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The development of abstract syntax: Evidence from structural priming and the lexical boost

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ABSTRACT

Structural priming paradigms have been influential in shaping theories of adult sentence processing and theories of syntactic development. However, until recently there have been few attempts to provide an integrated account that explains both adult and developmental data. The aim of the present paper was to begin the process of integration by taking a developmental approach to structural priming. Using a dialog comprehension-to-production paradigm, we primed participants (3–4 year olds, 5–6 year olds and adults) with double object datives (*Wendy gave Bob a dog*) and prepositional datives (*Wendy gave a dog to Bob*). Half the participants heard the same verb in prime and target (e.g. *gave–gave*) and half heard a different verb (e.g. *sent–gave*). The results revealed substantial differences in the magnitude of priming across development. First, there was a small but significant abstract structural priming effect across all age groups, but this effect was larger in younger children than in older children and adults. Second, adding verb overlap between prime and target prompted a large, significant increase in the priming effect in adults (a lexical boost), a small, marginally significant increase in the older children and no increase in the youngest children. The results support the idea that abstract syntactic knowledge can develop independently of verb-specific frames. They also support the idea that different mechanisms may be needed to explain abstract structural priming and lexical priming, as predicted by the implicit learning account (Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology – General, 129*(2), 177–192). Finally, the results illustrate the value of an integrative developmental approach to both theories of adult sentence processing and theories of syntax acquisition.

1. Introduction

Structural priming paradigms have shaped both theories of adult sentence processing and theories of syntactic development. However, until recently there have been few attempts to provide integrated theories that explain both adult and developmental data. The aim of the present paper was to begin this process of integration by investigating how structural priming changes across development. We addressed three central questions: (1) How do priming effects differ in children and adults; (2) What can these differences tell us about how children learn and represent syntactic structure, and (3) Do accounts of adult processing make predictions that can explain both the developmental and the adult data?

In structural priming studies, participants are presented with a prime sentence and then asked to produce a target sentence. Participants who are primed show a significant tendency to re-use the structure of the sentence they have just heard, even when prime and target share no lexical items (Bock, 1986). For example, participants primed with

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a double object dative such as *the boy gave the girl some cake* are more likely to produce, subsequently, a double object dative (e.g. *John sent Mary a parcel*) than a prepositional dative (*John sent a parcel to Mary*). In other words, people tend to repeat the basic structure of a sentence that they have either just heard (Bock, Dell, Chang, & Onishi, 2007) or just produced (Bock, 1986). This effect is unintentional, and has been demonstrated in speech production (Bock, 1986), written language production (Branigan, Pickering, & Cleland, 1999) and in dialog (Branigan, Pickering, & Cleland, 2000). This structural priming effect cannot be attributed solely to overlap in open or closed class words (Pickering & Branigan, 1998), to prosodic or semantic similarities between prime and target (Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992), or to the repetition of information structure (Hartsuiker & Westenberg, 2000). The broad consensus is that priming occurs in sentence production because adults build, and thus represent, sentence structure independently of lexical content (Bock & Loebell, 1990). However, the presence of lexical overlap between prime and target boosts the size of the priming effect (a phenomenon known as the *lexical boost*), showing that these abstract representations are linked in some way to lexical representations (Pickering & Branigan, 1998).

Work on priming in the adult processing literature has focused on the syntactic processes underlying the priming effect. Two theories have been proposed to explain why priming occurs. The first theory, the residual activation model (Cleland & Pickering, 2003; Pickering & Branigan, 1998) proposes that priming results from the short-term activation of the lemma nodes that represent verbs and syntactic structures in the mental lexicon. The second theory, the implicit learning theory, argues that priming is a consequence of implicit learning: a "dynamic vestige of the process of learning to perform language" (Bock & Griffin, 2000, p. 189). This theory has recently been implemented in a connectionist model of sentence production and language acquisition, which learns syntactic structure via an error-driven implicit learning mechanism (Chang, 2002, 2009; Chang, Dell, & Bock, 2006; Chang, Dell, Bock, & Griffin, 2000; Chang, Janciauskas, & Fitz, 2012). Recent work in this literature has largely focused on distinguishing between these theories by testing their predictions about the origin of the structural priming effect and the lexical boost. In the residual activation model, both the lexical boost and structural priming effects result from the residual activation of nodes and links between nodes in the lemma stratum of the mental lexicon. In the implicit learning model, structural and lexical priming effects are attributed to two separate mechanisms (see Chang et al., 2006).

Unlike adult studies, priming studies with children have not focused on the origin of the priming effect but on what priming can tell us about children's syntactic representations. In particular, studies have attempted to establish the age at which children show structural priming effects, in order to test the predictions of lexicalist and early abstraction accounts of acquisition. Lexicalist accounts propose that children's syntactic knowledge begins in the form of lexically-dependent generalizations bound to specific lexical items such as verbs (Goldberg, 2006; Ninio, 1999, 2006; Tomasello, 1992, 2000, 2003), pronouns (Childers & Tomasello, 2001) or frequently attested arguments (Pine, Lieven, & Rowland, 1998). Children's knowledge during the early stages of acquisition is said to be dominated by these lexically-dependent representations, which become abstract (i.e. lexically-independent) as children develop. Under early abstraction accounts, however, children are said to have categories above the level of the lexical item (i.e. abstract categories) from the beginning (Fisher, 2001; Naigles, 2002; Pinker, 1989). The precise nature of the earliest representations varies from theory to theory, but, crucially, children's knowledge of syntactic relations does not go through a lexically-dependent stage of development.[1] In order to distinguish between lexicalist and early abstraction accounts, researchers have focused on establishing whether young children pass through a stage in which they only show priming when prime and target share lexical items (e.g. verbs or pronouns) before developing the abstract categories required for lexically-independent (abstract) priming (Bencini & Valian, 2008; Huttenlocher, Vasilyeva, & Shimpi, 2004; Messenger, Branigan, & McLean, 2011; Messenger, Branigan, McLean, & Sorace, 2012; Savage, Lieven, Theakston, & Tomasello, 2003; Shimpi, Gamez, Huttenlocher, & Vasilyeva, 2007; Thothathiri & Snedeker, 2008).

In summary, structural priming paradigms have played an important role both in research on sentence processing and in research on syntactic development. However, until recently these two fields have discussed the issues in isolation from each other. At the moment, none of the approaches to syntactic development takes much account of the effects reported in the adult priming literature or the theories proposed to explain these effects (though see Thothathiri and Snedeker (2008) for a preliminary attempt to consider how they might be integrated). Similarly, theories of priming in adults do not incorporate an explanation of how the adult system develops (although the implicit learning account provides an outline of a theory; see Chang et al., 2006). Since the end-product of development is the adult state, it seems to us that integrating developmental and adult-state processing theories would provide important constraints on both. Theories of adult processing would be required to explain how the systems they propose develop, while developmental theories would have to consider what processing mechanisms might be involved in the creation of syntactic representations.

1.1. The present study

The aim of the present study was to inform both literatures by testing priming effects across development. We took two of the most robust findings in the adult literature – the abstract structural priming effect and the lexical boost – and tracked them throughout development, comparing the performance of 3–4 year old children, 5–6 year

[1] For example, Pinker (1989) proposes that children work with both abstract syntactic and abstract semantic roles from the start, as well as possessing innate linking rules governing how to map one onto the other. Fisher (2001), however, proposes a less comprehensive inventory of abilities – pre-syntactic structural cues to meaning that allow children to make simple structure-meaning mappings – but these are, nonetheless, tied to abstract participant roles, not lexical items.

old children and adults in a structural priming task. To achieve this, we established three objectives. The first objective was to investigate whether abstract lexically-independent priming effects (where prime and target share no open class items) were present at all three ages tested, and whether the size of this priming effect changed across development. We were particularly interested in testing whether the priming effect was larger in younger children than older children and adults, because this might imply developmental differences in the strength or number of syntactic representations. It is fairly well established that less skilled speakers show larger priming effects either because they know fewer structures, so there is less competition between structures to convey meaning (Hartsuiker & Kolk, 1998; Pickering & Branigan, 1999), or because they have only weakly represented structures, which are more susceptible to change (Chang et al., 2006; Ferreira, 2003; Jaeger & Snider, 2007). These effects have been demonstrated in studies with adult aphasics (Hartsuiker & Kolk, 1998), children with specific language impairment (Leonard et al., 2000) and second language learners (Flett, 2006). However, the data from typically developing children are less clear-cut. Many existing studies report large priming effects in children (between 12% and 33% for 3-year-olds; Bencini & Valian, 2008; Shimpi et al., 2007), which are much higher than the typical 4–10% effect reported in adult studies (Chang et al., 2006). However, these differences may be due to substantial differences in methodology. For example, unlike adult studies, studies with children tend to present multiple prime sentences (Savage et al., 2003; Thothathiri & Snedeker, 2008), use slightly different coding schemes (e.g. Bencini & Valian's (2008) 'lax' coding scheme), or use a between-participants or a blocked design, thus reinforcing the use of one particular structure throughout the study or block (Bencini & Valian, 2008; Savage et al., 2003; Shimpi et al., 2007). These differences make it impossible to compare the size of the priming effect in children and adults directly. In the first two studies to apply the same methodology and scoring criteria with 3-year-old children and adults, Messenger and colleagues reported no significant differences across age groups (Messenger et al., 2011, 2012). However, an inspection of their data shows some evidence for slightly larger priming effects in children than in adults, at least when utterances coded as 'Other' are excluded (Tables 1 and 4 in Messenger et al. (2012), Table 1 in Messenger et al. (2011)). In addition, Messenger et al. (2011) reported that children produced a greater proportion of passives than adults, which "may reflect a greater susceptibility to priming in children" (Messenger et al., 2011, p. 272). Thus, the first objective of the current study was to make cross-age comparisons of the size of the priming effect in order to assess whether priming effects are larger in younger children than older children and adults.

The second objective was to compare the size of the priming effect in the presence and in the absence of verb overlap between the prime and target. A robust finding in the adult literature is that the size of the priming effect is greater when there is lexical overlap between prime and target, especially when prime and target share a verb. The additional priming that results when prime and target share a verb is called the lexical boost (Pickering & Branigan, 1998). We assessed priming both with and without verb overlap in our study in order to establish whether the lexical boost is present in children as well as adults and to assess whether the size of the lexical boost changes with development. This has implications for our understanding of whether children and adults differ in how they represent verbs, syntactic structure and the links between them. In particular, verb-based lexicalist accounts predict that young children should show a large lexical boost because their syntactic representations are tied to verbs or predicate-based constructions (e.g. GIVER–*give*–THING GIVEN-*to*-GIVEE; Goldberg, 2006; Ninio, 1999, 2006; Tomasello, 2003). The development of abstract (lexically-independent) representations occurs as the child develops more and more verb-specific patterns with experience of the language, until she eventually generalizes across them on the basis of commonalities in form and meaning. Thus, verb-based lexicalist theories predict that very young children (2 years or younger) will not initially demonstrate verb-independent abstract priming because they possess only verb-based representations (see Savage et al., 2003). More importantly for the present study, such theories predict that there will be substantial additional priming when prime and target share a verb (a large lexical boost) in children, even in older children who have already abstracted a verb-general pattern. This is because both verb-based representations and abstract representations are available to be primed when prime and target share a verb, making priming more likely. Under early abstraction accounts, however, children are said to have categories above the level of the lexical item (i.e. abstract categories) from the beginning (e.g. Fisher, 2001; Naigles, 2002; Pinker, 1989). On this model, since children's representations are never more lexically-dependent than those of adults, we might expect a similar sized lexical boost across development.

Previous work has not provided conclusive evidence about the presence of abstract and lexically-dependent priming in young children. On the one hand, Savage et al. (2003) found that 4-year-olds were only primed to produce passive sentences when there was lexical overlap in the pronouns and grammatical markers between the prime and target sentences. Lexically independent abstract priming (i.e. priming in the absence of lexical overlap) only appeared from 6 years of age. On the other hand, Bencini and Valian (2008) reported that 3-year-olds showed significant priming effects even when prime and target shared no open class lexical items. Similarly, Thothathiri and Snedeker (2008) have reported comparable levels of priming in 3-year-olds whether or not the prime and target sentences shared a verb, although the priming effect was slightly (but not significantly) larger when prime and target shared a verb. The second objective of the present study was, then, to test whether young children show a larger priming effect when prime and target share a verb (i.e. a large lexical boost), as predicted by verb-based lexicalist accounts.

The third objective was to attempt to integrate development and adult processing literatures in order to derive developmental predictions from two sentence processing theories; the residual activation model and the implicit learning theory. Our aim is not to draw strong conclusions about the theories themselves, but simply to explore possible developmental predictions. We acknowledge that some of the authors of the theories may disagree with our attempts at integration. However, the process of establishing what needs to be explained and of exploring possible solutions derived from the current literature may nevertheless prove informative.

The residual activation model (Cleland & Pickering, 2003; Pickering & Branigan, 1998) is not a developmental model. However, because of the way it conceptualizes syntactic representations, it seems to be potentially compatible with either early abstraction or lexicalist theories of development. Within the activation model, the priming effect results from the activation of lexical entries within the lemma stratum of the mental lexicon (Levelt, 1989; Roelofs, 1992, 1993). The lemma stratum contains a network of lemma nodes corresponding to verbs (e.g. *give*), which are connected to combinatorial nodes that represent the verbs' syntactic properties and specify the syntactic structures in which they can occur (e.g. double object dative). During production or comprehension of the prime sentence (e.g. *give* in a double object dative), the verb (*give*) node, and the relevant (double object) combinatorial node are both activated and the link between them is strengthened. Afterwards, the nodes and the links between them maintain a level of residual activation for a short period of time. As a result, when the participant then wants to produce a target sentence, the residual activation that remains in the combinatorial node makes the choice of the same structure for the target utterance more likely. The lexical boost occurs because the link between the verb lemma node and the combinatorial node is also strengthened by the presentation of the prime sentence, which makes it even more likely that this structure will be chosen for the target utterance when prime and target share a verb.

If we combine the activation model with an early abstraction theory of acquisition, we must posit that both the syntactic combinatorial nodes and the verb lemma nodes are set up and available for activation early on in the acquisition process. Thus, both lexically-independent priming effects (resulting from activation of the combinatorial nodes) and the lexical boost (resulting from the additional strengthening of the link between the combinatorial and verb nodes) should be visible from an early age. If we combine the activation theory with a verb-based lexicalist theory of acquisition, we must posit that children's knowledge of syntactic structure starts off tied to individual verbs and, thus, to particular verb lemma nodes. Therefore, we would expect stronger priming effects in children than in adults when prime and target share a verb, due to the activation of the verb-based representations shared across prime and target.

In addition, the activation model, at least as it currently stands, should predict that any structural priming effect should always be accompanied by a lexical boost when prime and target share a verb, whatever the age of the participant. This is because when the prime sentence is presented, the link between the verb and combinatorial node is always strengthened. As a result, when the target contains the same verb as the prime, the strengthened link means that additional priming (the lexical boost) must occur. The link between verb lemma and combinatorial nodes is an integral part of the theory because it is required to explain why the lexical boost occurs when prime and target share a verb but not when there is overlap in tense, aspect, number or function word: The combinatorial nodes "link directly to, and only to, the lemma nodes" within the model (Pickering & Branigan, 1998, p. 695; see also Cleland & Pickering, 2003). Thus, although the model could be adapted to incorporate developmental differences (e.g. by proposing that the strengthening of the link decays more quickly or more slowly for children than adults), as it stands, it predicts that structural priming effects will always be accompanied by a lexical boost when prime and target share a verb.

Unlike the residual activation model, the implicit learning theory has already integrated developmental and adult processing predictions in a connectionist model (Chang et al., 2006). The model is made up of two pathways: one that learns syntactic constraints and one that learns how to activate meaning elements (Dual-path architecture). In this model, structural priming is a consequence of the same error-driven implicit learning process that drives syntactic development. Learning occurs when the model attempts to predict the next word at each point in a sentence. Any mismatch between the next word and the target word (called error) is used to adjust the model's internal representations. In other words, the *child* model learns syntactic structure by gradually adjusting its internal representations so that it can correctly predict heard sentences. Structural priming occurs because this implicit error-based learning process stays ON in the *adult* model. Experiencing a prime sentence causes adjustments in the model's internal representations that slightly bias it to produce a similar structure when it is required to produce a target sentence to express a particular message, creating structural priming. These priming effects can be seen from the age-equivalent of 3 years (age-related developmental stages are attributed to the model by comparing its linguistic behavior to that of children of different ages: Fig. 24 in Chang et al. (2006)). Thus, in common with other developmental theories, the model predicts that lexically-independent (abstract) priming effects will be present in children as young as 3 years of age.

Unlike the activation model, the Dual-path model does not use a single mechanism to explain both structural priming and the lexical boost. Only structural priming is said to result from the implicit learning mechanism. Lexical boost effects are attributed to a different underlying mechanism, partly because these effects are large and highly variable compared to abstract structural priming effects, which tend to be smaller and less variable. For example, unless one posits a learning mechanism that is highly sensitive to task differences, it is difficult to see how the same learning mechanism could capture both the 73% priming effect reported in Hartsuiker, Bernolet, Schoonbaert, Speybroeck, and Vanderelst's (2008) Experiment 1 and the 45% effect reported in their Experiment 2 (in both experiments the verb was shared between prime and target). In fact, it would be very difficult to implement this type of variable learning mechanism in a connectionist network such as the Dual-path model, because large weight changes would be needed to model such large effects. Large weight changes are problematic in connectionist implementations because they tend to lead to catastrophic interference, where previously learned knowledge is destroyed by recently experienced input (McCloskey & Cohen, 1989). For these reasons, Chang and colleagues (Chang et al., 2006, 2012) argued that the lexical boost must be due to a different mechanism from the implicit learning mechanism involved in long-term structural priming.

In concert with the work suggesting that memory is composed of multiple memory systems (Cohen & Eichenbaum, 1993; James, 1890), Bock and Griffin (2000) and Chang et al. (2006) suggest that the lexical boost should be attributed to short-term activation of explicit memory traces. On this dual mechanism account, the presence of the same verb in the target as in the prime sentence would act as a retrieval cue, enabling speakers to base their target response on a memory trace of the structure of the prime sentence. In support of this idea, Hartsuiker et al. (2008) reported that, unlike abstract structural priming effects, lexical boost effects dissipated quickly, which made their time course similar to short term lexical-semantic priming effects (Levelt et al., 1991). Importantly for the present paper, if explicit awareness of repetition is the basis of the lexical boost, we might expect the lexical boost to develop with age. This is because children's ability to form, store and retrieve memory traces across a range of tasks increases with age (for reviews, see Kail, 1990; Schneider & Pressley, 1997). For example, Dempster (1981) and Gathercole, Pickering, Ambridge, and Wearing (2004) have documented robust developmental differences in children's performance in working memory tasks (e.g. digit span, word span and letter span) across the childhood years (from 2 years to adulthood). In a different domain, Thomas and Nelson (2001) have reported that 10-year olds are better able than 4- and 7-year olds to recall the sequence of events in an object tracking task, and Coyle and Bjorklund (1997) have reported that children's performance in sort recall tasks (that require children to explicitly recall lists of words) increased from 8 to 10 years. In other words, because adults and older children have a much greater chance of recognizing and recalling lexical information than children, if the lexical boost has a strong lexical memory component, we would predict that it would also increase with development. Thus, the final aim of the present study was to test whether the lexical boost develops with age.

To conclude, the present study investigated the development of syntactic structures by comparing structural priming effects in young children (3–4 years), older children (5–6 years) and adults. We investigated whether children and adults could be primed to produce double object and prepositional dative sentences in a dialog priming task both (a) when prime and target shared a verb (same verb condition; e.g. *give–give*) and (b) when the prime modelled a different verb to the target (different verb condition: e.g. *send–give*). We assessed the size of the priming effect across development to establish whether structural priming effects are bigger in children than adults, and we tested whether the size of the lexical boost was greater in children than adults, as predicted by verb-based lexicalist theories of development, or a similar size across development, as predicted by early abstraction accounts. We also tested whether structural priming effects are always accompanied by a lexical boost when prime and target share a verb, as predicted by the activation model, and whether the lexical boost increases with development, as predicted by the dual mechanism (implicit learning) account.

In order to ensure we could make comparisons across ages, we designed a study that mimicked many of the design strengths of adult priming studies but that could be administered in the same format to children and adults. The design was adapted from Branigan et al.'s (2000) confederate scripting method. In common with many adult priming studies, we specified (a) that there should only be one prime sentence per target utterance; (b) that each prime–target utterance-pair should be followed by fillers; (c) that all participants should be primed with both structures (within-participants design); and (d) that a range of verbs and different sentences should be used.

2. Method

2.1. Participants

Participants were sixty-three 3- and 4-year-olds (mean age 3;8, range 3;1 to 4;10), forty-eight 5–6 year olds (mean age 5;11 range 5;5 to 6;4) and 57 adults. A further five 3–4 year olds and twelve 5–6 year olds were recruited but were excluded due to experimenter error (10) or because they produced fewer than five target responses (7). All participants were monolingual British English speakers with no identified language delay or disorder. The children were recruited from local nurseries and schools and were tested in their nurseries/schools or in the laboratory at the University of Manchester. Adults were undergraduate students at the University of Liverpool, recruited through an experiment participation scheme, who received course credits for taking part. They were tested in the language development laboratory at the University of Liverpool.

2.2. Design and materials

We used a $3 \times 2 \times 2$ mixed design with two between-participants variables: Age (3–4 year olds/5–6 year olds/adults), and Verb match (same verb/different verb in prime and target), and with one within-participants variable: Prime type (double object dative [DOD] or prepositional dative [PD]).[2] Participants were randomly allocated to the same or different verb condition and one of two counterbalance groups.

2.2.1. Sentence stimuli

We chose six dative alternating verbs familiar to young children in both prepositional and double object structures – *give*, *show*, *send*, *pass*,[3] *throw*, *bring*. Verbs were included

[2] Testing both Verb match and Prime type as within-participants variables would have meant testing each participant with 48 test items and fillers. We judged that this would make the testing sessions too long for the 3–4 year olds, so opted to manipulate Verb match as a between-participants variable.

[3] *Pass* is common in British English and is used in the same contexts in which US parents use the verb *hand*.

Table 1
Prime and target sentences.

Verb	Sentences (prime or target, depending on counterbalance condition)	
Brought	Wendy brought a rabbit to Bob/Bob a rabbit The prince brought a baby to the princess/the princess a baby	The king brought a puppy to the queen/the queen a puppy Dora brought a fish to Boots/Boots a fish
Gave	The king gave the baby to the queen/the queen a baby Dora gave a rabbit to Boots/Boots a rabbit	Wendy gave a fish to Bob/Bob a fish The prince gave a puppy to the princess/the princess a puppy
Passed	The boy passed a fish to the girl/the girl a fish Wendy passed a puppy to Bob/Bob a puppy	Piglet passed a cat to Tigger/Tigger a cat The king passed a baby to the queen/the queen a baby
Sent	The prince sent a cat to the princess/the princess a cat Piglet sent a baby to Tigger/Tigger a baby	Dora sent a puppy to Boots/Boots a puppy The boy sent a fish to the girl/the girl a fish
Showed	Piglet showed a cat to Tigger/Tigger a cat The boy showed a puppy to the girl/the girl a puppy	The boy showed a rabbit to the girl/the girl a rabbit Piglet showed a baby to Tigger/Tigger a baby
Threw	Dora threw a fish to Boots/Boots a fish The king threw a rabbit to the queen/the queen a rabbit	The prince threw a cat to the princess/the princess a cat Wendy threw a puppy to Bob/Bob a puppy

either because they were documented in both structures in corpora of speech to UK children (e.g. in the Manchester corpus; Theakston, Lieven, Pine, & Rowland, 2001) or because published studies have reported that they are produced by young children or their parents (Campbell & Tomasello, 2001; Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989; Snyder & Stromswold, 1997).

Forty-eight sentences were created by pairing each verb with four different sets of characters in PD (24 sentences) and DOD (24 sentences) structures. This gave eight different possible sentences per verb (see Table 1). Each verb was presented four times per participant: twice in the prime sentence (once as a PD and once as a DOD) and twice in the target sentence (preceded once by a PD prime and once by a DOD prime). No participant heard or was asked to produce the same sentence twice. Sentences were always modelled in the past tense (*gave, showed, sent, passed, threw*, *brought*).

Overall, each participant was presented with 12 prime–target pairs, interspersed with 12 filler–filler pairs, divided into two sessions. There were also eight practice items that consisted of non-causal actions described with intransitive sentences (e.g. *Piglet and Tigger were waving; Wendy pointed at Bob and the fish*; see Appendix A).

The stimuli were designed so as to remove all overlap except that provided by the verb (in the same verb condition) and the preposition (*to*). In order to avoid lexical overlap and stress-pattern/syllable-length overlap in the noun phrase, primes that contained determiner noun phrases (e.g. *the princess*) were always followed by targets with proper noun phrases (*Bob*) and vice versa. In order to minimize phonological overlap between the prime and target sentences (except for the verb in the same verb condition), verbs were presented in simple past-tense form, to minimize overlap in the use of morphemes such as present progressive *-ing* or 3rd singular *–s*.

The presentation of the prime–target pairs was counterbalanced to control for verb/sentence-specific preferences. Each sentence always occurred in both DOD and PD primes (across counterbalance groups). The use of both proper noun and determiner noun phrases also ensured that the results were not influenced by a preference for DOD structures with proper noun recipients or for PD structures with determiner noun phrase recipients.

The order in which the sentences were presented in the counterbalance conditions was semi-random, except for the constraint that all 6 verbs occurred once in session 1 (in one structure) and then again in session 2 (in the other structure). This enabled us to present each verb in both PD and DOD structures, but minimized verb–verb priming across prime–target pairs. Each prime–target pair was separated by a filler–filler pair to minimize priming effects between pairs (see Appendix A).

2.2.2. Visual stimuli

The visual stimuli were cartoon movies, created in Anime Studio Pro. Each cartoon contained three characters who were familiar to young British children and who played out transfer actions. There were six pairs of donor and recipient characters. Three had proper noun names: *Tigger and Piglet*, *Dora [the Explorer] and Boots*, *Bob [the Builder] and Wendy*. Three pairs were referred to with determiner noun phrases: *The prince and the princess*, *The king and the queen*, *The boy and the girl*. To make it easier for children to formulate the target utterances, donor and recipient characters were always paired in a familiar manner (e.g. *Tigger and Piglet*).

Five characters acted as objects: a baby, a cat, a fish, a puppy, and a rabbit. All characters were animate in order to ensure that priming effects were not enhanced by animacy contrasts between object and recipient roles (Bock et al., 1992). However, all objects were plausibly capable of being received by the recipient.

We created 24 cartoons depicting the six different transfer actions (giving, showing, sending, passing, throwing, bringing). We also created 24 filler cartoons and 8 practice items, all depicting non-causal actions (e.g. Bob and Wendy waving).

Each prime picture was always paired with a target picture that depicted different characters. We also controlled for whether the action unrolled from right-to-left or from left-to right in prime–target pairs. The movies were presented in E-Prime 2 on a laptop computer.

The experiment was run as a Bingo game, so Bingo cards were created that depicted pictures that corresponded to half of the experimental item and filler videos. We also created Bingo grids – pieces of card divided into 6 squares.

2.3. Procedure

The study took the form of a Bingo game. The experimenter and participant took it in turns to describe videos on the laptop screen to the confederate. The experimenter produced the prime sentence and the participant produced the target sentence. After each sentence, the confederate looked to see if she had the Bingo card corresponding to that sentence. If so, she gave the card to the experimenter or participant as appropriate. The first to fill up their bingo grid (all 6 squares) with cards won the game.[4]

Like Pickering and Branigan (1998), we used a stem completion technique to ensure that the target sentence contained the target verb, even when the prime had contained a different verb. The experimenter modelled the subject and verb of the target sentence and the participant then had to complete the sentence to describe the video. For example, the experimenter might say "*the king gave*..." and the participant had to produce either "*the queen a dog*" or "*a dog to the queen*". Use of the stem completion technique meant that the vast majority of responses, even from the youngest children, were PO or DO datives. Each prime–target pair was followed by a filler–filler pair. Here the experimenter and participant took turns to describe videos depicting non-causal events (e.g. *Bob was flying*).

In total, each participant took part in two sessions (separated by a 2–10 min break). Each session contained 24 items; 12 described by the experimenter (6 of which were primes and 6 fillers) and 12 described by the participant (6 targets and 6 fillers). Session 1 was preceded by 8 practice items – 4 for the experimenter and 4 for the participant – to familiarize participants with the task.

2.4. Coding

During the experiment, the experimenter recorded the participant's response automatically using the response coding function of E-Prime 2. The experiment was also audio or videotaped and the participant responses were checked by the first author.[5] The rate of agreement between coders (calculated over 10% of the data) was 97%. Most discrepancies were easily resolved by listening to the tapes. Where discrepancies could not be resolved, the response was coded as a non-target response and excluded from the analysis.

In 0.7% of cases, the experimenter did not model the prime correctly (e.g. used the wrong dative or the wrong verb; 1.3% for 3–4 year olds, 0.5% for 5–6 year olds and 0.3% for adults). These cases were excluded. The participants' responses were then coded as Prepositional dative, Double object dative or Non-target responses. Double object datives were responses in which the participant produced the post-verbal phrase in the order Recipient-Theme (*Piglet brought* ... *Tigger the cat*). Prepositional datives were responses in which the participant produced the post-verbal phrase in the order Theme-to-Recipient (*Piglet brought* ... *the cat to Tigger*). This was a strict definition of the Prepositional dative and excluded responses with an omitted preposition (*Piglet brought* ... *the cat Tigger*), responses with *for* (*Piglet brought* ... *the cat for Tigger*) and responses with *at (Piglet threw* ... *the cat at Tigger)*.[6] Responses in which the participant used the wrong noun (e.g. queen instead of princess) were rare but were included as target responses. Participants almost never used pronouns. For 22% of the 3–4 year olds' responses, the experimenter had to prompt the child to complete the sentence. This only occurred in the prepositional dative condition, for example:

E: Piglet threw...
C: the cat (pause)
E: to...
C: Tigger.

These were coded as prepositional datives, although we also re-ran the analyses without them and obtained the same pattern of results.

Non-target responses included responses in which the participant did not produce either a *to*-prepositional dative or a double object dative (e.g. *Piglet passed* ... *Tigger and the cat*) and responses in which the participant used the wrong verb. There were very few of these responses – 5% for 3–4 year olds, 0.7% for 5–6 year olds and 2% for adults. All Non-target responses were excluded from all analyses (both descriptive and inferential statistical calculations). The dependent variable for the descriptive statistics was calculated as the proportion of dative responses that were double object datives (the dispreferred structure). The inferential statistics were conducted on the raw data.

3. Results

The aim of the study was to investigate whether we could find structural priming effects in a comprehension-to-production priming task with young children (3–4 years), older children (5–6 years) and adults. We tested both lexically-independent structural priming (different verb condition) and lexically-dependent priming (when prime and target share a verb: same verb condition). Fig. 1 shows the mean proportion of datives produced that were double object datives both after a DOD prime (i.e. match between prime structure and target response) and after a PD prime (i.e. mismatch between prime structure and target response; see Appendix B for the mean number of different responses produced by condition).

The results were analyzed with logistic mixed effect models, which are well suited to analyzing binary dependent measures like structure choice (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). They are similar to logistic

[4] The game was rigged so the participant always won, but not until all the prime-target pairs had been completed.

[5] 20% of the 5–6 year olds' data was not recorded due to a fault, so these responses are based on one coder only.

[6] Although prime and target share a general syntactic frame here, the participants' failure to model the preposition of the prime mean that the amount of lexical overlap differed. Since we are explicitly testing the effect of lexical overlap, we decided to code these as Non-target responses. In practice, there were very few such responses (2% of all responses for the 3–4 year olds, 0.35% for the 5–6 year olds and 1.32% for the adults).

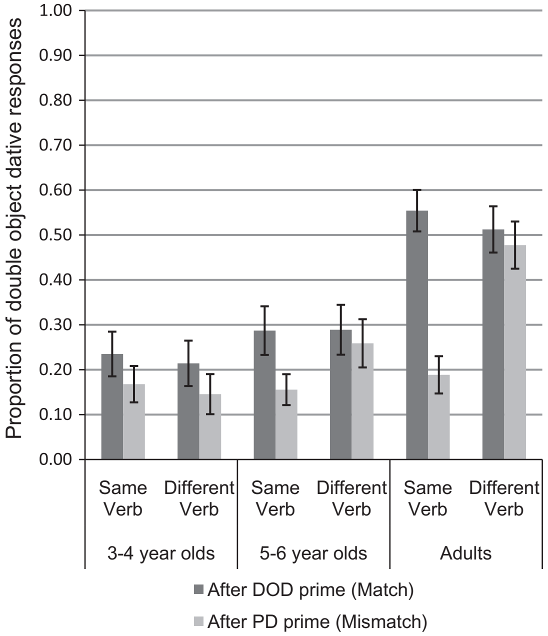

Fig. 1. Mean proportion of datives that were double object datives after DOD and PD primes (SE in error bars).

regression but allow us to model both random subject and item effects together.[7] In the first model we analyzed the full dataset. The model included as fixed effects (a) Verb match condition (same/different verb), (b) Age group (3–4 years/5–6 years/adult) and (c) Prime type (DOD, PD). Age was centered to reduce multi-collinearity (Neter, Wasserman, & Kutner, 1985) and other factors were effect/sum coded (Wendorf, 2004). Both participant and item (verb) were included as random effects.[8]

The model revealed a main effect of Prime type; $\beta = 0.86$ (SE = 0.13), $z = 6.82$, $p < .001$, indicating that the participants were significantly more likely to produce a double object dative after a double object dative prime (and thus conversely more likely to produce a prepositional dative after a prepositional dative prime). There was also a main effect of age group; $\beta = 0.11$ (SE = 0.02), $z = 5.51$, $p < .001$, indicating that, overall, double object dative production increased with age. There was an interaction of Prime type and Age group; $\beta = 0.05$ (SE = 0.02), $z = 2.59$, $p = .001$, indicating that overall, the size of the priming effect increased with age. There was an interaction of Prime type and Verb match condition, $\beta = 1.02$ (SE = 0.25), $z = 4.06$, $p < .001$, because priming effects were larger when prime and target shared a verb (lexical boost). However, these effects must be considered in the light of a significant three-way interaction between Verb match condition, Prime type and Age group; $\beta = 0.13$ (SE = 0.04), $z = 3.65$, $p < .001$, which suggests that the magnitude of the lexical boost varied across the different age groups.

3.1. Analyses by age

Separate logistic mixed effect models were run at each age to investigate the interactions. At 3–4 years there was a significant main effect of Prime type only, $\beta = 0.72$ (SE = 0.26), $z = 2.74$, $p = .006$, with no effect of Verb match condition and no interaction. In other words, the 3–4 year olds produced more double object datives after double object dative primes than prepositional dative primes and did so to the same extent in both the same verb (23.5% vs. 16.8%) and different verb (21.4% vs. 14.6%) conditions – there was no lexical boost. At 5–6 years, there was a main effect of Prime type; $\beta = 0.59$ (SE = 0.22), $z = 2.66$, $p = .008$, and a marginal interaction between Prime type and Verb match condition; $\beta = 0.77$ (SE = 0.44), $z = 1.73$, $p = .08$. Thus, the 5–6 year olds also produced more double object datives after double object dative primes than prepositional dative primes in both the same verb (28.7% vs. 15.6%) and different verb (28.9% vs. 25.9%) conditions, but here the effect was marginally larger for the same verb condition (i.e. there was a small lexical boost). For the adults, there were both main effects of Prime type and Verb match condition (both $ps < 0.05$) and a significant interaction between Prime type and Verb match condition; $\beta = 2.12$ (SE = 0.38), $z = 5.64$, $p < .001$. Thus, although there was, once again, an overall priming effect, the adults, unlike the children, showed significantly more priming in the same verb condition (55.4% vs. 18.9%) than in the different verb condition (51.2% vs. 47.7%) – a large lexical boost.

In summary, all three age groups showed a lexically-independent (different verb) structural priming effect of between 3% (adults and 5–6 year olds) and 7% (3–4 year olds). However, no lexical boost was evident in the data from the 3–4 year olds (the size of the priming effect for both same and different verb conditions was 7%). There was some evidence of a slightly larger lexical boost in the data from the 5–6 year olds (priming effect of 13% in the same verb condition, 3% in the different verb condition, so a 10% lexical boost) but this difference was only marginally significant ($p = .08$). It was only the adults who showed a substantial and significant lexical boost (priming effect of 37% in the same verb condition but only 3% in the different verb condition, so a 34% lexical boost).

3.2. Analyses by verb condition

Separate logistic mixed effects models were run for each verb condition to investigate how the size of the priming effect changed across development. We also calculated Cohen's *d*, which provide an effect size measure of the magnitude of priming that factors out variability

[7] We also ran the more traditional by-items and by-subjects ANOVAs on empirical logit transformed scores. All ANOVAs gave the same results as the logistic models.

[8] Similar results were found when maximal models with random slopes and intercepts for both subjects and items were tested for each of the analyses. Each model was tested by building a maximal model and removing the highest order slope terms that accounted for the lowest amount of variance until the model converged. Analysis of variance confirmed that none of the models with random slopes were significantly different from the random intercept models, so we have chosen to report the simpler model only.

across different groups of participants (Cohen, 1992). It was important to control for participant variability because there were large differences in the baseline preferences for the two datives across ages. The children, in particular the 3–4 year olds, used fewer double object datives overall than the adults; each 3–4 year old produced only two double object datives on average, whereas the adults produced an average of five each. This means that similar sized priming effects between adults and children may hide very different sized proportional increases.[9] Table 2 reports the size of the priming effect for each age group and verb match condition, calculated first as the difference in the proportion of DODs produced in each prime condition (difference score) and then as Cohen's *d* for repeated measures samples (Dunlap, Cortina, Vaslow, & Burke, 1996).

The results of the logistic mixed effect model indicated that, in the same verb condition, there was a significant effect of Age, $\beta = 0.08$ (SE = 0.03), $z = 3.12$, $p = .01$, and Prime type, $\beta = 1.35$ (SE = 0.18), $z = 7.66$, $p < .001$, and importantly an interaction between Age and Prime type, $\beta = 0.11$ (SE = 0.03), $z = 4.29$, $p < .001$. In other words, the size of the priming effect in the same verb condition increased significantly across development. Priming effects were significantly larger for adults than for 3–4 year olds (37% for adults vs. 7% for 3–4 year olds; $\beta = 0.12$ (SE = 0.03), $z = 4.18$, $p < .001$, and 5–6 year olds (13% for 5–6 year olds; $\beta = 0.09$ (SE = 0.03), $z = 2.91$, $p = .004$), although there was no significant difference between the two groups of children, $\beta = 0.51$ (SE = 0.46), $z = 1.12$, $p = .27$. Cohen's *d* confirmed that the size of the priming effect was substantially greater in adults than children. Cohen's *d* was small for 3–4 year olds (0.26), medium for 5–6 year olds (0.52) and large for the adults (1.47).[10]

In the different verb condition, the results of the logistic mixed effect model indicated a significant effect of Age, $\beta = 0.13$ (SE = 0.03), $z = 4.58$, $p < .001$, and Prime type, $\beta = 0.36$ (SE = 0.18), $z = 1.97$, $p = .05$, but no interaction between Age and Prime type, $\beta = -0.02$ (SE = 0.03), $z = -0.77$, $p = .44$. In other words, the size of the priming effect did not differ significantly across age groups (3–4 year olds = 7%, 5–6 year olds = 3%, adults = 3%).

However, the magnitude of the effect size expressed as Cohen's *d* did seem to indicate that the 3–4 year olds were primed more than the other two groups, with an effect size of 0.28 compared to the very small effect for the 5–6 year olds (0.12) and the adults (0.12). In other words, there was some indication that the least skilled speakers (the 3–4 year olds) showed larger priming effects when we controlled for participant variability and sample size.

3.3. Analyses excluding participants who never produced DODs

Some of the participants never produced a double object dative at all. Instead, these children only produced prepositional datives. Nineteen of these were 3–4 year olds, meaning that 32% of our youngest children showed no evidence of being able to produce double object datives and, thus, no evidence of priming. As a result, as a precautionary measure, we re-ran the analyses with these participants excluded. The results were very similar to those for the full sample; there was a significant three-way interaction between Verb match condition, Prime type and Age group; $\beta = 0.12$ (SE = 0.04), $z = 3.41$, $p = .0006$, indicating that all age groups were primed and that the size of the lexical boost increased with age. Models run for each age group separately also showed similar results to the original analyses with the full sample; at 3–4 years there was a main effect of Prime type only; $\beta = 0.71$ (SE = 0.26), $z = 2.72$, $p = .007$, at 5–6 years there was a main effect of Prime type; $\beta = 0.58$ (SE = 0.22), $z = 2.64$, $p = .008$, and a marginal interaction between Prime type and Verb match condition; $\beta = 0.76$ (SE = 0.44), $z = 1.72$, $p = .09$, and for the adults there was a significant interaction between Prime type and Verb match condition; $\beta = 2.08$ (SE = 0.37), $z = 5.55$, $p < .001$.

3.4. Analyses by verb: 3–4 year olds

We also considered the possibility that we failed to find a lexical boost in the youngest age group because these children did not know some of the verbs, or were less familiar with them than the older children and adults. It has already been established that different verbs may show different levels of resistance to priming. For example, Gries (2005) found that sentences with double object dative biased verbs like *give* are less likely to be affected by priming than more equi-biased verbs (see also Bernolet & Hartsuiker, 2010). Thus, it may be that knowledge of specific verb forms may interact with the lexical boost. In order to test this, we analyzed the youngest children's data for each verb individually. We hypothesized that if the lack of the lexical boost resulted from unfamiliarity with the verb, the most frequent verbs or the earliest-learnt verbs would be those that were most likely to show a lexical boost. *Give* is the most frequent of the six dative verbs we tested (595 dative uses in the ICE-GB corpus) and *show* is the second most frequent (90 in the ICE-GB corpus). *Give* is also often the first dative verb that children learn (at about 2 years of age), with *show* often appearing only a few weeks or months later (Gropen et al., 1989). It has also been suggested that *give* is the verb most likely to show lexical effects because it is considered to be a path-breaking verb according to some lexicalist theories (e.g. Ninio, 1999). In these theories, generalization from path-breaking verbs to other later-learnt verbs is responsible for the development of more abstract syntactic knowledge. We ran separate mixed effects logistic models on the data for the 3–4 year old children for each of the six verbs individually. There were no effects of

[9] For example, a priming effect of 5% that represented an increase in DODs from 5% to 10% would constitute a 100% proportional increase in the number of DODs produced (i.e. priming would effectively double the number of DODs produced). A priming effect of 5% that represented an increase in DODs from 50% to 55% constitutes only a 10% increase.

[10] Cohen's *d* is considered small (greater than 0.2), medium (greater than 0.5) or large (greater than 0.8).

Table 2
Size of priming effect calculated both as the difference in the proportion of DODs produced in each prime condition (difference score) and effect size (Cohen's *d*).

Age group	Size of priming effect					
	Same verb in prime and target			Different verb in prime and target		
	Difference score	Standard error	Cohen's *d*	Difference score	Standard error	Cohen's *d*
3–4 years	0.07	0.03	0.26	0.07	0.02	0.28
5–6 years	0.13	0.03	0.52	0.03	0.04	0.12
Adults	0.37	0.03	1.47	0.03	0.02	0.12

Verb match condition and no interactions between Prime type and Verb match condition for any of the verbs (all $ps > .2$). In other words, there was no evidence for a lexical boost for any of the verbs, even the frequent early-learnt verbs *give* and *show*. In fact, for both *give* and *show*, there were slightly, though not significantly, larger priming effects when prime and target did not share a verb.

3.5. Results summary

Overall, the results showed significant differences in priming across development, from age 3–4 years, through 5–6 years to adulthood. Structural priming occurred in all three age groups, with evidence for a larger magnitude priming effect size (Cohen's *d*) in the youngest children than in the older children and adults when prime and target sentences contained different verbs. The size of the lexical boost, however, increased across development. Only adults showed a large and significant lexical boost in the size of the priming effect when prime and target shared a verb. There was some evidence that adding verb overlap between prime and target produced a moderate (marginally significant) lexical boost in the 5–6 year old group, but it had no effect on the size of the priming effect for the 3–4 year old children.

4. Discussion

The aim of the study was to investigate whether we could find structural priming effects in a comprehension-to-production priming task with young children (3–4 years), and to compare these effects to those found with older children (5–6 years) and adults. We tested developmentally (a) the size of the lexically-independent structural priming effect (different verb condition) and (b) the size of the lexical boost (when prime and target share a verb, same verb condition).

Our first finding was that all age groups, including the 3–4 year old children, showed evidence of abstract structural priming. There were significant main effects of structural priming both when we considered all age groups together and when we considered them separately at each age. These results suggest that 3–4 year old children already have representations of dative structure that are independent of lexical items. This finding fits with other work on structural priming in children, which reports such effects in 4-year-old children (Huttenlocher et al., 2004; Kidd, 2012a, 2012b) and in 3-year-olds (Bencini & Valian, 2008; Messenger et al., 2011, 2012; Shimpi et al., 2007; Thothathiri & Snedeker, 2008).

There was also some evidence in our data that the magnitude of the structural priming effect size (Cohen's *d*) was greater in the youngest group then in the older children and adults in the different verb condition, although the difference did not reach significance in the mixed effect model. This finding, if confirmed, would support those of other studies that show that structural priming effects are larger in less skilled speakers (Flett, 2006; Hartsuiker & Kolk, 1998; Leonard et al., 2000) and in children (Messenger et al., 2011). This may be because less skilled speakers know fewer structures, so there is less competition between structures to convey meaning (Hartsuiker & Kolk, 1998; Pickering & Branigan, 1999). Alternatively, if priming involves error-based learning (Chang et al., 2006), it may be that it is easier to prime children than adults because their knowledge is more weakly represented: less predictable utterances yield more error and hence more weight change. For example, if the younger children's knowledge of the double object dative was weakly represented, hearing the double object dative in the prime would produce a large priming effect precisely because it was less predicted. Older children and adults, who have stronger representations of the double object dative, would then be primed less strongly. In fact, this possibility is given support by the fact the 3–4 year olds had a clear preference for the prepositional dative, which suggests that they are more familiar with that structure than with the double object dative (and see Conwell and Demuth (2007), Rowland and Noble (2011) and for other evidence that prepositional datives are easier for 3–4 year olds to produce and comprehend). It is not possible for us to test this explanation directly in the present study because we do not know whether priming effects were stronger with double object dative primes than with prepositional dative primes. Future work could incorporate a baseline measure of children's syntactic preferences in order to establish whether priming is stronger with double object dative primes.

It is also worth pointing out that the size of the priming effect is smaller in our study than in other studies that have used a similar task with adults (Hartsuiker et al., 2008) and children (Messenger et al., 2011, 2012). However, it is probable that these differences can be attributed to differences in the task and stimuli used. In particular, both Hartsuiker and Messenger tested participants in a true dialog task, in which two speakers were conversing with each other, whereas in our study both speakers were describing pictures to a third party, which may produce smaller priming effects (see Branigan, Pickering, McLean, & Cleland, 2007). In addition, both Hartsuiker and Messenger asked their participants to describe still pictures, whereas our participants described dynamic videos in which the events unfolded over time, which may have introduced different response biases. Finally, Messenger primed for passives, whereas we primed for datives. It, thus, seems most likely that task differences are responsible for differences in the magnitude of the priming effect across studies.

Our second finding was that there were substantial differences in the size of the priming effects across age groups when the prime and target sentences contained the same verb (same verb condition). There was no evidence that the 3–4 year old children were sensitive to verb overlap in prime and target, the priming effect was the same size in both same and different verb conditions. By 5–6 years, there was a small (but marginally significant) increase in the size of the priming effect in the same verb condition, and by adulthood there was a substantial and highly significant increase. Thus, the size of the additional priming provided by verb overlap – the lexical boost – increased with development.

Theories of development that propose that children's syntactic knowledge begins as verb-specific generalizations have problems explaining why we found no lexical boost in the youngest children's data (Goldberg, 2006; Ninio, 1999, 2006; Tomasello, 2003). Even if we assume that children have already started to develop abstract representations before the age of 3 years, we would still expect some evidence of the earlier-built verb-specific formulae to remain. For example, if children start to learn the double object dative by building verb-based schemas (e.g. GIVER–*give*–GIVEE–THING GIVEN) and then generalize across such schemas to formulate an abstract double object dative construction, these early-built schemas should be available for priming, just like the abstract double object dative construction. They should thus contribute to additional priming (a lexical boost). We can see no reason within the theory why this would not be the case, since verb-specific schemas are seen as equivalent to more abstract schemas (GIVER–*give*–GIVEE–THING given is seen as functionally equivalent to NP–V–NP–NP; Goldberg, 2006; Tomasello, 2003).

One way of explaining why we find no lexical boost might be to argue that our study is not tapping into the relevant lexically specific knowledge, because this knowledge is tied to lexical items other than verbs. For example, given that most double object datives contain pronominal recipients, we might posit that children start by building dative frames around pronouns or combinations of pronouns/nouns and verbs (e.g. lexical patterns such as *give him X* or *pass Mummy X* [where *X* stands for a variety of NPs]). Although these frames remain available even after children have generalized across them, they will only be activated when the incoming sentence contains the same lexical material (i.e. not when the prime is *Dora gave Boots the fish*). Alternatively, even if they are activated, the frames may not constitute appropriate templates for the construction of the target sentence (e.g. *the king gave the queen a dog*) and may be unavailable for use. This might explain why other studies have found that young children show lexical boost effects when prime and target sentences share pronouns (e.g. *it got caught by it* primed *it got broken by it*; Savage et al., 2003) and nouns (van Beijsterveldt & van Hell, 2009), but why we found no effect when prime and target shared verbs.

Our results are less problematic for early abstraction accounts, which propose that children have categories above the level of the lexical item from the beginning (i.e. abstract categories) and do not predict a larger lexical boost early in development. Yet, even for these theories, the lack of any lexical boost at all in the youngest children's data is surprising given that such effects are so robust in adults. One possible explanation is provided by Thothathiri and Snedeker (2008). They also reported no significant difference between same and different verb priming for 3–4 year old children tested in a comprehension priming study that tracked eye movements at critical points in the presentation of the target sentence (although the same verb priming effect was marginally greater). Thothathiri and Snedeker suggest that, although we must credit adults with both abstract and lexical knowledge in order to explain findings showing that adults represent links between individual verbs and abstract nodes (Trueswell & Kim, 1998), children might begin with abstract representations only. On this model, abstract structural representations are built first in development, perhaps on the basis of structure-meaning mapping biases (Fisher, 2001). Building the links between abstract structural nodes and particular verbs takes longer because it relies on prior exposure to the verb in that syntactic structure. These links develop verb-by-verb, as the child is exposed to more instances of correct verb use. This account would explain the lack of a lexical boost early in development – the link between the primed verbs and the syntactic structure is not yet available to provide additional priming. However, further work is required to test whether it makes accurate predictions about how the verb-structure links develop.

4.1. Testing integrated accounts of language development and language processing

The final aim of the study was to test whether accounts of adult processing make predictions that can explain both the developmental and the adult data. The activation model of adult priming does not make direct predictions about the mechanism of development but it is potentially compatible with early abstraction accounts of development, which, as we have seen above, are compatible with our results. However, the activation account also predicts that structural priming will be accompanied by a lexical boost when prime and target share a verb, whatever the age of the participant. This is because the presentation of a verb in the prime sentence is said to activate the lemma node associated with that word (e.g. *give*) and this, then, in turn, strengthens the link with the combinatorial node associated with that verb. In other words, the link between the verb lemma and combinatorial node is always strengthened on the presentation of the prime sentence; it is just that this does not lead to additional priming when the target contains a different verb. This makes it difficult for the theory to explain how structural priming can occur without a lexical boost when prime and target share a verb in our younger children; the strengthening of the link between the nodes should always occur and thus should always cause a lexical boost.

One solution might be to integrate the activation model with the early abstraction account suggested by Thothathiri and Snedeker (2008) and summarized above. Thothathiri and Snedeker suggested that children begin with abstract representations only; lexical entries are annotated for syntactic structure over a longer time frame as a result of exposure to verbs in particular syntactic structures. We could hypothesize that the (abstract) combinatorial nodes within the activation model are built first as a product of a learning mechanism that generalizes across all of the heard instances of a structure. Each of these instances will contribute to the reinforcement of the combinatorial node (e.g. every instance of a double object dative will reinforce the double object combinatorial node). However, since only those instances that contain the relevant verb will reinforce the link with that verb node, the process of annotating the verb nodes for the structures in which they can occur takes longer. This is a similar adaptation to that suggested by Coyle and Kaschak (2008), who proposed that experience with language could result in long-term changes to the strength of the links between combinatorial and verb lemma nodes within the lexicon. This adapted model could then potentially explain the lack of a lexical boost early in development by proposing that the link between the verb node and the combinatorial node is not strong enough to provide additional priming in younger children's representations. It might also provide a direct explanation of why structural priming effects are larger in younger children than older children and adults by incorporating developmental differences in the strength of the links between verbs and combinatorial nodes.

Unlike the activation model, the Dual-path (implicit learning) account already predicts a developmental dissociation between structural priming and the lexical boost (Bock & Griffin, 2000; Chang et al., 2006). On this model, multiple memory and learning systems are involved in language processing and language acquisition. Structural priming is seen as a consequence of the implicit statistical learning mechanism that is responsible for learning syntactic representations in the first place. This implicit learning mechanism was implemented in the Dual-path model of Chang et al. (2006) as a simple recurrent network (SRN, Elman, 1990) that developed abstract categories via distributional learning and a separate meaning component that learnt how to use meaning to sequence these categories to generate grammatical sentences. Both learning and structural priming occurred because the model responded to error between predicted and actual sentences by changing the weight of connections between nodes, which strengthened the network's predictive abilities. This model can explain both why we find a small but consistent abstract priming effect across all ages, as reported in this study, and why the younger children showed a slightly larger priming effect than the adults. Young children's syntactic representations are less strongly represented than those of older children and adults, and less strongly represented structures yield stronger priming effects because they are less predictable and result in more error (Chang et al., 2006; Ferreira & Bock, 2006; Jaeger & Snider, 2007).

The implicit learning account is also compatible with the finding that the lexical boost, but not the abstract priming effect, increases with development; the lexical boost is attributed to short-term activation of explicit memory traces, which are formed, stored and retrieved more easily as children age (Chang et al., 2006). Chang et al. (2012) have since expanded on the ideas in Chang et al. (2006), proposing a complementary systems account that draws on ideas in cortical/hippocampal systems theories (McClelland, McNaughton, & O'Reilly, 1995; O'Reilly and Rudy, 2001). In these theories, long-term knowledge in cortical systems is updated through slow changing implicit learning mechanisms, while the hippocampus has a fast-changing binding mechanism that quickly links different cortical representations. The original Dual-path model can be seen as instantiating an account of the cortical language system in that it uses a slow learning mechanism, and lesions to the two pathways in the model yield deficits that mimic those with cortical lesions in Broca's and Wernicke's areas (Chang, 2002). Chang et al. (2012) suggest that, if we assume that the hippocampus can create fast bindings between verb semantics and structural representations, then those bindings could support the lexical boost.

This complementary systems account would help to explain the rapid decay of the lexical boost (Hartsuiker et al., 2008), as the fast binding in the hippocampus can causes old verb-structure bindings to be overwritten (unlike the slow learning in the cortical language networks). It is also known that hippocampal systems can bind many different types of cortical representations (e.g. spatial cues, task context; Komorowski, Manns, & Eichenbaum, 2009) and this could help explain why the lexical boost varies in magnitude across different tasks in the adult priming literature (e.g. Hartsuiker et al., 2008, reported a 73% same-verb priming effect in Experiment 1 but only a 45% same-verb priming effect in Experiment 2). In contrast, the cortical language system is not tightly linked to the task context so abstract priming should vary less over tasks (see Kaschak, Kutta, and Coyle (2012) for some evidence that this is the case). Since the slow implicit learning is independent of the hippocampus, we would also predict that amnesiacs with impaired medial temporal/hippocampal structures should show normal structural priming, and there is evidence in support of this prediction (Ferreira, Bock, Wilson, & Cohen, 2008).

Finally, the sensitivity of the hippocampal system to the task context can provide an explanation for the growth in the lexical boost over development. If young children have more trouble maintaining a constant context across prime and target trials compared with adults, then their ability to use these bindings should be diminished and that could explain why the lexical boost is absent. Since this account depends on task context, which is not specific to structural priming, we should predict similar developmental dissociations in other linguistic and non-linguistic tasks. There is some evidence for such dissociations in the literature. For example, some statistical learning studies report similar levels of learning across children and adults while others report more learning in adults than children (Saffran, 2001; Saffran, Newport, Aslin, Tunick, & Barrueco, 1997). Similarly, Thomas and Nelson (2001) found that 4-, 7- and 10-year olds showed equivalent levels of learning in an implicit object tracking task but reported that 10-year olds were better able to make explicit predictions about these sequences. In summary, although the details of the mechanism still need to be made explicit, the complementary systems account ties a working model of abstract structural priming to an account of why the lexical boost varies across tasks and increases with development, and suggests ways in which different brain regions may support these phenomena.

5. Conclusion

In conclusion, the present study is the first to demonstrate that, although both children and adults can be primed to produce particular sentence structures, there are substantial differences in the magnitude of priming across development. In particular, the size of the structural priming effect seems to be slightly larger in younger children than older children and adults, but the size of the lexical boost increases substantially with development. This last finding means that in addition to the task-specific factors that seem to influence the magnitude of the lexical boost in adult studies, the effect also changes with development.

The results support the idea that abstract syntactic knowledge can develop independently of verb-specific frames. They also support the idea that different mechanisms may be needed to explain lexically-dependent and lexically-independent priming. Finally, they illustrate how an integrated, developmental approach can contribute to theory building. The activation model of priming (Pickering & Branigan, 1998) can explain lexical boost effects in adults but would need to implement a developmental component to explain the lack of a lexical boost in young children. Implicit learning theories (Bock & Griffin, 2000; Chang et al., 2006) already argue for a common mechanism underlying syntactic adaptation in acquisition and adult processing, and can explain why abstract priming and the lexical boost show different developmental profiles. However, future work in this framework is required in order to implement developmental lexical boost and structural priming effects within a single model.

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Appendix A

Practice items and fillers

Practice items	
Piglet and Tigger bounced to the rabbit	The king and queen waved
The prince was rocking with the puppy	The princess was rocking with the cat
Boots waved at Dora and the baby	Wendy pointed at Bob and the fish
The boy was waving	The girl was waving
Fillers	
Boots was flying	Dora was flying
Piglet was rocking	Tigger was rocking
The king and the queen waved	Dora and Boots waved
Wendy and Bob jumped	The princess jumped
The cat was swinging	Bob was swinging
Piglet was washing	Tigger was washing
The prince was rocking	The princess was rocking
Piglet and Tigger bounced	The king and the queen bounced
Wendy was flying	Bob was flying
Dora was washing	Boots was washing
Wendy pointed at Bob	Boots pointed at Dora
Dora was swinging	Bob was swinging

Appendix B

Mean number (SD) of double object datives prepositional datives and unclassified responses (experimenter error + child non-target responses).

Age	Verb match condition	Double object dative prime			Prepositional dative prime		
		Mean no. DOD responses	Mean no. PD responses	Mean no. unclass. responses	Mean no. DOD responses	Mean no. PD responses	Mean no. unclass. responses
3–4 years	Same verb	1.29 (1.55)	4.32 (1.70)	0.39 (0.72)	0.97 (1.30)	4.81 (1.38)	0.23 (0.50)
	Different verb	1.23 (1.53)	4.31 (1.49)	0.46 (0.81)	0.81 (1.30)	4.85 (1.43)	0.35 (0.56)
5–6 years	Same verb	1.67 (1.62)	4.19 (1.66)	0.15 (0.46)	0.93 (1.07)	4.96 (1.06)	0.11 (0.32)
	Different verb	1.71 (1.52)	4.19 (1.50)	0.10 (0.30)	1.52 (1.47)	4.38 (1.50)	0.10 (0.30)
Adults	Same verb	3.28 (1.55)	2.66 (1.58)	0.06 (0.25)	1.13 (1.41)	4.84 (1.42)	0.03 (0.18)
	Different verb	2.90 (1.64)	2.81 (1.70)	0.29 (0.53)	2.77 (1.69)	3.06 (1.73)	0.16 (0.37)

References

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*(4), 390–412.

Bencini, G. M. L., & Valian, V. V. (2008). Abstract sentence representations in 3-year-olds: Evidence from language production and comprehension. *Journal of Memory and Language, 59*(1), 97–113.

Bernolet, S., & Hartsuiker, R. J. (2010). Does verb bias modulate syntactic priming? *Cognition, 114*(3), 455–461.

Bock, K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18*(3), 355–387.

Bock, K., Dell, G. S., Chang, F., & Onishi, K. H. (2007). Persistent structural priming from language comprehension to language production. *Cognition, 104*(3), 437–458.

Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology – General, 129*(2), 177–192.

Bock, K., & Loebell, H. (1990). Framing sentences. *Cognition, 35*(1), 1–39.

Bock, K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations – Bridging the syntactic cleft. *Psychological Review, 99*(1), 150–171.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (1999). Syntactic priming in written production: Evidence for rapid decay. *Psychonomic Bulletin and Review, 6*(4), 635–640.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition, 75*(2), B13–B25.

Branigan, H. P., Pickering, M. J., McLean, J. F., & Cleland, A. A. (2007). Syntactic alignment and participant role in dialogue. *Cognition, 104*(2), 163–197.

Campbell, A. L., & Tomasello, M. (2001). The acquisition of English dative constructions. *Applied Psycholinguistics, 22*(2), 253–267.

Chang, F. (2002). Symbolically speaking: A connectionist model of sentence production. *Cognitive Science, 26*(5), 609–651.

Chang, F. (2009). Learning to order words: A connectionist model of heavy NP shift and accessibility effects in Japanese and English. *Journal of Memory and Language, 61*, 374–397.

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review, 113*(2), 234–272.

Chang, F., Dell, G. S., Bock, K., & Griffin, Z. M. (2000). Structural priming as implicit learning: A comparison of models of sentence production. *Journal of Psycholinguistic Research, 29*(2), 217–229.

Chang, F., Janciauskas, M., & Fitz, H. (2012). Language adaptation and learning: Getting explicit about implicit learning. *Language and Linguistics Compass.*

Childers, J. B., & Tomasello, M. (2001). The role of pronouns in young children's acquisition of the English transitive construction. *Developmental Psychology, 37*(6), 739–748.

Cleland, A. A., & Pickering, M. J. (2003). The use of lexical and syntactic information in language production: Evidence from the priming of noun-phrase structure. *Journal of Memory and Language, 49*(2), 214–230.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155–159.

Cohen, N. J., & Eichenbaum, H. (1993). *Memory, amnesia, and the hippocampal system*. Cambridge, MA: MIT Press.

Conwell, E., & Demuth, K. (2007). Early syntactic productivity: Evidence from dative shift. *Cognition, 103*(2), 163–179.

Coyle, J. M., & Kaschak, M. P. (2008). Patterns of experience with verbs affect long-term cumulative structural priming. *Psychonomic Bulletin and Review, 15*(5), 967–970.

Coyle, T. R., & Bjorklund, D. F. (1997). Age differences in, and consequences of, multiple- and variable-strategy use on a multi-trial sort-recall task. *Developmental Psychology, 33*(2), 372–380.

Dempster, F. N. (1981). Memory span: Sources of individual and developmental differences. *Psychological Bulletin, 89*(1), 63–100.

Dunlap, W. P., Cortina, J. M., Vaslow, J. B., & Burke, M. J. (1996). Meta-analysis of experiments with matched groups or repeated measures designs. *Psychological Methods, 1*, 170–177.

Elman, J. L. (1990). Finding structure in time. *Cognitive Science, 14*, 179–211.

Ferreira, V. S. (2003). The persistence of optional complementizer production: Why saying "that" is not saying "that" at all. *Journal of Memory and Language, 48*(2), 379–398.

Ferreira, V. S., & Bock, K. (2006). The functions of structural priming. *Language and Cognitive Processes, 21*(7–8), 1011–1029.

Ferreira, V. S., Bock, K., Wilson, M. P., & Cohen, N. J. (2008). Memory for syntax despite amnesia. *Psychological Science, 19*(9), 940–946.

Fisher, C. (2001). Partial sentence structure as an early constraint on language acquisition. In B. Landau, J. Sabini, J. Jonides, & E. L. Newport (Eds.), *Perception, cognition, and language: Essays in honor of Henry and Lila Gleitman* (pp. 275–290). Cambridge, MA: MIT Press.

Flett, S. (2006). *A comparison of syntactic representation and processing in first and second language production*. Unpublished PhD thesis. University of Edinburgh.

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology, 40*(2), 177–190.

Goldberg, A. E. (2006). *Constructions at work. The nature of generalization in language*. Oxford: Oxford University Press.

Gries, S. T. (2005). Syntactic priming: A corpus-based approach. *Journal of Psycholinguistic Research, 34*(4), 365–399.

Gropen, J., Pinker, S., Hollander, M., Goldberg, R., & Wilson, R. (1989). The learnability and acquisition of the dative alternation in English. *Language, 65*(2), 203–257.
Hartsuiker, R. J., Bernolet, S., Schoonbaert, S., Speybroeck, S., & Vanderelst, D. (2008). Syntactic priming persists while the lexical boost decays: Evidence from written and spoken dialogue. *Journal of Memory and Language, 58*(2), 214–238.
Hartsuiker, R. J., & Kolk, H. H. J. (1998). Syntactic facilitation in agrammatic sentence production. *Brain and Language, 62*(2), 221–254.
Hartsuiker, R. J., & Westenberg, C. (2000). Word order priming in written and spoken sentence production. *Cognition, 75*(2), B27–B39.
Huttenlocher, J., Vasilyeva, M., & Shimpi, P. (2004). Syntactic priming in young children. *Journal of Memory and Language, 50*(2), 182–195.
Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language, 59*(4), 434–446.
Jaeger, T. F., & Snider, N. (2007). Implicit learning and syntactic persistence: Surprisal and cumulativity. *University of Rochester Working Papers in the Language Sciences, 3*(1).
James, W. (1890). *The principles of psychology*. New York: Henry Holt.
Kail, R. (1990). *The development of memory in children*. New York: W.H. Freeman.
Kaschak, M. P., Kutta, T. J., & Coyle, J. M. (2012). Long and short term cumulative structural priming effects. *Language and Cognitive Processes*.
Kidd, E. (2012a). Implicit statistical learning is directly associated with the acquisition of syntax. *Developmental Psychology, 48*, 171–182.
Kidd, E. (2012b). Individual differences in syntactic priming in language acquisition. *Applied Psycholinguistics.*
Komorowski, R. W., Manns, J. R., & Eichenbaum, H. (2009). Robust conjunctive item-place coding by hippocampal neurons parallels learning what happens where. *Journal of Neuroscience, 29*(31), 9918–9929.
Leonard, L. B., Miller, C. A., Grela, B., Holland, A. L., Gerber, E., & Petucci, M. (2000). Production operations contribute to the grammatical morpheme limitations of children with specific language impairment. *Journal of Memory and Language, 43*(2), 362–378.
Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
Levelt, W. J. M., Schriefer, H., Vorberg, D., Meyer, A. S., Pechmann, T., & Havinga, J. (1991). The time course of lexical access in speech production: A study of picture naming. *Psychological Review, 98*(1), 122–142.
McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning-systems in the hippocampus and neocortex – Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review, 102*(3), 419–457.
McCloskey, M., & Cohen, N. J. (1989). Catastrophic interference in connectionist networks: The sequential learning problem. *The Psychology of Learning and Motivation, 24*, 109–165.
Messenger, K., Branigan, H. P., & McLean, J. F. (2011). Evidence for (shared) abstract structure underlying children's short and full passives. *Cognition, 121*(2), 268–274.
Messenger, K., Branigan, H. P., McLean, J. F., & Sorace, A. (2012). Are children's early passives semantically constrained? Evidence from syntactic priming. *Journal of Memory and Language.*
Naigles, L. R. (2002). Form is easy, meaning is hard: Resolving a paradox in early child language. *Cognition, 86*(2), 157–199.
Neter, J., Wasserman, W., & Kutner, M. H. (1985). *Applied linear statistical models: Regression, analysis of variance, and experimental designs*. Homewood, IL: Irwin.
Ninio, A. (1999). Pathbreaking verbs in syntactic development and the question of prototypical transitivity. *Journal of Child Language, 26*(3), 619–653.
Ninio, A. (2006). *Language and the learning curve: A new theory of syntactic development*. Oxford: Oxford University Press.
O'Reilly, R. C., & Rudy, J. W. (2001). Conjunctive representations in learning and memory: Principles of cortical and hippocampal function. *Psychological Review, 108*(2), 311–345.
Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language, 39*(4), 633–651.
Pickering, M. J., & Branigan, H. P. (1999). Syntactic priming in language production. *Trends in Cognitive Sciences, 3*(4), 136–141.
Pine, J. M., Lieven, E. V. M., & Rowland, C. F. (1998). Comparing different models of the development of the English verb category. *Linguistics, 36*(4), 807–830.
Pinker, S. (1989). *Learnability and cognition: The acquisition of argument structure*. Cambridge, MA: MIT Press.
Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition, 42*, 107–142.
Roelofs, A. (1993). Testing a non-decompositional theory of lemma retrieval in speaking: Retrieval of verbs. *Cognition, 47*, 59–87.
Rowland, C. F., & Noble, C. H. (2011). Knowledge of verb argument structure in early sentence comprehension: Evidence from the dative. *Language Learning and Development, 7*(1), 55–75.
Saffran, J. R. (2001). The use of predictive dependencies in language learning. *Journal of Memory and Language, 44*(4), 493–515.
Saffran, J. R., Newport, E. L., Aslin, R. N., Tunick, R. A., & Barrueco, S. (1997). Incidental language learning: Listening (and learning) out of the corner of your ear. *Psychological Science, 8*(2), 101–105.
Savage, C., Lieven, E. V. M., Theakston, A. L., & Tomasello, M. (2003). Testing the abstractness of children's linguistic representations: Lexical and structural priming of syntactic constructions in young children. *Developmental Science, 6*(5), 557–567.
Schneider, W., & Pressley, M. (1997). *Memory development between two and twenty*. Mahwah, NJ: Lawrence Erlbaum Associates.
Shimpi, P. M., Gamez, P. B., Huttenlocher, J., & Vasilyeva, M. (2007). Syntactic priming in 3-and 4-year-old children: Evidence for abstract representations of transitive and dative forms. *Developmental Psychology, 43*(6), 1334–1346.
Snyder, W., & Stromswold, K. (1997). The structure and acquisition of English dative constructions. *Linguistic Inquiry, 28*(2), 281–317.
Theakston, A. L., Lieven, E. V. M., Pine, J. M., & Rowland, C. F. (2001). The role of performance limitations in the acquisition of verb-argument structure: An alternative account. *Journal of Child Language, 28*(1), 127–152.
Thomas, K. M., & Nelson, C. A. (2001). Serial reaction time learning in preschool- and school-age children. *Journal of Experimental Child Psychology, 79*(4), 364–387.
Thothathiri, M., & Snedeker, J. (2008). Syntactic priming during language comprehension in three- and four-year-old children. *Journal of Memory and Language, 58*(2), 188–213.
Tomasello, M. (1992). *First verbs: A case study of early lexical development*. Cambridge: Cambridge University Press.
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*. Harvard: Harvard University Press.
Trueswell, J. C., & Kim, A. E. (1998). How to prune a garden path by nipping it in the bud: Fast-priming of verb argument structures. *Journal of Memory and Language, 39*, 102–123.
van Beijsterveldt, L. M., & van Hell, J. G. (2009). Structural priming of adjective–noun structures in hearing and deaf children. *Journal of Experimental Child Psychology, 104*(2), 179–196.
Wendorf, C. A. (2004). Primer on multiple regression coding: Common forms and the additional case of repeated contrasts. *Understanding Statistics, 3*, 47–57.