Syntactic priming as implicit learning in German child language

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Abstract

We investigated syntactic priming in German children to explore crosslinguistic evidence for implicit learning accounts of language production and acquisition. Adult descriptions confirmed that German speakers (N=27) preferred to spontaneously produce active versus passive transitive and DO versus PO dative forms. We tested whether German-speaking children (N=29, M_{age}=5.3, 15 girls/14 boys) could be primed to produce these dispreferred forms and whether such priming effects would persist across a target phase. Children first heard a block of priming sentences and then described a block of target pictures. They demonstrated significant priming effects for passive and PO dative structures, and these priming effects did not differ between the first and second halves of the block of target trials. These patterns of German child language production are consistent with implicit learning accounts of syntactic priming.

Introduction

In the process of language acquisition, one challenge for children is to acquire a language's system for organising words into structured sentences, its grammar. One means to understanding how and when children achieve this is *syntactic priming*. Syntactic priming is the tendency for speakers to reuse recently experienced syntactic structures (Bock, 1986; Dell & Chang, 2014). That is, after recently encountering an utterance with a particular syntactic form, for example, a double-object (DO) dative utterance (e.g., "*The farmer is giving the horse an apple*"), a speaker would be more likely to repeat the DO structure in a new description of their own, when presented with a similar scenario (e.g., "*The zookeeper is feeding the penguin the fish*" and less likely to use the alternative dative phrase, the prepositional object (PO) dative, to describe the event (e.g., "*The zookeeper is feeding the fish to the penguin*"). Since this effect is based on unconscious repetition of grammatical structure (and not lexical, morphological or prosodic content; Bock, 1989; Bock & Loebell, 1990; Pickering & Branigan, 1998), syntactic priming has become a widely used tool to tap into the mental representations of grammar that underlie comprehension and production of syntactic forms (Branigan & Pickering, 2017). From a developmental perspective, syntactic priming effects are therefore useful for establishing what children acquiring their first language know about the grammar of that language (Messenger, 2022). Moreover, in at least one account, syntactic priming effects are thought to be a vestige of the mechanisms by which language is acquired (Chang, Dell, & Bock, 2006). Individual instances of processing syntactic structures involve prediction- and error-based learning mechanisms which have lasting and cumulative, not just immediate, effects on speakers' use and representation of syntactic structures. These manifest as an increased tendency to reuse a recently-experienced syntactic structure, not just in immediately following utterances, but also across subsequent utterances (Bock & Griffin, 2000; Huttenlocher, Vasilyeva, & Shimpi, 2004; Kaschak, 2007).

Such lasting priming effects are therefore indicative of implicit learning from recent experiences of how grammatical structures map onto events and can be used to describe them; essentially, tuning in to which structural choices to use in that language. Syntactic priming is therefore a powerful tool for examining different aspects – both representational and mechanistic – of child language development (Messenger, Branigan, Buckle, & Lindsay, 2022).

Immediate and lasting syntactic priming effects are well-attested in adult speakers across a variety of languages, language modalities, and grammatical structures, (see Mahowald, James, Futrell, & Gibson, 2016, for a review) and there is growing evidence that child speakers similarly show immediate and lasting effects of syntactic priming (see Messenger et al., 2022, for a review). However, one limitation in the developmental literature is in the range of languages tested – most evidence comes from English-speaking children with a limited number of studies from a limited range of other languages (see Atkinson (2022) and Foltz (2022) for further discussion). If syntactic priming effects reflect the underlying mechanisms by which language is acquired and stored, such effects should be universally evidenced; lasting priming effects should be observed in child learners of different languages. Moreover, the nature of such mechanisms can only be fully understood by examining if and how they manifest across different languages (Pickering & Branigan, 2019). For example, how viable a prediction- and error-based learning model of priming (and language acquisition) is can only be confirmed by exploring immediate and lasting syntactic priming effects in languages that differ in the extent to which the word order of a sentence can be predicted. This study therefore extends previous developmental syntactic priming work to address these issues: we investigate lasting syntactic priming effects in children acquiring German, a language which, unlike English, allows flexible word order of constituents within a structure.

Syntactic Priming as Implicit Learning

Initial explanations for syntactic priming effects proposed that syntactic persistence is a short-lived effect from transient activation of mental representations of syntactic structures (Pickering & Branigan, 1998). However, further evidence suggests that syntactic priming has a lasting effect: priming is attested on target utterances that occur up to ten filler trials after the initial prime, not just on immediately adjacent prime and target trials (Bock & Griffin, 2000). As such, it is argued that syntactic priming emerges from implicit learning or adaptation processes triggered by the activation of such representations (Bock & Griffin, 2000; Chang et al., 2006; Jaeger & Snider, 2013). Different models root these learning effects in different mechanisms, such as short- and long-term memory and activation levels (Malhotra, Pickering, Branigan, & Bednar, 2008; Reitter, Keller, & Moore, 2011) or rational implicit learning mechanisms (Jaeger & Snider, 2013), but one influential model specifically links immediate and lasting syntactic priming effects to language acquisition processes via prediction and error-based implicit learning (Chang et al., 2006). In this model, comprehenders actively predict upcoming words (and consequently, structures) in an utterance. When their expectations do not match the input, this causes an error signal that leads to adjustments in the weighting of their representations in order to reduce the likelihood of error occurring in the future. Such adjustments increase the likelihood of that representation being selected in subsequent processing, for example when producing an immediately following description. As such, in implicit learning accounts, priming effects can be cumulative as well: with increasing experience of a structure, the likelihood of priming increases. These processes therefore lead to immediate priming of syntactic structures, but also long-term priming effects which persist until future experience leads to further changes in the weighting of representations. Such persistent priming effects rely on existing representations to support the prediction- and error-based learning, thus, in this

context, they reflect natural language adaptation processes rather than learning *ab initio* (but see Chang et al., 2006, for discussion of how such models are based on and can also explain earlier language acquisition). Short- and long-term priming effects are consequently indicative of a speaker's implicit learning of structural choices based on the input and can be observed in young children who have begun to acquire a structural alternation.

In support of the idea that syntactic priming effects reflect implicit learning mechanisms, there is much evidence that syntactic priming effects are lasting (beyond an immediate trial) in adult speakers. Adults repeat syntactic structures that they heard or read a number of trials previously (Bock, Dell, Chang, & Onishi, 2007; Bock & Griffin, 2000). Furthermore, if they have experienced blocked input of a structure, adults increase their use of that syntactic structure when later asked to describe a block of target images, both within the same experimental session (Kaschak, 2007; Kaschak, Loney, & Borreggine, 2006) and across experimental sessions separated by a week (Kaschak, Kutta, & Schatschneider, 2011) with effects of priming accumulating with increasing exposure, (Kaschak, Kutta, & Jones, 2011). These findings support accounts of syntactic priming as implicit learning.

There is growing evidence that children also show lasting priming effects consistent with implicit learning accounts. Huttenlocher et al. (2004) first showed that priming in children lasted beyond one trial. They found children were more likely to persistently use an English syntactic structure across an entire testing phase that followed a priming phase in which that structure was presented, compared to a priming phase in which an alternative structure was presented. This effect has been replicated (Fazekas, Jessop, Pine, & Rowland, 2020; Kidd, 2012a) and has been shown to occur even when the priming phase involves mixed primes and the testing phase is delayed (Messenger, 2021). Moreover, priming effects have also been shown to persist beyond the initial experimental session, as in adults: Branigan & Messenger (2016) demonstrated that children produced more of a primed

structure in a second priming session that occurred a week after an initial priming task, while Savage, Lieven, Theakston, and Tomasello (2006) found that, with reinforcement after a week, priming effects persisted for a month. There is some evidence that priming effects accumulate in children: two studies have shown that with increasing experience of passive primes, children are more likely to attempt to produce passives, even if those responses are not complete, or fully accurate, passives (Branigan & McLean, 2016; Buckle, Branigan, Lindsay & Messenger, 2024). However, current evidence comes largely from children acquiring English (Branigan & McLean, 2016; Branigan & Messenger, 2016; Buckle et al., 2024; Fazekas et al., 2020; Huttenlocher et al., 2004; Kidd, 2012a; Messenger, 2021; Savage et al., 2006). There is some evidence for implicit learning via syntactic priming in Spanish-speaking and Mandarin Chinese-speaking children. For example, children who heard (and repeated) a block of passive primes in Spanish were more likely to produce passives in a subsequent block of target items than those who heard active primes and compared to a baseline test (Gámez & Shimpi, 2016). Similarly, Mandarin-Chinese-speaking children who heard a block of *ba*-primes, produced more *ba*-targets in a subsequent block than those who heard SVO primes, and their production in the second half of the block was greater than the first (Hsu, 2014a). However, evidence for the extent to which these effects are indicative of *universal* language learning mechanisms remains limited by the small number of different languages tested.

It is important to examine whether these effects are attested in different languages since languages vary in their word order rules and in their systems for marking argument roles – any explanation for how these are acquired should be able to account for such variation. A connectionist model of the error-based learning account of syntactic priming has been shown to be able to model acquisition of Japanese (Chang, 2009) and German (Chang, Baumann, Pappert, & Fitz, 2015) as well as English (Chang et al., 2006; Chang, Janciauskas,

& Fitz, 2012), but behavioural evidence is needed to confirm the psychological reality of such effects. In particular, it is important to establish that an account of priming that relies on prediction and error-based learning is supported by behavioural evidence from languages that differ in the prevalence and reliability of cues that enable a comprehender to predict upcoming utterances.

Syntactic Development in German-Speaking Children

While German is closely related to English, its grammar involves some differences. In English, transitive sentences (those with a verb [V], subject [S] and object [O]) are almost exclusively expressed with SVO word order (e.g. example 1.a). In German, they are typically expressed with SVO word order in main clauses too (1.a), but SOV word order is used when the transitive phrase occurs in a subordinate clause (1.b). When the main clause contains an auxiliary verb (e.g. a modal verb or a past tense auxiliary; 1.c), the auxiliary occurs after the subject but the main verb remains in sentence-final position. Children acquiring German must learn these word order facts.

1.a) *Der Frosch$_{[S]}$ küsst$_{[V]}$ die Königin$_{[O]}$*

The frog$_{[S]}$ kisses$_{[V]}$ the queen$_{[O]}$

1.b) *Ich sehe, dass der Räuber$_{[S]}$ den Tiger$_{[O]}$ beißt*$_{[V]}$

I see that the robber$_{[S]}$ is biting$_{[V]}$ the tiger$_{[O]}$

1.c) *Der Mann$_{[S]}$ hat eine Maus$_{[O]}$ gefangen$_{[V]}$*

The man$_{[S]}$ has caught$_{[V]}$ a mouse$_{[O]}$

Moreover, while there are preferred word orders, such as SVO for active transitives in main clauses, German allows for flexible word ordering because semantic roles are fairly reliably indicated through local cues (i.e. case-marking inflections) on noun phrases. For example, the recipient and theme roles of dative sentences are marked on the determiners of each noun phrase. Therefore, whilst the (recipient-theme) DO structure (2.a) is preferred in

German over the PO structure (2.c; Loebell & Bock, 2003; Melinger & Dobel, 2005), a dative can also be expressed as a shifted DO sentence in which the order of the theme and recipient are inverted (2.b) and where case-marking, not word order, is the cue to thematic role assignments.

2.a) *Die Kuh bringt der Königin*$_{[recipient]}$ *den Zwerg*$_{[theme]}$

The cow brings the king$_{[recipient]}$ the gnome$_{[theme]}$

2.b) *Die Kuh bringt den Zwerg*$_{[theme]}$ *der Königin*$_{[recipient]}$

The cow brings the king$_{[recipient]}$ the gnome$_{[theme]}$

2.c) *Die Kuh bringt den Zwerg*$_{[theme]}$ *zu der Königin*$_{[recipient]}$

The cow brings the gnome$_{[theme]}$ to the king$_{[recipient]}$

Due to these different features, children acquiring German may encounter greater word order variability than children acquiring English and so how and when they learn to recognise different structures, and the cues that they rely on to do so, may differ, (Chan, Lieven, & Tomasello, 2009). Some have argued that German-speaking children's comprehension and acquisition of sentence structures is facilitated by the combination of more than one cue (Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008b) or by the presence of non-canonical word orders (Aschermann, Gülzow, & Wendt, 2004; Schaner-Wolles, 1989). However, others have observed that German-speaking children are not able to use case-marking to comprehend non-prototypical word order until relatively late in acquisition (Brandt, Lieven, & Tomasello, 2016; Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008a) suggesting that word order may be an important cue for German-speaking children too, though they may not use it as early in acquisition as English-learning children (Chan et al., 2009). Given these crosslinguistic differences, it is relevant to ask whether syntactic priming effects occur in a language such as German as they have been shown to do in English. For example, a child learning English, which has fixed word order and a strong preference for

active transitives over passive, might strongly predict that the first noun they encounter is an agent yielding a stronger error signal when the sentence unfolds as a passive structure. A child learning a language with more flexible word order, such as German, may less strongly predict an agent for the first noun or may use the case-marking cues to successfully identify a patient, yielding a weaker error signal and less priming. On the other hand, if German-speaking children are not able to use case-marking to distinguish structural roles in early comprehension, they should show benefits of error-based learning. Evidence of lasting priming effects in German would therefore be informative about whether such explanations of syntactic priming and language learning have crosslinguistic relevance.

Syntactic Priming in German-Speaking Children

There is some evidence that children show susceptibility to priming in German with both very early acquired structures – pre- vs post-nominal adjective structures (Foltz, Thiele, Kahsnitz, & Stenneken, 2015) and the transitive-intransitive alternation (Foltz, Knopf, Jonas, Jaecks, & Stenneken, 2021) – and more difficult, later-acquired structures, such as object vs subject relative clauses (Brandt, Nitschke, & Kidd, 2017) but, to our knowledge, only one study has tested other verb phrase (dative) structures in German-speaking children (Kholdova et al., 2023). These previous findings reveal some interesting patterns of development. For example, Foltz and colleagues (2021) examined priming effects for transitive-intransitive alternating verbs in two-year-olds. They found that children aged 2;7 to 2;11 were primed by non-alternating transitive verbs ((*Baby) kitzeln* "to tickle (baby)") to produce transitive utterances with an alternating verb (e.g. *Saft trinken* "to drink juice/drinking juice") rather than intransitive utterances (i.e., *trinken* "to drink/drinking") whereas younger children, aged 2;1 to 2;6, were not. Moreover, they found that children were only primed to re-use the specific verb form of the primes. For example, they showed priming of infinitival transitive responses (*Saft trinken*) that matched the form of the preceding prime (*Baby kitzeln*) but not

of conjugated verb phrases (*(sie) trinkt Saft* "(she) drinks juice"), though children did use both conjugated and infinitival verb forms across the experiment. Given the word order differences between conjugated (verb-second) and infinitival (verb-final) responses, these results suggest that either children rely on the word order of the utterance they have just heard or that in early stages of language acquisition, they develop separate representations for conjugated and infinitival word orders such that priming of one form does not lead to priming of the other. By contrast, German-speaking adults show effects of priming between utterances with the same structure but different word orders (verb-second/verb-final), though priming is stronger when the word order and structure overlap (Chang et al., 2015).

Kholdova et al. (2023) found significant priming of PO datives in children aged between three- and eight-years, with stronger cumulative effects of exposure to primes in the younger children; the lasting effects of priming for datives were not however tested. Brandt et al. (2017) found that priming facilitated older (nine-year-old) children's comprehension of object relative clauses but not younger (six-year-old) children's, suggesting that this structure may be relatively late acquired. The study also found that, for nine-year-olds, this priming effect was lasting – the facilitation effect persisted into a post-test phase supporting the idea that syntactic priming provides a form of implicit learning of structural choices, albeit in older children. Evidently, there is scope for further research examining the extent to which different structures can be primed in children between the ages of 2 and 6, and whether such priming is persistent in German-speaking children's earlier language.

The Present Study

By the pre-school years, German children are able to comprehend active and passive transitives (Armon-Lotem et al., 2016; Aschermann et al., 2004; Dittmar, Abbot-Smith, Lieven, & Tomasello, 2014) and (DO) dative structures (Scherger, Kizilirmak, & Folta-Schoofs, 2022) suggesting they have acquired a representation of these structures that should

be susceptible to implicit learning from recent input. The present study tests whether experiencing a blocked input of structural primes would lead German-speaking children to increase their production of these structures in a subsequent target phase. Following the design of Huttenlocher et al.'s (2004) Experiment 3, we examined whether such priming effects would persist, and not decrease, across the block of target trials with no difference in the frequency of target structures in the first and second halves of the block (see also Gámez & Shimpi, 2016; Messenger, 2021). Such persistent priming effects are consistent with implicit learning explanations of syntactic priming, (Huttenlocher et al., 2004; Kaschak, 2007): hearing and processing the block of prime structures should create lasting weight changes to their representations of those structures, which makes them more available and therefore more likely to be used in the subsequent target phase, particularly given the alternative structure is not primed until after the target phase. If priming input has this kind of lasting impact on speakers' representations, then the tendency to reuse the primed structure should last beyond the earliest trials of the target phase and be observed across the entire target phase. Moreover, in implicit learning accounts, these lasting effects of priming should therefore accumulate with increasing experience of the structure, such that with increasing experience, the likelihood of using the primed structure increases. In the blocked design of the current study, this cannot be observed over increasing prime trials but whether priming effects accumulate over target productions can be measured for further evidence that the prior priming experience led to lasting changes in the children's representations of the target structures. We examined two syntactic alternations: transitive (active (1.a) versus passive (1.b) sentences) and dative (DO (2.a) versus PO (2.b) sentences).

First, we collected adult native German speakers' production preferences for the relevant structures through an online survey (Norming Study). Establishing adult production preferences informs which structures children may typically hear and may be able to use

themselves in the priming experiment. Without priming, adult speakers described images depicting scenarios meant to elicit transitive and dative constructions. We expected adults to use more active than passive sentences to describe the transitive scenarios as the active is the canonical transitive structure, and more DO than PO sentences to describe the dative scenarios, as PO datives in German are restricted to a smaller set of verbs making the PO structure less frequent in German (Loebell & Bock, 2003; Melinger & Dobel, 2005).

Second, we investigated priming in young German-speaking children to determine whether children's use of certain grammatical structures can be affected by prior exposure to different forms (Experiment 1). Specifically, we explored the effect of priming on children's use of the *dispreferred* structures for each event type, since priming effects are typically observed with less preferred structures (Jaeger & Snider, 2013). We therefore predicted that German-speaking children would be more likely to repeat passive and PO forms after hearing those structures in a set of trials than after hearing the alternative. Critically, we also predicted that this priming effect would persist over the entire set of target trials indicating lasting effects of priming consistent with implicit learning, as observed in children acquiring English (Huttenlocher et al., 2004; Kidd, 2012a; Messenger, 2021). Implicit learning accounts of priming also predict cumulative effects of previous experience of syntactic structures such that children should be more likely to produce target structures with increasing production experience. The materials and data for the Norming Study and Experiment 1 can be found online at: https://osf.io/2ynup/?view_only=ca8c63b0937d4fad91a871f696f88f4a.

Norming Study

This study collected adult speakers' structural preferences for describing transitive and dative events without priming through an anonymous online survey. We explored the

likelihood of adult German speakers spontaneously using active vs. passive and DO vs. PO structures.

Method

Participants

A sample of 27 native German-speaking adults (aged 18-65) participated in the online survey. Most participants (n=23) were living in eastern German states, four were from western states. As such, the collected responses were predominantly from an adult sample representing the same eastern region and dialects of the child participants in Experiment 1. Participants were recruited via email lists with the additional request to forward the survey to possible interested parties. The University Research Ethics Committee granted ethical approval for the study. There was no compensation for participation.

Materials

Participants described three sets of ten items, with each set containing five different verb-picture combinations depicting transitive events and five verb-picture combinations depicting different dative events. Each verb-picture combination showed the event with human and animal characters and the verb presented above; items within each set were presented in randomized order. We used five transitive verbs and five dative verbs (see Table 1) three times each to create the three sets of items. We chose the German equivalent of verbs used in previous English-language child-directed syntactic priming studies (Messenger, Branigan, McLean, & Sorace, 2012; Rowland, Chang, Ambridge, Pine, & Lieven, 2012). No German dative verbs with separable prefixes were used because separable prefixes affect word order and eliminate the need for a preposition in some instances; to ensure flexibility in use both with and without a preposition, i.e., in double object *and* prepositional dative phrases, these verbs were avoided. While German has a more restricted range of verbs that

can be used in a PO structure, these verbs were all judged, by a native speaker, to create grammatical PO sentences in the East German dialect.

Table 1. German verbs used in Norming Study and Experiment 1 with English translations.

Transitive		Dative	
German	English	German	English
beißen	to bite	*geben*	to give
jagen	to chase/hunt	*zeigen*	to show
küssen	to kiss	*bringen*	to bring
antippen	to poke/tap	*liefern*	to deliver
ziehen	to pull	*schicken*	to send

Procedure

An online (Google) survey presented the verb-picture combinations with the instruction to describe the scenario depicted in the drawing using the given verb. Participants typed their responses in a text box below each picture. The task was not timed.

Coding

Transitive descriptions were coded as complete active responses when they involved an agent as the subject in the sentence with a transitive verb and a post-verbal noun phrase expressing the patient as the object of the sentence (e.g. 1.a). Passive sentence constructions required the patient to be in the subject position of the sentence and the agent to be expressed in the object position, after the auxiliary verb. Two sentence forms were coded as complete passive responses: those with the auxiliary verb *werden* and the past participle of the main verb (3.a) and those with the reflexive paraphrase of the passive form constructed with *lassen sich* and the infinitive form of the main verb (3.b). Nearly all passives in the Norming Study

(and all passives in Experiment 1) used the *werden* + past participle construction; only two participants produced passives with *lassen sich* + infinitive (see Table 2).

3.a) *Der Tierarzt wird vom Pferd gebissen*

The vet is bitten by the horse

3.b) *Der Tierarzt lässt sich vom Pferd beißen*

'The vet lets himself be bitten by the horse'

The vet is bitten by the horse

Dative descriptions were categorized as a complete DO dative phrase when they used correct declension of articles, contained all three arguments of the dative verb, and expressed the description without a preposition (2.a); note that this means that scrambled DOs (example 2.b) were included alongside canonical DOs (2a). Sentences were categorized as complete PO datives when they used correct declension of articles, contained all three arguments of the dative verb, and expressed the description with a preposition (2.c).

Descriptions which did not contain all the arguments were coded as *incomplete* (e.g., *Der Hund bringt den Gartenzwerg,* "The dog brings the gnome"). When descriptions did not accurately describe the events in the drawing or instructions were not followed, the responses were coded as *other*.

Results and Analysis

Most of the pictures elicited a complete response as desired; only 3% descriptions were coded as *other* and 9% were coded as *incomplete* overall. Adult German speakers produced more active transitives (84% descriptions) than passive transitives (14% descriptions; see Table 2). They also produced more DO descriptions (53% pictures) than PO descriptions (24% pictures), though almost a quarter of the dative picture descriptions were not a complete DO or PO phrase: 18% of the descriptions were coded as *incomplete* (and 5% as *other*).

Table 2. Frequencies (proportions) of adults' transitive and dative descriptions.

Pictures	Description structure			
	Active	Passive	Incomplete	Other
Transitive	339 (84%)	58* (14%)	0	8 (2%)
	Double-Object	Prepositional-Object	Incomplete	Other
Dative	214 (53%)	98 (24%)	73 (18 %)	20 (5%)

*3 (<1%) were passives with *lassen sich*.

Discussion

Overall, the pictures in the Norming Study prompted the intended responses from participants: transitive pictures elicited complete transitive descriptions 98% of the time, and dative pictures prompted complete dative descriptions 77% of the time. This confirmed that the experiment materials could effectively elicit both structures of each alternation (active/passive, DO/PO) examined in Experiment 1. Though adults produced both preferred and dispreferred structures, the survey results confirmed that German-speaking adults were more likely to spontaneously use active rather than passive descriptions for the transitive pictures and DO rather than PO descriptions for the dative pictures.

In Experiment 1, we explored how children described the pictures after hearing primes that were complete transitive or dative descriptions; specifically, we tested whether German-speaking children would be more likely to produce dispreferred syntactic structures after hearing these syntactic structures repeated over a series of trials. Moreover, we explored whether the effect of priming persists beyond the first target trials following the priming phase, such that participants were as likely to produce target responses in the second half of

the target phase as the first, indicating a form of implicit learning via syntactic priming in German.

Experiment 1

Method

Participants

29 native German-speaking children (15 female, 14 male) aged 4;5–6;11 years[1] (53–83 months, M=63.9 months; SD=9.43) were randomly selected and recruited from a database where families volunteer to engage in child development research. Two further children were excluded due to failure to produce target responses during the experiment. The children came from mixed socio-economic backgrounds in a midsized German city and were mainly monolingual, with no known language impairments. Additional demographic data were not collected. The University Research Ethics Committee granted ethical approval for the study.

Design

The experiment had a 2 x 2 mixed design: Prime Structure (target (passive/PO) vs. alternative (active/DO)) and Block Half (first vs. second half of the target response block) were all within-participant variables; Prime Structure, but not Block Half, was a within-items variable within each structure.

Materials

The priming experiment materials consisted of 80 pictures depicting different transitive (40) and dative (40) events. Experiment 1 used the same transitive and dative verbs as in the Norming Study (Table 1). Each verb was used four times each with different combinations of characters (animals and humans) to create 20 target pictures and a further four times each to create 20 prime pictures for each structural alternation. Across pictures, we counter-balanced the left-right placement of the characters.

The sets of transitive/dative prime and target items were divided into two groups of 10 items per construction and presented as blocks of items; each block of prime items was paired with a block of target items of the same alternation (transitive, dative). We created two versions of each prime block (version A and B) such that in one version, a given block of prime items was described with one structure (e.g. actives, DOs) and in the other it was described with the other structure (e.g. passives, POs). Active primes were always present tense SVO forms and passive primes were also present tense *werden* auxiliary + past participle forms. DO primes were always present tense forms with the canonical word order, the recipient preceding the theme, and PO primes were always present tense with the theme preceding the recipient which was expressed in a prepositional phrase headed by *zu* (to; see Appendix A). Each participant experienced one version of each block such that they only experienced each item once with one prime structure but across the whole experiment each item was described equally with both structures.

Each block of prime items was immediately followed by the paired block of 10 target items (see below for a description of the storybook task). The order of presentation of these paired blocks of prime and target items was rotated between participants such that half the participants heard one structure of the alternation first and half heard the other structure first (see Appendix B for a schematic of the study set up).

The paired blocks of prime and target items were presented within a storybook context. Children were introduced to a character, *Norbert, das neugierige Nashorn* 'Norbert the Curious Rhino', who is going on an adventure in each storybook. Each story opened in a different environment (mountains, desert, ocean, or river), where Norbert would explore the setting with "magic binoculars". There was a different story book for each block of primes and targets (i.e. there were two for transitive trials and two for dative trials for version A of

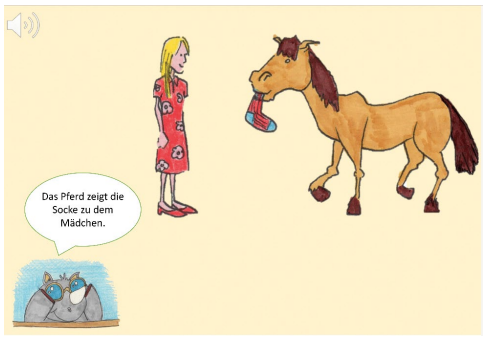
the items and two per structure for version B) such that children never heard the same story twice (see Appendix B). Within each storybook, the order of items was fixed.

For the prime items, Norbert described the events he could see (see Figure 1a). After hearing the block of ten prime sentences, the children were given a turn to "use the magic binoculars" and were instructed by Norbert to describe what they could see – these pictures were the target items (see Figure 1b). Prompts were given for each item: *Was siehst du?* "What do you see?"; *Was passiert hier?* "What is happening here?"; *Was machen die da?* "What are they doing?". No additional feedback was given in the target portion of the experiment. Note that no filler items were included between individual target trials.

a. Example passive prime item:

"*der Affe wird von der Prinzessin gejagt*"
"the monkey is chased by the princess"

Example PO prime item:



"*das Pferd zeigt die Socke zu dem Mädchen*"
"the horse is showing the sock to the girl"

b. Example transitive target item:

"*der Arzt wird von dem Pferd gebissen*"
"the vet is bitten by the horse"

Example dative target item

"*die Ziege gibt die Maus zu der Hexe*"
"the goat is giving the mouse to the witch"

Figure 1: Example prime and target items from the storybook.

Before the priming tasks, children also participated in a warm-up task. This consisted of six items (depicting three transitive events meant to elicit the verbs *antippen* "to poke", *ziehen* "to pull", and *beißen* "to bite", and three dative events meant to elicit the verbs *geben* "to give", *bringen* "to bring", and *zeigen* "to show" also presented in the same storybook context. This warm-up task introduced the task and ensured that children understood it. It also elicited children's baseline descriptions of transitive and dative events to examine children's unprimed descriptions of these events.

Procedure

Children were individually tested through an online video conferencing platform. Each child completed five storybook interactions: one warm-up/baseline storybook and the four prime-target stories. After the short warm-up task, each child was informed that they would hear four stories where they would first listen and then describe what they see in the stories. The stories were presented on Microsoft PowerPoint slides. Within each story, Norbert spoke the ten prime sentences. These were pre-recorded by a male native speaker of German from the same region of Germany that the experiment took place in, and were played once as each prime picture was displayed. Next, Norbert prompted the child to describe the remaining ten pictures that were presented on individual slides. The experimenter advanced the slides after each description had been provided. The children's descriptions were audio-recorded using an external recording device to be later transcribed, coded, and analyzed. As a reward, children were given a certificate celebrating their participation in research.

Coding

Children's descriptions were coded twice according to strict and lenient criteria (Bencini & Valian, 2008). This permits an analysis of the priming effects when children

produced well-formed, complete target utterances and of the pattern of effects when taking into account all their attempts to produce the target forms (Messenger et al., 2022).

Transitives. For the strict coding, utterances were coded as active when they correctly described the transitive image and included an agent as the sentence subject followed by a transitive verb and a patient as the sentence object, (1.a). Utterances that omitted nouns but included appropriately case-marked articles were also coded as active where the intended meaning was clear, either through using proper grammatical cases or through disclosing sufficient detail in the description; utterances where the patient and agent were ambiguous were coded as incomplete for the strict coding. Additionally, sentences were coded as a complete active when they occurred in a subclause (1.b) or in present perfect tense (1.c), despite the changes to word order (see online materials for a full set of example utterances for each coding).

Utterances were coded as passive when the sentence had the patient in the subject position, the auxiliary verb *werden* with the past participle of the main verb, and the agent was expressed in a prepositional phrase headed by *von*, (3.a). As noted above, though two adults produced passives with *lassen* in the Norming Study, no children produced them in the priming experiment. As with actives, passive sentences within a subclause (4.a) and using present perfect tense (4.b) were included. Responses that could not be coded as active or passive were coded as "other"; when the child did not respond, the trial was excluded.

4.a) *Ich sehe, dass die Prinzessin von dem Frosch geküsst wird*

I see that the princess is being kissed by the frog

4.b) *Die Maus ist von dem Mann gefangen worden*

The mouse has been caught by the man

4.c) *Ich sehe eine Ziege, die der Hexe eine Maus gibt*

I see a goat who gives the witch a mouse

A lenient coding also included incomplete passive and active sentences. Target responses where information was omitted or unclearly spoken but the response still provided enough to signify a passive or active construction (e.g., the use of *werden* in an incomplete passive sentence) were coded as active or passive. Additionally, sentences that used a modal verb were included in the lenient analysis when the modal verb could be used in both active and passive forms (e.g., *Der Feuerwehrmann muss die Maus fangen* "The fireman must catch the mouse"; or *Die Maus muss vom Feuerwehrmann gefangen werden* "The mouse must be caught by the fireman"). No passives were used with a modal verb but modal verbs were used in active target responses.

Finally, an inclusive coding included all utterances coded as active or passive in the strict and lenient codings plus reversed active and passive responses where the response was grammatically correct but semantically incorrect, describing the image with patient and agent roles reversed. For example, where children gave the description *Das Pferd wird von dem Arzt gebissen* "The horse is being bitten by the doctor", where the correct target response would have been *Der Arzt wird von dem Pferd gebissen* "The doctor is being bitten by the horse". These responses reveal an attempt to produce the grammatical structure of the prime and were therefore included in the inclusive coding.

Datives. For the strict coding, sentences were coded as complete DO datives when they contained all three arguments of the dative verb appropriately case-marked, and expressed the description without a preposition; both variations of indirect object and direct object orders were included (2.a/2.b). Sentences were coded as complete PO datives when they included all three arguments of the dative verb appropriately case-marked and expressed the description with a preposition (2.c). Additionally, sentences were coded as complete when a DO or PO phrase was used within a subclause (4.c).

Inaccurate utterances and those where the noun phrases were incorrectly case-marked were both coded as DO or PO in the lenient analysis only. Children made mistakes with case-marking the dative article (e.g., errors marked in bold, correct article in brackets, *Das Schaf bringt* ***das*** *[dem] Mädchen den Hund*, "The sheep is bringing the girl the dog"); the accusative article (*Ich sehe, dass der Frosch dem Räuber* ***ein*** *[einen] Hund bringt*, "I see that the frog is bringing the robber a dog"), and sometimes on both articles (e.g., *Das Schweinchen gibt* ***das*** *[dem] Mädchen* ***dem*** *[den] Zwerg*, "The piglet is giving the girl the gnome"). Inaccurate utterances were those where the utterance did not accurately describe the scenario or where descriptions were incorrectly formed (e.g., DO: *Eine Giraffe macht der Tierarzt einen Papagei*, "A giraffe makes the vet a parrot"; PO: *Der Elefant gibt den Pinguin* ***bei*** *[zu] der Königin,* "The elephant gives the penguin at [to] the queen").

Results and Analysis

For the purpose of the analyses, we present the data from the baseline and priming tasks for transitives separately from the tasks for datives.

Transitive Data

In the warm-up task, participants described 69% of the three transitive events with actives, 0% as passives, 26% as other (5% were excluded) showing that the children had a clear baseline preference to use actives for transitive events. In the priming task, 77% of strict scored transitive sentences were active and 11% were passive (12% of the responses were coded as other), indicating a clear effect of the priming task in comparison to the baseline data. A total of 66 target responses were coded as complete passives in the strict analysis, two more responses were included in the lenient analysis and six more responses in the inclusive (Table 3). Of the 29 participants, 20 attempted a passive sentence at least once.

Table 3. Frequency of children's utterances that were transitive descriptions by the strict coding scheme and the frequency of responses added in the lenient and inclusive coding schemes.

	Strict (complete)		Lenient (incomplete)		Inclusive (reversed)			
	Active	Passive	Active	Passive	Active	Passive	Other	Excluded
Active Prime	255	17	6	1	2	0	9	0
Passive Prime	192	49	2	1	9	6	17	14

Children produced consistent numbers of passive (and active) responses in the first and second halves of the target trial block, they also produced numerically more passives following passive primes than active primes in both the first and second halves of the target trial block (Table 4). The order in which the priming stories were presented was randomly assigned such that some children heard active stories before passive stories and vice versa, however we found that passive responses were only produced following the active primes block when the active story was the final condition presented in the experiment, which was the case for 6 of the 29 participants. Correspondingly, the children produced more passives when the passive prime block occurred earlier in the study than later (see Table 4). These results within and across blocks imply lasting effects of the prime blocks.

Table 4. Frequency of transitive responses by prime condition and target block half (first vs second half), and by prime condition and counter-balancing of priming blocks (blocks 1/2 vs blocks 3/4).

	Active responses		Passive responses	
	1st half	*2nd half*	*1st half*	*2nd half*
Active Prime	130	125	7	10

Passive Prime	91	101	26	23

	Active responses		Passive responses	
	Block 1/2	*Block 3/4*	*Block 1/2*	*Block 3/4*
Active Prime	103	152	0	17
Passive Prime	125	67	32	17

Mixed-effects models were used to analyze the frequency of passive responses in the target blocks (see Figure 2a). Since the data involve binomial categorical responses (active or passive; DO or PO), generalized linear mixed models with a logit link function are more suitable than ANOVA and account for participant and item variation (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). We used the lme4 package (Bates, Mächler, Bolker, & Walker, 2014) in R (version 4.2.1) and for all analyses, we fitted maximal models with a full random effects structure (Barr, Levy, Scheepers, & Tily, 2013) including random slopes by participants for within-subjects predictors (Prime Structure, Block Half) and by items for within-items predictors (Prime Structure). Where a maximal model did not converge, the random slopes structure was simplified by removing higher-order terms that explained the least variance first until the model converged.

Children's responses in active and passive priming conditions were analyzed to investigate whether a priming effect was found overall and whether it persisted over the two block halves: Target responses (passive, 1 and active, 0) were fitted to a model with Prime Structure (active, -0.5 vs. passive, 0.5) and Block Half (first half, -0.5 vs. second half, 0.5) as fixed effects. We also included Age (in months as a centered continuous predictor) but this was removed from all models due to models with Age not converging. The maximal model to converge included random slopes by participants for Prime Structure; these models are reported in Table 5.

Table 5. Summary of maximally converging logit mixed-effects model of passive responses.

Predictor	**Coefficient**	***SE***	**Wald Z**	***p-value***
Strict Analysis				
Intercept	-3.78	0.89	-4.27	<.001
Prime Structure	3.98	1.60	2.48	=.01
Block Half	0.18	0.52	0.45	0.74
Prime Structure × Block Half	-0.87	0.73	-1.19	0.23
Lenient Analysis				
Intercept	-3.81	0.87	-4.37	<.001
Prime Structure	3.92	1.57	2.51	.012
Block Half	0.24	0.52	0.46	0.65
Prime Structure × Block Half	-0.81	0.73	-1.11	0.27
Inclusive Analysis				
Intercept	-3.49	0.69	-5.04	<.001
Prime Structure	3.29	1.14	2.88	.004
Block Half	0.23	0.48	0.47	0.64
Prime Structure × Block Half	-1.08	0.70	-1.55	0.12

In the strict analysis, there was a main effect of Prime Structure indicating that more passive utterances were produced after passive primes (M= .18) than after active primes (M= .06), rendering a 12% priming effect (Figure 2a). There was no significant effect of Block Half or interaction between the two, suggesting that the likelihood of producing passives did not change across the target block, irrespective of whether the target block occurred after a block of passive or active primes. This pattern of results was consistent across the analyses of data from the strict, lenient, and inclusive coding schemes.

a. Transitive responses b. Dative responses

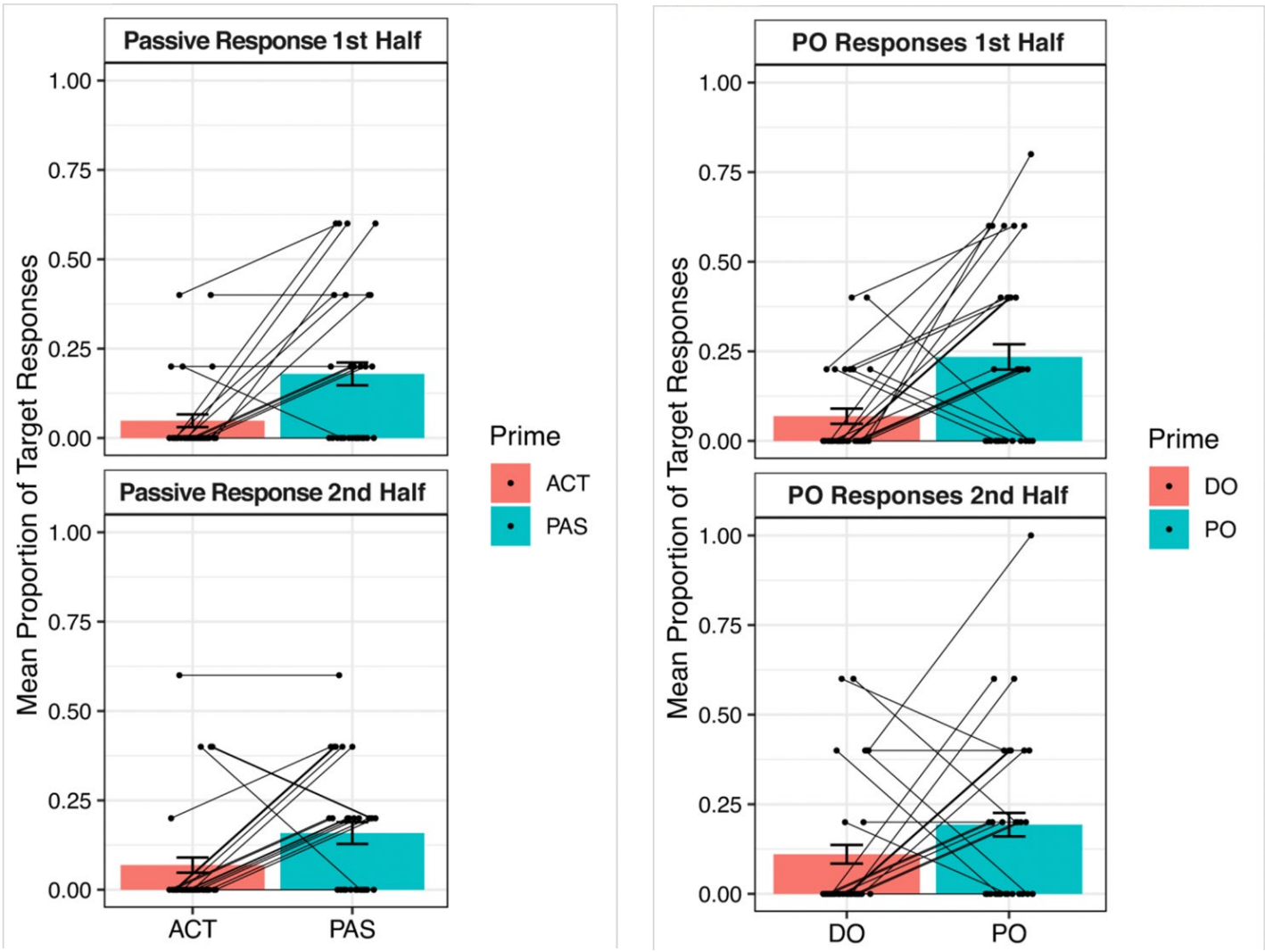


Figure 2. Mean proportion target responses in Experiment 1 (a) transitives and (b) datives by prime condition and first versus second half of target block. Dots indicate individuals' proportion of target responses in each condition and lines connecting dots represent the difference between conditions for each participant (i.e., priming effects).

Since it is difficult to interpret null effects, we turned to Bayes factor analysis to assess the likelihood of the interaction between Prime Structure and Block Half being null. We calculated the Bayes factor in favour of the null hypothesis (that there is no interaction) over the alternative hypothesis (that there is an interaction; BF_{01}) (Wagenmakers, 2007). We created a null model without the interaction between Prime Structure and Block Half and

used the Bayesian Information Criterion (BIC) of this and the alternative model with the interaction to estimate the Bayes factor as $e^{(BIC\_alternative - BIC\_null)/2}$. BF_{01} was 10.43 which provides positive/strong evidence (Jarosz & Wiley, 2014) in support of the null model (without the interaction) over the alternative model (with the interaction). This suggests that it is more likely that the effect of prime structure did not differ across the two halves.

We also checked whether these implicit learning effects could in fact be the result of self-priming from previous productions, that is, the result of a chain of priming from one trial to the next[2]. Following Huttenlocher et al. (2004), we calculated the frequency of passive responses that were produced immediately after another passive response and the frequency of passive responses that were not immediately preceded by another passive. We found that the majority of target structures were produced following other forms: 68% of passive responses did *not* follow an immediately previous passive response, only 32% did. This suggests that our priming effects were likely not the result of a chain of priming from one target response to the next.

Lastly, we examined cumulative effects of priming by adding a cumulative production of passives predictor which was the cumulative frequency on a given trial of previously produced passives across the experiment (since the prime manipulation was blocked, we could not test a trial-by-trial effect of hearing passive primes). We fit a new model of the transitive target responses (passive, 1 and active, 0) with Prime Structure (active, -0.5 vs. passive, 0.5) and the cumulative passives factor, which was a continuous predictor. The maximal model to converge included random effects for items but not participants and no random slopes. In this model, Prime Structure was again significant (β= 2.27, SE= 0.67, Z=3.38, p< .001) and there was a significant effect of cumulative passives (β= 0.01, SE= 0.12, Z=7.77, p< .001) but no interaction between the two (Z=1.48, p= .14).

This suggests that children produced more passives after passive primes but they were also increasing likely to produce passives as they produced more passives.

Datives Data

In the baseline task, children described 26% of the three dative events with a DO structure, 6% as PO; 63% were coded as other (5% excluded). Children had a baseline preference to use the DO relative to the PO dative, however they frequently produced non-ditransitive descriptions, such as listing or describing the characters individually, when not primed. Children also preferred DO phrases for the priming task: 56% of their strict-coded descriptions were DO, 15% were PO (and 29% were coded as other), which nonetheless shows a clear effect of the priming task, as for the transitives. They produced 89 complete and correctly case-marked PO utterances; an additional 42 PO utterances were included in the lenient analysis (Table 6). Of the 29 participants, 24 participants attempted a PO phrase at least once.

Table 6. Frequency of children's utterances that were dative descriptions by the strict coding scheme and the frequency of responses added in the lenient and inclusive coding schemes.

	Strict (complete)		Lenient (inaccurate)		Lenient (case-marking)			
	DO	PO	DO	PO	DO	PO	Other	Excluded
DO Prime	182	26	1	4	54	13	9	1
PO Prime	140	63	2	3	52	22	8	0

As observed in the transitive trials, children produced consistent numbers of PO (and DO) responses in the first and second halves of the target trial block and produced more PO responses following PO primes than DO primes in each half (Table 7). Children were similarly more likely to produce PO responses following a PO prime block earlier in the

experiment than later and following a DO prime block that was later in the experimenter (Table 7), again suggesting lasting effects of the priming with and across blocks.

Table 7. Frequency of dative responses by prime condition and target block half (first vs second half), and by prime condition and counter-balancing of priming blocks (blocks 1/2 vs blocks 3/4).

	DO responses		PO responses	
	1st half	*2nd half*	*1st half*	*2nd half*
DO Prime	94	88	10	16
PO Prime	69	71	34	28
	DO responses		PO responses	
	Block 1/2	*Block 3/4*	*Block 1/2*	*Block 3/4*
DO Prime	94	88	2	24
PO Prime	55	85	43	19

Children's responses across priming conditions were analyzed to investigate whether a priming effect was found overall and whether it persisted across both halves. We used the same method of analysis as described for the transitive responses. The maximal models to converge included random slopes by participants for Prime Structure; these models are reported in Table 8. The strict analysis revealed a main effect of Prime Structure as more PO phrases were produced after PO primes (M= .21) than after DO primes (M= .09), yielding a 12% priming effect. As was observed in the transitive model, there was no significant effect of or interaction with Block Half, which suggests that the likelihood of producing a PO response did not change across the target trial block, irrespective of prime condition (see Figure 2b). The pattern of results was the same with the lenient-scored responses (see Table

8). We again tested the likelihood of the interaction being null by calculating the Bayes factor in favour of the null hypothesis (there is no interaction) over the alternative hypothesis (there is an interaction; BF_{01}), using the same calculation as previously. BF_{01} was 5.59 which provides positive/substantial evidence in support of the null model (without the interaction) over the alternative model (with the interaction; Jarosz & Wiley, 2014). This again suggests that it is more likely that the effect of prime structure did not differ across the two halves.

We again checked whether these implicit learning effects could in fact be the result of self-priming from previous productions by calculating the frequency of PO responses that were produced immediately after another PO response and those that were produced after a different response form. As with the transitives, we found that most of the target structures were produced following other forms: 63% of PO responses did *not* follow an immediately previous PO response, 37% did.

Lastly, we again examined whether priming effects were cumulative by adding a predictor which was the cumulative frequency on a given trial of previously produced PO responses across the experiment. We fit a new model of the dative responses (PO, 1 and DO, 0) with Prime Structure (DO, -0.5 vs. PO, 0.5) and the cumulative PO responses predictor. The maximal model to converge included random effects for items and participants but no random slopes. In this model, the main effect of Prime Structure was no longer significant (β= 0.88, SE= 0.50, Z=1.76, p= .08) but there was a significant effect of cumulative PO responses (β= 0.69, SE= 0.11, Z=6.04, p< .001) and an interaction between the two (β= 0.60, SE= 0.18, Z=3.32, p< .001). This suggests that children were increasing likely to produce PO responses as they produced more PO responses and this effect was greater after PO primes than after DO primes.

Table 8. Summary of maximally converging logit mixed-effects model of PO responses.

Predictor	Coefficient	*SE*	Wald Z	*p-value*
Strict Analysis				
Intercept	-2.07	0.48	-4.30	< .001
Prime Structure	1.83	0.64	2.87	.004
Block Half	0.18	0.45	0.40	0.69
Prime Structure × Block Half	-1.07	0.68	-1.58	0.11
Lenient Analysis				
Intercept	-2.06	0.46	-4.46	<.001
Prime Structure	1.71	0.48	3.55	<.001
Block Half	-0.24	0.41	-0.06	0.95
Prime Structure × Block Half	-0.94	0.55	-1.71	0.09

Discussion

In the syntactic priming tasks, young German-speaking children were more likely to produce passive and PO structures after hearing a block of the same primes than after hearing a block of alternative (active and DO) primes. Passives were never used to describe transitive events on the baseline trials but, after hearing passive primes, children used passives in 19% of their responses, compared to 6% of their responses after active primes. Similarly, POs were used for only 6% of the dative events in the baseline trials whereas children's production increased to 30% of their responses after they heard PO primes, compared to 12% after hearing DO primes. Note that for both structural alternations, children produced more target structures in each priming condition (the target prime and the alternative) compared to the baseline trials. The production of target responses did not decrease across the target block but effects of priming did accumulate across the experiment, thus, exposure to a block of

target structure primes had immediate and lasting effects on the likelihood of children using those structures.

General Discussion

In this study we explored young and older German speakers' production preferences when describing pictures of transitive and dative events. We first collected adult speakers' descriptions of target images without priming. The responses revealed that German-speaking adults preferred to produce active structures over passive for transitive events and DO structures over PO for dative events. Baseline data collected from child participants in Experiment 1 showed the same pattern. Like adults, German-speaking children showed a preference for the active transitive structure; in fact, they never produced passives prior to the priming input. Also like adults, the children produced a lot of "other" responses for the dative items without priming, but showed a preference for DO dative structures. We then examined whether we could prime young children to use the dispreferred structures when describing the same events. We used a blocked design (Huttenlocher et al., 2004) to test lasting effects of syntactic priming in children, with prime and target trials embedded in a picture book description task. The children were more likely to produce the passive and PO sentences to describe transitive events after having heard a block of passive/PO primes than after having heard a block of active/DO primes. These priming effects were not transient but rather maintained across a block of ten trials – children did not differ in how likely they were to produce passive/PO structures in the second half of the block as in the first half. Moreover, children's production was also increased by their cumulative prior productions. These findings confirm that preschool-aged German-speaking children comprehend, produce and are susceptible to syntactic priming effects for two different, dispreferred verb phrase structures.

When they heard a block of passive or PO primes, children produced more passive and PO responses compared to when they heard active or DO primes. These results suggest that by four to five years of age, German-speaking children have acquired an abstract representation of each structure that is susceptible to priming. Moreover, this effect did not diminish for the second half of the target block, children remained more likely to use these structures beyond the immediate input. Consistent with previous research (e.g. Gámez & Shimpi, 2016; Hsu, 2014a; Huttenlocher et al., 2004; Kidd, 2012a; Messenger, 2021), this finding suggests that experience of these less preferred structures had a lasting effect of further strengthening the representation of those structures making it more available to be used across the target phase. This supports the idea that syntactic priming effects reflect implicit learning mechanisms.

We also observed cumulative effects on the children's responses – children were more likely to produce target responses as their own productions of the structures increased. Implicit learning accounts predict that priming effects should accumulate since priming is the result of adaptations to prior experience. One possibility is that children's sustained productions were the result of a chaining of self-priming from their own productions: their representation for a target structure was activated by their own production making it more likely to be used on the subsequent trial. However, our analysis of how frequently their target responses immediately followed previous target responses suggests this was not the case. In most instances, target responses were not immediately preceded by another target structure. Taken together, these results are better explained by an implicit learning account in which experiences of target structures effect lasting changes on speakers' representations for those structures.

In further support, the priming task increased the production of target structures across different priming conditions in comparison to the baseline trials: the percentage of

target responses in the priming phases was greater than in the baseline phases, irrespective of prime block. Additionally, and more critically, the frequency data show long-term effects of priming in that, for example, passive responses were only produced following active primes when the passive priming block occurred earlier in the experiment and the passive prime block occurred later, and not when the active prime block occurred before the passive prime block. This suggests that the early priming experience of passives lasted across the experiment (a similar pattern was observed for PO/DO responses). Overall, it is clear that a small amount of input had immediate and lasting effects on children's production choices. This study does not however tease apart whether such learning occurs via prediction and error-based learning (e.g. Dell & Chang, 2014) or via increased base-level activation of representations (e.g. Reitter et al., 2011). Further research is needed to better understand the precise mechanisms of implicit learning via syntactic priming.

Previous research has shown that while children acquiring German comprehend canonical active sentences (those with SVO word order) from early in language acquisition, around two and a half to three years of age (Brandt et al., 2016; Dittmar et al., 2008a, 2008b, 2014), comprehension of passive structures emerges slightly later, around four and a half to five years of age (Armon-Lotem et al., 2016; Aschermann et al., 2004; Dittmar et al., 2014; Schaner-Wolles, 1989), and comprehension of non-canonical structures emerges even later (Brandt et al., 2016; Dittmar et al., 2008a). Non-canonical word orders are generally challenging for young speakers in production and comprehension and therefore are less common than agent-first structures (Brandt et al., 2016). Similarly, previous research shows that children comprehend and produce canonical (recipient-theme) DO datives by five years of age, with comprehension of non-canonical orders and consistent production of accurate case-marking emerging later (Scherger et al., 2022). Our priming results extend these findings, showing that at the same age (four to five years), comprehension experience of

passives and PO datives leads to immediate and lasting increased production of the same structures across different lexical items, suggesting that these children have a representation of these structures that can be activated. Similarly to previous research, we also found that children made errors with case-marking, even in primed production, supporting the idea that this aspect of grammar develops later. However, our analyses of different levels of coding showed that the pattern of priming results did not change when their erroneous responses were included suggesting that what is primed is the constituent structure of the sentences, independent of morphological features such as case-marking.

Indeed, it is worth noting that consistent with previous priming research in German, children's production of the target structures tended to follow the form of the primes (Foltz et al., 2021). The vast majority of transitive sentences followed the form of the active and passive primes: the children produced a small number of active phrases in subordinate clauses (9) and even fewer perfective phrases where the main verb moves to sentence-final position (3); they were even less likely to vary the form of their passive responses, producing only two subordinate clauses with passives. In the same vein, though they varied their production of DO responses, including a number of subordinate DO phrases (30) and perfective verb-final phrases (2); their production of PO responses closely followed the form of the primes – no perfective and only six subordinate PO phrases were produced. Interestingly, children produced more reversed passives after passive primes (6 instances) than after active primes (1 instance), matching the prime phrase structure not the order of the nouns (Messenger, Branigan & McLean, 2012); but they also produced more reversed actives following passive primes (9 occurrences) than following active primes (2 occurrences), in this case matching the order of the nouns of the passive prime but not the phrase structure. Similarly, in their dative descriptions, children did produce some DO datives with non-canonical (theme-recipient) word order and they produced more following PO primes (with

the same order of roles; 31) than following DO primes (16). Note that one possibility is that these scrambled DO responses are in fact attempts to produce PO structures that omitted the preposition; it is not possible to discern whether the children intended a scrambled DO or a PO. Together, these data suggest that children's production of target responses, particularly of the dispreferred structures, was highly influenced by the form of the primes. This may reflect the fact that these are relatively nascent structures for German children at this age and priming facilitates production of the modelled form. Evidence from adults suggests that eventually it is possible to prime production of dative structures across different verb positions (Chang et al., 2015) and across different types of semantic roles (Pappert & Pechmann, 2013), as well as to prime different semantic role orders when structure is held constant (Köhne, Pickering, & Branigan, 2014). Whilst it was not an aim of this study to examine whether different forms could be elicited, it remains an open question as to when in language development German-speaking children acquire syntactic representations that permit such flexibility in word order production and whether, up until that point, children maintain distinct representations for different structures. Further cross-sectional work across a wide age-range would be required to investigate this.

Conclusion

In investigating the nature of underlying language mechanisms, it is important for syntactic priming research to examine whether results are supported across various languages. The current study builds on existing evidence by testing preschool-aged German-speaking children in a priming experiment looking at transitive and dative structures. The results indicate that by four to five years of age, German speakers show priming effects for passive and PO structures, with priming effects persisting across a block of trials supporting an implicit learning account of syntactic priming. Future research is needed to examine the precise nature of such representations and how these change across age.

Endnotes

[1.] This represents a relatively wide age range, but in actuality, most (25) children fell between the ages of 4;6 and 6;2, which is a similar age range to many priming studies. Early recruitment included four older children (aged 6;10-6;11) because it was not clear initially at what age children might succeed in this task. We have included these older children in the analyses reported here but we also repeated all the analyses excluding the four oldest children and the pattern of results remained the same.

[2.] We thank an anonymous reviewer for highlighting this alternative possible explanation.

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Supplementary Materials

The materials, data and analysis scripts for the Norming Study and Experiment 1 can be found online at: https://osf.io/2ynup/?view_only=ca8c63b0937d4fad91a871f696f88f4a.

Appendix A. Experiment 1: Prime and Target Sentences

A.1 Active / Passive Transitive Prime Items in German (Associated Picture)

1. *Der Affe beißt den Arzt. / Der Arzt wird von dem Affen gebissen.* (monkey biting doctor)

2. *Der Feuerwehrmann beißt den Hasen. / Der Hase wird von dem Feuerwehrmann gebissen.* (fireman biting rabbit)

3. *Die Katze jagt den Piraten. / Der Pirat wird von der Katze gejagt.* (cat chasing pirate)

4. *Der Bär jagt den Hund. / Der Hund wird von dem Bären gejagt.* (bear chasing dog)

5. *Der Frosch küsst den Arzt. / Der Arzt wird von dem Frosch geküsst.* (frog kissing doctor)

6. *Das Schaf küsst den Frosch. / Der Frosch wird von dem Schaf geküsst.* (sheep kissing frog)

7. *Der Frosch tippt den Cowboy an. / Der Cowboy wird von dem Frosch angetippt.* (frog poking cowboy)

8. *Die Katze tippt den Arzt an. / Der Arzt wird von der Katze angetippt.* (cat poking doctor)

9. *Die Fee zieht den Tiger. / Der Tiger wird von der Fee gezogen.* (fairy pulling tiger)

10. *Der Arzt zieht den Bären. / Der Bär wird von dem Arzt gezogen.* (doctor pulling bear)

11. *Der Tiger beißt die Krankenschwester. / Die Krankenschwester wird von dem Tiger gebissen.* (tiger biting nurse)

12. *Der Räuber beißt den Tiger. / Der Tiger wird von dem Räuber gebissen.* (robber biting tiger)

13. *Der König jagt den Hund. / Der Hund wird von dem König gejagt.* (king chasing dog)

14. *Die Prinzessin jagt den Affen. / Der Affe wird von der Prinzessin gejagt.* (princess chasing monkey)

15. *Das Schaf küsst die Katze. / Die Katze wird von dem Schaf geküsst.* (sheep kissing cat)

16. *Der Tiger küsst das Schwein. / Das Schwein wird von dem Tiger geküsst.* (tiger kissing pig)

17. *Der Tiger tippt die Hexe an. / Die Hexe wird von dem Tiger angetippt*. (tiger poking witch)

18. *Der Löwe tippt den Jungen an. / Der Junge wird von dem Löwen angetippt.* (lion poking boy)

19. *Der Löwe zieht die Hexe. / Die Hexe wird von dem Löwen gezogen.* (lion pulling witch)

20. *Die Giraffe zieht die Ballerina. / Die Ballerina wird von der Giraffe gezogen.* (giraffe pulling ballerina)

A.2 Transitive Target Pictures

1. Postman biting penguin

2. Tiger pulling fireman

3. Cow kissing boy

4. Cat poking boy

5. Frog chasing pirate

6. Tiger poking clown

7. Dog biting robber

8. Mouse pulling policeman

9. Duck kissing pig

10. Nurse chasing chicken

11. Horse biting doctor

12. Horse kissing witch

13. Horse pulling doctor.

14. Queen chasing bear

15. Witch poking monkey

16. Rabbit biting penguin

17. Frog kissing queen

18. Chicken chasing bear

19. Witch pulling lion

20. Frog poking clown.

A.3 DO / PO Dative Prime Items in German (Associated Picture)

1. *Das Kaninchen gibt dem Räuber die Katze. / Das Kaninchen gibt die Katze zu dem Räuber.* (rabbit giving cat to robber)

2. *Das Schaf gibt der Königin den Affen. / Das Schaf gibt den Affen zu der Königin.* (sheep giving monkey to queen)

3. *Die Giraffe zeigt der Fee den Pinguin. / Die Giraffe zeigt den Pinguin zu der Fee.* (giraffe showing penguin to fairy)

4. *Das Pferd zeigt dem Mädchen die Socke. / Das Pferd zeigt die Socke zu dem Mädchen.* (horse showing sock to girl)

5. *Der Hund bringt dem Jungen den Zwerg. / Der Hund bringt den Zwerg zu dem Jungen.* (dog bringing gnome to boy)

6. *Das Kaninchen bringt der Krankenschwester die Katze. / Das Kaninchen bringt die Katze zu der Krankenschwester.* (rabbit bringing cat to nurse)

7. *Die Kuh liefert dem Räuber die Blume. / Die Kuh liefert die Blume zu dem Räuber.* (cow delivering flower to cow)

8. *Das Pferd liefert der Fee den Kuchen. / Das Pferd liefert den Kuchen zu der Fee.* (horse delivering cake to fairy)

9. *Der Bär schickt dem Jungen den Affen. / Der Bär schickt den Affen zu dem Jungen.* (bear sending monkey to boy)

10. *Die Kuh schickt dem Arzt die Maus. / Die Kuh schickt die Maus zu dem Arzt.* (cow sending mouse to doctor)

11. *Der Hund gibt dem Arzt den Pinguin. / Der Hund gibt den Pinguin zu dem Arzt.* (dog giving penguin to doctor)

12. *Der Hund gibt dem Jungen den Pinguin. / Der Hund gibt den Pinguin zu dem Jungen.* (dog giving penguin to boy)

13. *Der Frosch zeigt dem Arzt den Zwerg. / Der Frosch zeigt den Zwerg zu dem Arzt.* (frog showing gnome to doctor)

14. *Der Elefant zeigt der Königin den Affen. / Der Elefant zeigt den Affen zu der Königin.* (elephant showing monkey to queen)

15. *Die Kuh bringt der Königin den Zwerg. / Die Kuh bringt den Zwerg zu der Königin.* (cow bringing gnome to king)

16. *Die Giraffe bringt dem Clown den Affen. / Die Giraffe bringt den Affen zu dem Clown.* (giraffe bringing monkey to clown)

17. *Der Hund liefert dem Mädchen das Buch. / Der Hund liefert das Buch zu dem Mädchen.* (dog delivering book to girl)

18. *Der Tiger liefert der Hexe die Banane. / Der Tiger liefert die Banane zu der Hexe.* (tiger delivering banana to witch)

19. *Der Hund schickt dem Feuerwehrmann die Katze. / Der Hund schickt die Katze zu dem Feuerwehrmann.* (dog sending cat to fireman)

20. *Die Katze schickt dem Clown den Pinguin. / Die Katze schickt den Pinguin zu dem Clown.* (cat sending penguin to clown)

A.4 Dative Target Pictures

1. Goat giving mouse to witch

2. Cat bring penguin to queen

3. Goat send gnome to king

4. Elephant deliver flower to king

5. Elephant show penguin to queen

6. Giraffe bring mouse to clown

7. Elephant deliver ice cream to queen.

8. Frog show puppy to robber

9. Sheep give puppy to girl

10. Frog send gnome to queen

11. Frog show cat to fairy

12. Sheep give dog to queen

13. Frog send gnome to boy

14. Giraffe deliver sock to doctor

15. Pig bring gnome to girl

16. Tiger deliver hat to witch

17. Giraffe give monkey to fairy

18. Horse show puppy to queen

19. Horse send puppy to robber

20. Tiger bring penguin to witch

Appendix B: Schematic of Study Set Up.

Structure is counterbalanced within items across Versions A and B; the order of each alternation was rotated between participants.