What children learn from adults' utterances: An ephemeral lexical boost and persistent syntactic priming in adult–child dialogue

Holly P. Branigan [a,*], Janet F. McLean [b]

[a] Department of Psychology, University of Edinburgh, United Kingdom
[b] Division of Psychology, Abertay University, United Kingdom

ABSTRACT

We show that children's syntactic production is immediately affected by individual experiences of structures and verb–structure pairings within a dialogue, but that these effects have different timecourses. In a picture-matching game, three- to four-year-olds were more likely to describe a transitive action using a passive immediately after hearing the experimenter produce a passive than an active (abstract priming), and this tendency was stronger when the verb was repeated (lexical boost). The lexical boost disappeared after two intervening utterances, but the abstract priming effect persisted. This pattern did not differ significantly from control adults. Children also showed a cumulative priming effect. Our results suggest that whereas the same mechanism may underlie children's immediate syntactic priming and long-term syntactic learning, different mechanisms underlie the lexical boost versus long-term learning of verb–structure links. They also suggest broad continuity of syntactic processing in production between this age group and adults.

© 2016 Elsevier Inc. All rights reserved.

Introduction

There is increasing interest in understanding the relationship between children's language development and adult language processing: to what extent might models of adult language processing inform our understanding of children's language? One important question concerns the way in which language use might be affected by speakers' previous language experiences, and in particular the role that previous experiences of words and structures might play in determining child and adult speakers' syntactic behavior. In this paper we investigate how 3–4 year-olds' syntactic choices in an interactive context are dynamically influenced by the lexical and syntactic content of their interlocutor's utterances, and the extent to which the magnitude and timecourse of these effects converge with those found in adults.

Many studies have shown that children's early use of language reflects properties of the input to which they have been exposed (e.g., Lieven, 2010). Young children's language production appears not only to be influenced by the frequency with which they have experienced abstract syntactic structures, but also by the frequency with which they have experienced particular word–structure pairings. Observational studies have demonstrated individual differences in children's syntactic development as a function of individual differences in the syntax of their caregivers' speech, including the frequency of occurrence of particular structures in conjunction with particular lexical items (e.g., Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002;

* Corresponding author at: Psychology, 7 George Square, Edinburgh EH8 9JZ, United Kingdom.
E-mail address: Holly.Branigan@ed.ac.uk (H.P. Branigan).

Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Naigles & Hoff-Ginsberg, 1998; Newport, Gleitman, & Gleitman, 1977; Theakston, Lieven, Pine, & Rowland, 2002). Experimental studies have likewise suggested that children's early production of syntactic structures is closely linked to the structures to which they have been exposed, and the lexical content with which those structures have been experienced (e.g., Abbot-Smith, Lieven, & Tomasello, 2001; Akhtar, 1999; Ambridge, Pine, Rowland, & Young, 2008; Brooks, Tomasello, Dodson, & Lewis, 1999; Matthews, Lieven, Theakston, & Tomasello, 2005).

On the basis of this and related evidence, some researchers have suggested that word–structure frequencies play a particularly important role in children's early language, and specifically that children's early production draws on representations that are lexically specified to at least some degree (e.g., stored sequences of words, structural frames that are associated with particular lexical items; Bannard & Matthews, 2008; Goldberg, 2006; Ninio, 1999; Tomasello, 2003). Increasing exposure to language allows children to gradually abstract over these representations using frequency-based learning mechanisms (e.g., transitional probability or chunking mechanisms; Bannard, Lieven, & Tomasello, 2009; McCauley & Christiansen, 2011) to form generalized (abstract) representations. Abstract syntax of the type evidenced in adult language production is therefore argued to be gradually emergent from the accumulation of individual experiences involving particular words.

The evidence for longitudinal correspondences between children's lexico-syntactic input and their output, at a range of ages and when measured over a range of intervals, suggests that children's syntactic processing is continuously and cumulatively affected by individual experiences of structures and word–structure pairings. This implies that they are sensitive on a turn-by-turn basis to the structures, and especially the specific combinations of words and structures, that their partner produces, and moreover that the influences of individual utterances do not dissipate immediately, but instead persist and accumulate with those of other utterances. If these influences were sufficiently strong, then they might be manifested in children's immediate language production. For example, hearing their conversational partner produce an utterance using a particular syntactic structure might raise the likelihood of a child subsequently using that structure in her own production, and hearing their partner produce an utterance using a particular verb in a particular syntactic structure might raise the likelihood of the child subsequently using that structure with that verb.

Such a pattern would be broadly consistent with evidence of structural priming effects in adult production, which has shown a robust tendency for adults to repeat syntactic structure (*abstract syntactic priming* (Bock, 1986, 1989; Bock & Loebell, 1990; Branigan, Pickering, & Cleland, 2000; Pickering & Branigan, 1998), and for this tendency to be strongly enhanced when the lexical head is repeated from *prime* to *target* sentence (the *lexical boost*; Branigan et al., 2000; Cleland & Pickering, 2003; Gries, 2005; Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008; Pickering & Branigan, 1998; Schoonbaert, Hartsuiker, & Pickering, 2007). Abstract priming effects have been shown to persist over two or more intervening utterances (Bock, Dell, Chang, & Onishi, 2007; Bock & Griffin, 2000; Hartsuiker et al., 2008), and to accumulate over a series of individual experiences (Kaschak, 2007; Kaschak, Loney, & Borreggine, 2006). However, lexical boost effects appear to be less persistent (Hartsuiker et al., 2008), and there are conflicting findings about whether they accumulate over individual experiences (Coyle & Kaschak, 2008; Kaschak & Borreggine, 2008).

A number of different mechanisms have been put forward to explain these effects. One approach attributes priming and the lexical boost to a single activation-based mechanism within the lemma stratum (Pickering & Branigan, 1998). When a head is used with a particular syntactic structure, its lemma is activated along with a shared combinatorial node representing a particular combinatorial possibility. Residual activation of the combinatorial node gives rise to priming of abstract structure; residual activation in the links between lemma nodes and combinatorial nodes accounts for the lexical boost. Malhotra, Pickering, Branigan, and Bednar (2008) showed how a dynamical systems-based implementation of an activation-based account involving unsupervised learning and short- and long-term memory components could capture immediate and persistent abstract priming, and a lexical boost only to immediate priming.

A different account that explicitly aims to account for language acquisition and adult processing explains syntactic priming as error-based implicit learning, resulting from changes in weights associated with mappings from message-level representations to abstract syntactic representations determining word order (the Dual Path model; Chang, Dell, & Bock, 2006; see also Jaeger & Snider, 2013). In this account, comprehenders use the error between the predicted and actual structure of a sentence to adjust weights in the underlying system. Weight changes persist and hence can affect syntactic choices in subsequent production, yielding immediate, persistent and cumulative abstract priming. Links between lexical and syntactic representations also undergo weight adjustments, but with a slow learning rate, so that individual experiences contribute to the long-term development of verb biases but do not yield immediate effects. The lexical boost is assumed to have a distinct origin, in an explicit memory for the prime sentence (Bock & Griffin, 2000; Chang, Janciauskas, & Fitz, 2012; Chang et al., 2006).

Other accounts suggest distinct mechanisms for immediate priming and the lexical boost versus long-term priming (e.g., Ferreira & Bock, 2006; Hartsuiker et al., 2008; Reitter, Keller, & Moore, 2011). For example, Reitter et al. proposed a model in which immediate abstract priming and the lexical boost arise from spreading activation within the lexicon: Retrieving a lexical representation from memory boosts its activation, and this activation spreads to related representations (e.g., from lexical to syntactic nodes), facilitating their subsequent use. But retrieval of a structure from memory also results in a long-term change to its base level of activation, yielding persistent and cumulative facilitation.

These accounts therefore suggest a range of possible mechanisms by which individual experiences of abstract

structures and verb–structure pairings might immediately affect syntactic choices. If there is continuity between language development and adult language processing (e.g., Chang et al., 2006; Rowland, Chang, Ambridge, Pine, & Lieven, 2012), the same mechanisms might also apply to children's syntactic processing to yield immediate effects of individual structural and verb–structure experiences, in ways that would be consistent with – and might indeed explain – children's well-documented sensitivity to long-term regularities of syntactic structures and verb–structure pairings.

In fact, recent studies using structural priming paradigms have shown that children's syntactic production in interactive contexts is affected by individual structural experiences. Messenger, Branigan, McLean, and Sorace (2012) showed that when 3–4-year-olds were exposed to equal numbers of active and passive structures in a competitive card game, they flexibly switched between producing active and passive descriptions depending on which structure their partner had most recently used. This tendency occurred between sentences that shared no open-class lexical content (i.e., different verbs as well as different nouns), and was unaffected by whether the descriptions involved overlapping or distinct thematic roles (e.g., experiencer-theme, e.g., *A girl is being shocked by a sheep* vs. patient-agent, e.g., *A witch is being chased by a cow*). Rowland et al. (2012) and Peter, Chang, Pine, Blything, and Rowland (2015) found that when 3–4-year-old and 5–6-year-old children were exposed to both Prepositional Object (PO) and Double Object (DO) descriptions during a game, both age groups showed immediate sensitivity to the syntax of the experimenter's preceding utterance, producing more PO target descriptions after overhearing PO prime sentences involving a different verb (e.g., *Wendy brought a rabbit to Bob*) than after DO prime sentences (e.g. *Wendy brought Bob a rabbit*). Together, these studies demonstrate that individual structural experiences can exert an immediate influence on children's syntactic production.

In contrast, there is very little evidence for immediate verb–structure effects in children's production. Only two studies have addressed this question (see Thothathiri & Snedeker, 2008, for additional evidence from comprehension). Rowland et al. (2012) found that 3–4-year-olds were no more likely to repeat their partner's choice of PO or DO structure when their utterance involved the same verb than when it involved a different verb; 5–6-year-olds showed only a marginal trend in this direction (although note that children produced completions for the experimenter's description [subject NP + verb], hence did not actually produce the verb); control adults, in contrast, showed a reliable effect of verb repetition. Peter et al. (2015) found no immediate effect of verb repetition in either age group, despite children in both age groups showing sensitivity to long-term verb–structure biases in the language as a whole (manifested by stronger priming when the verb + structure combination in the prime was infrequent, and when the structure that had been primed matched the target verb's bias).

Thus experiencing a verb in a particular structure did not reliably influence children's syntactic choice for an immediately subsequent utterance involving the same verb. The paucity of evidence for immediate verb–structure effects is perhaps surprising, given the considerable evidence for long-term correspondences between children's experiences of verb–structure pairings and their later language use, and in particular the claim that children's early syntactic representations are initially associated with specific lexical content. It also contrasts with the consistent evidence for immediate verb–structure effects in adults (Branigan et al., 2000; Hartsuiker et al., 2008; Peter et al., 2015; Pickering & Branigan, 1998; Rowland et al., 2012).

The current study

In the current study, we set out to investigate whether 3–4-year-old children would show immediate effects of individual experiences of verb–structure pairings in an interactive context. We further investigated the time-course of any such effects, and how they compared with effects of individual experiences of abstract structure. We also sought to determine whether children are influenced by individual experiences of abstract structure and verb–structure pairings in the same ways and to the same extent as adults, to study the extent to which there is continuity of syntactic processing between childhood and adulthood. Two important questions were the extent to which mechanisms that have been proposed to explain syntactic priming effects in adults are applicable to children, and whether such mechanisms might in principle explain the emergence of long-term correspondences between children's experiences of structures and verb–structure pairings, and their subsequent language production.

To address these issues, we carried out an experiment in which three- and four-year-old children and adult controls described pictures of transitive events with a conversational partner (the experimenter) as part of a game. In the game – a variation of the popular British children's game 'snap' – the experimenter and the child alternated in turning over and describing picture cards to each other (Branigan, McLean, & Jones, 2005). We manipulated the structure (active vs. passive) of the experimenter's *prime* descriptions, and whether the child's *target* picture involved the same action as the experimenter's picture (same vs. different verb). We also manipulated whether the child described his or her picture immediately after hearing the experimenter describe her picture, or after two intervening descriptions (one produced by the child, one produced by the experimenter; Lag 0 vs. Lag 2). All of these manipulations were within-participants. Participants experienced equal numbers of active and passive primes in a randomized order, allowing us to examine whether children were primed by the experimenter's utterances on a trial-by-trial basis.

Our dependent measure was the syntactic structure of the child's target description. Thus, we examined whether children's syntactic choices were affected by the abstract syntax of their partner's description, and whether any tendency to repeat a partner's syntactic structure was affected by repetition of the verb. Additionally, we investigated whether any such effects persisted across time and intervening linguistic material by comparing children's

tendency to repeat structure directly following the experimenter's description and after two intervening utterances. We also examined whether there were any cumulative effects of experience, by examining whether children's likelihood of producing a passive increased with increasing exposure to passives within the experiment.

Based on previous research (Messenger, Branigan, & McLean, 2012), we expected that children would show an immediate tendency to repeat the syntax of the experimenter's preceding description (i.e., abstract syntactic priming). This pattern would be consistent with the extensive body of evidence that children are sensitive to long-term frequencies of abstract structures, and with all existing models of syntactic priming in adults. Models of syntactic priming that include a learning or memory component that is sensitive to the frequencies of structural alternatives (e.g., Chang et al., 2006; Malhotra et al., 2008; Reitter et al., 2011) would also predict that such effects would accumulate over the course of the experiment, so that children would be increasingly likely to use a passive the more passives they had experienced.

Children might be expected to show stronger abstract priming than adults, either because less skilled speakers experience reduced competition between structural alternatives because they know fewer structures (Hartsuiker & Kolk, 1998; Pickering & Branigan, 1999), or because children's syntactic knowledge would be more weakly represented and therefore yield greater prediction errors – and hence stronger learning – than adults' knowledge (Chang et al., 2006; Jaeger & Snider, 2013). For the same reason, error-based accounts also predict that cumulative effects would be stronger in children.

However, our main concern was whether children would show a stronger tendency to repeat structure when the verb was repeated (i.e., a lexical boost). Any such tendency would be consistent with the observational evidence that children are sensitive to long-term frequencies of particular verb–structure pairings. It would also be compatible with usage-based lexicalist accounts of syntactic development, in which children develop abstract representations of syntactic structure via an earlier stage in which structure is represented with respect to specific lexical content (e.g., Bannard et al., 2009). Under such accounts, children's abstract syntactic representations are gradually emergent and would therefore be expected to retain a strong lexical component even if they were no longer strictly lexically-dependent, and might therefore be facilitated through verb repetition, either because of co-existing abstract and (vestigial) lexically-dependent representations that could provide convergent sources of facilitation for re-use, or through their links with the lexicon. Accounts of syntactic priming in which syntactic structures are accessed in conjunction with lexical entries (e.g., Pickering & Branigan, 1998; Reitter et al., 2011) would also predict enhanced effects with lexical repetition, because co-activation of lexical entries and syntactic structures would automatically strengthen associations between particular verbs and particular structures.

Chang et al.'s (2006) error-based implicit learning account of syntactic priming predicts a different pattern. In this account, each experience of a verb–structure pairing yields a small amount of learning (via weight changes to verb–structure links), but this is insufficient to yield an immediate lexical boost. Instead, the boost to priming when a verb is repeated arises from an explicit memory of the prime sentence (with the target verb acting as a retrieval cue), and is therefore contingent on explicit memory functions. The ability to form, store and retrieve explicit memories appears to develop with age (Naito, 1990; Sprondel, Kipp, & Mecklinger, 2011), and children's explicit memory functions may differ from those of adults on the basis of differences in cognitive control, attention, and motivation (Chang et al., 2012). If so, then young children would be expected to show either no or inconsistent lexical boost effects, depending on the ease with which they could form an explicit memory and retrieve it in response to the cue provided by the verb.

Predictions are less clear concerning the persistence of a lexical boost. On the one hand, observational studies provide strong evidence that children are sensitive to long-term frequencies of verb–structure pairings, suggesting that if there are detectable effects of individual experiences of verb–structure pairings, these might be persistent (and accumulate); and this pattern would also be consistent with usage-based accounts of syntactic development.

On the other hand, previous research has found that the lexical boost is short-lived in adults (Hartsuiker et al., 2008), and existing models of syntactic priming other than Pickering and Branigan (1998) accordingly predict that a lexical boost would not persist (in Chang et al.'s model, because the lexical boost arises from an explicit memory, and such memories decay rapidly; in Reitter et al.'s model, because activation between lexical and syntactic representations quickly dissipates; and in Malhotra et al.'s model, because the memories that encode co-temporal use of verbs and structures are ephemeral.) If models of syntactic priming in adults also apply straightforwardly to children, then the lexical boost should not persist. In that case, alternative mechanisms would be needed to explain children's long-term sensitivity to verb–structure pairings.

If young children's syntactic representations have a strong lexical component, as predicted by usage-based lexicalist accounts, then we might expect any lexical boost to be stronger in children than in adults, although these accounts do not make any clear predictions about differences in its persistence. Chang et al.'s (2006) account, in contrast, predicts the reverse pattern, because in this account the lexical boost reflects explicit memory, and adults are likely to create, retain and retrieve explicit memories more strongly than children. Adults should therefore show a stronger lexical boost than children; moreover, this boost should persist to a greater extent in adults than in children (note that it would be predicted to dissipate rapidly even in adults; but the rate of decay would be slower than in children). Other models of syntactic priming make no predictions.

Experiment

Method

Participants

The participants were 32 pre-school children (20 female, 12 male), ranging in age from 3;5 to 5;0 (mean age 4;4). They were recruited from and tested in local nurseries. Parents/caregivers provided written consent for their participation. All were acquiring English as their first language; no developmental or language delays were reported. A control group of 32 adult, native speakers of English, (26 female, 6 male), ranging in age from 19 to 25 (mean age 22) from the University of Edinburgh student population volunteered to participate.

Materials

We created 48 experimental items, each comprising a prime picture, its associated prime description, a target picture, an experimenter-filler picture and its associated description, and a participant-filler picture. The prime and target pictures depicted a transitive event with animal characters as agents and human characters as patients (see Fig. 1); there was no overlap between the characters that

appeared in a prime picture and associated target picture. There were six transitive event types, corresponding to six verbs (*bite, chase, kiss, lift, pull, push*), each of which was used in an eight prime pictures and eight target pictures. Filler pictures depicted an intransitive event (e.g., skipping, crying) involving one or more identical human or animal characters as agents.

There were two versions of each prime picture, one depicting the same kind of event as the target picture (e.g., prime: a kissing event; target: a kissing event; *same-verb* condition), and one depicting a different kind of event to the target picture (e.g., prime: a chasing event; target: a kissing event; *different-verb* condition). Each of these versions was associated with two prime descriptions (an active and a passive). Hence each item was associated with four prime descriptions: an *active same-verb* sentence, an *active different-verb* sentence, a *passive same-verb* sentence, and a *passive different-verb* sentence. There were two orders for each item: Prime–Target–Experimenter-Filler–Participant-Filler (*Lag 0* condition), and Prime–Participant-Filler–Experimenter-Filler–Target (*Lag 2* condition). Overall this yielded eight conditions for each item (1a–h; see Appendix A for a complete list of the experimental items).

1a.	A tiger is pulling a soldier HORSE PULLING GIRL A man is sleeping ELEPHANT SKIPPING	[Prime] [Target] [Experimenter-filler] [Participant-filler]	active same-verb lag-0
1b.	A tiger is pulling a soldier ELEPHANT SKIPPING A man is sleeping HORSE PULLING GIRL	[Prime] [Participant-filler] [Experimenter-filler] [Target]	active same-verb lag-2
1c.	A pig is pushing a witch HORSE PULLING GIRL A boy is crying ELEPHANT SKIPPING	[Prime] [Target] [Experimenter-filler] [Participant-filler]	active different-verb lag-0
1d.	A pig is pushing a witch ELEPHANT SKIPPING A boy is crying HORSE PULLING GIRL	[Prime] [Participant-filler] [Experimenter-filler] [Target]	active different-verb lag-2
1e.	A soldier is being pulled by a tiger HORSE PULLING GIRL A boy is crying ELEPHANT SKIPPING	[Prime] [Target] [Experimenter-filler] [Participant-filler]	passive same-verb lag-0
1f.	A soldier is being pulled by a tiger ELEPHANT SKIPPING A boy is crying HORSE PULLING GIRL	[Prime] [Participant-filler] [Experimenter-filler] [Target]	passive same-verb lag-2
1g.	A witch is being pushed by a pig HORSE PULLING GIRL A boy is crying ELEPHANT SKIPPING	[Prime] [Target] [Experimenter-filler] [Participant-filler]	passive different-verb lag-0

1h.	A witch is being pushed by a pig	[Prime]	passive different-verb lag-2
	ELEPHANT SKIPPING	[Participant-filler]	
	A boy is crying	[Experimenter-filler]	
	HORSE PULLING GIRL	[Target]	

We also created sixteen 'snap' items (eight actives and eight passives) depicting transitive actions corresponding to four further verbs (*lick, pat, squash, wash*), which served as filler (non-experimental) items; these 'snap' items required the experimenter and the child to have identical cards. The 'snap' and experimental items were depicted on cards and used as the playing cards for the game. We created an additional set of four practice items using different actions and entities to the experimental and 'Snap' items.

We produced eight lists, such that across the eight lists each target picture occurred once in each of the eight priming conditions and within a list six target pictures (one per experimental verb) occurred in each of the eight priming conditions. The items were rotated so that participants saw each prime picture only once, either in the same-verb condition or in the different-verb condition. Each list was split into two blocks. Each block contained equal numbers of items in each condition, plus eight snap items; in each block, each experimental verb appeared in two active primes and two passive primes. Block order was counterbalanced across participants. Each participant received an individually randomized order, with the constraint that 'snap' items were distributed approximately evenly across the session to maintain the child's interest and attention.

Design

We used a $2 \times 2 \times 2 \times 2$ mixed design, with Group (children vs. adults) as a between-participants and within-items factor, and Prime (active vs. passive), Verb (same- vs. different-verb) and Lag (Lag 0 vs. Lag 2) as within-participants and -items factors.

Procedure

The experiment began with a practice session in which the experimenter and child played a short game of Snap (involving two active and two passive descriptions from the experimenter) using the practice items, ending on a snap item. In both the practice and the main experiment, the experimenter placed a set of pre-arranged picture cards face down in front of each player (the experimenter and the participating child). She told the participant that they would take it in turns to describe the pictures and look for 'Snap' items to win. The experimenter began each game by turning over the top card and describing it (following a script); this constituted the prime. The participant then took their top card and described it. For target cards, this description constituted the target response.

The cards were ordered so that in the Lag 0 conditions, the child's target card directly followed the experimenter's prime card (and was followed by the Experimenter-Filler and Participant-Filler cards, in that order); in the Lag 2 conditions, the child's target card did not directly follow the experimenter's prime card and instead followed the

Participant-Filler and Experimenter-Filler cards. Players alternated turns until all cards had been described. If the same picture appeared on both players' upturned card, the first player to shout "snap" won the cards in play. Following the first block, there was a short break during which children played with sticker books. We used the same procedure for adult participants, who were informed that the experiment was designed to test young children, in order to explain the child-oriented nature of the task and materials. The experimental sessions were audio-recorded; participants' responses were transcribed and scored according to the criteria outlined below.

Scoring

Scoring followed Messenger et al.'s (2012) criteria. Thus we scored the first target description that a child produced on each trial as *complete* or *incomplete*. Descriptions were coded as *complete* if they contained a subject, verb, and object; they were coded as *incomplete* if the participant's first response included only a subject and main verb, or subject and passive auxiliary, and hence were clearly the start of an incomplete active or passive.

A target description was scored as an *Active* if it was a complete sentence that provided an appropriate description of the transitive event in the target picture (i.e., included an appropriate verb and appropriate nouns), and contained a subject bearing the agent role, a verb, and a direct object bearing the patient role, and could also be expressed in the alternative form (i.e., a passive). A target description was scored as a *Passive* if it was a complete sentence that appropriately described the picture's event and
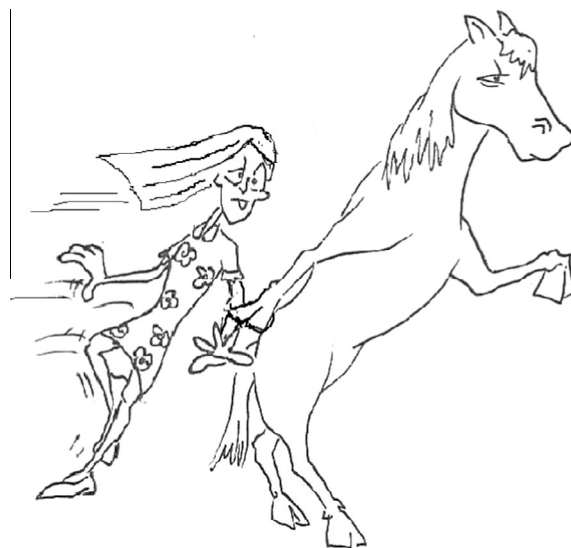

Fig. 1. An example target picture.

contained a subject bearing the patient role, an auxiliary verb (*get* or *be*), a main verb, the preposition *by* and an object bearing the patient role, and that could also be expressed in the alternative form (i.e., an active). All other descriptions, including short passives, reversed passives, incomplete utterances and non-transitive utterances, were scored as *Other*. If a participant initially produced an incomplete description but subsequently produced a complete description (e.g., "*a frog is getting kiss – a frog kissed the doctor*", only the first (incomplete) description was scored (as *Other*). In addition, if the participant did not produce the intended verb in the same-verb condition (i.e., did not use the verb in the prime), this was also scored as *Other*.

This scoring scheme corresponds to the scoring criteria typically used in adult research; note that it excludes some responses that would be scored as actives or passives in some other child studies (e.g., utterances containing only a subject and verb, e.g., *the flower was eaten*; Huttenlocher, Vasilyeva, & Shimpi, 2004: 185). Analyses were based on the proportions (descriptive statistics) and frequency (inferential statistics) of Active and Passive responses according to these criteria.

For children, we additionally carried out analyses using a more lenient scoring scheme (comparable to the criteria used in some other child studies) that also included: actives and passives that were incomplete (i.e., included the subject, auxiliary, and/or main verb, but not the object) or included two pronouns; short passives (omitting the *by*-phrase); and passives that included prepositions other than *by*; this led to the inclusion of 56 further active responses and 35 further passive responses. (For adults, analyses using the lenient scoring scheme [including 14 further active responses] yielded an identical pattern of results to the strict scoring scheme, and are therefore not reported.)

Results

The frequencies of Active, Passive, and Other target responses in each condition under the strict scoring scheme are shown in Table 1. One trial from the children's data was eliminated because the cards were presented in the wrong order. The total for the Other target responses includes responses scored as Reversed Passive (37 produced by children, of which 28 followed Passive primes; 3 produced by adults, of which 2 followed Passive primes), and trials where the participants did not use the intended verb in the same-verb conditions (children: 148; adults: 41).

Abstract syntactic priming and lexical boost effects

Our main analyses considered the immediate effects of individual experiences of syntactic structure and verb–structure pairings, and whether such effects persisted over two intervening utterances. Fig. 2 shows the mean proportion of passive descriptions (out of the total number of active and passive responses, excluding others) produced after a passive prime (i.e. match between prime structure and target response) and after an active prime (i.e. mismatch between prime structure and target response) in each of the experimental conditions. Effects of syntactic structure (abstract priming) are manifested as a higher

Table 1
Frequency of Active, Passive, and Other target responses by condition (strict scoring scheme).

Group	Prime	Verb	Lag	Target response		
				Active	Passive	Other
Children	Active	Same	0	120	19	53
			2	75	34	83
		Different	0	111	30	51
			2	96	34	62
	Passive	Same	0	40	72	79
			2	58	56	78
		Different	0	68	61	63
			2	76	53	63
Adults	Active	Same	0	164	17	11
			2	121	44	27
		Different	0	153	29	10
			2	135	45	12
	Passive	Same	0	63	115	14
			2	95	68	29
		Different	0	110	69	13
			2	118	63	11

proportion of passive responses after passive primes that after active primes; effects of verb–structure pairings (lexical boost) are manifested as a greater difference in the same-verb than different-verb conditions.

As the dependent variable was the production of passive structures (passive = 1, active = 0), we modeled the responses using logit mixed effects models (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). All models were calculated using the glmer function from the lme4 package (lme4: version 1.1.7; Bates, Maechler, Bolker, & Walker, 2014). The first model analyzed the full dataset and included as predictors: Group (children vs. adults), Prime (active vs. passive), Verb (same vs. different), Lag (lag 0 vs. lag 2). All predictors were centered prior to analysis in order to reduce collinearity in the models. The random effects structure included by-participant and by-item effects. For this and every other model reported, we attempted to fit the maximal model (Barr, Levy, Scheepers, & Tily, 2013). If the fully maximal model did not converge, we simplified random slope structure until convergence was achieved. We report which random slopes were included with each model summary.

The most maximal model to converge included random slopes for Prime and Verb by participants, and for Prime by items (Table 2). Coefficients are given in log-odds; significant positive coefficients indicate increased log-odds and represent the increased probability of a Passive sentence structure in the target sentence.

There was a significant main effect of Prime (p_z < .001; participants were significantly more likely to produce a passive after a passive prime (i.e., an abstract priming effect). There was a two-way interaction between Prime and Verb (p_z < .001); priming effects were larger when the same verb appeared in the prime and target (i.e., a lexical boost). There was a two-way interaction between Prime and Lag (p_z < .001); participants were more likely to produce a passive immediately after a passive prime than when two utterances intervened. Finally, there was a three-way interaction between Prime, Verb and Lag
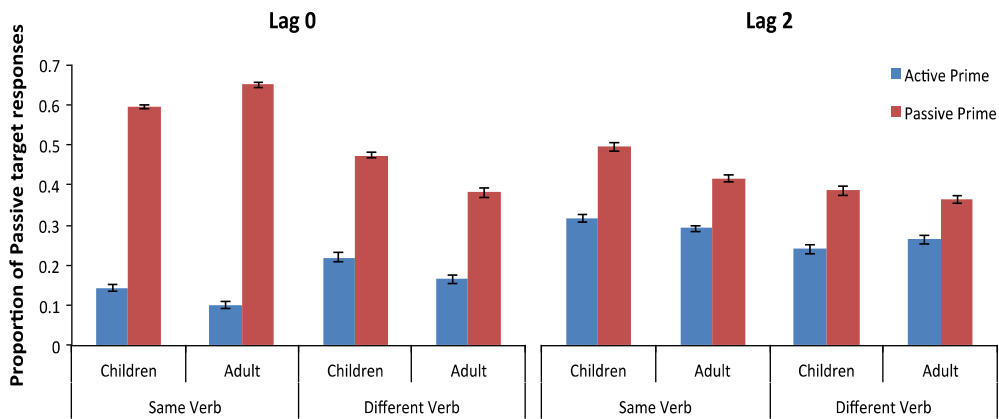
Fig. 2. Mean proportions of observed passive responses (out of total active + passive responses) following active and passive primes in the same- and different-verb conditions by lag. Bars indicate standard error for proportions calculated by condition.

Table 2
Summary of logit mixed effect model with all data included (strict scoring).

Predictor (independent variable)	Parameter estimates		Wald's test	
	Log-odds	SE	Z	p_z
Main effects				
Group	0.39	0.31	1.25	.21
Prime	−1.22	0.14	−8.43	<.001
Verb	−.11	0.11	−.94	.34
Lag	0.08	0.10	0.89	.42
2-way interactions				
Group × Prime	0.43	0.28	1.53	.12
Group × Verb	0.20	0.22	0.89	.37
Group × Lag	−0.04	0.20	−0.20	.84
Prime × Verb	−0.10	0.21	−4.64	<.001
Prime × Lag	−1.29	0.20	−6.50	<.001
Verb × Lag	−0.03	0.20	−0.15	.88
3-way interactions				
Group × Prime × Verb	0.49	0.43	1.14	.25
Group × Prime × Lag	0.92	0.40	0.99	.32
Prime × Verb × Lag	−1.27	0.40	−3.20	<.01
4-way interaction				
Group × Prime × Verb × Lag	0.99	0.79	1.23	.22

(p_z < .01); the lexical boost to priming dissipated when two utterances intervened between the prime and target. Importantly, for all significant effects, there were no interactions with Group.

Analyses for child and adult groups

In further analyses, we ran separate logistic mixed effects models for each age group. In addition, we calculated effect sizes (Cohen's *d*) to allow us to directly compare groups while factoring out differences in variability (Cohen, 1992; Dunlap, Cortina, Vaslow, & Burke, 1996). Table 3 reports the size of the priming effect by age group and verb condition calculated as a difference score (proportion of passive responses produced after passive primes minus proportion of passive responses produced after active primes, as in Fig. 2) and as Cohen's *d*.

Child group
Strict scoring. The maximal model to converge included by-participants and by-items random slopes for Prime and

Verb. Table 4 shows that the Child group considered alone showed a similar pattern to the model that included all the data (i.e., a significant main effect of Prime, and significant Prime by Verb, Prime by Lag, and Prime by Verb by Lag interactions).

Simple main effects were conducted to explore effects for each verb condition at each lag. When the verb was repeated between the prime and target, there was a significant effect of Prime for lag 0 (β = −3.25, *SE* = −.40, *Z* = −8.23, p_z < .001) and for lag 2 (β = −1.17, *SE* = −.33, *Z* = −3.50, p_z < .001). When the verb was not repeated between the prime and target, there was a significant effect of Prime for lag 0 (β = −1.44, *SE* = −.31, *Z* = −4.72, p_z < .001) and for lag 2 (β = −0.81, *SE* = −.30, *Z* = −2.69, p_z < .01). Thus children showed a reliable priming effect at each lag, both when the verb was repeated and when it was not repeated.

Lenient scoring. Analysis using the lenient scoring scheme showed an identical pattern of effects.

Table 3
Size of priming effect in the same- and different-verb conditions by Lag. The standard error and Cohen's d are based on by-participants data.

	Same verb			Different verb		
	Difference score	Standard error	Cohen's d	Difference score	Standard error	Cohen's d
Lag 0						
Children	0.45	0.095	1.72	0.25	0.096	0.85
Adults	0.55	0.101	2.35	0.22	0.119	0.75
Lag 2						
Children	0.18	0.062	0.50	0.15	0.081	0.46
Adults	0.13	0.081	0.46	0.10	0.072	0.32

Table 4
Summary of logit mixed effects models for the child (strict and lenient scoring) and adult groups separately.

Group	Predictor (independent variable)	Parameter estimates		Wald's test	
		Log-odds	SE	Z	p_z
Children (strict scoring)	*Main effects*				
	Prime	−1.76	0.25	−7.18	<.001
	Verb	−0.00	0.26	−0.00	.99
	Lag	0.19	0.17	1.10	.27
	2-way interactions				
	Prime × Verb	−1.54	0.53	−2.88	<.01
	Prime × Lag	−1.50	0.34	−4.37	<.001
	Verb × Lag	0.43	0.34	1.26	.21
	3-way interaction				
	Prime × Verb × Lag	−1.61	0.68	−2.36	<.05
Children (lenient scoring)	*Main effects*				
	Prime	−1.52	0.20	−7.47	<.001
	Verb	−0.20	0.15	−1.36	.17
	Lag	0.05	0.15	0.31	.75
	2-way interactions				
	Prime × Verb	−0.87	0.30	−2.89	<.01
	Prime × Lag	−1.32	0.30	−4.33	<.001
	Verb × Lag	0.19	0.30	0.61	.53
	3-way interaction				
	Prime × Verb × Lag	−1.33	0.60	−2.21	<.05
Adults	*Main effects*				
	Prime	−1.62	0.20	−8.08	<.001
	Verb	−0.25	0.17	−1.51	.13
	Lag	0.15	0.16	0.93	.35
	2-way interactions				
	Prime × Verb	−.86	0.32	−2.65	<.01
	Prime × Lag	−1.33	0.32	−4.11	<.001
	Verb × Lag	0.31	0.32	0.95	.34
	3-way interaction				
	Prime × Verb × Lag	−1.38	0.64	−2.14	<.05

Adult group

The maximal model to converge included random slopes for Prime by-participants and by-items. Table 4 shows that the Adult group considered alone showed a similar pattern to the model that included all the data (i.e., a significant main effect of Prime, and significant Prime by Verb, Prime by Lag, and Prime by Verb by Lag interactions).

Simple main effects were conducted to explore effects for each verb condition at each lag. When the verb was repeated between the prime and target, there was a significant effect of Prime for lag 0 ($\beta = -3.76$, $SE = -.38$, $Z = -9.97$, $p_z < .001$) and for lag 2 ($\beta = -0.81$, $SE = -.28$, $Z = -2.90$, $p_z < .01$). When the verb was not repeated between the prime and target, there was a significant effect of Prime for lag 0 ($\beta = -1.62$, $SE = -.30$, $Z = -5.42$, $p_z < .001$) and for lag 2 ($\beta = -0.65$, $SE = -.27$, $Z = -2.41$, $p_z < .05$). Thus adults showed a reliable priming effect at each lag, both when the verb was repeated and when it was not repeated.

Cumulative priming effects

Further analyses investigated cumulative effects of syntactic experience within the experiment, with respect to the total number of passive primes that had been experienced prior to the current trial. A predictor for this effect was included for the dataset for each age group separately (model convergence issues precluded including both

Table 5
Summary of logit mixed effects models including cumulative priming, for the child (strict and lenient scoring) and adult groups separately.

Group	Predictor (independent variable)	Parameter estimates		Wald's test	
		Log-odds	SE	Z	p_z
Children (strict scoring)	*Main effects*				
	Prime	−1.64	0.16	−9.93	<.001
	Verb	−0.22	0.16	−1.42	.16
	Lag	0.14	0.17	0.89	.37
	Cumulative passive primes	−0.02	0.01	−1.67	.09
	2-way interactions				
	Prime × Verb	−0.86	0.32	−2.69	<.01
	Prime × Lag	−1.32	0.32	−4.11	<.001
	Lag × Verb	0.26	0.32	0.81	.42
	3-way interaction				
	Prime × Verb × Lag	−1.33	0.64	−2.07	<.05
Children (lenient scoring)	*Main effects*				
	Prime	−1.54	0.15	−9.94	<.001
	Verb	−0.20	0.15	−1.31	.19
	Lag	0.03	0.15	0.21	.83
	Cumulative passive primes	−0.03	0.01	−2.37	<.05
	2-way interactions				
	Prime × Verb	−0.87	0.30	−2.88	<.01
	Prime × Lag	−1.28	0.30	−4.25	<.001
	Lag × Verb	0.13	0.30	0.42	.67
	3-way interaction				
	Prime × Verb × Lag	−1.32	0.60	−2.19	<.05
Adults (strict scoring)	*Main effects*				
	Prime	−1.72	0.15	−11.2	<.001
	Verb	−0.33	0.15	−2.27	<.05
	Lag	0.24	0.15	1.64	.10
	Cumulative passive primes	0.01	0.01	0.61	.54
	2-way interactions				
	Prime × Verb	−1.18	0.29	−4.01	<.001
	Prime × Lag	−1.98	0.30	−6.65	<.001
	Lag × Verb	−0.15	0.29	−0.53	.60
	3-way interactions				
	Prime × Verb × Lag	−2.03	0.59	−3.46	<.001

groups together, nor was it possible to include any interactions between the cumulative predictor and other predictors). Table 5 summarizes the effects of the predictors for each age group. No random slopes were included, as no models would converge when these were included.

Child group
Strict scoring. Table 5 shows an identical pattern of effects to our primary analyses. There was no significant cumulative priming effect (p_z = .09).

Lenient scoring. Analysis using the lenient scoring scheme showed an identical pattern of effects, except that there was a significant cumulative priming effect (p_z < .05); the more passive primes children had previously been exposed to during the experimental session, the more likely they were to produce a passive structure.

Adult group. Adults displayed the same pattern of main effects and interactions as the children with respect to Prime, Verb, and Lag, but there was no effect of cumulative priming under either scoring scheme (p_z > .10).

General discussion

In this study, we used a picture description game to investigate whether three- to four-year-old children's syntactic choices were immediately affected by individual experiences of verb–structure pairings as well as by individual experiences of syntactic structure, and the time-course of such effects, in order to draw inferences about the nature of young children's syntactic production and syntactic development.

Children showed a strong tendency to repeat their conversational partner's syntactic structure. They were reliably more likely to use a passive structure to describe a transitive action immediately after hearing the experimenter use a passive description for a different event, involving different entities, than after an active description (25% abstract priming effect). But critically, this tendency was enhanced when the child's description used the same verb as the experimenter's description (45% priming effect, i.e., a 20% lexical boost). However, the lexical boost to priming dissipated rapidly when two unrelated descriptions intervened between the experimenter's and the child's descriptions (a 3% boost), whereas the abstract

priming effect persisted (15% priming). This overall pattern of effects did not differ significantly from that found in adults. Children also showed an increasing likelihood to produce passive structures (including short passives excluding a *by*-phrase and passives that used a preposition other than *by*) with increasing exposure to passives within the experiment; adults did not show such an effect.

Abstract syntactic priming in children's syntactic production

Our results replicate previous findings that children's syntactic choices are immediately affected by individual structural experiences in dialogue (Messenger et al., 2012; Peter et al., 2015; Rowland et al., 2012). They confirm that by 3–4 years, children have already developed an abstract representation of the passive that is not bound to specific lexical items (Messenger et al., 2012; see also Bencini & Valian, 2008; Peter et al., 2015; Rowland et al., 2012; Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007), and that can be facilitated by exposure to a single instance.

Our results demonstrate further that the influence of individual structural experiences persists over time and the production/comprehension of unrelated utterances. Although this tendency was smaller (by 10%) than when the prime and target utterances were adjacent, children still showed a reliable 5% greater likelihood of producing a passive after hearing a passive two turns earlier. We cannot tell how long such effects might persist, but previous research with adults has shown priming over up to six intervening utterances in dialogue (Hartsuiker et al., 2008; see also Bock & Griffin, 2000).

Additionally, we found some evidence that effects of individual structural experiences accumulate across a dialogue on a trial-by-trial basis. Increasing exposure to full passive structures increased the overall likelihood of children producing a passive structure of some type (including short and incomplete passives, as well as passives involving a preposition other than *by*). Within the experiment, children were exposed to a large number of passives (24 passive primes). The cumulative effect therefore seems to reflect a long-term change in the baseline availability of passive structures with increasing experience of this normally infrequent structure (Gordon & Chafetz, 1990).

The lexical boost in children's syntactic production

Our results showed that children were more likely to immediately repeat their partner's syntax when the verb was repeated than when it was not, and hence that they were immediately influenced by individual experiences of verb–structure pairings. This result is in keeping with consistent findings from adult studies (e.g., Branigan et al., 2000; Hartsuiker et al., 2008). However, it is the first demonstration of such effects in children of this age. Rowland et al. (2012) found a reliable lexical boost for PO/DO structures only in adults, with 5–6 year-olds showing a marginal effect and 3–4 year olds showing no effect, and Peter et al. (2015) similarly found a lexical boost in adults but no such effect in 3–4-year-olds or 5–6-year-olds. In our study, the 20% boost to priming conferred by verb repetition was of a similar magnitude to the abstract

priming effect itself; moreover, the effect size of priming when the verb was repeated was considerably larger than when the verb was not repeated (1.72 vs. .85, though note that both are standardly considered a large effect size). Thus our results provide convincing evidence that 3–4-year-olds' syntactic production is immediately influenced not only by their partner's syntax, but also by their specific pairings of verbs and structures.

There are many differences between the studies (e.g., experimental paradigm, use of still images vs. videos, structural alternation under study) that could explain the difference in results. One possibility is that priming in Rowland and colleagues' studies was too weak to detect a lexical boost (e.g., the immediate abstract priming effect for 3–4-year-olds was 7%, with a small effect size of .28, in Rowland et al., 2012, compared to 25%, with a large effect size of .85, in our study). Relevantly, in our study the experimenter addressed the prime to the child, and the child produced their target picture description from scratch (without any prompt), whereas in Rowland and colleagues' studies, the addressee of the prime was a third person, and children were prompted to produce target descriptions using sentence stems. Additionally, in our study children had an incentive to attend to the experimenter's prime sentence carefully: If the child was first to detect that the experimenter's and their own picture matched, they would win the cards in play. Previous research has suggested that priming effects are stronger when the prime is addressed to the participant rather than a third person, and this pattern has been explained in terms of a more general tendency to stronger priming with greater depth of processing that is linked to e.g., greater attention (Branigan, Pickering, McLean, & Cleland, 2007). The characteristics of our game might therefore have been particularly conducive to eliciting sufficiently large priming effects to be able to detect a lexical boost. For the same reasons, our task might have been more likely to lead to the formation of an explicit memory for the prime in children, which may be critical to the occurrence of the lexical boost (see below).

However, and in contrast to the persistent abstract priming effect, the influence of individual verb–structure experiences did not persist. When two unrelated utterances intervened between the prime and target, children were as likely to repeat structure when the verb was not repeated as when it was repeated, implying that the tendency to repeat structure was driven by the recent experience of abstract structure alone. The ephemeral nature of the verb–structure effect in the experiment, even in the absence of relevant input (i.e., utterances that might prime the pairing of the verb with the alternative structure), is perhaps surprising, given the strong evidence for long-term verb–structure effects in children's language development, and suggests that immediate and long-term verb–structure effects are of fundamentally different natures; we return to this point below.

The continuity of syntactic processing

The current study provides evidence for continuity of syntactic processing between children and adults in at

least some respects. Both groups showed strong immediate influences of individual structure and verb–structure experiences, but persistent influences of abstract structure only, replicating previous findings from adult studies (Branigan et al., 2000; Hartsuiker et al., 2008).

The magnitude of abstract priming was very similar between groups, indexed both by the absence of any interactions with group, and the generally high degree of correspondence in effect sizes (arguably a more sensitive measure, as they accommodate variability between participants; see Rowland et al., 2012). Hence we found no evidence that children were more susceptible to immediate effects of individual structural experiences than adults (in keeping with Messenger, Branigan, McLean, et al., 2012, and Peter et al., 2015). The timecourse of abstract priming also showed a similar slow rate of decay (in keeping with previous adult research; Hartsuiker et al., 2008).

More importantly, we did not find any evidence that children's syntactic processing had a stronger lexical basis, e.g., drew on vestigial verb-specific representations as well as generalized representations (consistent with Peter et al., 2015; Rowland et al., 2012). If so, we might have expected to find a greater sensitivity to repetition of the verb in children. We cannot rule out the possibility that earlier stages of language development involve representations that are lexically dependent (Goldberg, 2006; Ninio, 1999; Tomasello, 2003). However, any such representations do not appear to be implicated in syntactic production in children in this age group.

In fact, although we did not find any significant difference in the lexical boost between the child and adult groups (i.e., no significant Group interactions), there was some suggestion in the (large) effect sizes of the immediate lexical boost that children were *less* likely than adults to immediately repeat syntactic structure when the verb was repeated (children: 1.72; adults: 2.35). (In contrast, the effect sizes were very similar in the Lag 2 conditions; children: .50; adults: .46.)

Taken together, these results suggest that by three to four years, children's syntactic production draws on similar structural representations to adults, and that it is affected in the same ways, and along the same timecourse, by immediate verb-structural experiences (although there may be some quantitative differences) as well as by structural experiences, implicating common processing mechanisms. Thus, there is at least some continuity in syntactic processing between childhood (from around three to four years) and adulthood.

In one respect, children did show a different pattern from adults: Whereas children showed cumulative priming through the course of the experiment (with respect to production of passive structures under the lenient scoring scheme), adults did not. Previous research on adults has shown cumulative effects in production of PO/DO structures (e.g., Kaschak et al., 2006), implying that they are cumulatively affected by repeated structural experiences under some circumstances (see also Fine, Jaeger, Farmer, & Qian, 2013). However, our results imply that given exposure to the same input, children's syntactic production is more strongly influenced by repeated experiences than adults.

Mechanisms of syntactic priming and syntactic production

Our study shows that children's syntactic production is affected by individual experiences of both abstract structures and verb–structure pairings. However, the disparity in the timecourses of these effects implies that they must have different sources, and cannot be explained using the same mechanism. Moreover, the rapid dissipation of the lexical boost implies that its underlying mechanism cannot be one that yields long-term learning. In contrast, the persistence and cumulativity of the abstract priming effect implicates the involvement of some kind of learning mechanism.

The overall pattern of results therefore suggests that the learning mechanism giving rise to abstract priming could in principle account for the long-term correspondences between structural experiences in children's input and their later syntactic behavior that have been identified in extensive previous research. In contrast, the mechanism giving rise to the lexical boost cannot directly account for the long-term correspondences between verb–structure experiences in children's input and their later behavior. Hence the immediate effect of experiencing a verb–structure pairing in our study appears qualitatively different in nature from the process that gives rise to long-term verb–structure preferences.

Our results are therefore broadly compatible with adult models that explain abstract priming and the lexical boost in different ways. The activation mechanisms in Malhotra et al.'s (2008) dynamical systems-based model, which assumes two sources of activation that affect lexical–syntactic representations during grammatical encoding (a long-term activation arising from long-term experiences, and a short-term activation associated with recent experiences), can account for an ephemeral lexical boost alongside immediate and persistent abstract priming. They can also account for cumulative priming, via a boost to short-term activation of the passive node through repeated usage. The fact that only children showed cumulative effects could be modeled via differences in the magnitude of this boost in children versus adults.

The spreading activation and base level learning mechanisms assumed in Reitter et al.'s (2011) hybrid model can account for immediate priming and the lexical boost through spreading activation of lexical representations. It can also account for cumulative effects, via an unsupervised implicit learning mechanism that changes the base level of activation for a structure with each instance of use. However, it is not clear whether it is possible to determine distinct sets of child vs. adult parameters that could capture the fact that only children showed cumulative effects, whereas the two groups did not differ with respect to effects of individual experiences. Although differences in base levels of activation (as a result of different amounts of language experience) might be able to capture the distinct patterns of cumulative effects, such differences would also be likely to yield differences between the groups in immediate priming (since the activation boost associated with processing a prime is dependent on the base-level of activation for that structure).

The error-based implicit learning mechanism assumed in Chang et al.'s (2006) Dual Path model can account for abstract priming from individual experiences, as well as cumulative priming. This mechanism uses the prediction error between the structure predicted for the prime and its actual structure to adjust weights in the underlying language network. Adjustments in mappings from message representations to abstract structural representations make it more likely that the structure used in the prime will be chosen again in a subsequent utterance. These weight changes persist (yielding priming over intervening material) and accumulate (yielding cumulative priming). Chang et al.'s assumption that children have a higher learning rate for these mappings than adults can explain why only children showed cumulative effects (and predicts that adults would show such effects with exposure to more stimuli). Their assumption of a similar learning mechanism (but with a lower learning rate) that affects links between lexical entries and syntactic structures accounts for the gradual development of verb–structure preferences, and hence explains long-term verb–structure experience effects (Twomey, Chang, & Ambridge, 2014).

Chang et al.'s model explains the lexical boost in a different way, as arising from an explicit memory for the prime that is rapidly overridden by intervening material (Sachs, 1967). In previous research, the absence of a lexical boost in children has been explained as a consequence of children's more fragile explicit memory system compared to adults, so that they either do not form or retain the memories that subserve the lexical boost in adults, or alternatively do so on an inconsistent basis, depending on factors such as attention, motivation, and cognitive control (Chang et al., 2012; Peter et al., 2015; Rowland et al., 2012).

If explicit memory traces underlie the lexical boost, then the fact that our 3–4-year-olds demonstrated a lexical boost implies that they are capable of forming and maintaining such memories under at least some circumstances, and that these traces can be retrieved and affect processing in the same way as in adults. The disparity between our results and earlier studies might then be attributable to differences in the extent to which children in the relevant studies attended to the prime, and hence the strength of the memories that they formed. The suggestion in our study of a reduced lexical boost in children (as reflected in a smaller effect size) is compatible with generally more inconsistent or weaker formation of explicit memory traces in children than in adults. We did not find that the lexical boost decayed more rapidly in children than in adults, as might have been expected under this account. However, even in adults explicit memory for sentences dissipates rapidly. Any group differences in decay rates might only be discernible at a shorter lag (i.e., with one intervening utterance).

Our results appear less consistent with the Dual Path model's error-based learning mechanism with respect to the relative magnitude of priming between groups, as it predicts stronger immediate priming in children, on two grounds: First, their representation of the passive is (presumably) weaker than adults, and experiencing a passive prime should therefore yield a greater error between prediction and outcome; second, they have a faster learning rate, and hence undergo stronger weight changes in response to error. The model also predicts that abstract priming would not decay over two intervening utterances.

Taken together, these models suggest a range of mechanisms that might affect children's syntactic production and syntactic development. We now consider how our effects may have arisen, within a framework that draws heavily on Chang et al.'s (2006) Dual Path model but also incorporates activation-based mechanisms. We assume that when comprehending and producing sentences, children's syntactic choices are affected by existing long-term preferences, as well as by changes in the language system brought about by individual recent experiences. We further assume that these changes reflect both activation-based and implicit learning mechanisms. Finally, we assume that comprehension and production can give rise to explicit memories of an utterance at many levels of representation (e.g., its lexical content, its structure, its meaning, its phonology; Bernolet, Colleman, & Hartsuiker, 2014).

When a child heard the experimenter produce an utterance, she carried out lexical retrieval and syntactic analysis, drawing on abstract representations that were linked to lexical entries but that were not defined for lexical content. For example, she activated the lexical entry *pull* and the associated combinatorial information specifying that *pull* could appear in a passive structure. Coactivation of these elements yielded a small increase in the weighting of the link between them; because the learning rate for these lexical-syntactic (verb-structure) links was small, the adjustment was correspondingly small. Because she was highly motivated to attend to the experimenter's utterances (in the game context), she also formed an explicit memory of the sentence and its linguistic representation at different levels. She also made predictive mappings between the unfolding syntactic representation and a corresponding semantic representation, and adjusted the weightings of these mappings in response to the prediction error; because passive structures were more unexpected, they yielded a greater adjustment. The learning rate for these mappings was higher than for the verb–structure links, and hence the adjustment was relatively larger.

Immediately after comprehending the experimenter's sentence, the child's language system was therefore in a state involving residual activation of lexical entries and the syntactic representations to which they were connected, and a small strengthening of the link between them, alongside a more pronounced strengthening of mappings between semantic and syntactic representations. She also had an explicit memory for the sentence that included its semantic, syntactic and lexical content. The residual activation and the explicit memory trace would subsequently decay relatively quickly (over the course of an utterance); in contrast, the weight changes to the verb–structure link and semantic–syntactic mappings would persist (until further relevant input was processed).

When the child subsequently wished to express a message involving another transitive event, she would consider alternative structural possibilities in parallel

(Melinger, Branigan, & Pickering, 2014). Her final choice would be determined by multiple factors, including preferences for mapping certain meaning structures to certain syntactic structures, and overall preferences for certain syntactic structures, in addition to verb-specific structural preferences (e.g., Bock & Ferreira, 2014). As such her choice would be affected by the weightings on the mappings between semantic and syntactic structures; the current level of activation of alternative syntactic structures; the strength of the links between the lexical entries that she wished to express and associated syntactic structures; and potentially by her memory of recently processed mappings, links and structures.

If she produced her utterance immediately after comprehending the prime, then residual activation of the recently used syntactic representation would increase the likelihood of that structure's use (irrespective of whether lexical content were repeated). An explicit memory of the sentence's syntactic structure would similarly increase the likelihood of its use, with this memory being particularly strongly retrieved (hence influential) when lexical content was repeated and so acted as a strong retrieval cue for the memory. (Note that the relevant memory must be a memory of abstract syntactic structure, otherwise it could only facilitate verbatim repetition of the prime sentence.) The tendency to re-use structure would be further enhanced by the increased weightings on the semantic–syntactic mappings. There would therefore be a strong immediate tendency to choose the same structure as the experimenter had previously used, arising from convergent residual activation of syntactic representations, an explicit memory of the prime, and implicit learning of semantic–syntactic mappings. Moreover, this tendency would be enhanced if the child's utterance involved the same verb, because of the explicit memory trace associated with retrieval of the verb; this lexical boost would be variable in magnitude, depending on the strength of the initial memory.

However, if she produced her utterance after a delay, then her likelihood of re-using the same structure as she had previously experienced would be influenced by only the strength of the semantic–syntactic mappings and the lexical–syntactic links, as only these influences would persist. Moreover, the effects of the experimenter's previous utterance would be concentrated on the semantic–syntactic mappings, because the learning rate for lexical–syntactic links is slow. Both residual activation of syntactic representations and explicit memory traces would have dissipated and would therefore play no part in determining her choice. The child would therefore show an abstract priming effect, but it would be smaller than the immediate priming effect (because there would be no contribution of residual activation), and there would be no lexical boost (because there would be no contribution of explicit memory).

Because the implicit learning mechanisms associated with semantic–syntactic mappings and lexical–syntactic links continuously adjust weights in the light of new experience (albeit at different rates), she would also show long-term effects of structural and verb-structural experience. Cumulative structural effects would be detectable over a relatively small number of experiences, whereas cumulative verb-structural experiences would be much slower to emerge (see Peter et al., 2015, for discussion), although we would expect her to show such effects even within the timeframe of an experiment, given sufficient relevant exposure (e.g., multiple primes involving the same verb–structure pairing; Coyle & Kaschak, 2008).

Children's syntactic production in dialogue

A final important implication of our results is that a conversational partner's utterances can provide a scaffold for children's syntactic production during dialogue, inducing them to produce complex structures that they would not otherwise spontaneously produce (Messenger, 2009, found that children never spontaneously produced passives for these stimuli in a context where they were never exposed to passive primes), as well as influencing their long-term language development.[1] This scaffolding can occur across non-adjacent utterances, as well as building up through the course of a dialogue. Such scaffolded production may play an important role in children's syntactic development, supporting their use of complex structures until they are sufficiently practised to produce them independently.

The tendency for children to repeat their partner's syntax within a dialogue may also be important for successful communication in another respect. Pickering and Garrod (2004) suggested that convergence on common language use, including syntax, may play a causal role in the achievement of mutual understanding by bringing about the alignment of interlocutors' mental models. If so, then a tendency for children to repeat their partner's syntax and vice versa would make it more likely that they would correctly understand each other. This prediction remains to be tested in future research.

Conclusion

We have shown that children's syntactic production in dialogue is immediately influenced by individual experiences of both syntactic structure and verb–structure pairings in a conversational partner's utterances. However, these effects have different timecourses, suggesting that they are subserved by different mechanisms, consistent with existing models of adult syntactic priming. Our results further suggest broad continuity of syntactic processing between three and four year old children and adults in language production, with respect to structural representations and processes, and the contribution of the lexicon.

---

[1] We assume that the partner's utterances facilitate the use of a structure that the child has already acquired (but that may be relatively inaccessible for spontaneous use). This assumption is borne out by the fact that children did not require exposure to multiple primes to produce a passive. We do not address here the important question of how a partner's utterances within a dialogue might affect the process of initial acquisition itself.

Acknowledgments

Appendix A

A.1. Experimental materials

Materials are presented as Prime (same-verb active/passive; different-verb active/passive)–Target (Agent Verb Patient) pairs. (For brevity, we do not include fillers).

1. *A rabbit is biting a doctor/A doctor is being bitten by a rabbit; A cat is chasing a boy/A boy is being chased by a cat* – Tiger biting fireman
2. *A horse is chasing a soldier/A soldier is being chased by a horse; A sheep is kissing a queen/A queen is being kissed by a sheep* – Dog chasing robber
3. *A frog is kissing a doctor/A doctor is being kissed by a frog; An elephant is lifting a girl/A girl is being lifted by an elephant* – Horse kissing robber
4. *An elephant is lifting a witch/A witch is being lifted by an elephant; A horse is pulling a fairy/A fairy is being pulled by a horse* – Lion lifting doctor
5. *A tiger is pulling a soldier/A soldier is being pulled by a tiger; A pig is pushing a witch/A witch is being pushed by a pig* – Horse pulling girl
6. *A dog is pushing a girl/A girl is being pushed by a dog; A dog is biting a robber/A robber is being bitten by a dog* – Pig pushing king
7. *A horse is biting a fireman/A fireman is being bitten by a horse; A horse is kissing a witch/A witch is being kissed by a horse* – Dog biting clown
8. *A dog is chasing a queen/A queen is being chased by a dog; An elephant is lifting a nurse/A nurse is being lifted by an elephant* – Horse chasing boy
9. *A frog is kissing a queen/A queen is being kissed by a frog; A bear is pulling a witch/A witch is being pulled by a bear* – Sheep kissing boy
10. *A lion is lifting a witch/A witch is being lifted by a lion; A sheep is pushing a king/A king is being pushed by a sheep* – Elephant lifting boy
11. *A lion is pulling a doctor/A doctor is being pulled by a lion; A rabbit is biting a nurse/A nurse is being bitten by a rabbit* – Horse pulling soldier
12. *A dog is pushing a king/A king is being pushed by a dog; A tiger is chasing a soldier/A soldier is being chased by a tiger* – Sheep pushing girl
13. *A horse is biting a robber/A robber is being bitten by a horse; A sheep is lifting a witch/A witch is being lifted by a sheep* – Dog biting fireman
14. *A dog is chasing a fairy/A fairy is being chased by a dog; A tiger is pulling a fairy/A fairy is being pulled by a tiger* – Cat chasing queen
15. *A horse is kissing a witch/A witch is being kissed by a horse; A pig is pushing a girl/A girl is being pushed by a pig* – Frog kissing king
16. *A tiger is lifting a robber/A robber is being lifted by a tiger; A tiger is biting a doctor/A doctor is being bitten by a tiger* – Lion lifting nurse
17. *A bear is pulling a fireman/A fireman is being pulled by a bear; A horse is chasing a fairy/A fairy is being chased by a horse* – Lion pulling witch
18. *A sheep is pushing a witch/A witch is being pushed by a sheep; A horse is kissing a king/A king is being kissed by a horse* – Dog pushing fireman
19. *A tiger is biting a nurse/A nurse is being bitten by a tiger; A lion is pulling a girl/A girl is being pulled by a lion* – Horse biting boy
20. *A horse is chasing a queen/A queen is being chased by a horse; A sheep is pushing a fireman/A fireman is being pushed by a sheep* – Dog chasing king
21. *A horse is kissing a fireman/A fireman is being kissed by a horse; A dog is biting a boy/A boy is being bitten by a dog* – Sheep kissing clown
22. *A tiger is lifting a witch/A witch is being lifted by a tiger; A dog is chasing a witch/A witch is being chased by a dog* – Sheep lifting boy
23. *A horse is pulling a doctor/A doctor is being pulled by a horse; A sheep is kissing a fireman/A fireman is being kissed by a sheep* – Bear pulling girl
24. *A dog is pushing a witch/A witch is being pushed by a dog; A tiger is lifting a doctor/A doctor is being lifted by a tiger* – Pig pushing fireman
25. *A rabbit is biting a doctor/A doctor is being bitten by a rabbit; A cat is chasing a boy/A boy is being chased by a cat* – Horse biting witch
26. *A horse is chasing a soldier/A soldier is being chased by a horse/A sheep is kissing a queen; A queen is being kissed by a sheep* – Cat chasing fairy
27. *A frog is kissing a doctor/A doctor is being kissed by a frog; An elephant is lifting a girl/A girl is being lifted by an elephant* – Sheep kissing king
28. *An elephant is lifting a witch/A witch is being lifted by an elephant; A horse is pulling a fairy/A fairy is being pulled by a horse* – Sheep lifting nurse
29. *A tiger is pulling a soldier/A soldier is being pulled by a tiger; A pig is pushing a witch/A witch is being pushed by a pig* – Bear pulling doctor
30. *A dog is pushing a girl/A girl is being pushed by a dog; A dog is biting a robber/A robber is being bitten by a dog* – Sheep pushing doctor
31. *A horse is biting a fireman/A fireman is being bitten by a horse; A horse is kissing a witch/A witch is being kissed by a horse* – Rabbit biting fairy
32. *A dog is chasing a queen/A queen is being chased by a dog; An elephant is lifting a nurse/A nurse is being lifted by an elephant* – Horse chasing witch
33. *A frog is kissing a queen/A queen is being kissed by a frog; A bear is pulling a witch/A witch is being pulled by a bear* – Sheep kissing robber
34. *A lion is lifting a witch/A witch is being lifted by a lion; A sheep is pushing a king/A king is being pushed by a sheep* – Tiger lifting girl
35. *A lion is pulling a doctor/A doctor is being pulled by a lion; A rabbit is biting a nurse/A nurse is being bitten by a rabbit* – Tiger pulling fireman

36. *A dog is pushing a king/A king is being pushed by a dog; A tiger is chasing a soldier/A soldier is being chased by a tiger* – Cat pushing clown

37. *A horse is biting a robber/A robber is being bitten by a horse; A sheep is lifting a witch/A witch is being lifted by a sheep* – Tiger biting king

38. *A dog is chasing a fairy/A fairy is being chased by a dog; A tiger is pulling a fairy/A fairy is being pulled by a tiger* – Horse chasing king

39. *A horse is kissing a witch/A witch is being kissed by a horse; A pig is pushing a girl/A girl is being pushed by a pig* – Frog kissing fireman

40. *A tiger is lifting a robber/A robber is being lifted by a tiger; A tiger is biting a doctor/A doctor is being bitten by a tiger* – Lion lifting soldier

41. *A bear is pulling a fireman/A fireman is being pulled by a bear; A horse is chasing a fairy/A fairy is being chased by a horse* – Tiger pulling doctor

42. *A sheep is pushing a witch/A witch is being pushed by a sheep; A horse is kissing a king/A king is being kissed by a horse* – Rabbit pushing girl

43. *A tiger is biting a nurse/A nurse is being bitten by a tiger; A lion is pulling a girl/A girl is being pulled by a lion* – Rabbit biting boy

44. *A horse is chasing a queen/A queen is being chased by a horse; A sheep is pushing a fireman/A fireman is being pushed by a sheep* – Cat chasing witch

45. *A horse is kissing a fireman/A fireman is being kissed by a horse; A dog is biting a boy/A boy is being bitten by a dog* – Frog kissing fairy

46. *A tiger is lifting a witch/A witch is being lifted by a tiger; A dog is chasing a witch/A witch is being chased by a dog* – Elephant lifting robber

47. *A horse is pulling a doctor/A doctor is being pulled by a horse; A sheep is kissing a fireman/A fireman is being kissed by a sheep* – Lion pulling fairy

48. *A dog is pushing a witch/A witch is being pushed by a dog; A tiger is lifting a doctor/A doctor is being lifted by a tiger* – Cat pushing fireman

References

Abbot-Smith, K., Lieven, E., & Tomasello, M. (2001). What preschool children do and do not do with ungrammatical word orders. *Cognitive Development, 16*, 679–692. http://dx.doi.org/10.1016/S0885-2014(01)00054-5.

Akhtar, N. (1999). Acquiring basic word order: Evidence for data-driven learning of syntactic structure. *Journal of Child Language, 26*, 339–356. http://dx.doi.org/10.1017/S030500099900375X.

Ambridge, B., Pine, J. M., Rowland, C. F., & Young, C. R. (2008). The effect of verb semantic class and verb frequency (entrenchment) on children's and adults' graded judgements of argument-structure overgeneralization errors. *Cognition, 106*, 87–129. http://dx.doi.org/10.1016/j.cognition.2006.12.015.

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*, 390–412. http://dx.doi.org/10.1016/j.jml.2007.12.005.

Bannard, C., Lieven, E., & Tomasello, M. (2009). Modeling children's early grammatical knowledge. *Proceedings of the National Academy of Sciences of the United States of America, 106*, 17284–17289. http://dx.doi.org/10.1073/pnas.0905638106.

Bannard, C., & Matthews, D. (2008). Stored word sequences in language learning. *Psychological Science, 19*, 241–248. http://dx.doi.org/10.1111/j.1467-9280.2008.02075.x.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*, 255–278. http://dx.doi.org/10.1016/j.jml.2012.11.001.

Bates, D., Maechler, M., Bolker, B. M., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*. Available from1406.5823.

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*, 97–113. http://dx.doi.org/10.1016/j.jml.2007.12.007.

Bernolet, S., Colleman, T., & Hartsuiker, R. J. (2014). The "sense boost" to dative priming: Evidence for sense-specific verb–structure links. *Journal of Memory and Language, 76*, 113–126. http://dx.doi.org/10.1016/j.jml.2014.06.006.

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

Bock, K. (1989). Closed-class immanence in sentence production. *Cognition, 31*, 163–186. http://dx.doi.org/10.1016/0010-0277(89)90022-X.

Bock, K., Dell, G. S., Chang, F., & Onishi, K. H. (2007). Persistent structural priming from language comprehension to language production. *Cognition, 104*, 437–458. http://dx.doi.org/10.1016/j.cognition.2006.07.003.

Bock, K., & Ferreira, V. S. (2014). Syntactically speaking Retrieved fromhttp://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199735471.001.0001/oxfordhb-9780199735471-e-008.

Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General, 129*, 177–192. http://dx.doi.org/10.1037/0096-3445.129.2.177.

Bock, K., & Loebell, H. (1990). Framing sentences. *Cognition, 35*, 1–39. http://dx.doi.org/10.1016/0010-0277(90)90035-I.

Branigan, H. P., McLean, J. F., & Jones, M. W. (2005). A blue cat or a cat that is blue? Evidence for abstract syntax in young children's noun phrases. In A. Brugos, M. Clark-Cotton, & S. Ha (Eds.), *BUCLD 29: The proceedings of the twenty-ninth boston university conference on language development* (pp. 109–121). Somerville MA: Cascadilla Press.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition, 75*, 13–25. http://dx.doi.org/10.1016/S0010-0277(99)00081-5.

Branigan, H. P., Pickering, M. J., McLean, J. F., & Cleland, A. A. (2007). Syntactic alignment and participant role in dialogue. *Cognition, 104*, 163–197. http://dx.doi.org/10.1016/j.cognition.2006.05.006.

Brooks, P., Tomasello, M., Dodson, K., & Lewis, L. (1999). Young children's overgeneralizations with fixed transitivity verbs. *Child Development, 70*, 1325–1337. Retrieved fromhttp://www.academia.edu/9410401/Young_Children_s_Overgeneralizations_with_Fixed_Transitivity_Verbs.

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review, 113*, 234–272. http://dx.doi.org/10.1037/0033-295X.113.2.234.

Chang, F., Janciauskas, M., & Fitz, H. (2012). Language adaptation and learning: Getting explicit about implicit learning. *Linguistics and Language Compass, 6*, 259–278. http://dx.doi.org/10.1002/lnc3.337.

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*, 214–230. http://dx.doi.org/10.1016/S0749-596X(03)00060-3.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159. http://dx.doi.org/10.1037/0033-2909.112.1.155.

Coyle, J. M., & Kaschak, M. P. (2008). Patterns of experience with verbs affect long-term cumulative structural priming. *Psychonomic Bulletin & Review, 15*, 967–970. http://dx.doi.org/10.3758/PBR.15.5.967.

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. Retrieved from http://psycnet.apa.org/?&fa=main.doiLanding&doi=10.1037/1082-989X.1.2.170.

Ferreira, V. S., & Bock, K. (2006). The functions of structural priming. *Language and Cognitive Processes, 21*, 1011–1029. http://dx.doi.org/10.1080/016909600824609.

Fine, A. B., Jaeger, T. F., Farmer, T. A., & Qian, T. (2013). Rapid expectation adaptation during syntactic comprehension. *PLoS ONE, 8*, e77661. http://dx.doi.org/10.1371/journal.pone.0077661.

Goldberg, A. (2006). Constructions at work: The nature of generalization in language. *Constructions at work*. http://dx.doi.org/10.1093/acprof.

Gordon, P., & Chafetz, J. (1990). Verb-based versus class-based accounts of actionality effects in children's comprehension of passives. *Cognition, 36*, 227–254. http://dx.doi.org/10.1016/0010-0277(90)90058-R.

Gries, S. T. (2005). Syntactic priming: A corpus-based approach. *Journal of Psycholinguistic Research, 34*, 365–399. http://dx.doi.org/10.1007/s10936-005-6139-3.

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*, 214–238. http://dx.doi.org/10.1016/j.jml.2007.07.003.

Hartsuiker, R. J., & Kolk, H. H. (1998). Syntactic facilitation in agrammatic sentence production. *Brain and Language, 62*, 221–254. http://dx.doi.org/10.1006/brln.1997.1905.

Huttenlocher, J., Vasilyeva, M., Cymerman, E., & Levine, S. (2002). Language input and child syntax. *Cognitive Psychology, 45*, 337–374.

Huttenlocher, J., Vasilyeva, M., & Shimpi, P. (2004). Syntactic priming in young children. *Journal of Memory and Language, 50*, 182–195. http://dx.doi.org/10.1016/j.jml.2003.09.003.

Huttenlocher, J., Waterfall, H., Vasilyeva, M., Vevea, J., & Hedges, L. V. (2010). Sources of variability in children's language growth. *Cognitive Psychology, 61*, 343–365. http://dx.doi.org/10.1016/j.cogpsych.2010.08.002.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language, 59*, 434–446. http://dx.doi.org/10.1016/j.jml.2007.11.007.

Jaeger, T. F., & Snider, N. E. (2013). Alignment as a consequence of expectation adaptation: Syntactic priming is affected by the prime's prediction error given both prior and recent experience. *Cognition, 127*, 57–83. http://dx.doi.org/10.1016/j.cognition.2012.10.013.

Kaschak, M. P. (2007). Long-term structural priming affects subsequent patterns of language production. *Memory & Cognition, 35*, 925–937. http://dx.doi.org/10.3758/BF03193466.

Kaschak, M. P., & Borreggine, K. L. (2008). Is long-term structural priming affected by patterns of experience with individual verbs? *Journal of Memory and Language, 58*, 862–878. http://dx.doi.org/10.1016/j.jml.2006.12.002.

Kaschak, M. P., Loney, R. A., & Borreggine, K. L. (2006). Recent experience affects the strength of structural priming. *Cognition, 99*. http://dx.doi.org/10.1016/j.cognition.2005.07.002.

Lieven, E. (2010). Input and first language acquisition: Evaluating the role of frequency. *Lingua, 120*, 2546–2556. http://dx.doi.org/10.1016/j.lingua.2010.06.005.

Malhotra, G., Pickering, M., Branigan, H., & Bednar, J. A. (2008). On the persistence of structural priming: Mechanisms of decay and influence of word-forms. In *Proceedings of the 30th annual conference of the Cognitive Science Society* (pp. 657–662). Retrieved from http://www.psy.ed.ac.uk/people/martinp/pdf/46-persistence of structural priming2008.pdf.

Matthews, D., Lieven, E., Theakston, A., & Tomasello, M. (2005). The role of frequency in the acquisition of English word order. *Cognitive Development, 20*, 121–136. http://dx.doi.org/10.1016/j.cogdev.2004.08.001.

McCauley, S. M., & Christiansen, M. H. (2011). Learning simple statistics for language comprehension and production : The CAPPUCCINO model simulation 1 : Modeling comprehension and production. In L. Carlson, C. Hölscher, & T. Shipley (Eds.), *Proceedings of the 33rd annual conference of the Cognitive Science Society* (pp. 1619–1624). Retrieved from http://csjarchive.cogsci.rpi.edu/Proceedings/2011/papers/0363/paper0363.pdf.

Melinger, A., Branigan, H. P., & Pickering, M. J. (2014). Parallel processing in language production. *Language, Cognition and Neuroscience, 29*, 663–683. http://dx.doi.org/10.1080/23273798.2014.906635.

Messenger, K. (2009). *Syntactic priming and children's production and representation of the passive.* University of Edinburgh.

Messenger, K., Branigan, H. P., & McLean, J. F. (2012). Is children's acquisition of the passive a staged process? Evidence from six- and nine-year-olds' production of passives. *Journal of Child Language, 39*, 991–1016. http://dx.doi.org/10.1017/S0305000911000377.

Messenger, K., Branigan, H. P., McLean, J. F., & Sorace, A. (2012). Is young children's passive syntax semantically constrained? Evidence from syntactic priming. *Journal of Memory and Language, 66*, 568–587. http://dx.doi.org/10.1016/j.jml.2012.03.008.

Naigles, L. R., & Hoff-Ginsberg, E. (1998). Why are some verbs learned before other verbs? Effects of input frequency and structure on children's early verb use. *Journal of Child Language, 25*, 95–120. http://dx.doi.org/10.1017/S0305000997003358.

Naito, M. (1990). Repetition priming in children and adults: Age-related dissociation between implicit and explicit memory. *Journal of Experimental Child Psychology, 50*, 462–484. http://dx.doi.org/10.1016/0022-0965(90)90081-l.

Newport, E. L., Gleitman, H., & Gleitman, L. R. (1977). Mother, I'd rather do it myself: Some effects and non-effects of maternal speech style. In *Talking to children: Language input and interaction* (pp. 109–150).

Ninio, A. (1999). Pathbreaking verbs in syntactic development and the question of prototypical transitivity. *Journal of Child Language, 26*, 619–653. http://dx.doi.org/10.1017/S0305000999003931.

Peter, M., Chang, F., Pine, J. M., Blything, R., & Rowland, C. F. (2015). When and how do children develop knowledge of verb argument structure? Evidence from verb bias effects in a structural priming task. *Journal of Memory and Language, 81*, 1–15. http://dx.doi.org/10.1016/j.jml.2014.12.002.

Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language, 39*, 633–651. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S074959X9892592X.

Pickering, M. J., & Branigan, H. P. (1999). Syntactic priming in language production. *Trends in Cognitive Sciences.* http://dx.doi.org/10.1016/S1364-6613(99)01293-0.

Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *The Behavioral and Brain Sciences, 27*, 169–190. discussion 190–226.

Reitter, D., Keller, F., & Moore, J. D. (2011). A computational cognitive model of syntactic priming. *Cognitive Science, 35*, 587–637. http://dx.doi.org/10.1111/j.1551-6709.2010.01165.x.

Rowland, C. F., Chang, F., Ambridge, B., Pine, J. M., & Lieven, E. V. M. (2012). The development of abstract syntax: Evidence from structural priming and the lexical boost. *Cognition, 125*, 49–63. http://dx.doi.org/10.1016/j.cognition.2012.06.008.

Sachs, J. S. (1967). Recopition memory for syntactic and semantic aspects of connected discourse. *Perception & Psychophysics, 2*, 437–442. http://dx.doi.org/10.3758/BF03208784.

Schoonbaert, S., Hartsuiker, R. J., & Pickering, M. J. (2007). The representation of lexical and syntactic information in bilinguals: Evidence from syntactic priming. *Journal of Memory and Language, 56*, 153–171. http://dx.doi.org/10.1016/j.jml.2006.10.002.

Shimpi, P. M., Gámez, 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*, 1334–1346. http://dx.doi.org/10.1037/0012-1649.43.6.1334.

Sprondel, V., Kipp, K. H., & Mecklinger, A. (2011). Developmental changes in item and source memory: Evidence from an ERP recognition memory study with children, adolescents, and adults. *Child Development, 82*, 1638–1953. http://dx.doi.org/10.1111/j.1467-8624.2011.01642.x.

Theakston, A. L., Lieven, E. V. M., Pine, J. M., & Rowland, C. F. (2002). Going, going, gone: The acquisition of the verb "go". *Journal of Child Language, 29*, 783–811. http://dx.doi.org/10.1017/S030500090200538X.

Thothathiri, M., & Snedeker, J. (2008). Syntactic priming during language comprehension in three- and four-year-old children. *Journal of Memory and Language, 58*, 188–213. http://dx.doi.org/10.1016/j.jml.2007.06.012.

Tomasello, M. (2003). *Constructing a language. A usage-based theory of language acquisition.* Harvard University Press. Retrieved from http://scholar.google.com.tr/scholar?q=Tomasello+2003&btnG=Search&hl=en&as_sdt=2000#4.

Twomey, K. E., Chang, F., & Ambridge, B. (2014). Do as I say, not as I do: A lexical distributional account of English locative verb class acquisition. *Cognitive Psychology, 73*, 41–71. http://dx.doi.org/10.1016/j.cogpsych.2014.05.001.