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Structural priming of adjective–noun structures in hearing and deaf children

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ABSTRACT

We examined priming of adjective–noun structures in Dutch hearing and deaf children. In three experiments, hearing 7- and 8-year-olds, hearing 11- and 12-year-olds, and deaf 11- and 12-year-olds read a prenominal structure (e.g., *the blue ball*), a relative clause structure (e.g., *the ball that is blue*), or a main clause (e.g., *the ball is blue*). After reading each prime structure, children described a target picture in writing. Half of the target pictures contained the same noun as the prime structure and half contained a different noun. Hearing 7- and 8-year-olds and 11- and 12-year-olds, as well as deaf 11- and 12-year-olds, showed priming effects for all three structures in both the same-noun and different-noun conditions. Structural priming was not boosted by lexical repetition in the hearing and deaf 11- and 12-year-olds; a lexical boost effect was observed only in the 7- and 8-year-olds and only in the relative clause structure. The findings suggest that hearing and deaf children possess abstract representations of adjective–noun structures independent of particular lexical items.

Introduction

Structural priming refers to the tendency to repeat a particular structure that has recently been encountered. In a classical study, Bock (1986) found that adults who listened to and repeated a sentence in a passive form (e.g., *the boy was kissed by the girl*) were more likely to describe a new picture, containing different lexical items, in a passive form than in an active form (e.g., *the dog was chased by the cat* rather than *the cat chased the dog*). Structural priming has been replicated in later studies using

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different communicative settings such as spoken completion tasks (e.g., Branigan, Pickering, McLean, & Stewart, 2006), written completion tasks (e.g., Pickering & Branigan, 1998), and dialogue (Cleland & Pickering, 2003). Moreover, structural priming effects were obtained in the production of different linguistic structures, for example, in different noun phrase structures (Cleland & Pickering, 2003), in active and passive structures (e.g., Bock, 1986), and in dative structures (e.g., Corley & Scheepers, 2002). Furthermore, structural priming occurs within different languages, such as English (e.g., Bock, 1986) and Dutch (Hartsuiker & Westenberg, 2000), and across languages in bilinguals (e.g., Bernolet, Hartsuiker, & Pickering, 2007; Loebell & Bock, 2003; see Pickering & Ferreira, 2008, for a review of structural priming studies).

Explanations for structural priming typically refer to the mechanisms underlying the formulation of syntactic structures (Cleland & Pickering, 2003; Cleland & Pickering, 2006; Pickering & Branigan, 1998; Pickering & Ferreira, 2008). More specifically, it is proposed that a lemma node (representing the base form of a word, e.g., *sheep*) is linked to nodes that specify the kinds of grammatical constructions in which a word can occur, that is, nodes that specify combinatorial information (e.g., Pickering & Branigan, 1998, for verbs; Cleland & Pickering, 2003, for nouns). A picture of a red sheep can be described using a prenominal (PN) construction in which the adjective precedes the noun, *the red sheep*, or a postnominal construction containing a relative clause (RC), *the sheep that is red*. As such, there are different combinatorial nodes for each of the two constructions. Producing *sheep* in the construction *the red sheep* activates the lemma node *sheep*, the combinatorial node for PN constructions, and the link between them. Producing *sheep* in the construction *the sheep that is red* activates the lemma node *sheep*, the combinatorial node for RC constructions, and the link between them. The idea behind structural priming is that these specific syntactic representations (specific combinatorial nodes) used in the prime remain activated and are used when producing a subsequent syntactic structure. So, when first having encountered an RC structure, people are more likely to use an RC structure than a PN structure when describing another picture (e.g., Cleland & Pickering, 2003). Because structural priming effects are observed when prime and target sentences involve different lexical items, it is argued that adults have representations of syntactic forms at an abstract level independent of particular lexical items.

Although structural priming is observed in the absence of lexical overlap between the prime and target, several studies have found that priming is enhanced when prime and target sentences contain identical verbs (Corley & Scheepers, 2002; Schoonbaert, Hartsuiker, & Pickering, 2007) or nouns (Bernolet et al., 2007; Cleland & Pickering, 2003). That is, when the prime structure contains the same noun or verb as the target, people are more likely to use a structure similar to the one they encountered in the prime (often referred to as "lexical boost") than when the prime and target contain different nouns or verbs. Pickering and Branigan (1998) provided a one-locus explanation of structural priming and the lexical boost (see Pickering & Ferreira, 2008, for a more comprehensive discussion). As described above, structural priming in the case of different lexical items in prime and target sentences results from residual activation of the combinatorial node. When prime and target sentences contain identical (open class) lexical items, structural priming results from the residual activation of the combinatorial node (as in the case of different lexical items) as well as from residual activation of the preactivated lemma node and the strengthened link between this lemma node and the combinatorial node, leading to an enhanced priming effect.

In the current study, we examined structural priming in both hearing children (Experiments 1 and 2) and deaf children (Experiment 3). Research on structural priming in children can provide insight into how children acquire the structural properties of their language and syntax and whether children have similar or different representations of structural knowledge compared with adults. A few studies have investigated structural priming in children (Branigan, McLean, & Jones, 2005; Huttenlocher, Vasilyeva, & Shimpi, 2004; Miller & Deevy, 2006; Savage, Lieven, Theakston, & Tomasello, 2003; Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007). These studies aimed to determine whether the production of particular structures can be affected by prior exposure and whether young children, like adults, possess and use abstract representations of syntactic structure (independent of lexical items) or whether their syntactic representations are more lexically based. According to the latter view, children's syntactic constructions are initially organized around particular words from the input they receive, and only at a later stage do children develop abstract syntactic constructions to which they can freely assimilate new nouns (see Tomasello, 2000, for a representative theory based on this idea).

Huttenlocher and colleagues (2004) studied priming of transitive (i.e., active and passive) and dative (i.e., double object and prepositional phrase) sentences in 4- and 5-year-olds in three experiments. In the first experiment, the children saw a picture that was described by the experimenter. Children repeated the experimenter's sentence and were then shown a new picture to describe. The second experiment was like the first except that the children did not need to repeat the picture presented by the experimenter. In the third experiment, the children saw a block of 10 pictures, each of which was described by the experimenter. The children then described a block of 10 pictures without further input from the experimenter. In all experiments, primes and targets contained different nouns and verbs. Huttenlocher and colleagues observed that in all three experiments children were more likely to use a particular structure if they had heard it before, suggesting that children of this age have abstract representations of transitive and dative structures independent of lexical items (because primes and targets contained different nouns and verbs). Shimpi and colleagues (2007) observed similar priming effects of transitives and datives in 3- and 4-year-olds. Together, these studies showed productive evidence of abstract syntax.

Savage and colleagues (2003) studied priming of active and passive sentences in 3-, 4-, and 6-year-olds and also manipulated lexical overlap between the prime sentence and target picture. The children saw a picture that was described by the experimenter and were asked to repeat the experimenter's sentence. Then they were shown a new picture to describe. For half of the children in each age group, there was high lexical overlap between the prime sentence and the sentence children would likely produce to describe the target picture, and for the other half there was low lexical overlap. Specifically, in the high-overlap condition, the prime sentence contained pronouns that could be used in describing the target picture (e.g., prime: *it is pushing it*/target: *it is breaking it*), although different actions and objects appeared in primes and targets. In the low-overlap condition, prime sentences contained nouns and verbs that could not be used to describe the picture because different objects and actions were involved (e.g., prime: *the digger pushed the bricks*/target: *the hammer broke the vase*). The results showed that the 6-year-olds, in both the low- and high-overlap conditions, were more likely to produce a particular sentence construction when the experimenter had used it before, but the 3- and 4-year-olds showed such a structural priming effect only in the high-overlap condition. This priming effect was replicated in a second experiment using only the high-overlap condition and 4-year-olds who heard the experimenter's sentence and did not need to repeat it.

Together, the studies of Huttenlocher and colleagues (2004), Shimpi and colleagues (2007), and Savage and colleagues (2003) showed that exposure to particular structures increases children's use of these structures; that is, it increases the use of particular transitive (active and passive) and dative constructions, some of which are rare in young children's spontaneous language production. Specifically, for 3- and 4-year-olds, Huttenlocher and colleagues and Shimpi and colleagues observed structural priming effects even when the prime and target contained different lexical items, although Savage and colleagues found such priming effects only in the high-overlap condition. For 6-year-olds, however, savage and colleagues' study showed robust priming effects of transitive and dative constructions independent of lexical overlap between prime and target structures, suggesting that by 6 years of age children possess and use abstract transitive and dative rules independent of particular lexical items. Finally, Savage and colleagues' manipulation of low and high lexical overlap provided evidence for age-related differences in the sensitivity to lexical overlap (here: repetition of the pronoun *it*) between prime and target structures in the priming of transitive and dative structures.

The current study

Previous studies on structural priming in children typically focused on verb structures, in particular, actives versus passives and prepositional versus (double) direct objects (Huttenlocher et al., 2004; Miller & Deevy, 2006; Savage et al., 2003; Shimpi et al., 2007; cf. Branigan et al., 2005). Adjective–noun structures have not been investigated before in school-aged children, although two studies tested these structures in adults (Bernolet et al., 2007; Cleland & Pickering, 2003). Both studies examined the priming of PN clause (e.g., *the blue ball*) and RC (e.g., *the ball that is blue*) adjective–noun structures, Cleland and Pickering (2003) for English and Bernolet and colleagues (2007) for Dutch, and demonstrated priming effects in the production of adjective–noun structures. Although the use of RC structures was relatively low, adults can be primed into using this complex adjective–noun structure. Moreover, both studies found that the priming effect was boosted by lexical repetition. Priming effects were obtained when prime and target sentences contained different lexical items, but the priming effect was larger when prime and target sentences contained the same nouns.

In the current study, we examined priming of adjective–noun structures in Dutch 7- and 8-year-olds and 11- and 12-year-olds. In Experiments 1 and 2, we examined whether the production of adjective–noun structures in 7- and 8-year-olds and 11- and 12-year-olds, respectively, can be affected by prior exposure to these structures and whether children of these ages possess abstract representations of adjective–noun structures. In Dutch, as in English, an adjective (here color) can precede the noun to which it refers in a PN structure as in *de blauwe bal* [the blue ball], or the adjective can follow the noun in an RC structure as in *de bal die blauw is* [the ball that is blue] or in a main clause (MC) structure as in *de bal is blauw* [the ball is blue]. We primed children by having them read either a PN structure, an RC structure, or an MC structure. If school-aged children are sensitive to structural priming, we predicted that children, when describing a picture, are more likely to use as a prime the structure they had just read than one of the other structures.

Previous studies on priming of adjective–noun structures examined PN structures and RC structures in adults (Bernolet et al., 2007; Cleland & Pickering, 2003). Because the current study examines adjective–noun structures in children, we added the MC structure, a second postnominal structure, to explore whether priming occurs with MCs. An RC structure is a longer and syntactically more complex structure than an MC. We added the MC structure to examine whether priming of postnominal structures in children is restricted to the relatively easy MC structure or whether priming of postnominal structures also extends to the syntactically more complex RC structure.

We also manipulated the similarity of the objects in the prime and target descriptions. More specifically, half of the object nouns used in the prime structures were identical to the object in the target pictures, and the other half were different. If children show priming effects only when the prime and target structures contain similar nouns, and not when prime and target contain different nouns, this suggests that syntactic knowledge is (still) lexicalized and that children store syntactic knowledge with specific lexical entries. On the other hand, if children show structural priming effects in both the same-noun and different-noun conditions, this would suggest that children possess abstract representations for adjective–noun structures.

The manipulation of the similarity of the objects in the prime and target structures also allows one to test whether the structural priming effect is enhanced when the prime and target contain the same noun (i.e., lexical boost). Effects of a lexical boost to structural priming have been tested in studies with adult speakers (e.g., Bernolet et al., 2007; Cleland & Pickering, 2003; Pickering & Branigan, 1998; Schoonbaert et al., 2007) but have not yet been tested in school-aged children. Do children, like adults, show larger structural priming effects in the same-noun condition than in the different-noun condition (provided that priming effects do occur in the different-noun condition)? Larger effects in the same-noun condition than in the different-noun condition would suggest that abstract representations for adjective–noun structures are open to lexical influences (in line with, e.g., Pickering & Branigan's (1998) model).

In Experiment 3, we examined priming of adjective–noun structures in deaf children. Children who are deaf often have late or limited exposure to oral language because of their hearing impairment. Research in the field of language and deafness has focused predominantly on how hearing impairment affects reading, and there is far less systematic research on the writing of deaf children and adults (Marschark, Lang, & Albertini, 2002). The studies that have examined writing in deaf children typically focused on the errors children made in writing. They converged on the conclusion that deaf children's syntactic development is qualitatively different from that of hearing children and that deaf children rarely gain full mastery of syntactic forms in written language production (e.g., Ivimey & Lachterman, 1980; Mayberry, 2002; Quigley & King, 1980; Yoshinaga-Itano, Snyder, & Mayberry, 1996). Current knowledge on deaf children's and adults' writing is based mainly on studies with deaf people from English-speaking communities, but the few studies on languages other than English (i.e., Italian, Hebrew, and Dutch) corroborate deaf children's problems with syntax in writing (Taeschner, Devescovi, & Volterra, 1988; Tur-Kaspa & Dromi, 2001; van Beijsterveldt & van Hell, in press). Few studies have investigated the mechanisms underlying written language production in deaf children, however, and the extent to which deaf children attain abstract knowledge of syntactic structures in an oral language is as of yet unknown. In Experiment 3, therefore, we examined priming of adjective–noun structures in deaf school-aged children. Priming effects (in the absence of lexical repetition) in deaf school-aged children would provide evidence that children who are deaf have abstract representations of syntactic structures. It would also suggest that the difficulties that deaf children often experience with the syntax of a spoken language are not due to deficits in their abstract syntactic knowledge of the spoken language.

Finally, we compared deaf and hearing children's production of the three adjective–noun structures to explore whether differences in the amount and type of language input between deaf and hearing children affect the use of adjective–noun structures in deaf and hearing children. This is discussed in more detail in the introduction to the comparison between deaf and hearing children's production of the three adjective–noun structures in a separate section at the end of Experiment 3.

Experiment 1: Structure priming in hearing 7- and 8-year-olds

Method

Participants

A total of 20 7- and 8-year-olds (mean age = 7.62 years, SD = 0.59, 9 girls and 11 boys) participated in this experiment. All of the children grew up in monolingual Dutch families, and none of them had any known learning disabilities or developmental delays. They attended school in a small town. Children were tested at their schools, and parents had given permission for their children to participate in the study.

Materials

We created 42 pictures depicting an object that could appear in eight colors (blue, brown, green, orange, pink, purple, red, and yellow). Each object appeared in a target picture once, and each color appeared five or six times. The objects were easy-to-recognize, one-syllable nouns with a length of three to six letters. All nouns had common gender, so that for all nouns the same article (*de* [the]) or relative pronoun (*die* [that]) could be used. Age-of-acquisition norms indicated that all nouns are acquired before 6 years of age (van Loon-Vervoorn, 1985).

The stimulus materials construction procedure was based on Cleland and Pickering (2003). From the 42 pictures, we constructed 42 items (see Appendix A) defined as the pairing of a prime sentence and a target picture. The 42 prime sentences were of the following three types: a PN structure, an RC structure, or an MC structure. Each prime sentence had two variants: the same noun as the object depicted in the target and a different noun from the object depicted in the target. For example, the critical target picture of a red ball was primed by one of the following prime sentences:

1a. de rode bal [the red ball] (PN structure, same noun)
1b. de bal die rood is [literally: the ball that red is, "the ball that is red"] (RC structure, same noun)
1c. de bal is rood [the ball is red] (MC structure, same noun)
1d. de rode stoel [the red chair] (PN structure, different noun)
1e. de stoel die rood is [literally: the chair that red is, "the chair that is red"] (RC structure, different noun)
1f. de stoel is rood [the chair is red] (MC structure, different noun)

We constructed six item lists. Each list contained seven items in each of the six prime conditions. The 42 target pictures appeared once in each item list. Each list also contained 42 fillers that were also defined as a pairing of a prime sentence and a target picture. Fillers always involved different nouns and adjectives for prime sentences and target pictures. The fillers were pictures that had been used as primes or targets but always had a different color from that used in primes or targets. The order of presentation of trials varied for each list and for each child, with the constraint that the first trial was always a filler and one filler pair intervened between critical items.

Apparatus and procedure

Before the experiment, we presented the pictures used in the study to the child to familiarize him or her with the object names (following Miller and Deevy's (2004) study on structural priming in children with specific language impairment).

The prime sentences and target pictures were presented using E-Prime software. The procedure of the experimental trials was as follows. In each trial, the prime structure appeared word by word on the computer screen. Each word was presented 500 ms after the preceding word had been presented (this word remained on the screen). After all words were presented, the sentence remained on the screen for 800 ms and then disappeared. The children were instructed that they needed to read the sentence on the screen. They were then shown a picture of a particular object in a particular color that they should describe in a grammatically correct way in writing. Previous studies had shown that simply perceiving prime structures affects later target production in children (Huttenlocher et al., 2004; Savage et al., 2003) and in adults (Potter & Lombardi, 1998). We chose a written task rather than a spoken production task because we wanted to compare the data of the hearing children tested in Experiment 1 with the data of the deaf children tested in Experiment 3. As a result of their hearing loss, many deaf children have speech difficulties, making it difficult to separate the effects of sensory and motor processes from language and cognitive processes (Blamey, 2003).

Prior to the experimental trials, children were introduced to the experimental procedure in a brief practice session where one prime in each of the three structures (i.e., PN, RC, and MC) was presented visually and children were asked to describe the following picture.

Scoring

Children's responses were scored as "PN, same noun," "PN, different noun," "RC, same noun," "RC, different noun," "MC, same noun," or "MC, different noun." In scoring the responses, spelling errors, gender errors, use of indefinite articles instead of definite articles, article omissions, and noun or adjective substitutions were allowed (e.g., *het blauwe bal* rather than *de blauwe bal* [the blue ball], *een groene fiets* [a green bike] rather than *de groene fiets* [the green bike], *paarse hond* [purple dog] rather than *de paarse hond* [the purple dog], *het oranje schip* [the orange ship] rather than *de oranje boot* [the orange boat]). Responses in which a word (other than an article) was missing and responses containing word order violations were scored as "other" target descriptions (e.g., *de vork geel is* [the fork yellow is], *de boom is die bruin* [the tree is that brown].

Results and discussion

In the 7- and 8-year-olds, 2.1% (18) of the responses were scored as "other" responses. The remaining responses were classified as either PN, RC, or MC responses. For each priming condition, we then calculated the proportion of PN responses of all PN, RC, and MC responses for each participant and item (following other studies on structural priming, e.g., Bernolet et al., 2007; Cleland & Pickering, 2003). This same procedure was used for calculating the proportion of RC responses and the proportion of MC responses. The proportions of PN, RC, and MC structure responses were analyzed separately in 3 (Prime Structure: PN, RC, or MC) $\times$ 2 (Noun Repetition: same or different) analyses of variance (ANOVAs). We performed ANOVAs with participants (F_1) and items (F_2) as random effects. Prime structure and noun repetition were treated as within-participant and within-item factors. In all ANOVAs, alpha was set at 5% and post hoc analysis (Bonferroni) was used if appropriate. Table 1 presents frequencies, expressed in proportions and raw numbers, of PN structure, RC structure and MC structure responses in the different priming conditions following other studies on structural priming in children (e.g., Huttenlocher et al., 2004; Shimpi et al., 2007) and in adults (Bernolet et al., 2007). Frequencies are based on the participant analyses. Priming effects for PN, RC, and MC responses (collapsed across the noun repetition factor) are presented in Fig. 1.

Prenominal responses

The analyses showed a significant main effect of prime structure, $F_1(2, 38) = 21.43$, $p < .0001$, $\eta_p^2 = .53$; $F_2(2, 40) = 169.10$, $p < .0001$, $\eta_p^2 = .89$. Post hoc tests showed that 7- and 8-year-olds are sensitive to priming of PN structures; children were 22.6% more likely to use the PN structure after read-

Table 1
Frequencies, expressed in proportions and raw numbers, of children's prenominal, relative clause, and main clause responses.

		Children's responses		
		PN	RC	MC
Experiment 1				
Hearing 7- and 8-year-olds				
PN prime	Same noun	.46 (126)	.02 (1)	.04 (12)
	Different noun	.44 (121)	.02 (2)	.05 (14)
RC prime	Same noun	.21 (57)	.21 (58)	.07 (20)
	Different noun	.24 (64)	.16 (43)	.10 (28)
MC prime	Same noun	.19 (51)	.01 (6)	.29 (79)
	Different noun	.24 (64)	.01 (6)	.25 (69)
Experiment 2				
Hearing 11- and 12-year-olds				
PN prime	Same noun	.43 (121)	0 (0)	.07 (19)
	Different noun	.43 (119)	0 (1)	.07 (18)
RC prime	Same noun	.30 (82)	.11 (32)	.09 (25)
	Different noun	.33 (93)	.10 (28)	.06 (17)
MC prime	Same noun	.31 (87)	0 (0)	.18 (51)
	Different noun	.32 (88)	0 (0)	.19 (52)
Experiment 3				
Deaf 11- and 12-year-olds				
PN prime	Same noun	.42 (149)	.01 (1)	.08 (26)
	Different noun	.41 (148)	.02 (2)	.09 (30)
RC prime	Same noun	.07 (27)	.30 (105)	.11 (38)
	Different noun	.09 (30)	.30 (104)	.11 (38)
MC prime	Same noun	.06 (20)	.00 (2)	.44 (147)
	Different noun	.06 (22)	.01 (7)	.41 (141)

Note. Raw numbers are in parentheses. PN, prenominal adjective–noun structure; RC, relative clause structure; MC, main clause structure.

ing a PN prime (44.8%) than after reading an RC prime, and this 22.2% priming effect was significant (both p_1 and $p_2 < .0001$). The priming effect is typically defined as the difference between the use of a particular form following a similar form and the use of that particular form following an alternative form (see also Bernolet et al., 2007; Branigan et al., 2006; Cleland & Pickering, 2003). In this particular example, the priming effect is defined as the difference between PN responses after PN primes and PN responses after RC primes (collapsed across the noun repetition factor) (see Fig. 1).

Moreover, children were 23.7% more likely to use the PN structure after reading a PN prime (44.8%) than after reading an MC prime (21.1%) (23.7% priming effect, both p_1 and $p_2 < .0001$).

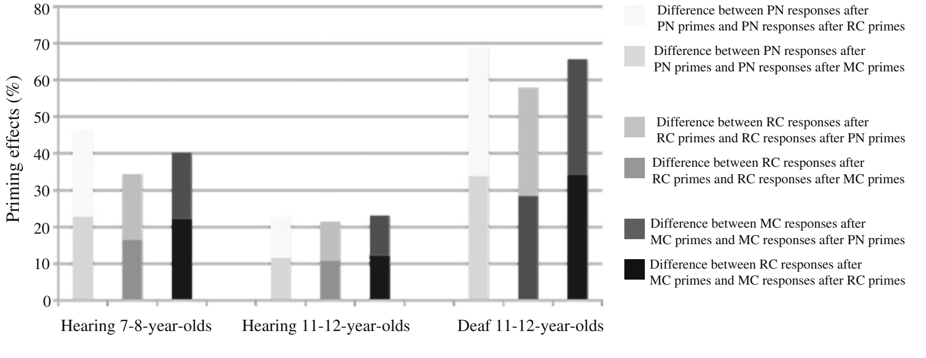

Fig. 1. Priming effects for prenominal (PN), relative clause (RC), and main clause (MC) responses in hearing 7- and 8-year-olds, hearing 11- and 12-year-olds, and deaf 11- and 12-year-olds.

The analyses also showed a significant main effect of noun repetition on the participant analysis, $F_1(1, 19) = 6.97$, $p < .05$, $\eta_p^2 = .27$, and this effect approached significance on the item analysis, $F_2(1, 41) = 2.62$, $p = .11$, $\eta_p^2 = .06$, as well as an interaction between prime structure and noun repetition, $F_1(2, 38) = 4.42$, $p < .05$, $\eta_p^2 = .19$; $F_2(2, 40) = 2.95$, $p = .06$, $\eta_p^2 = .13$. To gain more insight into possible lexical boost effects, we performed subsequent one-factor ANOVAs (noun repetition) for each prime structure. Although Table 1 suggests that children were more likely to use the PN structure after reading a PN prime when the noun was repeated, the effect of noun repetition was not significant. In the RC and MC prime conditions, however, children were somewhat more likely to use the PN structure in the different-noun condition than in the same-noun condition, although this effect reached significance only in the subject analyses: MC primes, $F_1(1, 19) = 5.70$, $p < .05$, $\eta_p^2 = .23$; RC primes, $F_1(1, 19) = 0.41$, $p < .05$, $\eta_p^2 = .19$.

Relative clause responses

The analyses showed a significant main effect of prime structure, $F_1(2, 38) = 15.73$, $p < .0001$, $\eta_p^2 = .45$; $F_2(2, 40) = 404.20$, $p < .0001$, $\eta_p^2 = .95$. Post hoc tests showed that children were 16.3% more likely to use the RC structure after reading an RC prime (18.6%) than after reading a PN prime (2.3%) (both p_1 and $p_2 < .0001$). Likewise, children were 18% more likely to use the RC structure after reading an RC prime (18.6%) than after reading an MC prime (0.6%) (both p_1 and $p_2 < .0001$). Furthermore, the analyses showed a main effect of noun repetition, $F_1(1, 19) = 4.90$, $p < .05$, $\eta_p^2 = .20$; $F_2(1, 41) = 3.22$, $p = .08$, $\eta_p^2 = .07$, and an interaction between prime structure and noun repetition, $F_1(2, 38) = 6.57$, $p < .01$, $\eta_p^2 = .26$, that approached significance on the item analysis, $F_2(2, 40) = 2.09$, $p = .14$, $\eta_p^2 = .10$.

One-factor ANOVAs (noun repetition) for each prime structure showed a lexical boost in the priming of RC structures; children were 5% more likely to use an RC structure after reading a similar RC structure when the noun was repeated between the prime and target (21%) than when the noun was not repeated (16%), $F_1(1, 19) = 7.56$, $p < .05$, $\eta_p^2 = .29$; $F_2(1, 41) = 3.82$, $p = .06$, $\eta_p^2 = .09$. The remaining one-factor analyses yielded no significant effects.

Main clause responses

The analyses showed a significant main effect of prime structure, $F_1(2, 38) = 20.46$, $p < .0001$, $\eta_p^2 = .52$; $F_2(2, 40) = 123.40$, $p < .0001$, $\eta_p^2 = .86$. Post hoc tests showed that children were 22% more likely to use the MC structure after reading an MC prime (26.7%) than after reading a PN prime (4.7%) (both p_1 and $p_2 < .0001$), and they were 18.1% more likely to use the MC structure after reading an MC prime (26.7%) than after reading an RC prime (8.6%) (both p_1 and $p_2 < .0001$). Furthermore, the main effect of noun repetition was not significant, but the interaction between prime structure and noun repetition was significant, $F_1(2, 38) = 4.49$, $p < .05$, $\eta_p^2 = .19$; $F_2(2, 40) = 3.03$, $p = .06$, $\eta_p^2 = .13$.

One-factor ANOVAs (noun repetition) for each structure showed that 7- and 8-year-olds were somewhat more likely to use the MC structure after reading an MC structure when the noun was repeated between the prime and target, $F_1(1, 19) = 3.70$, $p = .07$, $\eta_p^2 = .16$; $F_2(1, 41) = 3.50$, $p = .07$, $\eta_p^2 = .08$. The one-factor ANOVAs for the PN and RC prime structures yielded no significant effects.

The main effects of prime structure (including both same-noun and different-noun conditions) provided evidence for abstract representations. Even stronger evidence that children possess abstract representations would come from significant priming effects in the different-noun condition only, so priming effects in the absence of noun repetition. Therefore, we performed additional one-factor ANOVAs (prime structure) only for the different-noun conditions. These analyses showed significant priming effects for PN structures, $F_1(2, 38) = 14.80$, $p < .0001$, $\eta_p^2 = .44$; $F_2(2, 40) = 7.19$, $p < .0001$ $\eta_p^2 = .78$; for RC structures, $F_1(2, 38) = 11.45$, $p < .0001$, $\eta_p^2 = .45$; $F_2(2, 40) = 4.89$, $p < .0001$, $\eta_p^2 = .71$; and for MC structures, $F_1(2, 38) = 13.26$, $p < .0001$, $\eta_p^2 = .41$; $F_2(2, 40) = 7.79$, $p < .0001$, $\eta_p^2 = .80$, suggesting that 7- and 8-year-olds possess abstract representations of adjective–noun structures independent of particular lexical items.

To summarize, Experiment 1 showed substantial structure priming effects in 7- and 8-year-olds. When describing a picture, children were more likely to use the structure they had just read. This was true for all three adjective–noun structures: the PN structure and the two postnominal structures (i.e., the RC and MC structures). These results indicate that in 7- and 8-year-olds, the use of particular adjective–noun structures can be affected by prior exposure to these structures. Additional ANOVAs verified significant priming effects only in the different-noun condition, suggesting that 7- and 8-year-olds have abstract representations of adjective–noun structures independent of particular lexical items. Moreover, for the RC structures (and marginally so for the MC structures), priming effects were enhanced when the noun was repeated between the prime and target.

Experiment 2: Structure priming in hearing 11- and 12-year-olds

Method

Participants

A total of 20 11- and 12-year-olds (mean age = 11.25 years, SD = 0.75, 6 girls and 14 boys) participated in this experiment. All of the children grew up in native-speaking Dutch families, and none of them had any known learning disabilities or developmental delays. They attended school in a small town. Children were tested at their schools, and parents had given permission for their children to participate in the study.

Materials, apparatus, procedure, and scoring

The materials, apparatus, procedure, and scoring of responses were identical to those of Experiment 1.

Results and discussion

In the 11- and 12-year-olds, 0.7% (6) of the responses were scored as "other" responses. The remaining responses were classified as either PN, RC, or MC responses, and the procedure for calculating the proportions of PN, RC, and MC scores was identical to that of Experiment 1. As in Experiment 1, we ran 3 (Prime Structure) $\times$ 2 (Noun Repetition) ANOVAs on the PN, RC, and MC responses. We performed F_1 and F_2 ANOVAs, with prime structure and noun repetition treated as within-participant and within-item factors. See Table 1 for the response frequencies in all conditions, and see Fig. 1 for the priming effects for PN, RC, and MC responses.

Prenominal responses

The analyses showed a significant main effect of prime structure, $F_1(2, 38) = 5.15$, $p < .05$, $\eta_p^2 = .21$; $F_2(2, 40) = 7.31$, $p < .0001$, $\eta_p^2 = .79$. Post hoc tests showed that 11- and 12-year-olds are sensitive to priming of PN structures (see Table 1); children were 11.4% more likely to use the PN structure after reading a PN structure (42.9%) than after reading an RC structure (31.5%) ($p_1 = .09$, $p_2 < .0001$) or an MC structure (31.5%) ($p_1 = .11$, $p_2 < .0001$). The remaining effects were not significant.

Relative clause responses

The analyses on RC structure responses also showed only a significant main effect of prime structure, $F_1(2, 38) = 6.52$, $p < .01$, $\eta_p^2 = .26$; $F_2(2, 40) = 7.31$, $p < .0001$, $\eta_p^2 = .79$. Post hoc tests showed that 11- and 12-year-olds were more likely to use the RC structure after reading an RC structure (10.7%) than after reading a PN structure (0%) (both p_1 and $p_2 < .01$) or after reading an MC structure (0.2%) (both p_1 and $p_2 < .01$). The remaining effects were not significant.

Main clause responses

The analyses again showed only a significant main effect of prime structure, $F_1(2, 38) = 5.89$, $p < .01$, $\eta_p^2 = .24$; $F_2(2, 40) = 1.29$, $p < .0001$, $\eta_p^2 = .39$. Post hoc tests showed that 11- and 12-year-olds were approximately 12% more likely to use the MC structure after reading an MC structure (18.5%) than after reading a PN prime (6.7%) (both p_1 and $p_2 < .01$) and that children were 11% more likely to use the MC structure after reading an MC structure than after reading an RC prime (7.6%) (both p_1 and $p_2 < .01$). The remaining effects were not significant.

Finally, additional one-factor ANOVAs for only the different-noun condition showed significant priming effects for all three structures, indicating that 11- and 12-year-olds possess abstract representations independent of particular lexical items: PN structures, $F_1(2, 38) = 4.03$, $p < .05$, $\eta_p^2 = .17$; $F_2(2, 40) = 5.48$, $p < .01$, $\eta_p^2 = .22$; RC structures, $F_1(2, 38) = 5.48$, $p < .01$, $\eta_p^2 = .22$; $F_2(2, 40) = 6.59$, $p < .0001$, $\eta_p^2 = .77$; MC structures, $F_1(2, 38) = 7.28$, $p < .01$, $\eta_p^2 = .28$; $F_2(2, 40) = 7.74$, $p < .001$, $\eta_p^2 = .28$.

To summarize, as was observed in the 7- and 8-year-olds, Experiment 2 showed a clear effect of structure priming in the 11- and 12-year-olds. When describing a picture, children were more likely to use the structure they had just read. This priming effect was obtained for all three adjective–noun structures: the PN structure and the two postnominal structures (the RC and MC structures). An additional analysis verified that these effects also occurred only in the different-noun data, indicating that 11- and 12-year-olds possess abstract representations of adjective–noun structures independent of lexical items. No effects of lexical boost were found in the hearing 11- and 12-year-olds, so structural priming was not enhanced by the repetition of lexical items.

Experiment 3: Structure priming in deaf 11- and 12-year olds

In Experiment 3, we examined structural priming in deaf children. Previous studies that examined written language production in deaf children demonstrated that children who are deaf make substantially more syntactic errors in writing than do their hearing peers, leading researchers to conclude that deaf children have considerable delay in mastering the syntactic rules of spoken language (Ivimey & Lachterman, 1980; Mayberry, 2002; Quigley & King, 1980; Taeschner et al., 1988; Tur-Kaspa & Dromi, 2001; Yoshinaga-Itano et al., 1996). The extent to which deaf children have attained abstract knowledge of syntactic structures in an oral language (e.g., by the end of primary school) is as of yet unknown. In Experiment 3, we investigated whether deaf 11- and 12-year-olds have abstract representations of adjective–noun structures. Priming effects in the absence of lexical repetition in deaf school-aged children would provide evidence that children who are deaf have abstract representations of syntactic structures. It would also suggest that the difficulties that deaf children often experience with the syntax of a spoken language are not due to deficits in their abstract syntactic knowledge of the spoken language.

Method

Participants

A total of 26 deaf 11- and 12-year-olds (mean age = 11.69 years, SD = 0.79, 12 girls and 14 boys) participated in this experiment. The children had a hearing loss of more than 80 dB on the best ear and did not have additional known handicaps. All children were educated in special schools for deaf students in the Netherlands and received language instruction in oral Dutch (or sign-supported Dutch, which follows the grammatical rules of Dutch) and, for a few hours per week, Sign Language of the Netherlands (SLN). Children were tested at their schools, and parents had given permission for their children to participate in the study.

In one analysis, reported in the final part of the Results and discussion section of this experiment, we compared deaf and the hearing children's performance and explored whether knowledge of sign language influenced the use of PN, RC, and MC structures in deaf children. To assess deaf children's proficiency in SLN, we used a story comprehension test that is part of an assessment instrument for SLN in primary education (Hermans, Knoors, & Verhoeven, 2007). Children saw five stories in SLN, one at a time, on a laptop computer screen. After seeing each story, children subsequently were asked to answer four questions about each story. Children were instructed to answer the questions in SLN. They received 1 point for each question they answered correctly. Some questions referred to information literally present in the stories. Other questions were gap-filling or text-connecting questions. The mean score on this test was 17.34 (SD = 1.52, range = 15–20), indicating that children were proficient in SLN.

Materials, apparatus, and procedure

The materials, apparatus, and procedure were identical to those of Experiments 1 and 2 except for the language of instruction. Deaf children received instructions from a specialized SLN teacher who was the experimenter during the entire session. Like hearing children, deaf children described the target picture in written Dutch.

Scoring

The scoring of responses was identical to that of Experiments 1 and 2.

Results and discussion

In the first series of analyses, we examined whether deaf children were sensitive to structural priming, and we used the same procedure for data analysis as was used in Experiments 1 and 2.

In the deaf children, 5.1% (53) of responses were scored as "other" responses. The remaining responses were classified as either PN, RC, or MC responses, and the procedure for calculating the proportions of PN, RC, and MC scores was identical to that of Experiments 1 and 2. As in Experiments 1 and 2, we ran 3 (Prime Structure) × 2 (Noun Repetition) ANOVAs on the PN, RC, and MC responses. We performed F_1 and F_2 analyses, with prime structure and noun repetition treated as within-participant and within-item factors. See Table 1 for the response frequencies in all conditions, and see Fig. 1 for priming effects for PN, RC, and MC responses.

Prenominal responses

The analyses showed a significant main effect of prime structure, $F_1(2, 50) = 84.62$, $p < .0001$, $\eta_p^2 = .77$; $F_2(2, 40) = 583.10$, $p < .0001$, $\eta_p^2 = .97$. Post hoc tests showed that deaf children, like hearing children, are sensitive to priming of PN structures; they were 33.7% more likely to use the PN structure after reading a PN prime (41.5%) than after reading an RC prime (7.8%) (both p_1 and $p_2 < .0001$), and they were 35.4% more likely to use the PN structure after reading a PN prime (41.5%) than after reading an MC prime (6.1%) (both p_1 and $p_2 < .0001$). The remaining effects were not significant.

Relative clause responses

The analyses showed only a significant main effect of prime structure, $F_1(2, 50) = 49.50$, $p < .0001$, $\eta_p^2 = .66$; $F_2(2, 40) = 269.70$, $p < .0001$, $\eta_p^2 = .93$. Post hoc tests showed that deaf children were 28.3% more likely to use the RC structure after reading an RC structure (30%) than after reading a PN structure (1.7%) (both p_1 and $p_2 < .0001$), and they were 29.5% more likely to use the RC structure after reading an RC structure (30%) than after reading an MC structure (0.5%) (both p_1 and $p_2 < .0001$). The remaining effects were not significant.

Main clause responses

The analyses showed a significant main effect of prime structure, $F_1(2, 50) = 72.19$, $p < .0001$, $\eta_p^2 = .74$; $F_2(2, 40) = 722.20$, $p < .0001$, $\eta_p^2 = .97$. Post hoc tests again showed a structure priming effect; deaf children were approximately 34% more likely to use the MC structure after reading an MC prime (42.6%) than after reading a PN prime (8.7%) (both p_1 and $p_2 < .0001$). Moreover, they were 31.5% more likely to use the MC structure after reading an MC prime (42.6%) than after reading an RC prime (11.1%) (both p_1 and $p_2 < .0001$). The remaining effects were not significant.

Additional one-factor ANOVAs (prime structure) on the data of only the different-noun condition showed significant priming effects for each of the three structures, indicating that deaf 11- and 12-year-olds possess abstract representations independent of particular lexical items: PN structures, $F_1(2, 50) = 64.19$, $p < .0001$, $\eta_p^2 = .72$; $F_2(2, 40) = 257.50$, $p < .0001$, $\eta_p^2 = .93$; RC structures, $F_1(2, 50) = 36.35$, $p < .0001$, $\eta_p^2 = .59$; $F_2(2, 40) = 105.55$, $p < .0001$, $\eta_p^2 = .84$; MC structures, $F_1(2, 50) = 55.54$, $p < .0001$, $\eta_p^2 = .69$; $F_2(2, 40) = 128.76$, $p < .0001$, $\eta_p^2 = .87$.

To summarize, just like in hearing children, we found clear structural priming effects in deaf children for all three structures (PN, RC, and MC). Such priming effects were also obtained when primes and targets contained different nouns. These findings suggest that deaf children have abstract knowledge of adjective–noun structures independent of particular lexical items. Deaf children showed no effect of noun repetition; thus, as in their hearing age-matched peers, the structural priming effect was not boosted by the repetition of lexical items.

Comparison of deaf and hearing children on using adjective-noun structures

Experiment 3 showed that deaf children, like hearing children, are sensitive to priming of adjective–noun structures. In an additional analysis, we compared deaf and hearing children's production of the three structures regardless of priming. It is possible that differences in the amount and type of language input between deaf and hearing children (related to structural differences between signed language and spoken language) affect the use of adjective–noun structures in deaf and hearing children.

Many deaf individuals, including the deaf children examined in this experiment, use a signed language as their main language of communication. In SLN, as in many other signed and oral languages, sign order is not free. Although some sign order variations are possible in SLN, there is a basic unmarked sign order for adjective–noun constructions that is a postnominal order; the sign of the adjective is followed by the sign of the noun to which it refers (Schermer, 1991). For example, a picture of a blue ball is signed as BALL BLUE. Note that copulas, such as *is* in this example, are not signed in SLN. Thus, the unmarked sign order for adjective–noun constructions is postnominal, and SLN does not distinguish between several postnominal constructions as oral Dutch does.

Thus, deaf children who use a signed language and an oral/written language receive not only a quantitatively different amount of oral language input compared with hearing children (because of their hearing impairment) but also a qualitatively different type of language input. SLN uses a postnominal adjective–noun structure, and Dutch uses both PN and postnominal structures. Given the differences in the amount and type of language input between deaf and hearing children, it can be expected that the use of adjective–noun structures in Dutch will be different between deaf and hearing children.

In the analysis reported below, we compared deaf children with the age-matched hearing children from Experiment 2, and the younger 7- and 8-year-olds from Experiment 1, on the use of the different adjective–noun structures regardless of which prime had preceded the responses. For each group of children, we calculated the proportion of PN responses of all PN, RC, and MC responses. "Other" responses were excluded. This same procedure was used for calculating the proportion of RC responses and the proportion of MC responses. We compared deaf and hearing children on the use of the three adjective–noun structures with 3 (Group: deaf 11- and 12-year-olds, hearing 7- and 8-year-olds, or hearing 11- and 12-year-olds) × 2 (Response Structure: PN, RC, or MC) ANOVAs. We performed F_1 and F_2 analyses, with group treated as a between-participants and within-item factor and response structure treated as a within-participant and within-item factor. Alpha was set at .05, and post hoc analysis (Bonferroni/Games–Howell)[1] was used if appropriate. Proportions and raw frequencies are presented in Table 2.

The results showed a significant main effect of response structure, $F_1(2, 62) = 6.60$, $p < .0001$, $\eta_p^2 = .68$; $F_2(2, 122) = 401.50$, $p < .0001$, $\eta_p^2 = .87$. Post hoc tests showed that PN structures were used more often than RC structures (both p_1 and $p_2 < .0001$) and MC structures (both p_1 and $p_2 < .0001$), and MC structures, in turn, were used more often than RC structures ($p_1 < .01$, $p_2 < .0001$). The main effect of group was not significant. More interesting, the interaction between response structure and group was significant, $F_1(4, 126) = 4.34$, $p < .0001$, $\eta_p^2 = .12$; $F_2(4, 244) = 32.53$, $p < .0001$, $\eta_p^2 = .35$. To gain more insight into this interaction effect, we performed subsequent one-factor ANOVAs (group) for each of the three response structures. The analysis on PN structures showed a significant main effect of group, $F_1(2, 63) = 5.05$, $p < .001$, $\eta_p^2 = .20$; $F_2(2, 123) = 71.65$, $p < .0001$, $\eta_p^2 = .54$. Post hoc tests showed that deaf children used fewer PN structures than did hearing 11- and 12-year-olds ($p_1 < .001$, $p_2 < .0001$) and hearing 7- and 8-year-olds ($p_1 < .05$, $p_2 < .0001$). The analysis on RC structures also demonstrated a significant main effect of group, $F_1(2, 63) = 6.46$, $p < .01$, $\eta_p^2 = .18$; $F_2(2, 123) = 13.76$, $p < .0001$, $\eta_p^2 = .18$. Post hoc tests showed that deaf children used more RC structures than did hearing 11- and 12-year-olds ($p_1 < .01$, $p_2 < .001$) and hearing 7- and 8-year olds ($p_2 < .0001$; the subject analysis yielded no significant effect, $p_1 = .20$). Finally, the analysis on MC structures also showed a significant effect of group, $F_1(2, 63) = 3.47$, $p < .05$, $\eta_p^2 = .10$; F_2(2,

[1] Tests of equality of variance on the PN, RC, and MC responses showed that the equality of variance in deaf and hearing children was violated in the PN responses. For the post hoc analysis of the PN responses, therefore, we used the Games–Howell test.

Table 2
Frequencies, expressed in proportions and raw numbers of children's responses, in prenominal, relative clause, and main clause structures.

	Children's responses		
	PN	RC	MC
Hearing 7- and 8-year-olds	.59 (483)	.14 (116)	.27 (222)
Hearing 11- and 12-year-olds	.71 (590)	.07 (61)	.22 (182)
Deaf 11- and 12-year-olds	.38 (394)	.21 (221)	.41 (420)

Note. Raw numbers are in parentheses. PN, prenominal adjective–noun structure; RC, relative clause structure; MC, main clause structure.

123) = 60.70, $p < .0001$, $\eta_p^2 = .50$. As can be seen in Table 2, deaf children used more MC structures than did hearing 11- and 12-year-olds ($p_1 = .08$, $p_2 < .0001$) and hearing 7- and 8-year-olds ($p_1 = .08$, $p_2 < .0001$). These findings indicate that deaf children used more postnominal structures, but fewer PN adjective–noun structures, than did hearing children.

General discussion

We investigated structural priming of adjective–noun structures in Dutch children. The majority of previous structural priming studies involved adults, and researchers have only begun to examine how structural priming develops in children. Previous studies on structural priming in children focused mainly on verb phrases (Huttenlocher et al., 2004; Miller & Deevy, 2006; Savage et al., 2003; Shimpi et al., 2007) and showed that exposure to particular structures increases children's use of these structures, some of which are rare in children's spontaneous language production. The adjectival modification of nouns has not been investigated before in school-aged children. In the study reported in this article, we primed hearing 7- and 8-year-olds (Experiment 1), hearing 11- and 12-year-olds (Experiment 2), and deaf 11- and 12-year-olds (Experiment 3) by having them read three types of adjective–noun structures: (a) PN structures in which the adjective (here color) precedes the noun to which it refers, as in *de blauwe bal* [the blue ball]; (b) RC structures in which the adjective follows the noun, as in *de bal die blauw is* [the ball that is blue]; and (c) MC structures, as in *de bal is blauw* [the ball is blue].

The results showed that children in all three experiments, when describing a picture, were more likely to use the same structure as the one they had encountered before as a prime. This effect was observed in the PN structure and in the two postnominal structures (RC and MC). These results demonstrate syntactic priming of adjective–noun structures in children and add to findings of previous studies on younger children that focused on priming effects at the level of verb phrases (Huttenlocher et al., 2004; Savage et al., 2003; Shimpi et al., 2007).

As Cleland and Pickering (2003) noted, RCs are rarely used in spontaneous language production, and they are longer and syntactically more complex than the alternatives such as PN structures and MCs. Our results demonstrate that hearing 7- and 8-year-olds and hearing 11- and 12-year-olds, as well as deaf 11- and 12-year-olds, are sensitive to structural priming of adjective–noun structures and that it is possible to prime children into using the more complex RC construction they do not encounter very often in everyday language. Moreover, priming effects in all three structures were observed when the prime and target contained similar nouns as well as when the prime and target contained different nouns. The different-noun condition, in particular, indicates that school-aged children possess abstract representations of adjective–noun structures independent of particular lexical items.

Our results are also consistent with results from priming studies with adults that focused on adjective–noun structures and that showed that RCs are used more often after encountering RCs than after encountering PN structures in both English (Cleland & Pickering, 2003) and Dutch (Bernolet et al., 2007). Moreover, our results provide further evidence that structural priming can occur from comprehension to production. Early research on structural priming focused only on priming within production (see Pickering & Ferreira, 2008, for a review). Our study examined structural priming from comprehension to production and, in so doing, contributes to the growing body of evidence of priming from comprehension to production, even when participants merely heard or read the prime sentence without actually producing it (e.g., Bock, Dell, Chang, & Onishi, 2007; Huttenlocher et al., 2004; Potter & Lombardi, 1998; Savage et al., 2003). This suggests that structural priming engages mechanisms that are common to comprehension and production and that both types of processes draw on common abstract representations of syntactic information (see Pickering & Ferreira, 2008, for a more elaborate discussion of this issue).

Our findings can be interpreted in terms of the model proposed by Cleland and Pickering (2003), based on Pickering & Branigan, 1998) that describes how syntactic information is represented and organized in the mind. This model assumes that lemmas are linked to specific combinatorial nodes for specific syntactic structures (among others). When a particular structure is primed, specific combinatorial nodes remain active and are more likely to be used when the person must produce a new structure, for example, when describing a picture. Our data show that this mechanism also appears to apply to children. When children had just read a specific adjective–noun structure, they were more likely to use a similar structure than an alternative structure when describing a picture.

Previous studies on priming of adjective–noun studies examined PN structures and postnominal RC structures. We added the MC structure to explore whether priming of postnominal structures in children is restricted to the syntactically simple MC structure or whether priming of postnominal structures also extends to the syntactically more complex RC structure. We indeed found structural priming effects for PN, RC, and MC structures in all groups of children. It should be noted that, although the adjective followed the noun in the MCs we used, an MC structure describes a proposition and, thus, is semantically different from PN and RC adjective–noun structures. The structural priming effect in the MC, therefore, could be driven partly by abstract semantic priming.

Is structural priming enhanced by the repetition of lexical items? In all three experiments, we manipulated whether the noun was repeated between the prime and target or not. These are the first experiments to examine the lexical boost effect in school-aged children. We obtained limited evidence of a lexical boost. In the 7- and 8-year-olds, priming of the RC structures was enhanced when the noun was repeated in the prime and target sentences. A subtle enhancement was also observed for the MC structures, but the lexical boost effect did not reach significance. The data of the hearing and deaf 11- and 12-year-olds, however, showed no evidence of a lexical boost effect on any of the structures.

Previous structural priming experiments using adults showed effects of lexical boost (Bernolet et al., 2007; Branigan, Pickering, & Cleland, 2000; Cleland & Pickering, 2003; Corley & Scheepers, 2002; Pickering & Branigan, 1998; Schoonbaert et al., 2007), although such lexical boost effects tend to be smaller in Dutch than in English. Specifically, the Dutch speakers tested by Bernolet and colleagues (2007) and the English speakers tested by Cleland and Pickering (2003) showed comparable structural priming effects on RC structures (18% and 19%, respectively), but the lexical boost effect was smaller in Dutch (8%) than in English (15%). It seems unlikely that adjective–noun structures are less lexicalized in Dutch-speaking children and adults than in English-speaking children and adults. The different sensitivity to lexical repetition may be related to differences in the prevalence of RC structures in Dutch and English, and RCs may be less favored in Dutch than in English. In our study, children produced relatively few RC responses overall, in line with Bernolet and colleagues' (2007) observation that their adult Dutch speakers produced fewer RC responses than the English speakers tested by Cleland and Pickering (2003). Future cross-linguistic developmental studies may seek to further examine this issue.

Even though lexical boost effects obtained with RCs may be smaller in speakers of Dutch than in speakers of English, lexical boost effects did occur in the adult Dutch speakers tested by Bernolet and colleagues (2007). How can the absence of a clear lexical boost effect in children, at least in the hearing and deaf 11- and 12-year-olds, be explained? If we assume that a lexical boost effect emanates from residual activation as proposed by the lexical activation account (e.g., Pickering & Branigan, 1998), it may be that such residual activation effects are short-lived and do not persist over the prime–target trial (cf. Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008). This may be particularly true in child speakers whose syntactic and lexical knowledge is not (yet) as developed as in adult speakers.

Alternatively, the underlying mechanism that drives the structural priming effect might not be residual activation (as proposed by the residual activation account of, e.g., Cleland & Pickering, 2003, and Pickering & Branigan, 1998) but instead may reflect an implicit learning process (Chang, Dell, & Bock, 2006; Pickering & Ferreira, 2008). The basic idea is that language users continue to learn mappings between message-level representations and abstract syntactic representations. Structural priming reflects the operation of this implicit learning mechanism: By perceiving or producing a particular construction, language users implicitly learn to express a message with that structure so that they will be more likely to produce this same construction at some later point. In the implicit learning model, learning about particular syntactic constructions occurs independently from lexical items, and the model assumes differently grounded mechanisms for structural priming (implicit learning) and lexically boosted priming. Such a two-locus assumption means that the model can account for structural priming effects in the absence of lexical boost effects (see Chang et al., 2006, and Pickering & Ferreira, 2008, for more details), which is the basic pattern of findings in our study. Obviously, more research is needed to examine the viability of the residual activation and implicit learning accounts of structural priming and lexically boosted priming (cf. Hartsuiker et al., 2008; Kaschak & Borreggine, 2008). To fully understand the basic mechanisms, it is important to examine both child and adult language users. Our study indicates that structural priming can occur in the absence of lexically boosted priming and that there may be age- or proficiency-related differences in lexically boosted priming.

What remains intriguing is that in the 7- and 8-year-olds we did observe that the structural priming effect of RC structures was boosted by the repetition of nouns. Thus, the only significant lexical boost effect in our study was observed in the youngest children on the most complex adjective–noun structure. An RC is also the structure to which children probably have least exposure in everyday language because it is relatively infrequent. Interestingly, in a study with 3- and 4-year-olds, Branigan and colleagues (2005) found enhanced structural priming effects of adjective–noun structures when the head noun was repeated.[2] A tentative explanation for these results in terms of the lexical activation account could be that, for complex and infrequent syntactic structures that are processed by children who are still developing their language skills, the residual activation of the combinatorial node is relatively low. The priming process may be relatively strongly affected by residual activation of the lemma node and the link between this lemma node and the combinatorial node. Alternatively, the implicit learning account argues that lexical boost effects are due to explicit memory for the prime's wording: The repeated lexical item acts as a retrieval cue to the prime's wording, and this biases the language user to repeat the prime's structure (Chang et al., 2006). Tentatively, the current finding can be explained by assuming that this retrieval cue works differently for easier constructions (e.g., PN *the blue ball*) and more complex constructions (e.g., RC *the ball that is blue*) in the youngest children and that, particularly with complex and long RC primes, children may rely on the repeated nouns to formulate their responses. It is clear that, given the scarcity of studies that examined lexically boosted structural priming in children, these accounts remain highly speculative and more research is needed to further investigate structural priming, the lexical boost effect, and the role of structure complexity in children of different ages.

In the remainder of this section, we focus on structural priming and syntactic processing in deaf children. In Experiment 3, we examined whether deaf children are sensitive to priming in the production of adjective–noun structures. Previous studies on language production in deaf children showed that deaf children experience major difficulties with syntax in writing and reading (e.g., Ivimey & Lachterman, 1980; Mayberry, 2002; Quigley & King, 1980; Taeschner et al., 1988; Tur-Kaspa & Dromi, 2001; Yoshinaga-Itano et al., 1996). It is not known, however, whether the difficulties that deaf children encounter when writing are due to limited abstract knowledge of syntactic structures. We found that deaf children are sensitive to structural priming and that the pattern of priming effects in deaf children is similar to that in hearing children of the same age as well as that in hearing younger children who had just learned to read and write. Having read a particular adjective–noun structure increased the likelihood of using that structure when describing a picture. This shows that deaf children's use of particular syntactic forms can be affected by exposure to these forms. As was found in hearing children, priming effects occurred both in the condition where the noun was repeated between the prime and target and in the condition where the noun was not repeated. This indicates that

[2] We thank an anonymous reviewer for mentioning this study, and we thank Holly Branigan for sending us the report that appeared in the conference proceedings.

deaf children possess abstract knowledge of syntactic structures independent of particular lexical items. It also suggests that deaf children's difficulty with complex syntactic structures during writing is not due to limited abstract knowledge of syntax.

Although deaf (and hearing) children demonstrate priming effects for all three adjective–noun structures, the relative frequency of the three types of structures was substantially different between deaf and hearing children. Deaf children used fewer PN structures and more postnominal structures than did hearing age-matched peers and the younger children (7- and 8-year-olds). We propose that the difference in preference of using PN and postnominal structures between deaf and hearing children may be due to differences in language input between deaf and hearing children. As mentioned earlier, deaf children who use a signed language and an oral/written language receive not only a quantitatively different amount of oral Dutch language input compared with hearing children (because of their hearing impairment) but also a qualitatively different type of language input. In SLN, the standard construction for adjective–noun structures is postnominal; that is, the adjective sign follows the sign for the noun to which the adjective refers, whereas Dutch has both postnominal and PN constructions.

The proposal that deaf children's preference for postnominal structures over PN structures may be due to different language input in comparison with hearing children is in line with the literature on bilingualism. A key finding in research on bilingual children using two spoken languages is that the languages interact and that bilingual children are sensitive to differences in the overlap of structures in their two languages (e.g., Döpke, 2000; Hulk & Müller, 2000; Nicoladis, 2006; Shin & Milroy, 1999). Recently, researchers have begun to explore the issue of language interaction and transfer in bimodal bilinguals who use two languages in different modalities with the goal of characterizing the nature of this type of bilingualism (Emmorey, Borinstein, Thompson, & Gollan, 2008; Singleton, Morgan, DiGello, Wiles, & Rivers, 2004; van Beijsterveldt & van Hell, in press). Findings from these previous studies suggest that the mechanisms underlying transfer effects in hearing bilinguals also apply to bimodal bilinguals. The results from our study hint that deaf children are sensitive to differences in the overlap of adjective–noun structures in Dutch and SLN. Deaf children used structures that are absent in SLN (i.e., PN structures) less frequently than did hearing children, and they appear to favor structures that overlap in word order across SLN and Dutch. There is clearly a need for further empirical studies investigating how sign and written/spoken languages are represented in bimodal bilingual deaf children and the extent to which the languages interact.

Our study indicates that deaf 11- and 12-year-olds, as well as hearing 7- and 8-year-olds and hearing 11- and 12-year-olds, possess abstract representations of adjective–noun structures that are independent of particular lexical items. This suggests that deaf children's difficulty with complex syntax is not due to limited abstract knowledge of syntactic structures.

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Appendix A. Items for Experiments 1 to 3

The primes are listed in the following order with respect to the target picture: same-noun condition/different-noun condition; target [English translation].

1. blauwe bal/blauwe kraan; blauwe bal [blue ball/blue tap; blue ball]
2. bruine sok/bruine kast; bruine sok [brown sock/brown closet; brown sock]
3. gele bloem/gele pen; gele bloem [yellow flower/yellow pen; yellow flower]
4. groene boom/groene pan; groene boom [green tree/green pan; green tree]
5. oranje kip/oranje kaars; oranje kip [orange chicken/orange candle; orange chicken]

6. rode bril/rode taart; rode bril [red glasses/red cake; red glasses]
7. paarse broek/paarse poes; paarse broek [purple pants/purple cat; purple pants]
8. roze deur/roze jurk; roze deur [pink door/pink dress; pink door]
9. blauwe doos/blauwe leeuw; blauwe doos [blue box/blue lion; blue box]
10. bruine eend/bruine veer; bruine eend [brown duck/brown feather; brown duck]
11. gele fiets/gele muis; gele fiets [yellow bike/yellow mouse; yellow bike]
12. groene tas/groene koe; groene tas [green bag/green cow; green bag]
13. oranje boot/oranje vork; oranje boot [orange boat/orange fork; orange boat]
14. rode klok/rode vis; rode klok [red clock/red fish; red clock]
15. paarse kam/paarse hond; paarse kam [purple comb/purple dog; purple comb]
16. roze lamp/roze stoel; roze lamp [pink lamp/pink chair; pink lamp]
17. blauwe mond/blauwe bank; blauwe mond [blue mouth/blue sofa; blue mouth]
18. bruine jas/bruine schoen; bruine jas [brown coat/brown shoe; brown coat]
19. gele peer/gele schaar; gele peer [yellow pear/yellow scissors; yellow pear]
20. groene aap/groene rok; groene aap [green monkey/green skirt; green monkey]
21. oranje fles/oranje riem; oranje fles [orange bottle/orange belt; orange bottle]
22. rode riem/rode fles; rode riem [red belt/red bottle; red belt]
23. paarse rok/paarse aap; paarse rok [purple skirt/purple monkey; purple skirt]
24. roze schaar/roze peer; roze schaar [pink scissors/pink pear; pink scissors]
25. blauwe schoen/blauwe jas; blauwe schoen [blue shoe/blue coat; blue shoe]
26. bruine bank/bruine mond; bruine bank [brown sofa/brown mouth; brown sofa]
27. gele stoel/gele lamp; gele stoel [yellow chair/yellow lamp; yellow chair]
28. groene hond/groene kam; groene hond [green dog/green comb; green dog]
29. oranje vis/oranje klok; oranje vis [orange fish/orange clock; orange fish]
30. rode vork/rode boot; rode vork [red fork/red boat; red fork]
31. paarse koe/paarse tas; paarse koe [purple cow/purple bag; purple cow]
32. roze muis/roze fiets; roze muis [pink mouse/pink bike; pink mouse]
33. blauwe veer/blauwe eend; blauwe veer [blue feather/blue duck; blue feather]
34. roze leeuw/roze doos; roze leeuw [pink lion/pink box; pink lion]
35. gele jurk/gele deur; gele jurk [yellow dress/yellow door; yellow dress]
36. groene poes/groene broek; groene poes [green cat/green pants; green cat]
37. bruine taart/bruine bril; bruine taart [brown cake/brown glasses; brown cake]
38. oranje kaars/oranje kip; oranje kaars [orange candle/orange chicken; orange candle]
39. rode pan/rode boom; rode pan [red pan/red tree; red pan]
40. paarse pen/paarse bloem; paarse pen [purple pen/purple flower; purple pen]
41. blauwe kast/blauwe sok; blauwe kast [blue closet/blue sock; blue closet]
42. rode kraan/rode bal; rode kraan [red tap/red ball; red tap].

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