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Experience and Processing of Relative Clauses in German

Silke Brandt

Sanjo Nitschke and Evan Kidd

1. Introduction

Many studies have shown that both children and adults experience less difficulty processing and comprehending subject relative clauses (RCs), such as (1), than object RCs, such as (2) (e.g. de Villiers et al. 1979; Frazier & Clifton 1989; Friedmann & Novogrodsky 2004).

(1) *That's the dog that chased the cat.*

(2) *That's the cat that the dog chased.*

A number of different theoretical proposals aim to explain this asymmetry. For example, according to King and Just (1991), the processing of object RCs requires greater working memory than the processing of subject RCs (see also Gibson, 1998). For school-aged children, Booth, MacWhinney, and Harasaki (2000) found that children with greater short-term memory capacity tend to process object RCs more efficiently than children with comparatively lower short-term-memory capacity. Alternatively, MacWhinney and Pleh (1988) suggested that processing object RCs is difficult because this sentence type requires multiple shifts in perspective.

In the current study we focus on explanations that identify experience with different word orders within and across constructions as a potential explanation of sentence difficulty. Diessel and Tomasello (2005) suggested that English- and German-speaking children have less difficulty comprehending and producing subject RCs because these sentences have the same basic word order as simple transitive sentences, which children frequently encounter (see also Bever, 1970). That is, in both subject RCs and simple transitives the subject precedes the object. In object RCs, on the other hand, the object precedes the subject. In English, this OS word order only appears in object RCs and some cleft

[*] Silke Brandt, University of Basel, silke.brandt@unibas.ch; Sanjo Nitschke, Max Planck Institute for Evolutionary Atnthropology, sanjo.nitschke@googlemail.com; Evan Kidd, The Australian National University, evan.kidd@anu.edu.au

constructions.[1] In German, this OS order is also possible in simple transitives, but the vast majority of transitive sentences that German-speaking children hear have a SO word order (see Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008). Therefore, although English and German speakers actually hear more object RCs with an OS(V) order than transitive subject RCs with an SO(V) order (Brandt, Diessel, & Tomasello, 2008; Diessel & Tomasello, 2000), they find it easier to process subject RCs because the SO word order is more frequent overall.

That children and adults are sensitive to the word order regularities of their language has been shown by many cross-linguistic studies conducted within the framework of the Competition Model. How much speakers rely on word order to determine agent-patient relations depends on how reliable this cue is in their language (e.g., Bates & MacWhinney, 1989). Word order in Italian, for example, is more flexible and thus less reliable than it is in English. Consequently, Italian-speaking children and adults rely less on word order to interpret sentences than English-speaking children and adults (see Bates, Devescovi, & D'Amico, 1999; Bates, MacWhinney, Caselli, Devescovi, Natale, & Venza, 1984). This differential sensitivity to different cues operates across construction types; for example, Bates et al. (1999) showed that English-speaking adults are more sensitive to word order than Italian-speaking adults in their interpretation of both simple transitives and RCs.

Further support for the assumption that the processing of RCs is influenced by frequent word-order patterns comes from studies on children's and adults' processing of RCs in Chinese, where many studies have shown an object RC advantage (e.g., Chan, Matthews, & Yip 2011; Hsiao & Gibson, 2003; Yip & Matthews, 2007). This is likely to be due to the fact that Chinese object RCs have the same basic SO word order as simple transitives. Chinese subject RCs, on the other hand, have non-canonical OS word order.

To summarize, cross-linguistic studies suggest that we use the same processing strategies for simple and complex sentences. Those RC constructions that display the same or similar word-order patterns to (most) simple transitives are easier to process than those structures that have non-canonical word-order, which suggests that commonly experienced word orders facilitate processing across constructions. In English, non-canonical OS word orders only appear in object RCs and some cleft constructions and can thus only be learned by exposure to these specific constructions. This suggestion is supported by empirical and computational data (MacDonald & Christiansen, 2002; Wells, Christiansen, Race, Acheson, & MacDonald, 2009). Wells et al. (2009) used a self-paced reading paradigm to test English-speaking adults' processing of subject and object RCs before and after a training phase, during which the participants read the same number of subject and object RCs (and some unrelated structures). Reading times for both subject and object RCs decreased.

[1] Object wh-questions also have OSV word order, but require *do*-support, which could provide an additional cue to thematic role assignment.

However, despite the exact same frequencies of subject and object RCs in the training phase, the training effect for object RCs was significantly greater than for subject RCs. That is, differences in reading time for the critical main-verb region (e.g., object RC: *The clerk that the typist trained* ***told*** *the truth.* subject RC: *The clerk that trained the typist* ***told*** *the truth.*) decreased significantly. These results were argued to support the *frequency x regularity interaction* (cf., Seidenberg, 1985), according to which the processing of words with irregular spelling-sound relationships or sentences with irregular word orders, such as object RCs, can only be learned by direct exposure to these specific words or sentence types. On the other hand, the processing of words with regular spelling-sound relationships or sentence types following regular word-order patterns (e.g., subject RCs) is also supported by exposure to *other* items that follow this regular pattern, such as simple transitives. Increasing the frequency of a specific sentence type following an irregular pattern shows greater effects than increasing the frequency of a sentence type following a regular pattern because the latter is already supported by a great number of items.

Hutton and Kidd (2011) have also presented data in support of the frequency x regularity interaction. Following Wells et al. (2009) they tested English-speaking adults' processing of subject and object RCs with a self-paced reading paradigm. Instead of increasing the participants' experience with subject and object RCs during a training block, participants were asked to read subject and object RCs in prime-target pairs. That is, in the test trials, they read an object RC immediately after having read either a subject or object RC, or read a subject RC immediately after having read a subject or object RC. The priming effect for object RCs was significantly greater than for subject RCs. That is, participants profited more from reading an object RC immediately before processing another object RC than from reading a subject RC before processing another subject RC.

Finally, Nitschke, Kidd, and Serratrice (2010) used a priming paradigm to investigate how adults' experience with structurally ambiguous RCs can change their interpretation of these RC types. Compared to English, Italian and German have relatively flexible word orders: the object can precede the subject in RCs as well as simple transitives. In order to comprehend these non-canonical word orders, Italian- and German-speaking children and adults need to pay attention to animacy, case, and/or agreement cues. In the absence of these cues, children and adults tend to interpret NVN or NNV sentences as SVO or SOV, just like English-speaking children and adults (e.g., Bates et al., 1984; Dittmar et al., 2008).

In the baseline phase of their experiment, Nitschke et al. (2010) asked native speakers and L2 learners of German and Italian to interpret ambiguous NNV structures. In the absence of clear case marking, agreement, or animacy, these can be interpreted as either subject RCs (SOV) or object RCs (OSV):

(3) die Frau, die das Mädchen umarmt.

the$_{[Subj/Obj]}$ woman that$_{[Subj/Obj]}$ the$_{[Subj/Obj]}$ girl hugs
the woman that is hugging the girl/ that the girl is hugging.

In German, native speakers interpreted almost all of these ambiguous structures as SOV. The L2 learners also interpreted most of the target sentences as SOV, but were less consistent in the application of the word-order rule. Similar patterns were found for Italian.

In the subsequent prime phase participants were asked to interpret the same kinds of ambiguous RCs. However, the prime items were paired with pictures that only showed an OSV reading. The prime items thus had to be interpreted as OSV, whereas the target items, each immediately following a prime item, could once again be interpreted as either SOV or OSV. During the prime phase, both native speakers and L2 learners of German interpreted the ambiguous NNV structures as OSV significantly more often than in the baseline phase. This priming effect also carried over into the post-test phase where the ambiguous targets were no longer paired with prime items. Moreover, the priming effect for the L2 learners was stronger than for the native German speakers. In Italian, only the L2 were primed (for discussion see Nitschke et al., 2010).

These results support the assumption that priming can be considered as a kind of implicit learning process (Chang, Dell, & Bock, 2006). Being exposed to structurally ambiguous NNV sentences that must necessarily be interpreted as OSV can alter established (SOV) parsing preferences for these constructions. That the changes in the learners are greater suggests that their parsing preferences are less entrenched. Furthermore, for the processing of RCs, these results suggest that the processing asymmetry between subject and object RCs can be reduced when participants' exposure to object RCs is increased. In the current study we used the same priming paradigm as Nitschke et al. (2010) to test whether we can also manipulate German-speaking children's interpretation of ambiguous RCs.

2. Method

Participants

Seventy-two (N = 72) German-speaking children participated. 36 of them were between 6;0 and 6;11 (mean 6;5) and 36 were between 9;0 and 9;11 (mean 9;6). The six-year-olds were recruited and tested in kindergartens and the nine-year-olds were recruited and tested in schools in a midsize German city. All were growing up monolingual; none had any known language impairments.

Materials

The experiment contained 78 sentences. Thirty-six of these sentences served as targets. These target sentences were German NNV relative clauses with an ambiguous subject-object order. For example, in the sentence *Wo ist die Ballerina, die das Mädchen weckt?* 'Where is the ballerina$_{[Subj/Obj]}$, that the girl$_{[Obj/Subj]}$ wakes' *Ballerina* 'ballerina' or *Mädchen* 'girl' may take the subject role. Another 12 sentences served as primes. These were also NNV relative clauses. Depending on the condition, the prime sentences either contained an ambiguous subject-object order, just like the target sentences, or they were disambiguated by case marking. The remaining 30 sentences served as fillers to distract the children from the NNV structure. The filler sentences consisted of simple sentences with transitive (e.g., *Wo kitzelt das Mädchen den Jungen*? 'Where is the girl tickling the boy') or intransitive actions (e.g., *Wo tanzt der Großvater?* 'Where is the grandfather dancing'), sentences with prepositional phrases (e.g., *Wo fährt das Mädchen mit dem Fahrrad?* 'Where is the girl riding on her bicycle'), and sentences with ditransitive actions (e.g., *Wo grüßt der Großvater den Koch?* 'Where does the grandfather greet the chef').

All 78 sentences were pre-recorded by a male native speaker of German. Each of these 78 sentences was accompanied by two pictures (see Figure 1). The unit of one sentence and its corresponding pair of pictures will be called an *item.* The material was prepared for two between-subjects conditions: (i) an 'ambiguous primes' condition in which the prime sentences were ambiguous, but only one picture matched the sentence, and (ii) a 'case disambiguated primes' condition in which the prime sentences were disambiguated by case marking but also matched only one of the pictures.

In German case is marked on adjectives, determiners, and relative pronouns. For masculine nouns nominative and accusative case have distinct surface forms and therefore unambiguously signal thematic role assignment. This is not the case for feminine and neuter nouns, where nominative and accusative case are marked by the same forms. Therefore, in the 'ambiguous primes' condition all human characters were female or neuter, making the sentence ambiguous. In this condition, the 48 NNV RCs were assembled out of 12 different nouns of either feminine or neuter gender. Six different verbs were used. In the 'case disambiguated primes', the twelve prime sentences each contained one feminine or neuter and one masculine noun, which served to disambiguated the sentences. In half of the prime sentences the masculine NP took the position of the first NP, in the other half it took the position of the second NP. In this condition, the 48 NNV RCs were assembled out of the same 12 feminine or neuter nouns and the same six verbs from the 'ambiguous primes' condition. Additionally, twelve different masculine nouns were used in the prime sentences.

Procedure

Each child was assigned to one of two groups by age and randomly to one of the two prime conditions, see Table 1.

Table 1. The four participant groups

	Ambiguous primes condition	Case disambiguated primes condition
Age 6	*Age 6, ambig* (n = 18)	*Age 6, case* (n = 18)
Age 9	*Age 9, ambig* (n = 18)	*Age 9, case* (n = 18)

The structural priming task was presented using E-Prime 2 (MacWhinney, James, Schunn, Li, & Schneider, 2001) on a laptop computer. The children were told that they were going to play a game where they had to find pictures. Each child was tested individually.

Prior to participating in the experiment the children were tested on 24 warm-up items that required them to identify all characters that were used later in the experimental items. The children were shown two pictures (e.g. of a nurse and a grandmother) and and heard an audio (e.g., *Wo ist die Krankenschwester?* ‘Where is the nurse’). The overwhelming majority of children knew all characters. When a child could not name a character the experimenter named it for them.

The children then moved on to the experimental items. For each item the pictures were displayed first. Following a delay of 1000ms a pre-recorded description was played. The children’s task was to point to the appropriate picture. The picture display did not time out and the children were given the option to hear the sentence again if required.

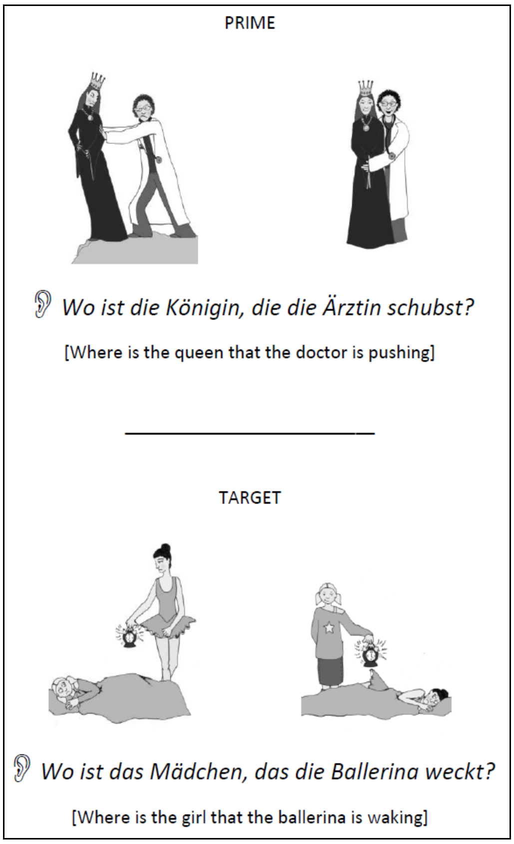

Figure 1. Example of a prime item and a target item

The picture selection task was divided into three continuous phases: (i) a baseline phase, (ii) a prime phase, and (iii) a post-test phase. All three phases contained pairs of NNV relative clauses separated by one or two fillers. In the baseline phase all ambiguous RCs were followed by pictures providing both the object RC reading (OSV) and the subject RC reading (SOV) of each sentence. This phase served to determine whether the children had an SOV or OSV preference for the ambiguous NNV RCs.

During the prime phase, the first RC of each RC pair was disambiguated to an OSV reading and served as a *prime*. Only one picture, which displayed the OSV reading, matched the prime sentence. Another picture in which the role assignment also corresponded to the OSV mapping, but which showed an action that did not match the verb of the description (see top panel of Figure 1), acted as a distracter. In the 'case disambiguated primes' condition, the prime was also disambiguated by case marking on the first or second NP. In both conditions, the second RC of each RC pair, the *target*, was fully ambiguous and provided both interpretations (SOV and OSV) (see bottom panel of Figure 1). The post-test phase was constructed like the baseline phase. Each phase contained 12 NNV RC target items; the prime phase contained an additional 12 NNV RC prime items. The logic behind the design was that, by restricting the choice to an OSV mapping in the prime items, the children would be primed to select the OSV scene in the target items despite also having the SOV scene available. There was no lexical overlap between prime and target items in any of the prime-target pairs.

Six fully balanced lists were created so that each target item occurred in each of the three phases across the participants. Additionally, the location of the picture with the OSV scene (left picture vs. right picture) was fully balanced throughout the experiment. In each picture to the NNV RCs the NP1 was on the left and the NP2 was on the right, allowing a left-to-right analysis of each picture.

3. Results

Figure 2 shows the proportions of OVS interpretations across age and conditions. Age affected children's interpretations. In both conditions the 9-year-old children showed clear increases in OSV interpretations from baseline to test and from test to post-test. In contrast, the 6-year-old children's interpretations were much more variable. Their baseline data suggest that they have a less consistent subject RC preference for ambiguous NNV RCs; their test and post-test data suggest that they are less likely than the 9-year-old children to be primed.

To investigate the patterns in Figure 2, the data were analysed using Generalized Linear Mixed Models (GLMM) (Baayen, Davidson, & Bates, 2008; Jaeger, 2008) with the lme4 package (version 0.999375-33) for Linear Mixed

Effects (Bates & Maechler, 2010) in R, version 2.10.1 (R Development Core Team, 2009).

Following Jaeger (2008) we tested for interactions between the random and fixed effects (i.e. random slopes and random intercepts). The initial model was over-specified and did not converge (i.e. false convergence error). We therefore tested each random slope separately. However, including a three-way interaction between age, condition, and phase also caused convergence errors; we therefore limited the maximum level of interactions between age, condition, and phase to two. None of the random slopes had an effect on the model (all $p > .50$); calculating a model with the two-way interactions as random slopes did not converge.

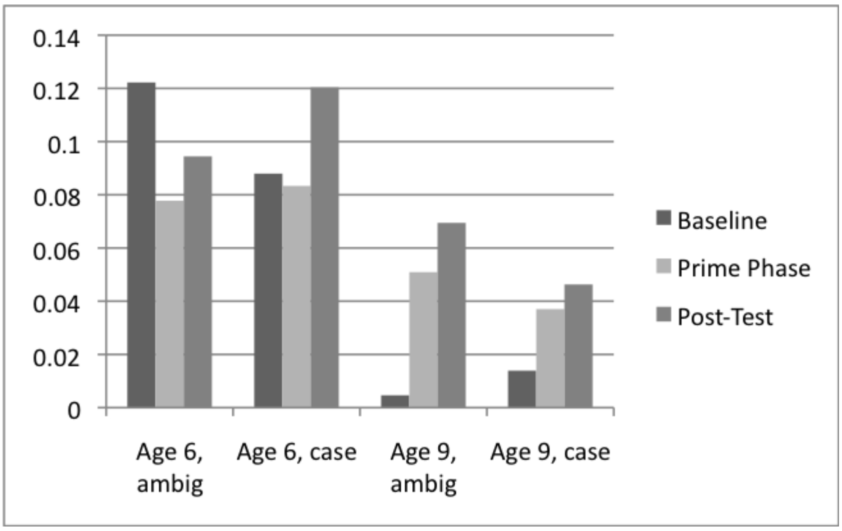

Figure 2. Proportions of OVS interpretations

We therefore built a GLMM that included age (6, 9), phase (baseline, prime, post-test), and condition (ambiguous primes, case disambiguation) as fixed factors, and participant and item as random factors, but limited the model to two-level interactions. The random slopes had no effect and the model did not converge; therefore the model contained no random slopes, see box R1.

```
full=lmer(response~(Age+Condition+Phase)^2
+(1|Participant)+(1|Item),family=binomial,data,REML=F)
```

R 1. The full model used for analysis

The full model fitted the data better than a null model that only contained the random factors ($\chi^2(6) = 22.33$, $p = .001$). Next we tested whether the two-way interactions between age, condition, and phase were significant. The full model was compared to a reduced model without any interactions. The difference was significant ($\chi^2(3) = 8.80$, $p = .032$).

To identify any significant interactions we created three new models that contained all three fixed factors (age, condition, phase) but only one two-way interaction between any two of the fixed factors. Each model was compared to a reduced model that contained no interaction. The age*condition ($\chi^2(1) = 0.09$, $p = .76$) and condition*phase ($\chi^2(1) = 0.23$, $p = .63$) interactions were not significant. However, the interaction of age*phase was significant ($\chi^2(1) =7.62$, $p = .006$). The final model is shown in Table 2.

The interaction between age and phase is plotted Figure 3. As Figure 3 shows, this interaction derives from the increase of OSV choices from the baseline phase to the prime phase in the 9-year-olds, whereas the 6-year-olds made less OSV choices from the baseline to the prime phase.

Table 2. Final model for the combined data of all four conditions

Predictor	Estimate	*SE*	*z*	*P*
(Intercept)	1.71	1.98	0.87	.39
Age	-0.80	0.22	-3.70	>.001
Phase	-1.21	0.56	-2.18	.029
Condition	0.004	0.02	0.19	.85
Age*Phase	0.21	0.08	2.66	.008

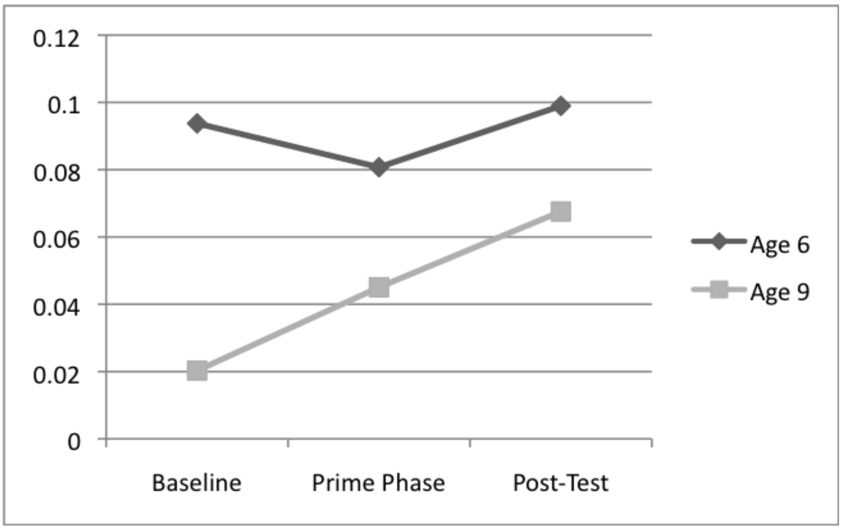

Figure 3. The significant interaction of condition*phase. The y-axis shows the proportions of OSV choices.

We next analysed the data for each of the four participant groups separately by creating four full models and four null models, which were compared using likelihood ratio tests. The code for the models is shown in the box R2.

```
lmer(response~Phase+(1|Participant)+(1|Item),
family=binomial, data, REML=F)
```

R 2. The model for each separate condition (ambiguous vs. case) separately

The results for each group are shown in Table 3. As Table 3 shows, an effect of phase was significant for the nine-year-olds only. Figure 2 shows that this is due to the increase of OSV choices across the experiment. In contrast the decreases and increases of OSV choices in the six-year-olds across the experiment were not significant.

Table 3. GLMMs for each condition

Condition	Predictor	Estimate	*SE*	*z*	*P*
Age 6, ambig	(Intercept)	-2.37	0.51	-4.70	>.001
	Phase	-0.17	0.19	-0.93	=.352
Age 6, case	(Intercept)	-3.11	0.48	-6.52	>.001
	Phase	0.21	0.18	1.21	.227
Age 9, ambig	(Intercept)	-7.68	1.12	-6.89	>.001
	Phase	1.12	0.33	3.37	>.001
Age 9, case	(Intercept)	-10.59	2.07	-5.11	>.001
	Phase	1.65	0.59	2.80	=.005

The nine-year-old children's data was analysed further by calculating new full models that only contained two of the three phases for both experiments. The results are shown in Table 4.

Table 4. Post-hoc analyses for the nine-year-olds

	Base vs. Prime-Phase				Base vs. Post-test			
	estimate	*SE*	*z*	*p*	estimate	*SE*	*z*	*p*
Age 9, ambig.	2.66	1.18	0.02	.024	1.65	0.59	2.80	.005
Age 9, case	1.03	0.80	1.28	.201	0.63	0.36	1.77	.078

As Table 4 shows, the nine year old children that were primed using ambiguous prime sentences showed an immediate effect of priming (i.e. from the Baseline to the Prime-Phase) as well as a long-term effect of priming over the Post-Test phase (i.e. from the Baseline to the Post-Test). The nine-year-olds that were primed using NNV RCs with case disambiguation showed no immediate effect of priming and only a marginal effect of priming over the Post-Test phase.

4. Discussion

We were successful in priming nine-year-old German-speaking children's comprehension of ambiguous NNV structures. Their preference to parse these ambiguous structures as subject RCs (SOV) was altered, or at least weakened, by exposing them to ambiguous NNV structures that necessitated an OSV interpretation. Comprehension priming occurred without any lexical overlap between prime and target items, and the priming effect persevered into the post-test phase where the children did not receive any additional primes, suggesting that the effect was not transient. However, the six-year-old children were not primed. In the remainder of this paper we discuss the implications of the successful priming of the nine-year-olds and these developmental differences.

As is argued on many accounts of language acquisition and processing, both children and adults derive semantic, lexical, syntactic, and contextual cues from distributional information in their input and use these cues in their sentence processing (e.g., Bates & MacWhinney, 1989; Kidd, Brandt, Lieven, and Tomasello, 2007; MacDonald, 1999). That is, experience with language leads to expectancies that guide future language use. The implication is that we should be able to alter children's and adults' processing strategies by changing the distribution of certain cues in their input. Indeed, the training and priming studies by Wells et al. (2009), Nitschke et al. (2010), and Hutton and Kidd (2011) suggest that we can alter adults' sensitivity to word order by exposing them to a relatively high number of non-canonical object-first (OSV) structures. This exposure weakens their default interpretation of ambiguous NNV structures as SOV in German and Italian (Nitschke et al., 2010; for German see also Scheepers & Crocker, 2004) and reduces the processing costs associated with non-canonical object-first patterns in English (Hutton & Kidd, 2011; Wells et al., 2009). The results from the nine-year-old children in the current study suggest that it is also possible to change children's parsing preferences by exposing them to input containing far more OSV patterns than usual.

In the current study and the adult study by Nitschke et al. (2010) the changes in parsing preference and processing difficulty persisted without further priming. These relatively long-term effects suggest that the representation of the alternative OSV structure is strengthened by experience, which is consistent with an explanation of syntactic priming as implicit learning (Chang et al., 2006). Further research is required to show whether these changes in parsing preference and processing difficulty are still evident following longer intervals, as has been shown for other structures in children and adults (e.g., Bock & Griffin, 2000; Huttenlocher, Vasilyeva, & Shimpi, 2004).

We only observed a significant priming effect in the 9-year-oild children. Developmental differences have also been reported in other priming studies (e.g., Savage, Lieven, Theakston, & Tomasello, 2003; Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007). Shimpi et al. (2007), for example, found more reliable priming effects in four-year-olds than in three-year-olds and suggested that this is driven by the fact that the younger children cannot access their abstract syntactic representations. This assumption is hard to prove or falsify. An alternative explanation for these developmental differences has been put forward by Kidd (2012). Independently of age, he found correlations between children's pattern-finding abilities, general grammatical knowledge, vocabulary score, and how likely they are to be primed to use the passive. This suggests that those children who are linguistically and cognitively more advanced have developed a stronger abstract representation of the passive and are thus more likely to be primed. In the current study we also found great individual differences *within* the age groups, suggesting that some children had developed stronger representations of the uncommon OSV pattern than others.

Finally, a very likely explanation for the lack of a priming effect in the younger children in our study is that, compared to adults and older children, the six-year-olds did not have such a strong preference to interpret the ambiguous NNV structures as SOV (see Figures 2 and 3). Priming is typically best observed in dispreferred structures, such as the passive vs. the active or double-object dative vs. prepositional dative. We tend to process language in a probabilistic way, following those patterns that are most frequently observed, such as SO word order, for example. In priming studies we typically alter the input in such a way that these processing routines do not work for a lot of items, leading to errors, which has been argued to lead to readjustments in the processing system (cf. Chang et al., 2006). Children also tend to follow probabilistic cues and show priming effects across a range of structures. However, the data from the six-year-old children suggest that priming might only clearly occur once children develop strong parsing preferences for ambiguous structures such German NNV RCs. The six-year-old children's baseline data suggest that at least some of the children still interpret these structures as OSV. This appears to be a late developing feature of German: Brandt, Lieven, and Tomasello (under revision) found that German-speaking three-year-olds are even more inconsistent than six-year-olds, interpreting these ambiguous NNV structures as SOV as often as they interpret them as OSV (Brandt, Lieven, & Tomasello, under revision). Future research is needed to further understand this developmental pattern.

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