioral repertoire, at the same time, studying infant syntax represents the frontier of our knowledge about the emergence of grammar.

Gaining a richer understanding of infants' sensitivities and their ability to make inferences from distributional observations to syntactic representations may ultimately help us to better understand how the language faculty allows us to acquire whatever language we are exposed to.

5.2 Syntactic categories and subcategories

Different words occur in different linguistic environments. For example, *arrive* can be used after an auxiliary verb like *will*, but *arrival* cannot.

(1) a. Elliott will arrive
b. *Elliott will arrival

By the same token, *arrival* can be used after an article like *the*, unlike *arrive*.

(2) a. *The arrive of Elliott surprised Grandma
b. The arrival of Elliott surprised Grandma

These distributional differences reflect the **grammatical categories** of the words. Even though *arrive* and *arrival* have similar meanings, their different grammatical categories (verb vs. noun) lead to different sentence distributions. Learning which words belong to which grammatical categories is one of the earliest syntactic problems that infants solve.

Grammatical categories come in two flavors: **lexical and functional**. Lexical categories have rich referential content and are open-class, in the sense that new words can be added to those categories freely. **Functional categories** have less referential content and are closed-class, in the sense that new words in those categories arise only through processes of historical change. Functional categories are generally higher-frequency (numerically) than lexical categories, and as such frequently signal when specific lexical categories are upcoming; for example, determiners are signals for nouns. These signals might provide useful information in helping children categorize novel words.

Children's acquisition of grammatical categories has been a central battleground for debates about the origins of productivity in syntax. Some researchers argue that words acquire their categories by an exemplar-driven process that discovers abstract categories by noticing similarities across words (Meylan et al. 2017; Pine and Lieven 1997; Pine and Martindale 1996; Tomasello 2000; 2003). Others argue that children are biased to find specific categories and that productivity is an automatic consequence of identifying the morphological cues to category membership (Valian 1986; Valian et al. 2009; Yang 2013). The empirical focus of these debates has been about detecting productivity in children's productions, with different ways of measuring productivity yielding different results. In such a situation, evidence from perception may be more enlightening, as it is not dependent on factors outside of the researchers' control, like the rates at which children happen to use particular words. Instead, by looking at infant perception we are

able to see what kinds of inferences children make about novel words and what kinds of morphological signals count as the evidence that drives these inferences.

5.2.1 Investigating knowledge of functional vs. lexical categories

From early in infancy, children appear sensitive to the differences between function words and content words, which tend to have different acoustic and phonological properties crosslinguistically. Across languages, function words are often unstressed, shorter than content words, have reduced vowels, and appear at prosodic boundaries (e.g. Monaghan, Chater, and Christiansen 2005; Shi, Morgan, and Allopenna 1998). Even newborns demonstrate sensitivity to these differences. In a study by Shi, Werker, and Morgan (1999), newborns heard repetitions of English words selected from an audio recording of natural maternal speech. Infants' attention to these audio stimuli was tested using a procedure called **High-Amplitude Sucking**, which measures infants' sucking strength and rate on pressure-sensitive pacifier. Infants learn that they can control the presentation of an audio stimulus by sucking harder, and the researchers measure how the rate of these high-amplitude sucks declines over time as infants lose attention. Once this rate declines to a certain threshold, infants are considered to be "habituated" to the stimulus, and a new test stimulus is played. If infants consider this new stimulus different from the previous one, they should recover attention ("dishabituate") and therefore increase their rate of high-amplitude sucks. Shi, Werker, and Morgan habituated infants either to a list of content words or to a list of function words, and then tested them on new words from the same category or the opposite category. Infants who were habituated to content words recovered attention and increased their sucking rate when they heard function words, and vice versa, but did not recover attention when they heard new content words. It therefore appears that newborns are able to discriminate the phonological differences between function and content words. This ability may enable infants to begin categorizing words into functional and lexical categories from the earliest stages of language acquisition.

Sensitivity to the acoustic differences between function and content words does not tell us how infants use these differences in building syntactic categories, however. To address this issue, we would need to additionally identify the role that such categories play in word segmentation and word learning.

Early on, function words can serve as anchors in the speech stream: 8-month-olds can use known function words to segment new content words (Shi and Lepage 2008), suggesting that function words play a special role in word learning (Christophe et al. 2008; Hochmann et al. 2010). Older infants can use function words as a signal for specific lexical categories (Hicks et al. 2007; Höhle et al. 2004; Shi and Melançon 2010). For example, Hicks, Maye, and Lidz (2007) used a **Head-Turn Preference** procedure to examine infants' categorization abilities. In this technique, infants hear speech coming from one of two speakers. When the speech occurs, a light connected to the speaker blinks. As long as infants look towards the light, the speech continues. If they look

away, the speech stops and a new trial begins. Hicks et al. (2007) familiarized 14- to 16-month-olds with a nonsense word preceded by a determiner (e.g. *my kets*). Then, infants heard trials with the same nonsense word paired with a different determiner (*her kets*) or with an auxiliary (*will kets*). Infants listened longer to words paired with function words from a different category than from the same category. Similarly, infants also listened longer when a familiarized nonsense word preceded by a modal (*will dak*) later occurred after a determiner (*my dak*) than when it occurred after a different modal (*can dak*) (Hicks et al. 2007). This suggests that children use the determiner and auxiliary functional categories to identify the lexical category of an unknown word: Hearing a determiner tells them that the novel word is a noun and therefore should only occur in places where nouns can occur, and hearing an auxiliary tells them that the novel word is a verb and should only occur in places where verbs can occur. Thus, at ages before children reliably produce multiword combinations, we can see that they understand the categorial status of certain function words and the consequences of occurring next to these function words.

Using the **Conditioned Head Turn** procedure (Kuhl 1985), Cauvet et al. (2014) showed that 18-month-old French-learning children use function words to identify known words during language comprehension. In this task, infants are seated at a table with an experimenter who has some toys to hold their attention. Infants learn that if they hear a particular word from a loudspeaker and orient towards it, away from the experimenter, an electronic toy will light up and make noise. In this case, infants were trained to respond to a target noun preceded by a determiner (e.g. *la balle* 'the ball') or a target verb preceded by a pronoun (*je mange* 'I eat'). At test, children turned towards the loudspeaker more frequently when the target words were preceded by another word from the correct functional category (*une balle* 'a ball', *on mange* 'we eat') than when they were preceded by a word from the wrong functional category (*on balle* 'we ball', *une mange* 'the eat'). This suggests both that infants use function words to parse the speech stream and that they treat function words drawn from the same category in the grammar of the community as a category in their own grammars. Other studies have found that 2-year-olds show better and faster sentence comprehension when singular nouns are preceded by determiners than by ungrammatical or missing function words (Gerken and McIntosh 1993; Kedar et al. 2006; Shipley et al. 1969).

Furthermore, children can use functional categories to infer aspects of a content word's meaning. Although grammatical categories do not correlate perfectly with semantic categories, some imperfect correlations do exist: For example, nouns tend to label object kinds, adjectives tend to label object properties, and verbs tend to label events. Children as young as 1 year old can these correlations to infer whether a novel word labels an object kind or property (Hall et al. 1993; Mintz and Gleitman 2002; L. B. Smith et al. 1992; Taylor and Gelman 1988; Waxman 1999; Waxman and Booth 2001; Waxman and Markow 1998). 12-month-olds who hear an object labeled as *a blicket* will select another object of the same kind when asked for another blicket (Waxman and Markow 1998). 13-month-olds who hear a purple horse labeled as *a daxish one* will prefer to select a novel purple object over a differently colored horse (Waxman 1999).

This behavior suggests that 1-year-old infants can distinguish the distribution of nouns and adjectives based on co-occurring functional categories, and use that knowledge to infer that a novel word in a noun context labels an object kind, whereas a novel word in an adjective context labels an object property.

Using a **Habituation** task, He and Lidz (2017) found that slightly older infants are also able to use the presence of functional verbal morphology to identify that a novel word labels an event rather than an object. This method follows the same logic as the High-Amplitude Sucking procedure, but uses infants' gaze towards a visual display as a measure of their attention. An experimenter live-codes infants' attention towards the display in a separate room, and the stimulus stops when infants look away for a specified length of time. Infants reach habituation once their attention declines below a particular threshold, upon which researchers measure whether infants dishabituate to a new test stimulus. He and Lidz (2017) habituated 18-month-olds to a scene of a penguin spinning, labeled either by a novel word in a noun context (e.g. *It's a doke*) or in a verb context (*It's praching*). At test, children saw a scene of the penguin performing a different action, labeled by the same audio. Children dishabituated when they heard *It's praching* label that new scene, but not when they heard *It's a doke*. These infants appear to have used the co-occuring functional categories to identify whether the novel word was a noun or verb, and therefore what concept it should label. Infants who heard the novel word after a determiner identified the word as a noun and therefore an object name, and were not surprised to hear this word label the same object performing a different action. By contrast, infants who heard the novel word in a verbal context, after the auxiliary *is* and with the inflectional suffix *-ing*, identified the word as a verb and therefore an event name, and were surprised to hear this word label a different action. Identifying the signals of a new word's grammatical category—its distributional context and co-occurring function words—allows children to both categorize and make inferences about the meaning of that word.

These experimental results show us that children's knowledge about grammatical categories in their language goes beyond the distribution of these categories, and includes information about other syntactic or interpretive properties of these categories. Before they productively combine words into phrases, children know that nouns label objects, adjectives label object properties, and verbs label events.

5.2.2 Syntactic bootstrapping: Sensitivity to subcategories

We'll now turn to infants' knowledge of the properties of *subcategories* of lexical items, reflected in the argument-taking properties of particular predicates. Under prominent theories of verb learning, infants use the syntactic properties of verbs to infer aspects of their meanings. This is **syntactic bootstrapping**: if children are aware of the relations between verbs' syntactic distributions and their meanings, and can observe those syntactic distributions, then they might be able to use those distributions to narrow down the candidate meanings of novel verbs (Gleitman 1990; Landau and

Gleitman 1985; Lasnik 1989). Although initially proposed as a theory of verb learning, this term has also been used to describe other cases in which children infer aspects of a word's meaning by using information about its syntactic distribution (Brown 1957).

How can we tell whether infants are sensitive to the syntactic properties of particular verbs, and whether they can use those properties to draw inferences about verb meanings? Many approaches to this question have considered infants' sensitivity to transitivity. Because causal events tend to be described by transitive clauses cross-linguistically, these studies have asked whether infants infer that a novel verb in a transitive clause is likely to label a causal event involving both an agent and a patient, whereas a novel verb in an intransitive clause is not (e.g. Arunachalam and Waxman 2010; Brandone, Addy, Pulverman, Golinkoff, and Hirsh-Pasek 2006; Fisher, Gertner, Scott, and Yuan 2010; Naigles 1990; Noble, Rowland, and Pine 2011; Pozzan, Gleitman, and Trueswell 2015; Yuan and Fisher 2009; Yuan, Fisher, and Snedeker 2012). The primary method used in these studies is called **Intermodal Preferential Looking** (Golinkoff et al. 1987): An auditory linguistic stimulus is played in the context of two visual stimuli, and infants' eye movements are recorded by a hidden camera. An experimenter then codes these eye movements frame by frame in order to determine the proportion of time infants look towards one visual stimulus versus the other, out of the total time spent looking at either stimulus. These looking preferences are taken as evidence for how infants interpreted the linguistic stimulus, under the assumption that infants will look longer at the image or scene that they perceive as a better match for the audio they are hearing. This assumption was originally established in non-linguistic tests of this method (Spelke 1976). A related method, the **Looking While Listening** paradigm, aims to provide a finer-grained measure of looking preferences by analyzing the time-course of looking to each visual stimulus on a frame-by-frame basis, time-locked to the unfolding audio stimulus (Fernald et al. 2008).

In one of the first studies to use a preferential looking method to investigate verb learning, Naigles (1990) presented 25-month-olds with a novel verb in the context of two scenes: a causal scene intended to be viewed with two participants (a duck pushing a bunny over), and a non-causal scene intended to be viewed as two separate one-participant events (a duck and a bunny each wheeling their arms independently). Naigles measured infants' looking preferences as a function of whether they heard the novel verb in a transitive clause or an intransitive clause. Infants who heard *The duck is gorping the bunny* looked longer at the pushing scene, and infants who heard *The duck and the bunny are gorping* looked longer at the arm-wheeling scene. It therefore appears that infants were sensitive to the syntactic frame of the novel verb, inferring that *gorp* in a transitive frame was more likely to label the causal event, whereas *gorp* in an intransitive frame was more likely to label the non-causal event.

These results supported an influential hypothesis about *how* infants use the syntactic properties of verbs to draw inferences about meanings. Under this hypothesis, infants take the nouns (or noun phrases) in a clause to be arguments, and expect the number of arguments in a clause to match one-to-one the number of participants in the event the clause describes (Fisher 1996; Gleitman 1990; Naigles 1990). Thus, a transitive clause

with two arguments should label an event perceived with two participants, whereas an intransitive clause with only one argument should label an event perceived with one participant. This is a potentially powerful learning strategy for infants at early stages of syntactic development because it requires very little syntactic knowledge: In order to narrow down the candidate events a clause refers to, infants only need to be able to identify the number of nouns or noun phrases in the clause, and do not need to identify their thematic roles or hierarchical position in the clause.

Extensive tests of this hypothesis have corroborated that infants as young as 22 months are sensitive to transitivity, and will infer that a novel transitive verb labels a causal event (Arunachalam and Waxman 2010; Brandone et al. 2006; Fisher et al. 2010; Noble et al. 2011; Pozzan et al. 2015; Yuan et al. 2012; Yuan and Fisher 2009). It furthermore appears that children are able to draw this inference on the basis of distributional information alone. Yuan and Fisher (2009) familiarized 28-month-olds with short dialogues containing novel transitive or intransitive verbs, without any informative visual context. At test, infants were then asked to identify the referent of the novel verb (e.g. *Find blicking!*) while viewing two candidate events, one causal and one non-causal. Infants who had heard the transitive dialogues looked longer at the causal event than infants who had heard the intransitive dialogue. This indicates that they had tracked the syntactic properties of the novel transitive verb and used those properties to draw inferences about its possible meanings, even without the support of referential context.

However, beyond Naigles' (1990) seminal study, further work has found inconsistent behavior with intransitive verbs. Infants who hear novel verbs in intransitive frames do not show a reliable preference for events intended to be viewed with one participant as opposed to two (e.g. Arunachalam and Waxman 2010; Noble, Rowland, and Pine 2011; Yuan et al. 2012). Because these results are not predicted under the participant-to-argument matching hypothesis, several methodological explanations have been proposed. First, many studies use intransitive sentences with conjoined subjects (e.g. *The duck and the bunny are gorping*) in order to control the number of nouns across conditions. It is possible that infants may not reliably perceive these sentences as intransitive: if they mistake the conjoined subject for two separate arguments, this might lead them to infer a causal meaning for the verb (Gertner and Fisher 2012; Yuan et al. 2012). Alternatively, it is possible that infants do not reliably perceive the presented scenes under the intended event representation. If infants conceptualize a scene of one actor pushing another as an event of two actors playing, then they might consider the intended "two-participant" scene a good referent for a novel intransitive verb (Arunachalam et al. 2016; Brandone et al. 2006; Pozzan et al. 2015). These concerns highlight the importance of carefully controlling for how children perceive both the linguistic and visual stimuli in a preferential looking task.

But it is also possible that infants' behavior with intransitives is due not to methodological confounds, but instead to an alternative weaker learning strategy. If infants merely expect that each argument of a clause will name an event participant, without necessarily matching participants one-to-one, then either a one-participant or a two-participant event could be a potential referent for an intransitive clause (Williams 2015).

Further work is therefore necessary to determine the specific inferences infants draw on the basis of hearing verbs in transitive vs. intransitive frames, and whether a participant-to-argument matching strategy best characterizes of infants' behavior across different clause types. This question is explored in Perkins (2019).

We've seen that infants can use transitivity information to draw inferences about verb meanings. Can they use information beyond the number of arguments in the clause, and draw inferences on the basis of *which* particular arguments are present? Cross-linguistically, subjects of transitive clauses tend to label agents of causal events, and objects tend to label patients (M. C. Baker 1988; Dowty 1991; Fillmore 1968; Jackendoff 1972). If an infant can identify the subject and object in a transitive clause, she may be able to infer that the clause labels not just any causal event, but one in which the referent of the subject is the agent and the referent of the object is the patient. Gertner, Fisher, and Eisengart (2006) tested the ability of 2-year-olds and 21-month-olds to draw this inference using another preferential looking task. Infants heard a transitive sentence (e.g. *The duck is gorping the bunny*) in the context of two causal scenes: one in which a duck pushed a bunny, and one in which the bunny pulled the duck. Both groups of infants looked preferentially at the scene in which the duck was the agent, indicating that they knew that the subject of a transitive clause labels the agent rather than the patient of a causal event. Furthermore, infants preferred the duck-agent and bunny-patient event even for sentences like *He is gorping the bunny*: Here, they could only rely on the referent of the object because the subject does not identify a unique referent in the discourse. This indicates that infants knew that the object of a transitive clause labels the patient rather than the agent of a causal event. These infants were able to exploit relationships between argument position (subject vs. object) and argument roles (agent vs. patient) in order to constrain the inferences they draw about transitive verb meanings.

For intransitive verbs these relationships are more complicated: the subject of an intransitive clause can label either an agent (e.g. *John baked*) or a patient (e.g. *The bread rose*). These sub-classes of intransitives also display differences in meaning: Intransitives whose subject is an agent tend to label actions of that agent, whereas intransitives whose subject is a patient tend to label changes undergone by that patient (e.g. Fillmore 1970; Levin and Hovav 2005; Williams 2015). Another line of work has asked whether children can draw these finer-grained inferences about verb meanings on the basis of the thematic role of the intransitive subject (Bunger and Lidz 2008; 2004; Naigles 1996; Scott and Fisher 2009). For example, Scott and Fisher (2009) familiarized 28-month-olds with a dialogue in which a novel verb alternated between transitive and intransitive uses. Infants either heard the intransitive with an animate subject (e.g. *Matt dacked the pillow. He dacked*) or an inanimate subject (e.g. *Matt dacked the pillow. The pillow dacked*). At test, infants heard the verb in a transitive frame in the context of two "two participant" scenes: a caused-motion event in which a girl pushes a boy over, or a contact-activity event in which the girl dusts the boy with a feather duster. Infants who were exposed to the animate-subject intransitive dialogue preferred to look at the contact-activity event, whereas infants who were exposed to the inanimate-subject dialogue preferred to look at the caused-motion event. These infants were able to use cues

to the thematic role of the intransitive subject, such as its animacy, to infer whether the novel verb labeled an action of an agent or a change undergone by a patient.

Thus, infants between 21 months and 2 years appear sensitive not only to the number of arguments in a clause, but also to the thematic roles of those arguments in drawing inferences about verb meanings. Infants can use cues such as argument position and animacy to infer whether an argument in a clause labels an agent or a patient in an event, constraining the type of events that the clause is likely to label. And syntactic bootstrapping doesn't end with simple transitive and intransitive clauses: Additional questions remain about how infants map sentences to events with three participants (Wellwood et al. 2015; Perkins 2019), and how children infer particular mental states from the types of complements that attitude verbs embed. The latter question has been investigated extensively in preschoolers (Fisher et al. 1991; Gleitman et al. 2005; Hacquard 2014; Harrigan et al. 2016; White et al. 2018); see Chapter 6 of this volume for more information. These observations invite further investigation into the nature of the inferences infants draw on the basis of the argument-taking properties of new verbs, and the syntactic representations these inferences are drawn from.

5.2.3 Summary

In this section we've reviewed behavioral evidence for the development of syntactic category knowledge in infancy. Sensitivity to the co-occurrence patterns of categories like determiners, nouns, and verbs tells us when infants have gained awareness of how categories distribute in their language, and sensitivity to the syntactic and interpretive properties of these categories tells us when infants represent these categories with the same features that adults do. We've further examined infants' sensitivity to lexical subcategories, revealed through the inferences infants draw from the argument-taking properties of verbs to the types of meanings those verbs can have. The studies we've reviewed here show that a great deal of syntactic category development takes place before children consistently produce these categories in their own speech, demonstrating the importance of comprehension measures in assessing the full extent of children's grammatical knowledge. But open questions remain—in particular, how rich are children's representations of these lexical categories and their combinatorial properties? We'll now explore this latter question in more detail as we turn to children's acquisition of clause structure.

5.3 Clause structure

Children's first multi-word utterances, shortly before their 2nd birthday, are often heralded as the first evidence of syntactic development beyond the word level. The ability to combine subjects with predicates, verbs with objects, indicates that a child has gained

knowledge of not only the syntactic properties of individual words, but also the syntactic properties of phrases and clauses. As we observe this ability emerging, what can we conclude about the nature of children's early clause structure representations? Do they show sensitivity to the properties that constrain clause structure cross-linguistically, such as hierarchical structure and the role of functional elements like tense? Do they show sensitivity to the properties specific to the child's target language, such as word order, overt tense marking, and obligatory vs. null subjects?

Here, much of the literature has debated the evidence from children's productions. Children's earliest combinatorial speech is far from adult-like, frequently omitting elements required in the grammar of the target language (e.g. Brown 1973). From this early production data, it is tempting to conclude that children's clause structure knowledge is quite incomplete at the age of two years. Yet comprehension studies suggest that this is not the full story. By the age of 18 months, children already demonstrate knowledge of the hierarchical structure of phrases and the order of subjects, verbs, and objects in their language (Hirsh-Pasek and Golinkoff 1996; Lidz et al. 2003). 20-month-olds potentially represent even more complex clausal structures such as *wh*-questions (Gagliardi et al. 2016), as we'll discuss in Section 5.4. The debate over children's early clause structure knowledge thus serves to illustrate the difficulty of drawing conclusions about children's linguistic representations from their behavior—and in particular, the challenge of separating the contributions of grammatical knowledge and other cognitive and linguistic factors in young children's early production data.

5.3.1 Comprehending basic clause structure: Subjects and objects

Cross-linguistically, subjects and objects are represented in an asymmetrical hierarchy within a clause: verbs and objects form a constituent to the exclusion of the subject (e.g. Baker 2001). But this underlying hierarchy is realized in different word orders from language to language. English typically displays SVO order: Subjects precede verbs, which precede objects. Because we know this canonical word order, we know that *the dog* is the subject and not the object in the sentence *The dog bit the cat*. This word order varies across languages: SOV word order is dominant in Japanese, VSO is common in Irish, and VOS in Malagasy. In order to arrive at the correct representation of clauses in their language, children must identify the relative order of the subject and object.

How can we tell when children know the canonical word order of their language? Children's utterances display the correct word order of their language as early as it can be observed—from the onset of combinatorial speech (L. Bloom 1970; Brown 1973). This knowledge must therefore be acquired before children begin producing sentences, requiring us to look prior to children's sentence productions at their early sentence comprehension. One approach is to probe children's sensitivity to the interpretive consequences of being a subject or an object. Subjects of active, transitive clauses tend to label agents of causal events, and objects tend to label patients—patterns that hold

robustly across the world's languages (M. C. Baker 1988; Dowty 1991; Fillmore 1968; Jackendoff 1972). If children are aware of these tendencies, then identifying the order of subjects and objects in a sentence may allow them to draw inferences about the likely thematic roles of the entities named by those arguments. And by observing the inferences children draw, we as researchers can infer which arguments in the clause children take to be subjects, and which they take to be objects.

Hirsh-Pasek and Golinkoff (1996) found that children could identify the order of subjects and objects in English as early as 17 months. They used a preferential looking task, in which children heard a transitive sentence (e.g. *Big Bird is washing Cookie Monster*) while viewing two scenes: one in which Big Bird was washing Cookie Monster, and one in which Cookie Monster was washing Big Bird. Children looked more at the scene where Big Bird was the agent when they heard *Big Bird is washing Cookie Monster*, and they looked more at the opposite scene when they heard *Cookie Monster is washing Big Bird*. This behavior suggests that children had identified the canonical word order of English: they knew that subjects precede objects, and inferred that the individual named by the subject was the agent of the event. In the previous section, we saw that older children could use this knowledge to constrain their hypotheses about the meanings of new verbs: 2-year-olds who heard *The duck is gorping the bunny* looked longer at an event in which the duck was the agent, rather than the bunny (Gertner et al. 2006).

These looking-time studies provide evidence that children can identify the order of subjects and objects in sentences during their second year of life, and can use that order to draw inferences about sentence meanings. How this early understanding develops is still an open question. One hypothesis proposes that children might bootstrap into the word order of their language by inferring the thematic relations in sentences they hear—a form of **semantic bootstrapping** (Grimshaw 1981; Pinker 1984; 1989). Suppose a child represents a scene of a dog biting a cat as an event where the dog is the agent and the cat is the patient, and knows that agents are typically realized as subjects and patients as objects of transitive sentences. If that child hears the sentence *The dog bites the cat* to describe this scene, and knows that *the dog* labels the dog and *the cat* labels the cat, then she can infer that *the dog* is the subject and *the cat* is the object. She may then assume that English has SVO word order.

This hypothesis rests on several critical assumptions: (1) that children perceive scenes in the world under conceptual structures differentiating thematic roles like "agent" and "patient"; (2) that these conceptual structures align straightforwardly with at least some of the sentence descriptions they hear; and (3) that children are aware of the mapping between conceptual and linguistic structure, specifically how agents and patients tend to be realized in particular argument positions in a clause. Investigating each of these assumptions is necessary in order to demonstrate the viability of the semantic bootstrapping hypothesis. Research with prelinguistic infants indicates that the first assumption is borne out: 6-month-olds represent agents as distinct from patients in events, attributing to them goals and intentions (Csibra et al. 1999; Leslie 1995;

Leslie and Keeble 1987; Luo et al. 2009; Woodward 1998). Further research is needed to confirm the second and third assumptions—particularly how children may handle challenges from so-called "non-basic" clauses like passive sentences, which obscure the mappings between argument positions and argument roles (Lidz and Gleitman 2004; Perkins et al. 2017; Pinker 1984), and from reversible predicates like *chase* and *flee*, which describe the same event from two different perspectives (Gleitman 1990). Because not all sentences children hear will provide equally informative data for inferring word order, it is necessary to determine whether children are able to ignore data that is uninformative for drawing these inferences.

A further question is how children represent subjects and objects as they learn their relative order in sentences. Do children begin by only representing the linear order of noun phrases (e.g. Fisher 1996), or do they represent these phrases *qua* subjects and objects, within a hierarchical clause structure? At the heart of this question is whether children's syntactic representations are constrained to be hierarchically structured from the earliest stages of development (Chomsky 1975).

Lidz, Waxman, and Freedman (2003) tested this question at the level of the noun phrase, using anaphora to probe 18-month-olds' representations of phrases like *a yellow bottle*. Consider the sentence *I'll give Adam this yellow bottle, and I'll give you that one*. The word *one* refers not merely to another bottle, but to another yellow bottle. Because *one* is anaphoric to *yellow bottle*, adults' noun phrase representations must be hierarchically structured: *yellow bottle* must be a nested constituent in the phrase [*this* [*yellow bottle*]]. Infants' interpretations of the word *one* should thus reveal whether they, too, represent this phrase with nested structure. The researchers used a preferential looking task to investigate these interpretations. First, they familiarized infants with a picture of a yellow bottle labeled with a determiner–adjective–noun sequence: *Look! A yellow bottle*. Then, they showed a display containing both a yellow bottle and a blue bottle, and measured infants' looking preferences upon hearing a sentence with anaphoric *one* (*Do you see another one*?) or a control sentence (*What do you see now*?). Infants in the anaphoric *one* condition looked more at the yellow bottle, whereas infants in the control condition looked more at the novel blue bottle. This indicates that infants interpreted *one* as anaphoric to *yellow bottle*—and therefore that their noun phrase representation contained *yellow bottle* as a nested constituent. At least by the age of 18 months, infants represent phrases with internal hierarchical structure.

It still remains to be determined whether hierarchical structure extends above the phrasal to the clausal level in children's early syntactic representations. Suggestive evidence for clause-level hierarchical structure comes from work on children's knowledge of constraints on pronoun interpretation, in particular Principle C (Lukyanenko et al. 2014; Sutton 2015; Sutton et al. 2012). If children's early interpretations are constrained by Principle C, a constraint defined over hierarchical structure, this would indicate that their clause representations are hierarchically structured. But testing for knowledge of Principle C in infants is not a trivial task. We'll return to this question in Section 5.4.

5.3.2 The view from production data: Telegraphic speech

Although open questions remain, the comprehension studies reviewed above support the view that a good deal of clause structure knowledge is in place even before children begin combining words into sentences in their own productions. However, when children do begin producing sentences, those utterances are "telegraphic," omitting clausal elements that are required by the adult grammar (Brown, 1973). On one view, these non-adultlike productions indicate that children's clause structure knowledge is quite incomplete even through their third year of life (e.g. Brown 1973; Guasti 2002; Guilfoyle and Noonan 1988; Radford 1990; Rizzi 1994), a position inconsistent with the view from comprehension described above. How do we reconcile these two positions?

Experimental methods may allow us to gain a fuller understanding of the factors underlying children's early telegraphic productions. Shipley, Smith, and Gleitman (1969) conducted one of the first experiments to address the following question: Do children's telegraphic utterances reflect immature grammatical knowledge or an immature performance system? The researchers reasoned that a child who produces telegraphic utterances due to immature grammatical knowledge would show better comprehension of telegraphic commands (e.g. *Throw ball!* or *Ball!*) compared to well-formed commands (e.g. *Throw me the ball!*). That is, if children's grammatical competence at this age is limited to generating telegraphic sentences, then their comprehension should be similarly limited. The researchers gave both telegraphic and well-formed commands to seven 1- to 2-year-old children whose own utterances were telegraphic, and measured how frequently each child obeyed the commands. Children who produced telegraphic speech did not show improved comprehension of telegraphic commands—they actually obeyed the telegraphic commands *less* frequently than the well-formed commands. This result suggests that children's own telegraphic speech is not primarily the result of immature grammatical competence. Instead, a variety of interacting factors may be at play, including the developing extralinguistic cognitive systems that allow children to deploy their grammatical competence during real-time speech production. This study highlights the difficulty in teasing apart the relative contributions of grammatical competence and performance in children's productions, and the role that experimental work can play in understanding this complex dynamic.

One phenomenon in children's telegraphic speech that has been hotly debated is the so-called "root infinitive" stage, during which children sometimes use the infinitive form of main clause verbs instead of the tensed form (Bar-Shalom and Snyder 1997; Haegeman 1995; Harris and Wexler 1996; Platzack 1990; Schaeffer and Ben Shalom 2004; Weverink 1989; Wexler 1994). The duration of this stage appears to vary crosslinguistically: It is rare in Italian-speaking children (Guasti 1993) and may extend past the 4th birthday for Dutch and English-speaking children (Haegeman 1995; Harris and Wexler 1996; Phillips 1995). Many accounts have taken this phenomenon as evidence for immature clause structure knowledge: If children's early productions lack tense morphology, then perhaps their early clause structure representations lack tense,

or their tense representations are in some way immature (e.g. Guasti 2002; Guilfoyle and Noonan 1988; Radford 1990; Rizzi 1994; Wexler 1994).

The large majority of the work on root infinitives has focused on analyzing patterns of verb productions in children's spontaneous speech to support different theories of grammatical development. German-speaking children's differentiation between finite and non-finite verbs when producing V2 sentences has been taken as evidence for early (although potentially immature) representations of tense, contra accounts that children's early clause structure lacks tense altogether (Guasti 2002; Phillips 1995; Poeppel and Wexler 1993; Wexler 1998). Correlations between the length of the root infinitive stage and the rate of unambiguous cues to overt tense-marking in the input have been taken as evidence that children in this stage are learning whether or not their target language marks tense overtly, rather than developing mature tense representations (Legate and Yang 2007). Yet few experimental studies have been conducted to test differing accounts of infants' grammatical development in the lab. To date, experimental work on root infinitives has been conducted only with older, preschool-aged children (Grinstead et al. 2009; Pratt and Grinstead 2007a; 2007b; Rice et al. 1998; 1999), using indirect grammaticality judgment methods that will be described in Chapter 6 of this volume. Furthermore, as Shipley, Smith, and Gleitman (1969) demonstrated, it is not easy to isolate grammatical development from developing extralinguistic factors that contribute to speech production when studying spontaneous speech corpora. The puzzle of root infinitives thus invites further experimentation, particularly with methods appropriate to younger children, in order to determine the factors responsible for both their appearance in infancy and their disappearance in later childhood.

The debate over root infinitives illustrates the difficulty about drawing conclusions from a child's productions about the linguistic knowledge that underlies those productions. Similar themes emerge in the literature on another hotly debated phenomenon in early child speech: so-called early "null subjects," in which children omit the subjects of main clauses even in languages like English that require them (e.g. Bowerman 1973; Hyams 1986). Like root infinitives, these omitted subjects were initially claimed to reflect immature grammatical knowledge. On one class of accounts, children are in the process of learning whether or not their language requires overt subjects (Hyams 1986; 1992; Hyams and Wexler 1993; Wexler 1998; Yang 2002); on another, null subjects are the result of immature clause structure representations that (perhaps optionally) lack functional projections such as tense that host subjects in adult grammars—a hypothesis motivated in part by the overlap between early null subjects and the root infinitive stage (Guasti 2002; Guilfoyle and Noonan 1992; Radford 1990; Rizzi 1993; 2005; Wexler 1994; 2014). However, other work has found that children acquiring languages that require overt subjects drop them less frequently than children acquiring languages that do not (Kim 2000; Valian 1991; Valian and Eisenberg 1996; Wang et al. 1992), and are sensitive to the discourse contexts in which they are licensed (Allen 2000; Clancy 1993; Serratrice 2005). This raises the possibility that children are sensitive to their target grammar's requirements for overt subjects, even if their own productions do not always satisfy these requirements.

Experimental investigations into early null subjects have implicated a range of factors beyond developing grammatical knowledge that may contribute to this phenomenon. Gerken (1991; 1994) used a method called **Elicited Imitation**, in which children are asked to imitate sentences produced by a puppet. Within the test sentences, the researcher systematically manipulates specific variables of interest. Gerken manipulated whether the test sentences had a full lexical subject (e.g. *the bear*) or a pronominal subject, and found that 2-year-olds were more likely to produce full lexical subjects than pronominal subjects in their own imitations. Because the type of noun phrase is not predicted to affect the rate of subject production under grammatical competency-based accounts, Gerken concluded that performance and prosodic factors were responsible: English-learning children with limited processing resources may prefer to align their productions to a dominant strong–weak syllable pattern, and thus preferentially omit unstressed subjects that are the first rather than the second syllable of a prosodic foot. These prosodic preferences may interact with information structure: Sentence elements that convey less information may be preferentially dropped if processing resources are taxed, yielding more subject than object omissions (subjects tend to convey "given" information more frequently than objects) and more pronominal than lexical subject omissions (Allen 2000; Clancy 1993; Serratrice 2005; Valian and Eisenberg 1996).

The same experimental method has been used to probe further effects of these limited processing resources (Nuñez del Prado et al. 1993; Valian et al. 1996; Valian and Aubry 2005). Valian, Hoeffner, and Aubry (1996) tested whether sentence length would affect children's subject imitations. If developing memory or other cognitive resources are responsible for children's early null subjects, then taxing these resources in the production of longer sentences might lead to higher rates of subject omissions (P. Bloom 1990; Valian 1991). The authors found that 2-year-olds imitated fewer subjects from long sentences than from short ones. However, this effect was only observed for children whose mean length of utterance in spontaneous speech (MLU) was below 3, suggesting that children's developing extralinguistic cognitive capacities contribute to their ability both to produce subjects and to produce longer sentences in their own spontaneous speech. A follow-up study tested whether a second chance to imitate the target sentence, after having already parsed it once, would lead to increased subject production due to reduced cognitive demands (Valian and Aubry 2005). Children did indeed increase their production of pronominal and expletive subjects when given a second chance to imitate the target sentence, further pointing to the role of extralinguistic cognitive capacities in their early subject omissions.

These experimental studies use controlled production tasks to demonstrate that factors unrelated to early clause structure knowledge—such as subject type, sentence length, and the opportunity to repeat a sentence twice—affect the rates at which young children omit subjects in their early speech. Their results indicate that systems outside of core grammatical competency may contribute to children's early subject omissions, including developing cognitive resources, information structure, and prosodic sensitivities. Yet they do not pinpoint exactly which system or systems are primarily

responsible: Whether early null subjects can be traced to a single source or stem from a combination of factors remains an open question.

More recently, an attempt has been made to investigate how children comprehend sentences with missing subjects. Orfitelli and Hyams (2012) used a variant of a **Truth Value Judgment Task** (see description in Chapter 6 of this volume) to test whether 2- to 5-year-olds would interpret subjectless sentences like *Play with blocks* as declaratives or imperatives. The researchers found that the youngest children failed to treat these sentences as imperatives when they did not include a clear imperative marker (e.g. *please*), which they took as evidence that young children's grammars allow subjectless declaratives. However, they also found inconsistent imperative interpretations up to the age of 4, raising the possibility that the pragmatic requirements of this task may have been particularly challenging for this age (Valian 2016). This topic awaits further research, with comprehension methods tailored to children's developing cognitive abilities.

The debate over early subject omissions further illustrates the difficulty of isolating the factors responsible for children's telegraphic speech: does this non-adultlike behavior reflect immature clause structure knowledge, or interference from other linguistic and extralinguistic systems that support sentence production? As in the case of root infinitives, this question is difficult to answer from spontaneous speech data alone, but experimental methods may provide greater insight into the relative contributions of developing grammatical knowledge and developing performance systems in children's early productions.

5.3.3 Summary

How complete are children's earliest clause structure representations? We've seen different perspectives from comprehension and production data. On the one hand, much of children's clause structure knowledge appears to be in place even before the onset of combinatorial speech: Children are sensitive to the order of subjects and objects in their language, and represent phrases with hierarchical structure. On the other hand, children's early sentences are strikingly incomplete, omitting required grammatical elements such as tense marking and overt subjects. This apparent conflict illustrates the challenges of inferring children's grammatical knowledge from their behavior, which may not faithfully reflect that grammatical knowledge. For phenomena like root infinitives and early null subjects, it remains an open question how best to isolate the contribution of the grammar from the contribution of other cognitive systems that interact in sentence comprehension and production.

5.4 Syntactic dependencies

Syntactic dependencies are relations between elements in a clause or across clauses, determined by the syntactic properties of those elements and the structures they occur

in. Here we will consider infants' knowledge and acquisition of three kinds of dependencies: morphosyntactic dependencies, movement dependencies, and referential dependencies.

Morphosyntactic dependencies express an abstract grammatical relation, such as agreement or selection, through morphological means. For, example, in (3a), there is a dependency between the auxiliary verb *is* and the *-ing* form of the verb, which work together to tell us that the sentence is in the present progressive.

(3) a. Jane is playing the piano
b. Jane is softly playing the piano
c. Jane is softly and beautifully playing the piano.

Such a dependency represents a head-to-head relation between the auxiliary and the main verb. This type of relation can hold across intervening material, as in (3b,c).

A second type of dependency occurs in questions like (4).

(4) a. **Which sonata** is Jane playing __ tonight?
b. *__Which sonata__ is Jane playing the piano tonight?

Here there is a dependency between the "*wh*-phrase" *which sonata* and the verb *play*: the verb *play* requires a direct object, typically to its right, and that requirement is satisfied by the *wh*-phrase, despite it not occurring to the right of the verb. Indeed, the *wh*-phrase cannot occur if there is an object in the postverbal position, as shown in (4b). We also find this type of relation in relative clauses (5a), clefts (5b), and topicalization (5c), among other constructions.

(5) a. I love **the sonata** that Jane is playing __ tonight.
b. It is **my favorite sonata** that Jane is playing __ tonight.
c. **That sonata**, Jane is playing __ tonight.

These kinds of dependencies can hold across an unbounded degree of intervening material (6a,b), but cannot hold across certain "island" configurations (6c,d) (Ross 1967).

(6) a. **Which sonata** did Tony think that the program said that Jane was playing __ tonight?
b. I love **the sonata** that everyone believed that the critics wanted Jane to play __ tonight.
c. *__Which sonata__ do you wonder why Jane is playing __ tonight
d. *I love **the sonata** that you wonder why Jane is playing __ tonight

Because the object of the verb appears to have "moved" to a different position in these sentences, these dependencies are called **movement dependencies**. They're also frequently called "filler-gap dependencies" because the moved element is a "filler" that becomes associated with a "gap" later on in the sentence.

An important property of both morphosyntactic and movement dependencies is the fact that they are defined over the hierarchical structure of elements in a sentence (Chomsky 1975). In other words, the relations that elements of a sentence can enter into depend on their structural positions with respect to each other. For instance, the dependency between *is* and *-ing* holds only between the auxiliary (*be*) and its verbal complement. Thus, no verbs or other auxiliaries can intervene between the auxiliary and the verb bearing the *-ing* (7).

(7) a. *Jane **is** try to eat**ing** her pizza.
b. *Jane **is** might play**ing** the piano
c. Jane might be playing the piano

Similarly, movement dependencies are structurally defined. Strings of words that function as syntactic constituents can move (8a), but those that are not constituents cannot (8b).

(8) a. **which sonata** is Jane playing __ in the concert?
b. ***which sonata in** is Jane playing __ the concert?

Structure dependence is also illustrated by a third type of dependency, namely **referential dependencies** that hold between pronouns and their antecedents, as in (9).

(9) a. **Jane** thinks that you saw **her** at the concert[1]
b. **Jane** saw **herself** on TV after the concert

In these dependencies the pronouns get their semantic values from their antecedents. These dependencies are constrained by structure. In the case of reflexive pronouns like *herself*, the antecedent must c-command the pronoun and the antecedent must be (roughly) in the same clause as the pronoun, as illustrated by the unacceptability of (10a,b).

(10) a. ***Jane's** brother saw **herself** on TV after the concert
b. ***Jane** thought that you saw **herself** on TV after the concert

In the case of pronominals like *her*, there are two relevant constraints. First, a pronominal may not take a locally c-commanding antecedent (11a), though it may take non-c-commanding antecedents (11b), or c-commanding antecedents across clause boundaries (9a). And, a pronominal may not c-command its antecedent (11c), though it may precede it (11d).

(11) a. ***Jane** saw **her** on TV.
b. **Jane's** brother saw **her** on TV.
c. ***She** thought that you saw **Jane** on TV.
d. When **she** was practicing, **Jane** thought the sonata sounded great.

[1] In the examples that follow, bold typeface is used to indicate intended coreference.

With these basic ideas about syntactic dependencies in mind, we now turn to the question of what infants know about these dependencies and how that knowledge arises.

5.4.1 Morphosyntactic dependencies in infancy

Experimental work with very young children has found that they can track the statistical signature of dependencies like the *is-ing* relation, but this ability is mediated by their memory resources. For example, Santelmann and Jusczyk (1998) used the head-turn preference procedure to examine the morphosyntactic dependency between *is* and *-ing*. Santelmann and Jusczyk (1998) played 18-month-olds sentences with the sequence *is* Verb-*ing*, a real English dependency, as well as sentences containing the sequence *can* Verb-*ing*, which is not an English dependency. Some children heard sentences like *Everybody is baking bread*, and other children heard sentences like **Everybody can baking bread*. 18-month-olds preferred to listen to sentences with the *is* Verb-*ing* sequence over sentences with the *can* Verb-*ing* sequence, indicating that they recognized that *is* and *-ing* stand in a dependency relation. 15-month-olds, however, showed no such preference. Moreover, the 18-month-olds preferred sentences with *is* Verb-*ing* when a 2-syllable adverb came between *is* and the verb, but not when a longer adverb intervened: they were still able to detect this dependency in sentences like *Everybody is often baking bread* but not *Everybody is effectively baking bread*. It appears that these infants' limited memory resources interfered with their ability to track this morphosyntactic dependency across longer distances. That is, children needed to be able to hold enough linguistic material in memory in order to detect the co-occurrence of *is* with *-ing*, and longer intervening adverbs taxed their limited memory resources enough to prevent them from doing so.

Santelmann and Jusczyk's (1998) results indicate that English-speaking children are aware of the morphosyntactic dependency between *is* and *-ing* by the age of 18 months, although their memory resources aren't always sufficient to detect this dependency in their input.

Höhle, Schmitz, Santelmann, and Weissenborn (2006) extended this finding to German, showing that a similar dependency is also detected by 18-month-old German-learning infants. However, Höhle et al. also found that the German infants could detect the dependency across a longer distance of intervening material. They argued that the difference between English- and German-learning infants was not due to differences in memory, but to whether infants could linguistically analyze the material that intervened between the auxiliary and the verb. In English, what intervened was not part of the VP complement to the auxiliary. However, in German it was, and hence could more easily be integrated into children's syntactic representations.

What allows children to become aware of this kind of dependency? Results from artificial language learning studies suggest that children can track co-occurrence patterns in their input to learn non-adjacent dependencies, like the one between *is* and *-ing* in English (Gómez 2002; Gómez and Maye 2005). Saffran, Aslin, and Newport (1996)

famously showed that infants as young as 8 months old could use statistics to track the probability that certain nonsense syllables would occur next to each other. Gómez and Maye (2005) asked whether children can track the probability that certain strings will occur together across intervening material, and what it takes to learn such dependencies. These authors tested 15-month-olds' abilities to detect these types of non-adjacent dependencies in an artificial language. These children heard "sentences" like *pel-vamey-rud, pel-wadim-rud*, and *pel-tapsu-rud*, in which a dependency between the nonwords *pel* and *rud* obtained across a variety of intervening nonwords. After training, these infants were able to recognize this *pel*-X-*rud* dependency in new "sentences" that contained it, as long as their training contained enough variety in the nonwords that came between *pel* and *rud*. This suggests that children as young as 15 months old are able to detect the statistical signature of non-adjacent dependencies, provided they hear enough variety in the intervening material. Gómez and Maye argue that the greater variety discourages the learner from tracking adjacent dependencies and hence promotes the ability to notice non-adjacent dependencies.

Omaki, Orita, and Lidz (in prep.) combined these findings together to ask whether the artificial language paradigm accurately models natural language acquisition. Omaki et al. provided 15-month-olds with experience of high variability in the verb intervening in the *is-ing* construction and then tested them using Santelmann and Jusczyk's (1998) method and materials. They found that 15-month-olds were able to learn the dependency given this highly concentrated input. This suggests that the learning procedure children used in the artificial language experiment may be applicable to the acquisition of a natural language.

Because morphosyntactic dependencies like the one between *is* and *-ing* in English are defined over hierarchical structures in a sentence rather than over the linear order of words, these relations can hold across certain kinds of intervening material. Children's ability to detect the statistical signatures of non-adjacent dependencies is therefore crucial for learning these morphosyntactic dependencies in their language. Detecting non-adjacent dependencies requires high variability among the items that intervene between the parts of the dependency, variability that promotes the discovery of the dependency. But these statistical sensitivities interact with extralinguistic cognition: Children need sufficient memory resources and the ability to analyze the intervening material in order to recognize these dependencies over longer distances. Infants may be unable to keep both parts of the dependency in memory if the amount of linguistic material between them grows too large or is not linguistically analyzable. Children's ability to detect morphosyntactic dependencies in their language thus develops in concert with their maturing memory resources.

It remains open, however, how infants represent these dependencies. Several questions arise here. First, do infants represent these dependencies as between particular morphological forms, or do they recognize that all forms of the auxiliary "be" are equivalent in this relation (Tincoff et al. 2000)? Second, do they represent it as a head-to-head relation between two verbs, as a relation between a head and its complement, or as a movement relation, as in Chomsky's (1957) affix-hopping analysis? Third, when

infants observe a discontinuous dependency between two morphemes, what is the range of possible relations that they consider for representing it (Fodor 1966)? Do infants distinguish head-to-head relations, head–complement relations, and movement relations on the basis of morphological patterns, or do they require additional syntactic information to identify specific grammatical dependency relations? We leave these questions for future research.

5.4.2 Movement dependencies in infancy

Learning movement dependencies involves both children's linguistic and extralinguistic capacities. In this section, we first consider what infants know about *wh*-movement and relativization. We then turn to the question of how infants identify the strings that might contain movement dependencies.

Some studies have found evidence that English-learning children might develop the ability to detect movement dependencies in English sentences between the ages of 15 and 20 months (Gagliardi et al. 2016; Seidl et al. 2003). Seidl, Hollich, and Jusczyk (2003) investigated 13-, 15-, and 20-month-old infants' understanding of *wh*-questions using a preferential looking technique. Infants saw an event of e.g. an apple hitting some keys, and then saw still images of the apple and the keys while being asked one of three questions: *Where are the keys?*, *What hit the keys?*, and *What did the apple hit?*. They found that 13-month-olds were unable to respond correctly to any of the questions, that 15-month-olds looked at the correct image for the "where" question and the subject question, but not the object question, and that 20-month-olds looked at the correct image for all three question types.

Gagliardi, Mease, and Lidz (2016) followed up on this research, testing comprehension of *wh*-questions like *Which dog did the cat bump?* and relative clauses like *Find the dog that/who the cat bumped*. These questions were asked after the infants watched a scene in which one dog bumped a cat, and then the cat bumped a second dog, making both the questions and relatives felicitous. Unlike Seidl et al. (2003), these authors did not find a subject–object asymmetry, but they did find an interesting U-shaped learning pattern. 15-month-olds appeared to arrive at the correct interpretation for both *wh*-questions and relative clauses. In an object question/relative they looked more at the dog that got bumped, rather than the dog that was the agent of bumping. 20-month-olds, on the other hand, only appeared to comprehend *wh*-questions and relative clauses with *who*, but not relative clauses with *that*. These authors argued that 20-month-olds' surprising failure with certain relative clauses might demonstrate the development of syntactic knowledge: They have learned to represent the full movement dependencies in these sentences, but have difficulty detecting when relative clauses with *that* contain these dependencies. The word *that* is ambiguous in English—it occurs in many contexts other than in relative clauses—so words like *who* or *which* are much clearer cues to movement dependencies. By this logic, then, 15-month-olds might arrive at the right answer through a heuristic that does not require them to parse the full

movement dependency, thereby avoiding these difficulties with relative clauses. In other words, 15-month-olds' success with both *wh*-questions and relative clauses may reflect more about their knowledge of argument structure than about their ability to represent long-distance dependencies. In support of this account, Perkins and Lidz (2020) found that 15-month-olds' apparent success on this task is modulated by their vocabulary, a correlate of developing verb knowledge.

We noted above that movement dependencies can only hold between structural units in a sentence. Because this structure-dependence is a universal property of human language, it is something that children might take for granted when learning their first language. In other words, it might be an intrinsic constraint imposed by their language learning mechanism (Chomsky 1975). This constraint would provide useful guidance for learning movement dependencies in their language: Once children can identify the hierarchical structure of a sentence, they will know that only units within that structure can move, and therefore will know which strings of words are candidates for movement.

Takahashi and Lidz (2008) and Takahashi (2009) used an artificial language-learning paradigm to test children's knowledge of structure-dependence. Following a method developed by Thompson and Newport (2007), they constructed artificial grammars in which phrasal categories were expressed through the probabilities that certain words and word categories could occur together, with the idea that two adjacent categories from within a phrase would be more likely to cooccur than two adjacent categories from across a phrase boundary. To create these differences in probabilities in a corpus, they included "rules" in the artificial grammar through which some sequences of nonsense word categories could be optional, repeated, or substituted by other categories. These sequences could thus be identified as constituents. After being exposed to this artificial language for several minutes, adults and 18-month-olds were tested on sentences that contained movement. Adults accepted sentences when one of the optional, repeated, or substituted category sequences were moved: They used the differences in transitional probabilities to group these sequences into units and recognized that those units could move. In a head-turn preference experiment, 18-month-olds likewise distinguished sentences with moved units from those with moved sequences that weren't units. In other words, these infants knew that only strings of words that formed a unit within a structural hierarchy could take part in movement relations, even though they had never heard movement before in this task. Once they were able to identify the hierarchical structure of these sentences, they were able to identify possible and impossible instances of movement in this artificial language. Their knowledge of structure-dependence allowed these learners to draw conclusions about syntactic relations beyond what they were exposed to in their input.

5.4.3 Referential dependencies

Sentence structure is contributor to many aspects of sentence meaning. For example, the interpretation of pronouns depends on their syntactic context. Pronouns make a

contribution to sentence meaning that is underspecified, requiring the context to fill in some aspects of reference. In the sentence *Allison thinks that she will get the job*, the pronoun can be interpreted either as referring to Allison or to some other salient female individual in the context.

In other cases, the pronoun's interpretation depends on the syntactic context rather than the discourse context. For example, the pronouns *she* or *her* may get their reference from (co-refer with) *Belinda* in sentences like (12).

(12) a. When **she** was in the interview, **Belinda** spilled some water.
b. **Belinda** said that my brother interviewed **her**.

However, the pronouns must all refer to someone other than Belinda in sentences like (13).

(13) a. *__She__ was in the interview when **Belinda** spilled some water.
b. *__Belinda__ interviewed **her**.

Thus, while pronouns can have their reference be determined by other parts of the sentence, the conditions under which such referential dependencies hold are constrained by syntactic hierarchy and syntactic locality.[2]

The role of hierarchy can be seen in the contrast between (12a) and (13a), above. In each of these sentences, the pronoun precedes *Belinda* in the linear order of words, but in (13a) the pronoun is "higher" in the structural hierarchy. The notion of height in linguistic structures is expressed though a relation called **c-command** (Reinhart 1981). One expression c-commands another if the smallest unit containing the first also contains the second. In (12a), the pronoun does not c-command *Belinda*, but in (13a), it does. In addition, one expression **binds** a second expression if it c-commands the second expression and co-refers with that expression (Chomsky 1981). But we can't interpret the second sentence above with the pronoun co-referring with *Belinda*: It has to refer to someone else. In other words, the pronoun cannot bind *Belinda*. The relevant constraint on pronoun interpretation, known as **Principle C**, is thus that a pronoun cannot bind its antecedent (Lasnik 1976), or, stated slightly differently, a referring expression like *Belinda* cannot be bound (Chomsky 1981).

Principle C has played a very prominent role in arguments concerning the origins of grammatical knowledge (Crain 1991). Because children are exposed only to grammatical sentence–meaning pairs, it is a puzzle how they acquire constraints like Principle C, which block certain sentences from expressing otherwise sensible interpretations. How can one acquire rules about the interpretations that sentences cannot have?

Crain and McKee (1985) observed that Principle C constrains children's interpretations as early as 3 years of age. This observation raises the question of the origin of this constraint. The success of 3-year-olds is often taken as strong evidence for the role of

[2] In certain discourse contexts, these constraints may be overridden (Bolinger 1979, Evans 1980, Harris and Bates 2002).

c-command in children's representations, and hence for the role of hierarchical structure in shaping children's interpretations throughout development. See Kazanina and Phillips (2001) for supporting evidence from Russian.

This view may be further bolstered by work demonstrating that 30-month-old infants display knowledge of Principle C. Lukyanenko, Conroy, and Lidz (2014) conducted a preferential looking experiment in which infants saw two videos side by side. In one video, a girl (Katie) was patting herself on the head. In the other video, a second girl patted Katie on the head. Infants were then asked to find the image in which "She is patting Katie," or the one in which "she is patting herself." Infants in the former condition looked more at the video in which Katie was getting patted by someone else, whereas those in the latter condition looked more at the video in which Katie was patting herself.

To determine whether children's interpretations were driven by Principle C, as opposed to an alternative non-structural heuristic, Sutton, Fetters, and Lidz (2012) and Sutton (2015) tested children in a preferential looking task like that in Lukyanenko et al. (2014) and also in a task measuring sensitivity to hierarchical structure. Children saw three objects—a big red train, a medium-sized yellow train and a small yellow train. They then were asked to find "the big yellow train." Correct interpretation requires restricting the adjective *big* to apply to the phrase *yellow train*. Sutton et al. measured the speed with which they looked to the correct object and used that to predict the speed with which they arrived at the correct interpretation of the Principle C sentences. They found that these structural processing measures were significantly correlated, though measures of lexical processing speed and vocabulary size were not predictive of Principle C performance. Together these findings suggest that the computation of hierarchical structure is a critical component of children's understanding of sentences, which are subject to Principle C as early as we can measure.

5.4.4 Summary

In summary, children have been shown to be sensitive to morphosyntactic, movement, and referential dependencies very early in development. Using behavioral methods based on simple attentional measures, we are able to see the emerging sensitivity to linguistic dependencies in the second year of life as well as children's use of statistical sensitivities to identify specific dependencies. Moreover, by taking into account constraints from early sentence processing mechanisms, we are able to better diagnose the structural nature of children's early successes and failures with syntactic dependencies. In all cases, it appears as though children represent syntactic dependencies in hierarchical terms.

5.5 Conclusion

Behavioral research provides a window into how core properties of a grammar are acquired in infancy. In this chapter, we have reviewed evidence for the development of grammatical categories, clause structure, and syntactic dependencies, much of which

precedes infants' earliest sentence productions. Behavioral methods thus allow developmental linguists to see earlier emergence, and potentially a truer picture, of grammatical competence than is revealed in the sentences children produce. Controlled experimental designs allow researchers to overcome the sampling limitations inherent in studying what children happen to say spontaneously. Furthermore, if designed well, these tasks can allow researchers to control for extralinguistic factors like working memory and executive function which interact with grammatical knowledge in influencing children's behavior.

Infants are of course limited in the behaviors they are able to control in response to a linguistic stimulus, particularly before they begin producing sentences of their own. Therefore, developmental researchers frequently rely on methods that use implicit measures of infants' linguistic comprehension. The methods we've surveyed include measures of attention—from High-Amplitude Sucking for newborns only able to control their sucking rate, to Habituation, Conditioned Head Turn, and Head Turn Preference procedures for older infants able to control their neck muscles and eye gaze. We've also seen tasks that measure eye movements at a finer-grained level, such as the Preferential Looking paradigm, which relies on infants' ability to coordinate their eye saccades in response to an auditory stimulus. And as a less implicit measure, we've discussed the Elicited Imitation procedure, which is one of the few production tasks used with children as young as 2 years old.

The evidence we've reviewed from these tasks reveals a rich and complex picture of infants' earliest syntactic development. In their acquisition of grammatical categories, infants appear sensitive to the differences between lexical and functional categories from birth (Shi et al. 1999), and to the syntactic and interpretive consequences of many of these categories and subcategories by 18–19 months (e.g. Fisher et al. 2010; He and Lidz 2017). In their acquisition of clause structure, infants appear to be aware of the canonical word order of their language by 17 months (Hirsh-Pasek and Golinkoff 1996), and are biased towards hierarchical structural representations (Lidz et al. 2003; Sutton 2015; Sutton et al. 2012). In their acquisition of syntactic dependencies, infants appear able to detect morphosyntactic dependencies and movement dependencies between 15 and 20 months (Gagliardi et al. 2016; Gómez and Maye 2005; Santelmann and Jusczyk 1998; Seidl et al. 2003), and are aware of the structural constraints on movement and referential dependencies between 18 and 30 months (Lukyanenko et al. 2014; Sutton 2015; Sutton et al. 2012; Takahashi 2009; Takahashi and Lidz 2008).

Yet this picture is by no means complete, and many open questions remain about the nature and development of infants' syntactic knowledge. How do we determine whether children are aware of the full syntactic and interpretive consequences of assigning a word to a particular category—e.g. that it is possible to extract out of the clausal complement of a verb but not a noun, or that determiners not only co-occur with nouns but have specific syntactic and semantic properties by virtue of being determiners? What is the nature of the inferences children draw about verb meaning on the basis of clausal arguments, and what can this tell us about how richly children represent those arguments? Are children's earliest clause structure representations

hierarchically structured and complete at the earliest stages of syntactic development, and if so, how do we explain production phenomena like early root infinitives and null subjects? How can we tell whether children represent syntactic dependencies in an adult-like, structure-dependent manner, and how do we determine whether children are aware of the syntactic consequences of identifying particular dependency types—e.g. that *wh*-movement is island-sensitive?

These questions push beyond the frontier of our knowledge of language acquisition, and answering them will involve increasingly creative, age-appropriate methods for assessing linguistic knowledge in a challenging population. But doing so brings us closer to understanding how such a highly structured cognitive system—a grammar—can be acquired by all humans exposed to similar linguistic experience, and to understanding the nature of the specialized language faculty that we share with even the youngest members of our species.

References

Allen, S. E. 2000. A discourse-pragmatic explanation for argument representation in child *Inuktitut*. Linguistics 38(3): 483–521.

Arunachalam, S., K. Syrett, and Y. Chen. 2016. Lexical disambiguation in verb learning: Evidence from the conjoined-subject intransitive frame in English and Mandarin Chinese. *Frontiers in Psychology* 7: 138.

Arunachalam, S., and S. R. Waxman. 2010. Meaning from syntax: Evidence from 2-year-olds. *Cognition* 114(3): 442–446.

Baker, M. C. 1988. *Incorporation: A theory of grammatical function changing*. Chicago: University of Chicago Press.

Baker, M. C. 2001. The natures of nonconfigurationality. In R. K. Baltin and C. Collins (eds), *The handbook of contemporary syntactic theory*, 407–438. Oxford: Blackwell.

Bar-Shalom, E., and W. Snyder. 1997. Root infinitives in child Russian: A comparison with Italian and Polish. In *Proceedings of the GALA '97 Conference on Language Acquisition: Knowledge Representation and Processing.*

Bloom, L. 1970. *Language development: Form and function in emerging grammars*. Cambridge, MA: MIT Press.

Bloom, P. 1990. Subjectless sentences in child language. *Linguistic Inquiry* 21(4): 491–504.

Bolinger, D. 1979. Pronouns in discourse. In T. Givón (ed), *Syntax and Semantics, Vol. 12: Discourse and Syntax*, 287–309. New York: Academic Press.

Bowerman, M. 1973. *Early syntactic development: A cross-linguistic study with special reference to Finnish*. Cambridge: Cambridge University Press.

Braine, M. D. S. 1963. The ontogeny of English phrase structure: The first phase. *Language* 39(1): 1–13.

Brandone, A., D. A. Addy, R. Pulverman, R. M. Golinkoff, and K. Hirsh-Pasek. 2006. One-for-one and two-for-two: Anticipating parallel structure between events and language. In Proceedings of the 30th annual Boston University Conference on Language Development, 36–47.

Brown, R. 1957. Linguistic determinism and the part of speech. *Journal of Abnormal and Social Psychology* 55(1): 1.

Brown, R. 1973. *A first language: The early stages*. Cambridge, MA: Harvard University Press.
Brown, R., and U. Bellugi. 1964. Three processes in the child's acquisition of syntax. *Harvard Educational Review* 34(2): 133–151.
Bunger, A., and J. Lidz. 2004. Syntactic bootstrapping and the internal structure of causative events. In *Proceedings of the 28th Annual Boston University Conference on Language Development*, 74.
Bunger, A., and J. Lidz. 2008. Thematic relations as a cue to verb class: 2-year-olds distinguish unaccusatives from unergatives. *University of Pennsylvania Working Papers in Linguistics* 14(1): 4.
Cauvet, E., R. Limissuri, S. Millotte, K. Skoruppa, D. Cabrol, and A. Christophe. 2014. Function words constrain on-line recognition of verbs and nouns in French 18-month-olds. *Language Learning and Development* 10(1): 1–18.
Chomsky, N. 1957. *Syntactic structures*. The Hague: Mouton.
Chomsky, N. 1975. *Reflections on language*. New York: Pantheon.
Chomsky, N. 1981. *Lectures on government and binding*. Dordrecht: Foris.
Christophe, A., S. Millotte, S. Bernal, and J. Lidz. 2008. Bootstrapping lexical and syntactic acquisition. *Language and Speech* 51(1–2): 61–75.
Clancy, P. 1993. Preferred argument structure in Korean acquisition. In *Proceedings of the 25th Annual Child Language Research Forum*, 307–314.
Crain, S. 1991. Language acquisition in the absence of experience. *Behavioral and Brain Sciences* 14(04): 597–612.
Crain, S., and McKee, C. 1985. The acquisition of structural restrictions on anaphora. *Proceedings of NELS* 15: 94–110.
Csibra, G., G. Gergely, S. Bíró, O. Koos, and M. Brockbank. 1999. Goal attribution without agency cues: The perception of "pure reason" in infancy. *Cognition* 72(3): 237–267.
Dowty, D. 1991. Thematic proto-roles and argument selection. *Language* 67(3): 547–619.
Evans, G. 1980. Pronouns. *Linguistic Inquiry* 11(2): 337-362.
Fernald, A., R. Zangl, A. L. Portillo, and V. A. Marchman. 2008. Looking while listening: Using eye movements to monitor spoken language. In I. A. Sekerina, E. M. Fernandez, and H. Clahsen (eds), *Developmental psycholinguistics: On-line methods in children's language processing*, 97–135. Amsterdam: Benjamins.
Fillmore, C. J. 1968. The case for case. In E. Bach and R. Harms (eds), *Universals in linguistic theory*, 1–88. New York: Holt, Rinehart, & Winston.
Fillmore, C. J. 1970. The grammar of "hitting" and "breaking." In R. A. Jacobs and P. S. Rosenbaum (eds), *Readings in English Transformational Grammar*, 120–133. London: Ginn.
Fisher, C. (1996). Structural limits on verb mapping: The role of analogy in children's interpretations of sentences. *Cognitive Psychology* 31(1): 41–81.
Fisher, C., Y. Gertner, R. M. Scott, and S. Yuan. 2010. Syntactic bootstrapping. *Wiley Interdisciplinary Reviews: Cognitive Science* 1(2): 143–149.
Fisher, C., H. Gleitman, and L. R. Gleitman. 1991. On the semantic content of subcategorization frames. *Cognitive Psychology* 23(3): 331–392.
Fodor, J. A. 1966. How to learn to talk: Some simple ways. In F. Smith and G. Miller (eds), *The genesis of language*, 105–122. Cambridge, MA: MIT Press.
Gagliardi, A., T. M. Mease, and J. Lidz. 2016. Discontinuous development in the acquisition of filler-gap dependencies: Evidence from 15-and 20-month-olds. *Language Acquisition* 23(3): 1–27.

Gerken, L. 1991. The metrical basis for children's subjectless sentences. *Journal of Memory and Language* 30(4): 431–451.

Gerken, L. 1994. A metrical template account of children's weak syllable omissions from multisyllabic words. *Journal of Child Language* 21(3): 565–584.

Gerken, L., and B. J. McIntosh. 1993. Interplay of function morphemes and prosody in early language. *Developmental Psychology* 29(3): 448.

Gertner, Y., and C. Fisher. 2012. Predicted errors in children's early sentence comprehension. *Cognition* 124(1): 85–94.

Gertner, Y., C. Fisher, and J. Eisengart. 2006. Learning words and rules: Abstract knowledge of word order in early sentence comprehension. *Psychological Science* 17(8): 684–691.

Gleitman, L. R. 1990. The structural sources of verb meanings. *Language Acquisition* 1(1): 3–55.

Gleitman, L. R., K., Cassidy, R. Nappa, A. Papafragou, and J. C. Trueswell. 2005. Hard words. *Language Learning and Development* 1(1): 23–64.

Golinkoff, R. M., K. Hirsh-Pasek, K. M. Cauley, and L. Gordon. 1987. The eyes have it: Lexical and syntactic comprehension in a new paradigm. Journal of Child Language 14(1): 23–45.

Gómez, R. L. 2002. Variability and detection of invariant structure. *Psychological Science* 13(5): 431–436.

Gómez, R. L., and J. Maye. 2005. The developmental trajectory of nonadjacent dependency learning. *Infancy* 7(2): 183–206.

Grimshaw, J. 1981. Form, function and the language acquisition device. In C. L. Baker and J. J. Mccarthy (eds), *The logical problem of language acquisition*, 165–182. Cambridge, MA: MIT Press.

Grinstead, J., J. De la Mora, M. Vega-Mendoza, B. Flores, et al. 2009. An elicited production test of the optional infinitive stage in child Spanish. In *Proceedings of the 3rd Conference of Generative Approaches to Language Acquisition—North America*, 36–45.

Guasti, M. T. 1993. Verb syntax in Italian child grammar: Finite and nonfinite verbs. *Language Acquisition* 3(1): 1–40.

Guasti, M. T. 2002. *Language acquisition: The growth of grammar*. Cambridge, MA: MIT Press.

Guilfoyle, E., and M. Noonan. 1988. Functional categories and language acquisition. Paper presented at 13th Annual Boston University Conference on Language Development.

Guilfoyle, E., and M. Noonan. 1992. Functional categories and language acquisition. *Canadian Journal of Linguistics/Revue canadienne de linguistique* 37(2): 241–272.

Hacquard, V. 2014. Bootstrapping attitudes. *Semantics and Linguistic Theory* 24: 330–352.

Haegeman, L. 1995. Root infinitives, tense, and truncated structures in Dutch. *Language Acquisition* 4(3): 205–255.

Hall, D. G., S. R. Waxman, and W. M. Hurwitz. 1993. How two-and four-year-old children interpret adjectives and count nouns. Child Development 64(6): 1651–1664.

Harrigan, K., V. Hacquard, and J. Lidz. 2016. Syntactic bootstrapping in the acquisition of attitude verbs: *Think*, *want* and *hope*. In *Proceedings of WCCFL*, 33.

Harris, C. L., and Bates, E. A. 2002. Clausal backgrounding and pronominal reference: A functionalist approach to c-command. *Language and Cognitive Processes* 17(3): 237–269.

Harris, T., and K. Wexler. 1996. The optional-infinitive stage in child English: Evidence from negation. In H. Clahsen (ed.), *Language acquisition and language disorders*, vol. 14, p. 1. Amsterdam: Benjamins.

He, A. X., and J. Lidz. 2017. Verb learning in 14-and 18-month-old English-learning infants. *Language Learning and Development*, 1–22. http://dx.doi.org/10.1080/15475441.2017.1285238

Hicks, J., J. Maye, and J. Lidz. 2007. The role of function words in infants' syntactic categorization of novel words. Paper presented at Linguistic Society of America Annual Meeting, Anaheim, CA.

Hirsh-Pasek, K., and R. M. Golinkoff. 1996. The intermodal preferential looking paradigm: A window onto emerging language comprehension. In D. McDaniel, C. McKee, and H. S. Cairns (eds), *Methods for assessing children's syntax*, 105–124. Cambridge, MA: MIT Press.

Hochmann, J.-R., A. D. Endress, and J. Mehler. 2010. Word frequency as a cue for identifying function words in infancy. *Cognition* 115(3): 444–457.

Höhle, B., M. Schmitz, L. M. Santelmann, and J. Weissenborn. 2006. The recognition of discontinuous verbal dependencies by German 19-month-olds: Evidence for lexical and structural influences on children's early processing capacities. *Language Learning and Development* 2(4): 277–300.

Höhle, B., J. Weissenborn, D. Kiefer, A. Schulz, and M. Schmitz. 2004. Functional elements in infants' speech processing: The role of determiners in the syntactic categorization of lexical elements. *Infancy* 5(3): 341–353.

Hyams, N. 1986. *Language acquisition and the theory of parameters*. Dordrecht: Reidel.

Hyams, N. 1992. A reanalysis of null subjects in child language. In J. Weissborn, H. Goodluck, and T. Roeper (eds), *Theoretical issues in language acquisition: Continuity and change in development*, 249–267. Brighton: Psychology Press.

Hyams, N., and K. Wexler. 1993. On the grammatical basis of null subjects in child language. *Linguistic Inquiry* 24(3): 421–459.

Jackendoff, R. 1972. *Semantic interpretation in generative grammar*. Cambridge, MA: MIT Press.

Kazanina, N., and C. Phillips. 2001. Coreference in child Russian: Distinguishing syntactic and discourse constraints. In *Proceedings of the 25th Boston University Conference on Language Development*.

Kedar, Y., M. Casasola, and B. Lust. 2006. Getting there faster: 18-and 24-month-old infants' use of function words to determine reference. *Child Development* 77(2): 325–338.

Kim, Y.-J. 2000. Subject/object drop in the acquisition of Korean: A cross-linguistic comparison. Journal of East Asian Linguistics 9(4): 325–351.

Kuhl, P. K. 1985. Methods in the study of infant speech perception. In G. Gottlieb and N. A. Krasnegor (eds), *Measurement of audition and vision in the first year of postnatal life: A methodological overview*, 223–251. Norwood, NJ: Ablex.

Landau, B., and L. R. Gleitman. 1985. *Language and experience: Evidence from the blind child*. Cambridge, MA: Harvard University Press.

Lasnik, H. 1976. Remarks on coreference. *Linguistic Analysis* 2: 1–22.

Lasnik, H. 1989. On certain substitutes for negative data. In R. J. Matthews and W. Demopoulos (eds), *Learnability and linguistic theory*, 89–105. Alphen aan den Rijn: Kluwer.

Legate, J. A., and C. Yang. 2007. Morphosyntactic learning and the development of tense. *Language Acquisition* 14(3): 315–344.

Leslie, A. M. 1995. A theory of agency. In D. Sperber, D. Premack, and A. J. Premack (eds), *Causal cognition: A multidisciplinary debate*, 121–141. Oxford: Oxford University Press.

Leslie, A. M., and S. Keeble. 1987. Do six-month-old infants perceive causality? *Cognition* 25(3): 265–288.

Levin, B., and M. R. Hovav. 2005. *Argument realization*. Cambridge: Cambridge University Press.

Lidz, J., and L. R. Gleitman. 2004. Yes, we still need universal grammar. *Cognition* 94(1): 85–93.

Lidz, J., S. Waxman, and J. Freedman. 2003. What infants know about syntax but couldn't have learned: Experimental evidence for syntactic structure at 18 months. *Cognition* 89(3): 295–303.

Lukyanenko, C., A. Conroy, and J. Lidz. 2014. Is she patting Katie? Constraints on pronominal reference in 30-month-olds. *Language Learning and Development* 10(4): 328–344.

Luo, Y., L. Kaufman, and R. Baillargeon. 2009. Young infants' reasoning about physical events involving inert and self-propelled objects. *Cognitive Psychology* 58(4): 441–486.

Meylan, S. C., M. C. Frank, B. C. Roy, and R. Levy. 2017. The emergence of an abstract grammatical category in children's early speech. *Psychological Science* 28(2): 181–192.

Mintz, T. H., and L. R. Gleitman. 2002. Adjectives really do modify nouns: The incremental and restricted nature of early adjective acquisition. *Cognition* 84(3): 267–293.

Monaghan, P., N. Chater, and M. H. Christiansen. 2005. The differential role of phonological and distributional cues in grammatical categorisation. *Cognition* 96(2): 143–182.

Naigles, L. R. 1990. Children use syntax to learn verb meanings. *Journal of Child Language* 17(2): 357–374.

Naigles, L. R. 1996. The use of multiple frames in verb learning via syntactic bootstrapping. *Cognition* 58(2): 221–251.

Noble, C. H., C. F. Rowland, and J. M. Pine. 2011. Comprehension of argument structure and semantic roles: Evidence from English-learning children and the forced-choice pointing paradigm. *Cognitive Science* 35(5): 963–982.

Nuñez del Prado, Z., C. Foley, and B. Lust. 1993. The significance of CP to the pro-drop parameter: An experimental study comparing Spanish and English. In *Proceedings of the 25th Annual Child Language Research Forum*, 146.

Omaki, A., N. Orita, and J. Lidz. In prep. Beyond artificial language: Statistical learning of an English non-adjacent syntactic dependency.

Orfitelli, R., and N. Hyams. 2012. Children's grammar of null subjects: Evidence from comprehension. *Linguistic Inquiry* 43(4): 563–590.

Perkins, L. (2019). How grammars grow: Argument structure and the acquisition of non-basic syntax. Doctoral dissertation, University of Maryland.

Perkins, L., N. H. Feldman, and J. Lidz. 2017. Learning an input filter for argument structure acquisition. In *Proceedings of the 7th Workshop on Cognitive Modeling and Computational Linguistics*.

Perkins, L., and J. Lidz. 2020. Filler-gap dependency comprehension at 15 months: The role of vocabulary. *Language Acquisition* 27(1): 98–115.

Phillips, C. 1995. Syntax at age two: Cross-linguistic differences. *MIT Working Papers in Linguistics* 26: 325–382.

Pine, J. M., and E. V. Lieven. 1997. Slot and frame patterns and the development of the determiner category. Applied Psycholinguistics 18(2): 123–138.

Pine, J. M., and H. Martindale. 1996. Syntactic categories in the speech of young children: The case of the determiner. *Journal of Child Language* 23(2): 369–395.

Pinker, S. 1984. *Language learnability and language development*. Cambridge, MA: Harvard University Press.

Pinker, S. 1989. *Learnability and cognition: The acquisition of argument structure*. Cambridge, MA: MIT Press.

Platzack, C. 1990. A grammar without functional categories: A syntactic study of early Swedish child language. *Nordic Journal of Linguistics* 13(2): 107–126.

Poeppel, D., and K. Wexler. 1993. The full competence hypothesis of clause structure in early German. *Language* 69(1): 1–33.

Pozzan, L., L. R. Gleitman, and J. C. Trueswell. 2015. Semantic ambiguity and syntactic bootstrapping: The case of conjoined-subject intransitive sentences. *Language Learning and Development* 12(1): 14–41.

Pratt, A., and J. Grinstead. 2007a. Receptive measures of the optional infinitive stage in child Spanish. Paper presented at Hispanic Linguistics Symposium, San Antonio, TX.

Pratt, A., and J. Grinstead. 2007b. Optional infinitives in child Spanish. In *Proceedings of the 2nd Conference on Generative Approaches to Language Acquisition North America*, 351–362.

Radford, A. 1990. *Syntactic theory and the acquisition of English syntax: The nature of early child grammars of English*. Oxford: Blackwell.

Reinhart, T. (1981). Definite NP anaphora and c-command domains. *Linguistic Inquiry* 12(4): 605–635.

Rice, M. L., K. Wexler, and S. Hershberger. 1998. Tense over time: The longitudinal course of tense acquisition in children with specific language impairment. *Journal of Speech, Language, and Hearing Research* 41(6): 1412–1431.

Rice, M. L., K. Wexler, and S. M. Redmond. 1999. Grammaticality judgments of an extended optional infinitive grammar: Evidence from English-speaking children with specific language impairment. *Journal of Speech, Language, and Hearing Research* 42(4): 943–961.

Rizzi, L. 1993. Some notes on linguistic theory and language development: The case of root infinitives. *Language Acquisition* 3(4): 371–393.

Rizzi, L. 1994. Early null subjects and root null subjects. In T. Hoekstra and B. D. Schwartz (eds), *Language acquisition studies in generative grammar*, 151–176. Amsterdam: Benjamins

Rizzi, L. 2005. Phase theory and the privilege of the root. In H. Broekhuis, N. Corver, R. Huybregts, U. Kleinherz, and J. Koster (eds), *Organizing grammar: Studies in honor of Henk van Riemsdijk*, 529–537. Berlin: Mouton de Gruyter.

Ross, J. R. 1967. Constraints on variables in syntax. Doctoral dissertation, Massachusetts Institute of Technology.

Saffran, J. R., R. N. Aslin, and E. L. Newport. 1996. Statistical learning by 8-month-old infants. *Science* 274(5294): 1926–1928.

Santelmann, L. M., and P. W. Jusczyk. 1998. Sensitivity to discontinuous dependencies in language learners: Evidence for limitations in processing space. *Cognition* 69(2): 105–134.

Schaeffer, J., and D. Ben Shalom. 2004. On root infinitives in child Hebrew. *Language Acquisition* 12(1): 83–96.

Scott, R. M., and C. Fisher. 2009. Two-year-olds use distributional cues to interpret transitivity-alternating verbs. *Language and Cognitive Processes* 24(6): 777–803.

Seidl, A., G. Hollich, and P. W. Jusczyk. 2003. Early understanding of subject and object wh-questions. *Infancy* 4(3): 423–436.

Serratrice, L. 2005. The role of discourse pragmatics in the acquisition of subjects in Italian. *Applied Psycholinguistics* 26(3): 437–462.

Shi, R., and M. Lepage. 2008. The effect of functional morphemes on word segmentation in preverbal infants. *Developmental Science* 11(3): 407–413.

Shi, R., and A. Melançon. 2010. Syntactic categorization in French-learning infants. *Infancy* 15(5): 517–533.

Shi, R., J. L. Morgan, and P. Allopenna. 1998. Phonological and acoustic bases for earliest grammatical category assignment: A cross-linguistic perspective. *Journal of Child Language* 25(1): 169–201.

Shi, R., J. F. Werker, and J. L. Morgan. 1999. Newborn infants' sensitivity to perceptual cues to lexical and grammatical words. *Cognition* 72(2): B11–B21.

Shipley, E. F., C. S. Smith, and L. R. Gleitman. 1969. A study in the acquisition of language: Free responses to commands. *Language* 45: 322–342.

Smith, L. B., S. S. Jones, and B. Landau. 1992. Count nouns, adjectives, and perceptual properties in children's novel word interpretations. *Developmental Psychology* 28(2): 273.

Snyder, W. 2001. On the nature of syntactic variation: Evidence from complex predicates and complex word-formation. *Language* 77(2): 324–342.

Spelke, E. 1976. Infants' intermodal perception of events. *Cognitive Psychology* 8(4): 553–560.

Stromswold, K. J. 1990. Learnability and the acquisition of auxiliaries. PhD thesis, Massachusetts Institute of Technology.

Sutton, M. 2015. Competence and performance in the development of Principle C. Doctoral dissertation, University of Maryland.

Sutton, M., M. Fetters, and J. Lidz. 2012. Parsing for Principle C at 30 months. In *Proceedings of the 36th Boston University Conference on Language Development*, 581–593.

Takahashi, E. 2009. Beyond statistical learning in the acquisition of phrase structure. Dissertation, University of Maryland.

Takahashi, E., and J. Lidz. 2008. Beyond statistical learning in syntax. In *Proceedings of Generative Approaches to Language Acquisition*.

Taylor, M., and S. A. Gelman. 1988. Adjectives and nouns: Children's strategies for learning new words. *Child Development* 59: 411–419.

Thompson, S. P., and E. L. Newport. 2007. Statistical learning of syntax: The role of transitional probability. *Language Learning and Development* 3(1): 1–42.

Tincoff, R., L. M. Santelmann, and P. W. Jusczyk. 2000. Auxiliary verb learning and 18-month-olds' acquisition of morphological relationships. In *Proceedings of the 24th Annual Boston University Conference on Language Development*, vol. 2, 726–737.

Tomasello, M. 2000. Do young children have adult syntactic competence? *Cognition* 74(3): 209–253.

Tomasello, M. 2003. *Constructing a language: A usage-based theory of language acquisition*. Cambridge, MA: Harvard University Press.

Valian, V. 1986. Syntactic categories in the speech of young children. *Developmental Psychology* 22(4): 562.

Valian, V. 1991. Syntactic subjects in the early speech of American and Italian children. *Cognition* 40(1–2): 21–81.

Valian, V. 2016. Null subjects. In J. Lidz, W. Snyder, and J. Pater (eds), *Oxford handbook of developmental linguistics*, 386–413. Oxford: Oxford University Press.

Valian, V., and Aubry, S. 2005. When opportunity knocks twice: Two-year-olds' repetition of sentence subjects. *Journal of Child Language* 32(3): 617–641.

Valian, V., and Z. Eisenberg. 1996. The development of syntactic subjects in Portuguese-speaking children. *Journal of Child Language* 23(1): 103–128.

Valian, V., J. Hoeffner, and S. Aubry. 1996. Young children's imitation of sentence subjects: Evidence of processing limitations. Developmental Psychology 32(1): 153.

Valian, V., S. Solt, and J. Stewart. 2009. Abstract categories or limited-scope formulae? The case of children's determiners. *Journal of Child Language* 36(4): 743–778.

Wang, Q., D. Lillo-Martin, C. T. Best, and A. Levitt. 1992. Null subject versus null object: Some evidence from the acquisition of Chinese and English. *Language Acquisition* 2(3): 221–254.

Waxman, S. R. 1999. Specifying the scope of 13-month-olds' expectations for novel words. *Cognition* 70(3): B35–B50.

Waxman, S. R., and A. E. Booth. 2001. Seeing pink elephants: Fourteen-month-olds' interpretations of novel nouns and adjectives. *Cognitive Psychology* 43(3): 217–242.

Waxman, S. R., and D. B. Markow. 1998. Object properties and object kind: Twenty-one-month-old infants' extension of novel adjectives. *Child Development* 69(5): 1313–1329.

Wellwood, A., A. X. He, J. Lidz, and A. Williams. 2015. Participant structure in event perception: Towards the acquisition of implicitly 3-place predicates. *University of Pennsylvania Working Papers in Linguistics* 21(1): 32.

Weverink, M. 1989. The subject in relation to inflection in child language. Dissertation, University of Utrecht.

Wexler, K. 1994. Optional infinitives, head movement and the economy of derivations. In D. Lightfoot and N. Hornstein (eds), *Verb movement*, 305–350. Cambridge: Cambridge University Press.

Wexler, K. 1998. Very early parameter setting and the unique checking constraint: A new explanation of the optional infinitive stage. *Lingua* 106(1): 23–79.

Wexler, K. 2014. A new theory of null-subjects of finite verbs in young children. In M. Becker, J. Grinstead, and J. Rothman (eds), *Generative linguistics and acquisition: Studies in honor of Nina M. Hyams*, 325–356. Amsterdam: Benjamins.

White, A. S., V. Hacquard, and J. Lidz. 2018. Main clause syntax and the labeling problem in syntactic bootstrapping. In *Semantics in acquisition*, 198–220. Amsterdam: Benjamins.

Williams, A. 2015. *Arguments in syntax and semantics*. Cambridge: Cambridge University Press.

Woodward, A. L. 1998. Infants selectively encode the goal object of an actor's reach. *Cognition* 69(1): 1–34.

Yang, C. 2002. *Knowledge and learning in natural language*. Oxford: Oxford University Press.

Yang, C. 2013. Ontogeny and phylogeny of language. *Proceedings of the National Academy of Sciences* 110(16): 6324–6327.

Yuan, S., and C. Fisher. 2009. "Really? She blicked the baby?" Two-year-olds learn combinatorial facts about verbs by listening. *Psychological Science* 20(5): 619–626.

Yuan, S., C. Fisher, and J. Snedeker. 2012. Counting the nouns: Simple structural cues to verb meaning. *Child Development* 83(4): 1382–1399.