Evidence for robust abstract syntactic representations in production before age three

Anouschka Foltz
University of Graz, Austria

Karolin Knopf
Bielefeld University, Germany

Kristina Jonas
University of Cologne, Germany

Petra Jaecks
Bielefeld University, Germany

Prisca Stenneken
University of Cologne, Germany

Abstract
This study investigated whether we can find reliable comprehension-to-production syntactic priming effects in children aged 2;0 to 2;11 and how phonological working memory and sentence production skills relate to the syntactic priming process. A finding of reliable syntactic priming effects would provide strong evidence that children’s syntactic representations are abstracted over individual lexical items. To test children at this young age, they were primed with simple and early-acquired transitive (e.g., tickling (a) baby) and unergative intransitive (e.g., running) syntactic structures. Children aged 2;7 to 2;11, primed with alternating prime structures, revealed a reliable syntactic priming effect. In addition, phonological working memory (moderated by age) and sentence production skills positively affected transitive productions. Children aged...
2;0 to 2;6, primed either with alternating or cumulative prime structures, showed no priming effect. Together, the data indicate that children have robust abstract syntactic representations for the tested structures before age three and that both phonological working memory and production skills relate to children’s syntactic priming behavior, albeit in different ways.

**Keywords**

Acquisition of syntax, early-abstraction accounts, generativist-nativist approaches, phonological working memory, sentence production skills, syntactic priming, transitive and intransitive sentences, usage-based-constructivist accounts

**Introduction**

Syntax is a highly abstract system that shows considerable structural complexity and idiosyncrasies: Some verbs can be used only intransitively (e.g., *Peter sneezed*, but not *Peter sneezed that table*), others can be used only transitively (e.g., *Mary saw the girl*, but not *Mary saw*), and still others can be used both intransitively and transitively (e.g., *Mary understood and Mary understood the argument*), often with a preference for one structure over another. When children learn these intricacies, they may rely on abstract concepts such as nouns, verbs, noun phrases, etc. (Fisher, 2002), which we typically assume for adults (e.g., Fisher, 2002; Tomasello, 2000; but see Ambridge, 2019, for an argument against syntactic abstractions). Alternatively, children’s syntactic structures may initially be based on concrete lexical items and may only later become abstract (e.g., Tomasello, 2003) in the sense that children can comprehend and produce these structures with novel verbs and arguments. While evidence for early syntactic abstraction tends to come from comprehension studies (e.g., Naigles, 1990), production paradigms tend to support late abstraction (e.g., Shimpi et al., 2007). In this study, we use a syntactic priming task to test for evidence of abstract syntactic representations in two-year-old children’s productions, and assess whether working memory capacity or syntactic skills modulate children’s productions of the primed structures.

**The development of abstract syntactic representations**

An intense debate in the language acquisition literature concerns when children’s syntactic representations become abstract (e.g., Bencini & Valian, 2008; Rowland et al., 2012; Savage et al., 2003; Shimpi et al., 2007; Valian et al., 2009), with generativist-nativist approaches positing abstraction from birth (e.g., Pinker, 1989; Wexler, 1998), early-abstraction accounts suggesting syntactic abstraction ‘early in the course of lexical learning’ (e.g., Gertner et al., 2006, p. 685), and usage-based-constructivist accounts arguing for gradually-occurring late abstraction (e.g., Tomasello, 1992, 2000, 2003). Specifically, syntactic abstraction in usage-based-constructivist approaches is believed to be a slow process (Thornton, 2016), with abstract syntactic representations for transitive structures assumed to be in place around the age of 3;0 at the earliest (Tomasello, 2000).

These approaches also differ in how they characterize abstractness, with generativist-nativist approaches referring to hierarchical syntactic representations (Thornton, 2016),
early-abstraction accounts invoking generalizations that apply readily to new cases (Gertner et al., 2006; Naigles, 2002), and usage-based-constructivist approaches positing syntactic representations that are initially tied to specific lexical items and that become abstract gradually as exemplars, from which children discern patterns, are accumulated (e.g., Abbot-Smith & Tomasello, 2006). The latter approach thus allows for different degrees of abstraction, such that children’s early syntactic representations for a sentence like *I kick ball* could, for example, resemble a slot-and-frame pattern like kicker-KICK-kickee or NP-KICK-NP (Pine & Lieven, 1997; Tomasello, 1992). Given enough exemplars, children can generalize syntactic constructions across different verbs, giving rise to robust abstract, i.e., lexically-independent, syntactic representations, such as S-V-O (Tomasello, 2000).

Evidence from comprehension and production paradigms diverges as to when children’s syntactic representations become abstract. Comprehension paradigms, such as preferential-looking or pointing, have found evidence for syntactic abstractions for transitive structures as early as 1;7 (e.g., Dittmar et al., 2011; Naigles, 1990; Yuan et al., 2012). In contrast, naturalistic observations (e.g., Tomasello, 1992) and production paradigms, including weird word order, nonce verb and syntactic priming studies (Bencini & Valian, 2008; Brooks & Tomasello, 1999; Kemp et al., 2005; Matthews et al., 2005; Miller & Deevy, 2006; Shimpi et al., 2007; Stumper & Szagun, 2008; but see Franck et al., 2011) have found evidence for abstract syntactic representations only from around three years of age. Usage-based-constructivist accounts suggest that comprehension tasks require merely weak syntactic knowledge derived from fewer exemplars (Abbot-Smith et al., 2004; Dittmar et al., 2008), and thus do not robustly test for syntactic productivity. Generativist-nativist and early-abstraction proponents instead propose that production tasks may pose too many demands on children to tap into their abstract syntactic representations (see Conwell & Demuth, 2007, for a discussion).

**Syntactic priming**

In this study, we use a syntactic priming production task (Bock, 1986) to test for strong abstract syntactic representations in children under the age of three. Syntactic priming refers to the spontaneous re-use of previously encountered syntactic structures. Importantly, priming effects ‘implicate a direct relationship between representation and behavior’ (Branigan & Pickering, 2017, p. 6), suggesting that syntactic priming is better suited to tap into abstract syntactic representations than naturalistic observations or other production paradigms.

In a typical syntactic priming task with children, the experimenter may describe a prime picture of a dog chasing a cat as either *the dog is chasing the cat* (active) or *the cat is being chased by the dog* (passive). A reliable syntactic priming effect occurs if children produce significantly more passive sentences following passive descriptions than following active descriptions (Bock, 1986). The basic assumption is that if the experimenter’s descriptions share no content/open-class words with the children’s descriptions, i.e., if there is no lexical overlap between prime and target, then the priming effect must rely on abstract, i.e., lexically-independent, syntactic representations because it reflects the ‘repetition of aspects of abstract linguistic structure’ (Branigan & Pickering, 2017, p. 2; but see Ziegler et al., 2018).
A reliable syntactic priming effect without lexical overlap has been found in several studies that include children under the age of three (e.g., children aged 2;11–3;6 in Bencini & Valian, 2008; 2;3–2;11 in Kemp et al., 2005; 2;8–4;5 in Miller & Deevy, 2006; and 2;6–3;6 in Shimpi et al., 2007). However, in all of these studies, such an effect occurred when children repeated the prime sentence before producing the target sentence (Bencini & Valian, 2008; Kemp et al., 2005; Miller & Deevy, 2006) and received concentrated input, either because they experienced only one of the syntactic alternatives (Bencini & Valian, 2008; Kemp et al., 2005; Shimpi et al., 2007) or because the prime structures were presented in blocks (Miller & Deevy, 2006). Thus, these studies reinforce the use of one structure and do not test whether children can alternate between different structures (Rowland et al., 2012). In addition, only comprehension-to-production priming is ‘directly informative about representation[s]’ (Branigan & Pickering, 2017, p. 6), whereas production-to-production priming may instead reflect production-specific aspects of processing. Similarly, comprehension paradigms may merely reflect comprehension-specific aspects of processing rather than information about representations. Strong evidence for robust and accessible abstract syntactic representations in young children therefore needs to come from a reliable syntactic priming effect in a comprehension-to-production task with alternating prime structures (Messenger et al., 2011; Shimpi et al., 2007). To the best of our knowledge, the current study is the first syntactic priming study that investigates whether two-year-olds show evidence for abstract syntactic representations using such a task.

Syntactic priming studies with children also typically yield rather large individual differences (Kidd, 2012b). To explain such individual differences, numerous studies have explored which factors may modulate children’s syntactic priming behavior (Foltz et al., 2015; Kidd, 2012b; Messenger et al., 2012; Shimpi et al., 2007). In order to contribute to this line of research, we additionally investigate how phonological working memory and syntactic skills (see below), two factors with currently inconclusive results, modulate children’s syntactic priming behavior.

The role of working memory

Working memory is a limited-capacity cognitive system that temporarily stores information being processed (Miyake & Shah, 1999). Verbal working memory is important for syntactic acquisition because it significantly predicts children’s syntactic skills (Verhagen & Leseman, 2016) and because it allows maintaining sequence information in the short term (Ellis, 1996), which is especially important for alternating between syntactic structures. In line with this, individual differences in children’s working memory capacity have been found to modulate children’s syntactic priming behavior. Foltz et al. (2015) primed children with alternating prenominal (e.g., the red bear) and relative-clause (e.g., the bear that’s red) structures. Children with lower working memory capacity produced fewer relative-clause structures overall than children with higher working memory capacity (see Bourdin et al., 2018, for similar results). Thus, working memory capacity positively interacted with the frequency of how often children produced a dispreferred (i.e., overall less frequently used) and more complex syntactic structure. It is thus possible that reliable syntactic priming effects, which would point to abstract syntactic representations, rely on sufficient working memory capacity.
The role of syntactic skills

Syntactic skills change rapidly during the third year of life and involve temporary regressions, but also rapid growth, which may index critical points in language acquisition (Bassano & Van Geert, 2007). In line with this, syntactic priming studies have explored how individual differences in children’s receptive and productive syntactic skills modulate their syntactic priming behavior, with inconclusive results: When primed with full passive sentences, children’s receptive syntactic skills positively correlated with their priming magnitude using a strict coding scheme (requiring passives to be produced with a by-phrase), but not using a lax coding scheme (allowing for passives without a by-phrase; Kidd, 2012b). Moreover, children’s productive syntactic skills did not affect relative-clause productions when children were primed with prenominal (e.g., the red bear) and relative-clause (e.g., the bear that’s red) structures (Foltz et al., 2015). It is therefore still unclear how syntactic skills and syntactic priming effects are related in young children.

The current study

The current study is the first to employ a comprehension-to-production syntactic priming paradigm with alternating syntactic structures and without lexical overlap to test for robust and accessible abstract syntactic representations in production before the age of three in German-acquiring children. To test such young children, we used early-acquired (unergative) intransitive and transitive structures (Miller & Deevy, 2006), similar to previous comprehension studies (e.g., Yuan et al., 2012). This differs from previous syntactic priming production studies, which have typically primed children with rather complex or late-acquired syntactic alternations, such as active vs. passive (Bencini & Valian, 2008; Huttenlocher et al., 2004; Kidd, 2012a, 2012b; Messenger et al., 2012; Savage et al., 2003; Shimpi et al., 2007) or the dative alternation (Huttenlocher et al., 2004; Rowland et al., 2012; Shimpi et al., 2007; but see Miller & Deevy, 2006). Complex or late-acquired structures may not be ideal for testing how early children show evidence for abstract syntactic representations in production, as processing limitations may prevent children from producing these structures despite having the relevant abstract representations (Branigan & Pickering, 2017).

To minimize working memory demands, the child and experimenter took turns in describing pictures (Shimpi et al., 2007). To minimize production demands (Kirjavainen et al., 2017; Rowland et al., 2012), we pragmatically embedded the prime and target sentences in a question-answer context with the overarching question What is Emma doing? In this context, pictures of Emma performing various actions could be felicitously described with one- and two-word sentences like drinking or drinking juice, which German-acquiring children typically start producing before their second birthdays (Stumper & Szagun, 2008).

Importantly, German allows for two transitive alternants in such a discourse context. A picture of Emma drinking juice, for example, can be described transitively as Saft trinken (literally: juice to drink; here called transitive infinitive) or (Sie) trinkt Saft (literally: (She) is drinking juice or (She) drinks juice; here called transitive conjugated). Importantly, these two transitive options differ both in word order and verb form, such
that possible task-based effects (such as mentioning the pictured object when the experimenter has, and not mentioning it when she hasn’t) can be disentangled from syntactic priming effects. Specifically, transitive infinitive primes should prime transitive infinitive forms, but not transitive conjugated forms, and vice versa.

We additionally measured children’s phonological working memory capacity and productive syntactic skills to contribute to the still sparse data on which factors may modulate children’s syntactic priming behavior.

The experiment included three participant groups. The two main groups received alternating prime structures, with the older-alternating group including children aged 2;7 to 2;11 and the younger-alternating group comprising slightly younger children aged 2;0 to 2;6. An additional younger-cumulative group had children aged 2;0 to 2;6 receiving cumulative prime structures. The groups had small age ranges since syntax develops rapidly during the third year of life. Reliable syntactic priming effects for the two alternating groups would suggest that two-year-olds have robust and accessible abstract syntactic representations for transitive structures and that they can alternate between these structures (Rowland et al., 2012). Such a result would be compatible with both generativist-nativist and early-abstraction approaches, but would provide evidence against usage-based-constructivist accounts of syntax acquisition, which assume syntactic abstraction for transitive structures not until the age of three (Tomasello, 2000). The cumulative group was included to allow for the possibility that the younger two-year-olds may have only weakly represented abstractions and may thus benefit from concentrated input that reinforces one syntactic structure across several trials (as in Bencini & Valian, 2008; Huttenlocher et al., 2004; Kidd, 2012a, 2012b; Miller & Deevy, 2006; Savage et al., 2003; Shimpi et al., 2007; but see Messenger et al., 2011, 2012; Rowland et al., 2012), allowing them to develop a routine (Messenger et al., 2011). Overall, we tested at what age children show robust and accessible abstract syntactic representations for transitive infinitive structures in speech production without lexical overlap.

**Methods**

**Participants**

Forty-nine monolingual German-speaking children aged 2;0 to 2;11 participated in the study. The older-alternating group included 18 children aged 2;7 to 2;11 (mean = 2;9, SD = 0;1, 10 male, 8 female), the younger-alternating group comprised 15 children aged 2;0 to 2;6 (mean = 2;3, SD = 0;2, 7 male, 8 female), and the younger-cumulative group consisted of 16 children aged 2;0 to 2;6 (mean = 2;3, SD = 0;2, 8 male, 8 female). Eight further children were excluded because they produced more than two null responses within one experimental condition. The ELFRA-2 (Elternfragebögen für die Früherkennung von Risikokindern, English: Parental questionnaires for the early detection of children at risk, Grimm & Doil, 2000) confirmed that none of the children were late-talkers.

**Materials, procedure, and response coding**

**Syntactic priming task.** Prime and target pictures were color photographs showing a girl named Emma performing various actions. Eighteen target pictures showed six different
actions, each with three different objects (for example, drinking juice, water, and milk) that could be described with optionally transitive verbs, i.e., verbs that can either be used transitorily or intransitorily (unergative). Each action occurred once in each condition (baseline, intransitive infinitive prime, and transitive infinitive prime).

Prime pictures preceded target pictures in the two prime conditions, but not the baseline condition, for a total of 12 prime pictures. Six of the prime pictures could be described with unergative intransitive verbs, the remaining six with transitive verbs, none of which participate in an intransitive-transitive alternation (see Appendix 1 for all prime and target items).

There were three experimental lists, all starting with six baseline trials followed by 12 priming trials. For the two alternating groups, primes with an intransitive verb alternated with primes with a transitive verb during the 12 priming trials. For the cumulative group, all transitive prime trials occurred before all intransitive prime trials yielding six baseline trials, followed by six transitive prime trials, followed by six intransitive prime trials. We did not test any children in the cumulative group with intransitive primes before transitive primes because intransitive priming may persist into the transitive prime trials. A priming effect for transitive structures was thus more likely to occur if children experienced transitive primes before intransitive primes.

Prime pictures and target picture actions were kept constant across lists, but target picture patients/themes were rotated across lists, such that target pictures (i.e., showing the same action and patient/theme) appear in the baseline and both priming conditions across the three experimental lists. To avoid lexical overlap between prime and target, the verbs and object names that could be used to describe the prime pictures differed from those of the target pictures. Nouns and verbs were early-acquired (see Grimm, 2000, and Grimm & Doil, 2000, for acquisition norms) and easily depictable in color photographs; verbs were also easily combined with nouns (if applicable) to create plausible scenarios.

Children were tested in a separate room at their daycare facility (n = 31), at home (n = 1) or at Bielefeld University (n = 17). The vast majority of children completed all three tasks (described in this and the following two sections) in under 15 minutes. Children were seated next to the experimenter in front of a computer screen. All pictures were presented in a PowerPoint presentation. The experimenter first showed the child a picture of a girl and introduced her as Emma. To elicit spontaneous baseline descriptions (i.e., without any priming), children were then shown the six baseline target pictures and asked what Emma was doing. After that, the experimenter announced that they would now play the game together. The experimenter and child then took turns describing pictures, until all 12 prime-target trials were completed. The experimenter either used a transitive infinitive, e.g., Baby kitzen (literally: baby to tickle), or an intransitive infinitive, e.g., laufen (literally: to run), in her prime picture descriptions. During the baseline and priming trials, the child saw pictures that could be described with an optionally transitive verb, e.g., (Saft) trinken / trinkt (Saft) (literally: (juice) to drink / drinks (juice)), and told the experimenter what Emma was doing. If the child needed prompting at any time, the experimenter repeated the question What’ s Emma doing?

Table 1 shows the detailed response coding scheme used for children’s productions, with the response types used for the prime picture descriptions given in bold type. The second author or a trained student assistant coded all responses. The first author checked
Table 1. Response types used for coding children’s responses.

| Response type         | Response description                                      | Example                                      |
|-----------------------|------------------------------------------------------------|----------------------------------------------|
| Intransitive infinitive| Infinitive of verb                                         | trinken (literally: to drink)                |
| Intransitive conjugated| Conjugated verb                                            | (sie) trinkt ((she) drinks)                  |
| Transitive infinitive  | Object noun + infinitive of verb                           | Saft trinken (literally: juice to drink)     |
| Transitive conjugated  | Conjugated verb + object noun                              | (sie) trinkt Saft ((she) drinks juice)       |
| Transitive incorrect   | Infinitive of verb + object noun; object noun + conjugated verb | *trinken Saft (literally: to drink juice); *Saft trinkt (literally: juice drinks) |
| Incompatible verb      | Verb that is not optionally transitive                      | Wäsche machen (literally: laundry to do); lacht (laughs) |
| Other                 | All other responses                                         | Saft (juice), lecker (yummy), no response, etc. |

all coded responses, and difficult cases were resolved within the research team. Only children’s first spontaneous response was coded. Two intransitive and three transitive response types constitute felicitous responses: Intransitive infinitive responses include an optionally transitive verb in the infinitive, and intransitive conjugated responses involve a conjugated, optionally transitive verb. Transitive infinitive responses contain an object noun followed by an optionally transitive verb in the infinitive, transitive conjugated responses include a conjugated, optionally transitive verb followed by an object noun, and transitive incorrect responses involve a transitive response with a mismatch in verb form and word order. Responses with verbs that differed from the intended ones, but that were also optionally transitive, were coded as above. Responses with non-optionally transitive verbs were coded as containing an incompatible verb. Responses which did not fit any of the above coding criteria were coded as other.

Phonological working memory test. Following the priming task, children performed a phonological working memory test. We chose a simple nonword-repetition test closely resembling the Mottier test (Risse & Kiese-Himmel, 2009), where children repeat nonwords with increasing numbers of syllables. Such a test is a relatively pure measure of phonological loop capacity because support from existing lexical knowledge is unlikely (Baddeley et al., 1998). The test consists of five blocks with six nonwords each, increasing in length from two to six syllables. All nonwords had a simple CV structure and exclusively contained early-acquired vowels (/a/, /u/, and /i/) and consonants (/t/, /d/, /p/, /b/, /n/, and /m/) that over 75% of German 18-month-olds can pronounce (Fox, 2011).

The experimenter first told the child that s/he would repeat some magic words. After a practice word, the experimenter moved through the blocks until the child repeated none of the nonwords in a block correctly, which was the criterion for ending the test.

Children received one point for each correctly repeated nonword and for each repeated nonword with the correct number of syllables and no more than two consonant omissions or substitutions. Such small deviations were scored as correct to minimize effects of
physiological pronunciation errors (analyses using strict coding that only count correctly repeated nonwords yielded the same results). Incorrectly repeated nonwords received no points. Children’s phonological working memory scores were calculated by adding the number of points, with a possible maximum score of 30.

**Sentence production test.** Following the working memory test, the *Production II: Sentences* subtest of the *SETK-2* (Sprachentwicklungstest für zweijährige Kinder; English: Language development test for two-year-old children; Grimm, 2000) measured children’s productive grammatical knowledge. The test consists of 16 pictures showing different situations and elicits various grammatical structures: Four pictures can be described with an intransitive verb, four pictures can be described with a transitive verb, and eight pictures require a prepositional phrase. The test was administered and coded as described in the *SETK-2* manual (Grimm, 2000). The maximum possible sentence production score was 96.

**Results**

**Descriptive statistics**

Table 2 shows children’s mean working memory and mean sentence productions scores across the three groups. The one-way ANOVA results presented in the table show similar working memory scores across all groups. Sentence production scores are significantly higher for the *older-alternating* group (ages 2;7 to 2;11) than the *younger-alternating* group (ages 2;0 to 2;6). In addition, the numerically higher sentence production scores for the *older-alternating* group (ages 2;7 to 2;11) just failed to reach significance compared to the *younger-cumulative* group (ages 2;0 to 2;6).

**Syntactic priming**

Our first analysis tested whether we can see reliable syntactic priming effects. Tables 3–5 show the numbers and percentages of the different types of children’s picture descriptions in the baseline and the two priming conditions for the *older-alternating, younger-alternating*, and *younger-cumulative* groups, respectively.

Across all three groups, children’s baseline responses show a strong preference for intransitive over transitive responses. We therefore focus our first analysis on whether transitive infinitive primes could increase children’s productions of the dispreferred (and more complex) transitive infinitives. For the analysis, responses were recoded to be binomial: transitive infinitive responses were coded as 1 and all other responses were coded as 0. We fit mixed-logit models (Baayen, 2008) using the `glmer()` function in R (R Development Core Team, 2008), which is fit by maximum likelihood with a Laplace Approximation. The initial model included children’s response (transitive infinitive or not) as response variable, prime type (baseline, intransitive infinitive prime, and transitive infinitive prime), group (*older-alternating, younger-alternating*, and *younger-cumulative*) and the prime type by group interaction as predictor variables, subject and item as random factors, and random slopes for the within-subject factor prime type. Fixed factors were centered to minimize collinearity. We used sum-coding here for ANOVA-style
Table 2. Mean working memory and sentence production scores across the three groups. One-way ANOVAs and, if applicable, Tukey HSD multiple comparisons gauge whether the means across groups are similar or different.

|                  | Older-alternating (OA) | Younger-alternating (YA) | Younger-cumulative (YC) | One-way ANOVA |
|------------------|-------------------------|--------------------------|-------------------------|---------------|
| Working memory   | 10.7 (SD = 5.3; range: 2–20) | 8.4 (SD = 3.6; range: 2–13) | 11.6 (SD = 5.4; range: 4–19) | $F(2,32) = 1.12$, $p = .34$ |
| Sentence production | 52.5 (SD = 15.3; range: 12–70) | 29.9 (SD = 15.7; range: 8–60) | 39.9 (SD = 13; range: 20–58) | $F(2,44) = 8.69$, $p < .001$ |

Tukey HSD:
- OA–YA: $p < .001$
- OA–YC: $p = .05$
- YA–YC: $p = .18$

Table 3. Total numbers and percentages for each response type in the baseline and priming conditions for older children aged 2;7 to 2;11 and alternating priming.

| Response type                  | Baseline | Prime |
|--------------------------------|----------|-------|
|                                | Intransitive infinitive | Transitive infinitive |
| Intransitive infinitive        | 27 (25.0%) | 47 (43.5%) | 42 (38.9%) |
| Intransitive conjugated        | 34 (31.5%) | 7 (6.5%) | 5 (4.6%) |
| Transitive infinitive         | 3 (2.8%) | 8 (7.4%) | 19 (17.6%) |
| Transitive conjugated         | 3 (2.8%) | 11 (10.2%) | 8 (7.4%) |
| Transitive incorrect          | 4 (3.7%) | 2 (1.9%) | 3 (2.8%) |
| Incompatible verb             | 11 (10.2%) | 8 (7.4%) | 10 (9.3%) |
| Other                         | 26 (24.1%) | 24 (23.2%) | 20 (19.4%) |
| Total                         | 108 (100%) | 108 (100%) | 108 (100%) |

Table 4. Total numbers and percentages for each response type in the baseline and priming conditions for younger children aged 2;0 to 2;6 and alternating priming.

| Response type                  | Baseline | Prime |
|--------------------------------|----------|-------|
|                                | Intransitive infinitive | Transitive infinitive |
| Intransitive infinitive        | 37 (41.1%) | 35 (38.9%) | 37 (41.1%) |
| Intransitive conjugated        | 14 (15.6%) | 5 (5.6%) | 6 (6.7%) |
| Transitive infinitive         | 4 (4.4%) | 13 (14.4%) | 6 (6.7%) |
| Transitive conjugated         | 1 (1.1%) | 2 (2.2%) | 2 (2.2%) |
| Transitive incorrect          | 2 (2.2%) | 2 (2.2%) | 3 (3.3%) |
| Incompatible verb             | 1 (1.1%) | 7 (7.8%) | 4 (4.4%) |
| Other                         | 31 (34.5%) | 26 (28.9%) | 32 (35.5%) |
| Total                         | 90 (100%) | 90 (100%) | 90 (100%) |
main effects and interactions because treatment contrasts (which we use below) are not recommended for models that include interactions (Singmann & Kellen, 2020). Random and fixed effects that did not contribute to model fit were removed from the initial model, and we report the final model from any model comparisons throughout.

The final model had prime type, group and the interaction as fixed effects and participant as random effect. The results revealed a significant main effect of prime type (coefficient = 0.41, \(SE = 0.17\), \(z = 2.35\), \(p = .019\)). A post-hoc test using the emmeans package shows significantly more transitive productions for intransitive primes compared to the baseline (coefficient = −1.03, \(SE = 0.38\), \(z = −2.69\), \(p = .02\)). The numerically higher number of transitive productions after transitive primes compared to the baseline just failed to reach significance (coefficient = −0.86, \(SE = 0.4\), \(z = −2.13\), \(p = .084\)). Finally, a similar number of transitive productions was observed for intransitive and transitive primes (coefficient = 0.18, \(SE = 0.33\), \(z = 0.55\), \(p = .848\)).

Importantly, the final model also included a significant prime type by group interaction (coefficient = −0.57, \(SE = 0.22\), \(z = −2.63\), \(p = .008\)). To explore the significant interaction, we fit separate models for each group, with prime type as fixed effect and the same random effects structure as above in the initial model. We used treatment coding for the prime type factor to directly compare the baseline with the transitive infinitive prime condition, and the intransitive infinitive prime condition with the transitive infinitive prime condition. The model comparison procedure was as described above.

We found clear syntactic priming effects for the older-alternating group, i.e., for children aged 2;7 to 2;11 and alternating prime structures. The final model included prime type as fixed effect and participant as random effect. Transitive infinitive responses increased significantly for transitive infinitive primes compared to the baseline (coefficient = 2.14, \(SE = 0.66\), \(z = 3.27\), \(p = .001\)) and compared to intransitive infinitive primes (coefficient = 1.07, \(SE = 0.47\), \(z = 2.29\), \(p = .022\)). The latter result suggests that priming occurred on a trial-by-trial basis.

In contrast, we found no priming effects for the two younger groups. The final model for the younger-alternating group, i.e., for children aged 2;0 to 2;6 and alternating prime structures, included prime type as fixed effect and participant as random effect. We found

### Table 5. Total numbers and percentages for each response type in the baseline and priming conditions for younger children aged 2;0 to 2;6 and cumulative priming.

| Response type               | Baseline | Prime |
|-----------------------------|----------|-------|
|                             | Intransitive infinitive | Transitive infinitive |
| Intransitive infinitive     | 25 (26.0%) | 27 (28.1%) | 28 (29.2%) |
| Intransitive conjugated     | 20 (20.9%) | 17 (17.7%) | 16 (16.7%) |
| Transitive infinitive       | 4 (4.2%) | 7 (7.3%) | 4 (4.2%) |
| Transitive conjugated       | 1 (1.0%) | 5 (5.2%) | 8 (8.3%) |
| Transitive incorrect        | 7 (7.3%) | 8 (8.3%) | 4 (4.2%) |
| Incompatible verb           | 9 (9.4%) | 8 (8.3%) | 7 (7.3%) |
| Other                       | 25 (26.0%) | 21 (21.9%) | 28 (29.2%) |
| Total                       | 96 (100%) | 96 (100%) | 96 (100%) |
a comparable number of transitive infinitive responses across all conditions for children aged 2;0 to 2;6. Specifically, children produced similar numbers of transitive infinitive responses for transitive infinitive primes compared to the baseline (coefficient = 0.48, SE = 0.7, z = 0.69, p = .492) and compared to intransitive infinitive primes (coefficient = −1.03, SE = 0.57, z = −1.81, p = .070), which just failed to reach significance. Note that in the latter case, children produced numerically more transitive responses following intransitive primes, not following transitive primes, suggesting that we do not even see a trend in the expected direction. The final model for the younger-cumulative group, i.e., for children aged 2;0 to 2;6 and cumulative prime structures, had no fixed and random effects, suggesting that children produced a similar number of transitive infinitive responses across all prime types.

Since we found evidence for clear priming effects only in the older-alternating group, i.e., in the older two-year-olds with alternating prime structures, we restrict all following analyses to this group. To test how structure-specific the priming effect for this group is, we performed an additional analysis to see if transitive infinitive primes also led to an increase in transitive conjugated responses. If so, this would either suggest that transitive structures in general were primed or that the priming effect may have been task-based in the sense that hearing transitive infinitive primes may have led children to believe that the experimenter wanted them to produce a picture description mentioning the pictured object (in addition to the verb) or simply produce a longer sentence. If not, then the priming effect would be restricted to transitive structures with the same word order and verb form as the prime, and we would argue that such a priming effect would be syntactic in nature rather than task-based.

For this analysis, we again recoded responses to be binomial, but with transitive conjugated responses coded as 1 and all other responses coded as 0. The initial model included children’s response (transitive conjugated or not) as response variable, prime type (baseline, intransitive infinitive prime, and transitive infinitive prime) as predictor variable, subject and item as random factors, and random slopes for prime type. We again used treatment coding for the prime type factor to directly compare the baseline with the transitive infinitive prime condition, and the intransitive infinitive prime condition with the transitive infinitive prime condition. The model comparison procedure was as described above. The final model included participant as a random factor, but no fixed effects, suggesting that children produced comparable numbers of transitive conjugated responses for transitive infinitive primes compared to the baseline and compared to intransitive infinitive primes. This result suggests that the priming effect is specific to the particular transitive structure that is being primed, and as such is unlikely to be a task-based effect.

Factors influencing production of transitives

Our second analysis investigated whether age, the sentence production score, and the phonological working memory score influenced how often children in the older-alternating group produced a transitive infinitive structure after being primed with this structure. Children with a missing working memory (n = 2) or sentence production (n = 1) score were included in the current analysis to maximize the amount of analyzable data and because mixed-effects models correct for missing values. Transitive infinitive
responses were coded as 1 and all other responses were coded as 0. We fit mixed-logit models for the subset of responses following transitive infinitive primes with children’s response (transitive infinitive or not) as response variable. The analysis used sum-coding for ANOVA-style main effects, and the initial model had age in months, the phonological working memory score, the sentence production score, and all two-way interactions as predictor variables (all centered prior to analysis to minimize collinearity), and participant and item as random effects. Model comparisons were done as before. The final model has phonological working memory, sentence production, age and the working memory by age interaction as fixed effects and no random effects. The results revealed a significant main effect of sentence production (coefficient = 0.85, SE = 0.34, z = 2.49, p = .013), such that a higher sentence production score relates to more transitive infinitive productions when primed with transitive infinitives. In addition, there was a significant age by phonological working memory interaction (coefficient = 0.69, SE = 0.22, z = 3.13, p = .002). This means that children’s phonological working memory positively affects transitive infinitive productions, but the extent to which it does so depends on children’s age. The model coefficient shows that if age increases by one month, the slope between phonological working memory score and transitive infinitive productions increases by 0.69. Thus, the higher the age, the smaller the effect of the phonological working memory score on transitive infinitive productions. There were no significant main effects of phonological working memory (coefficient = −0.2, SE = 0.24, z = −0.85, p = .393) and age (coefficient = −0.14, SE = 0.33, z = −0.42, p = .674).

**Discussion**

We found a clear syntactic priming effect across different lexical items from comprehension-to-production with alternating prime structures for the older-alternating group, a group of children exclusively under the age of three with ages ranging from 2;7 to 2;11. Thus, our data provide evidence for robust abstract syntactic representations (Messenger et al., 2011; Rowland et al., 2012), and against lexically-specific representations, for transitive structures in production before the age of three. Since syntactic priming occurs when already existing syntactic representations are activated (Kirjavainen et al., 2017), the children in this study must already have had robust abstract syntactic representations for transitive structures. Importantly, our data do not speak to other structures, and it is possible that less common and later-acquired structures, such as the passive, are not yet abstractly represented at this age. This could be the case, for example, if syntactic representations become abstract with usage, such as through encountering exemplars.

Importantly, previous syntactic priming studies with such young children have all employed production-to-production paradigms, which may not tap into abstract syntactic representations, but may instead reflect production-specific aspects of processing (Branigan & Pickering, 2017). Previous evidence for early abstract syntactic representations from comprehension studies may similarly reflect comprehension-specific aspects of processing rather than being directly informative about syntactic representations. We argue that the comprehension-to-production syntactic priming paradigm used here provides a stronger test of abstract syntactic representations than previous production and comprehension studies, and that this is the first study that shows evidence for early
abstract syntactic representations using a task that directly implicates syntactic representations and specifically rules out alternative processing-based explanations.

The current results from the older-alternating group also provide evidence that the syntactic priming effect is rather structure-specific. Priming children with one of the German transitive structures only increased productions of this particular transitive structure, not transitives in general, suggesting that priming involved both word order and verb form. In addition, the structure-specificity of the priming effect rules out that children were merely primed to mention vs. not to mention the object shown in the picture. This result is also in line with syntactic priming effects in adults, where constructions differing in word order do not always prime each other (e.g., Loebell & Bock, 2003; Pickering et al., 2002). In terms of theoretical approaches, this result is compatible with residual-activation accounts of syntactic priming (Bernolet et al., 2007), syntactic representations that are specified for both linear and hierarchical relations (Branigan & Pickering, 2017) and with implicit learning approaches that model syntactic priming as implicit sequence learning (Chang et al., 2012). The fact that priming in the current study occurred from comprehension to production is further compatible with implicit learning accounts of syntactic priming in that they assume that comprehension (rather than production) of syntactic structures drives learning and syntactic priming effects (Chang et al., 2006).

We further found that children in the older-alternating group with higher sentence production and phonological working memory scores (modulated by age) produced more transitive infinitive sentences when primed with a transitive infinitive than children with lower sentence production and phonological working memory scores. Thus, we find significant individual differences in syntactic priming for both working memory capacity and syntactic skills in that both skills modulate how often a primed structure is produced. It is therefore plausible, though not directly evidenced here, that working memory limitations and/or production/processing limitations related to more complex syntactic structures might be implicated in situations where children may not be able to produce structures for which they have abstract syntactic representations (Branigan & Pickering, 2017).

Finally, we found no evidence for a syntactic priming effect in children aged 2;0 to 2;6, regardless of whether prime structures were alternated or cumulative. On the contrary, children in the younger groups produced numerically more transitives following intransitive primes rather than transitive primes. It is unlikely that the lack of a priming effect is due to some of the children simply not producing transitives yet, since all but two children produced them in the sentence production task (see also Stumper & Szagun, 2008).

Bearing in mind that null effects are difficult to interpret, we tentatively propose that the lack of a priming effect in the younger children may relate to abstract syntactic representations. One possibility is that syntactic representations in the younger children may still be lexically-based or only weakly abstract. For example, children in the 2;0 to 2;6 age group may not have encountered enough exemplars to form strong abstract syntactic representations of intransitive and transitive structures (Abbot-Smith & Tomasello, 2006). Future studies could use comprehension-to-production syntactic priming tasks to test children on several different syntactic alternations with different input frequencies to explore the possibility that different structures become abstract at different times and that this relates to input frequency. A comparison of our results with those of Shimpi et al. (2007) suggests that such a systematic approach may be fruitful. We found reliable
syntactic priming for frequent transitive infinitives in children aged 2;7 to 2;11 in a comprehension-to-production task, a task that taps into abstract syntactic representations. In contrast, Shimpi et al. (2007) found reliable priming for less frequent passive and dative structures in slightly older children only in a production-to-production task, which may reflect production-specific aspects of processing rather than implicate abstract syntactic representations, but not in a comprehension-to-production task.

In conclusion, our results for the older age group provide stronger evidence than previous studies for the assumption that syntactic representations (for at least some structures) are fully abstract before the age of three. Thus, in terms of the question of when, our results are clearly only compatible with generativist-nativist approaches and early-abstraction accounts, but not usage-based-constructivist accounts. However, our data do not distinguish between generativist-nativist approaches, early-abstraction accounts, and usage-based-constructivist accounts in terms of the questions of what and how, i.e., in terms of what is the nature of abstract syntactic representations, how they come to be in place, and whether or not different levels of abstractness exist. Specifically, our results do not rule out that syntactic representations are initially tied to specific lexical items and become abstract as exemplars are accumulated (e.g., Abbot-Smith & Tomasello, 2006), but they suggest that this process could not occur as gradually as usage-based-constructivist accounts typically assume.

Acknowledgements

Parts of this project were presented at the 18th Annual AMLaP Conference, Riva del Garda, Italy. We would like to thank the children, their families and the day care facilities for their participation. We would also like to thank Vera Beste and Juliane Hoefker for helping with the data collection and transcription.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This project was funded by the Collaborative Research Centre 673 ‘Alignment in Communication’.

ORCID iD

Anouschka Foltz https://orcid.org/0000-0001-5117-3225

References

Abbot-Smith, K., Lieven, E., & Tomasello, M. (2004). Training 2;6-year-olds to produce the transitive construction: The role of frequency, semantic similarity, and shared syntactic distribution. Developmental Science, 7, 48–55.
Abbot-Smith, K., & Tomasello, M. (2006). Exemplar-learning and schematization in a usage-based account of syntactic acquisition. The Linguistic Review, 23(3), 275–290.
Ambridge, B. (2019). Against stored abstractions: A radical exemplar model of language acquisition. First Language. https://doi.org/10.1177/0142723719869731
Baayen, R. (2008). Analyzing linguistic data: A practical introduction to statistics using R. Cambridge University Press. https://doi.org/10.1017/CBO9780511801686
Baddley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. Psychological Review, 105, 158–173.
Bassano, D., & Van Geert, P. (2007). Modeling continuity and discontinuity in utterance length: A quantitative approach to changes, transitions and intra-individual variability in early grammatical development. *Developmental Science, 10*(5), 588–612.

Bencini, G. M., & 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.

Bernolet, S., Hartsuiker, R. J., & Pickering, M. J. (2007). Shared syntactic representations in bilinguals: Evidence for the role of word-order repetition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(5), 931–949.

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

Bourdin, B., Aubry, A., & Ibernon, L. (2018). Amorçage syntaxique de structures syntaxiques complexes chez des enfants de maternelle en français oral [Syntactic priming of complex syntactic structures in kindergarten children in oral French]. *Psychologie Française, 63*(2), 145–156.

Branigan, H. P., & Pickering, M. J. (2017). An experimental approach to linguistic representation. *Behavioral and Brain Sciences, 40*, Article e282.

Brooks, P. J., & Tomasello, M. (1999). Young children learn to produce passives with nonce verbs. *Developmental Psychology, 35*(1), 29–44.

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

Chang, F., Janciauskas, M., & Fitz, H. (2012). Language adaptation and learning: Getting explicit about implicit learning. *Language and Linguistics Compass, 6*(5), 259–278.

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

Dittmar, M., Abbot-Smith, K., Lieven, E., & Tomasello, M. (2008). Young German children’s early syntactic competence: A preferential looking study. *Developmental Science, 11*(4), 575–582.

Dittmar, M., Abbot-Smith, K., Lieven, E., & Tomasello, M. (2011). Children aged 2;1 use transitive syntax to make a semantic-role interpretation in a pointing task. *Journal of Child Language, 38*, 1109–1123.

Ellis, N. C. (1996). Working memory in the acquisition of vocabulary and syntax: Putting language in good order. *The Quarterly Journal of Experimental Psychology Section A, 49*(1), 234–250.

Fisher, C. (2002). The role of abstract syntactic knowledge in language acquisition: A reply to Tomasello. *Cognition, 82*, 259–278.

Foltz, A., Thiele, K., Kahsnitz, D., & Stenneken, P. (2015). Children’s syntactic-priming magnitude: Lexical factors and participant characteristics. *Journal of Child Language, 42*, 932–945.

Fox, A. V. (2011). *Kindliche Aussprachestörungen: Phonologischer Erwerb - Differenzialdiagnostik - Therapie* [Articulation and pronunciation difficulties in children: phonological acquisition – differential diagnostics – therapy] (6th ed.). Schulz-Kirchner.

Franck, J., Millotte, S., & Lassotta, R. (2011). Early word order representations: Novel arguments against old contradictions. *Language Acquisition, 18*(2), 121–135.

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

Grimm, H. (2000). *Sprachentwicklungstest für zweijährige Kinder - SETK-2* [Language development test for two-year-old children]. Hogrefe.

Grimm, H., & Doil, S. (2000). *ELFRA-2 - Elternfragebogen für zweijährige Kinder* [ELFRA2 - Parental questionnaire for two-year-old children]. Hogrefe.

Huttenlocher, J., Vasilyeva, M., & Shimpi, P. (2004). Syntactic priming in young children. *Journal of Memory and Language, 50*, 182–195.

Kemp, N., Lieven, E., & Tomasello, M. (2005). Young children’s knowledge of the determiner and adjective categories. *Journal of Speech, Language, and Hearing Research, 48*(3), 592–609.
Kidd, E. (2012a). Implicit statistical learning is directly associated with the acquisition of syntax. *Developmental Psychology, 48*(1), 171–184.

Kidd, E. (2012b). Individual differences in syntactic priming in language acquisition. *Applied Psycholinguistics, 33*, 393–418.

Kirjavainen, M., Lieven, E. V., & Theakston, A. L. (2017). Can infinitival to omissions and provisions be primed? An experimental investigation into the role of constructional competition in infinitival to omission errors. *Cognitive Science, 41*(5), 1242–1273.

Loebl, H., & Bock, K. (2003). Structural priming across languages. *Linguistics, 41*, 791–824.

Matthews, D., Lieven, E., Theakston, A., & Tomasello, M. (2005). The role of frequency in the acquisition of English word order. *Cognitive Development, 20*(1), 121–136.

Messenger, K., Branigan, H. P., & McLean, J. F. (2011). Evidence for (shared) abstract structure underlying children’s short and full passives. *Cognition, 121*, 268–274.

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.

Miller, C. A., & Deevy, P. (2006). Structural priming in children with and without specific language impairment. *Clinical Linguistics & Phonetics, 20*(5), 387–399.

Miyake, A., & Shah, P., (Eds.). (1999). *Models of working memory: Mechanisms of active maintenance and executive control*. Cambridge University Press.

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

Naigles, L. R. (2002). Form is easy, meaning is hard: Resolving a paradox in early child language. *Cognition, 86*, 157–199.

Pickering, M. J., Branigan, H. P., & McLean, J. F. (2002). Constituent structure is formulated in one stage. *Journal of Memory and Language, 46*(3), 586–605.

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

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

R Development Core Team. (2008). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing.

Risse, T., & Kiese-Himmel, C. (2009). Der Mottier-Test: Teststatistische Überprüfung an 4- bis 6-jährigen Kindern [The Mottier-test: Test-statistical verification with 4- to 6-year-old children]. *HNO, 57*, 523–528.

Rowland, C., 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.

Savage, C., Lieven, E., Theakston, A., & Tomasello, M. (2003). Testing the abstractness of children’s linguistic representations: Lexical and structural priming of syntactic constructions in young children. *Developmental Science, 6*(5), 557–567.

Shimpi, P., Gámez, P., 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.

Singmann, H., & Kellen, D. (2020). An introduction to mixed models for experimental psychology. In D. H. Spieler & E. Schumacher (Eds.), *New Methods in Cognitive Psychology* (pp. 4–32). Psychology Press.

Stumper, B., & Szagun, G. (2008). The acquisition of verb-argument structure in German-speaking children. In *Proceedings of the 2007 Child Language Seminar* (pp. 174–182). University of Reading.

Thornton, R. (2016, December 22). Children’s acquisition of syntactic knowledge. *Oxford Research Encyclopedia of Linguistics*. https://oxfordre.com/linguistics/view/10.1093/acrefore/9780199384655.001.0001/acrefore-9780199384655-e-72
Appendix 1. Prime and target items with optional items in square brackets and English translations in parentheses

**Intransitive prime items**

schlafen (sleeping)
schwimmen (swimming)
sitzen (sitting)
tanzen (dancing)
weinen (crying)
laufen (running)

**Transitive prime items**

Mama küssen (kissing Mommy)
Baby kitzeln (tickling baby)
Ball werfen (throwing ball)
Hase füttern (feeding bunny)
Eimer tragen (carrying bucket)
Banane fangen (catching banana)

**Target items**

[ Baum/Auto/Hund] malen (drawing [tree/car/dog])
[ Eier/Würstchen/Kartoffeln] kochen (boiling [eggs/sausages/potatoes])
[ Käse Suppe/Brot] essen (eating [cheese/soup/bread])
[ Hose/Pullover/Socken] waschen (washing [pants/sweater/socks])
[ Saft/Milch/Wasser] trinken (drinking [juice/milk/water])
[ Stuhl/Haus/Tisch] bauen (building [chair/house/table])