

Effects of immediate and cumulative syntactic experience in language impairment: Evidence from priming of subject relatives in children with SLI

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Abstract

We investigated the production of subject relative clauses (SRc) in Italian pre-school children with Specific Language Impairment (SLI) and age-matched typically-developing children (TD) controls. In a structural priming paradigm, children described pictures after hearing the experimenter produce a bare noun or an SRc description, as part of a picture-matching task. In a sentence repetition task, children repeated SRc. In the priming paradigm, children with SLI produced SRc after hearing the experimenter use SRc with the same or different lexical content; the magnitude of this priming effect was the same as in TDC. However, children with SLI showed a smaller cumulative priming effect than TDC. Children with SLI showed superior SRc performance in picture-matching than in sentence repetition. We propose that children with SLI have an abstract representation of SRc that can be facilitated by prior exposure, but exhibit impaired implicit learning mechanisms.

Keywords: Children with SLI, structural priming, Relative clauses, Cumulative priming.

Extensive research has shown that some children display developmental difficulties in expressive and/or receptive language despite normal opportunities for language learning and no other developmental or hearing disorders or brain injury (Bishop, 1997; Leonard, 1998). The precise manifestation of such *Specific Language Impairment* (SLI) varies from individual to individual, and may include impairments in aspects such as phonological processing, semantic-pragmatic processing, and grammatical processing. For example, where typically developing children (TDC) produce utterances such as *The girl who is reading is sad*, children with SLI often produce ungrammatical utterances such as *The girl is reading is sad* or syntactically well-formed but less complex utterances such as *The girl is reading, she is sad*. In this paper, we investigate the nature of this syntactic deficit: Does it reflect impairment in the children's representation of these structures or in their processing, and what factors may contribute to this impairment? To do so, we focus on the production of subject relative clauses (SRc) in children with SLI.

Cross-linguistic studies have shown that children with SLI have difficulties producing and comprehending relative clauses. These difficulties have been extensively investigated with respect to *object relative clauses* (ORc), such as *The girl who the boy is pushing is tall* (e.g.: Greek: Stavrakaki, 2001; French: Hamman, et al. 2007; Hebrew: Friedmann & Novogrodsky, 2007). Such difficulties persist into school age; for example, Hebrew-speaking children still manifest difficulties (e.g., producing subject relatives instead of object relatives) at the age of 10 years (Novogrodsky & Friedmann, 2006). Such difficulties are perhaps not entirely surprising, given that TD children acquire ORc relatively late (de Villiers et al., 1979; Diessel & Tomasello, 2005; Friedmann & Novogrodsky, 2004; Lempert & Kinsbourne, 1980), and even adults show

consistent processing difficulties in comprehending ORCs (e.g., King & Just, 1991; Traxler et al., 2002; Wanner & Maratsos, 1978).

However, there is increasing evidence that children with SLI also have difficulties in comprehending and producing *subject relative clauses (SRc)*, such as *La bambina che spinge il bambino è alta, The girl who is pushing the boy is tall*. In TD children, these structures are known to emerge early, with proficient comprehension and production appearing around the age of 2;8-3;0 (elicited production: Hamburger & Crain, 1982; Crain, McKee, & Emiliani, 1990; Labelle 1990; comprehension: Sheldon, 1974; de Villiers et al., 1979). In children with SLI, however, acquisition of SRc appears to be delayed, with characteristic errors of pronoun omission (e.g., *La bambina [che] spinge il bambino, The girl [who] is painting the boy*), and a 2-year delay in the onset of SRc production (English: Schuele & Dykes, 2005; Swedish: Hankansson & Hansson, 2000; Italian: Contemori & Garraffa, 2010, 2013). This impairment is manifested both in spontaneous speech, with significantly lower rates of SRc production than in TD children, and in elicited production, where SLI children show high error rates in tasks such as sentence repetition (e.g., *The girl is painting the boy* instead of *The girl who is painting the boy*; Conti-Ramsden et al., 2001; Riches, 2012). The avoidance of relative clauses appears to persist even into school age (Cipriani et al., 1998; van der Lely, 1997).

This evidence suggests that SRc, as well as ORc, develop differently in children with SLI than in TD children, in terms of both the time course of development and prevalence of use. The factors that underlie this abnormal pattern of development remain uncertain, however. The fact that children with SLI also display difficulties with other related types of syntactic construction such as Wh-questions (e.g., *Who did the girl see?*; Jakubowicz, 2011; Stravarakaki, 2006) has led some researchers to suggest that there may be a representational deficit of *syntactic*

dependencies, i.e., the grammatical relations between elements in a sentence (the Computational Grammatical Complexity hypothesis; Van Der Lely, 2005). The evidence for this domain-specific impairment comes from studies showing deficits in both comprehension and production of otherwise unrelated constructions that also involve syntactic dependencies (e.g., reversible and truncated passives: Van der Lely, 1996; Van der Lely & Harris, 1990; interpretation of pronominal anaphors: Van der Lely & Stollwerck, 1997; realization of verb agreement: Franck et al., 2004).

However, any such syntactic deficit for complex syntactic structure need not be representational in nature. That is, failures to develop appropriate syntactic representations in children with SLI could be caused by impairments in other aspects of processing. For example, children with SLI also show a slower learning rate than TD children. Relative to TD children, they require double the number of exposures before learning and using novel verbs spontaneously, and perform more poorly at maintaining novel words in long-term memory (Windfuhr et al., 2002; see also Rice et al., 1994). Moreover, they show deficits in implicit learning of non-linguistic patterns, such as sequences of visual patterns (Tomblin, Mainela-Arnold, & Zhang, 2007). Accordingly, some researchers have suggested that children with SLI have deficits in general learning mechanisms, which result in impaired development of grammatical representations (Ullman & Pierpont, 2005).

Additionally, children with SLI characteristically show other impairments that could impact on lexical learning and the development of grammar (see also Norbury et al., 2002). They score lower than age- and language-matched TD children in tasks tapping phonological memory, such as non-word repetition and sentence repetition (Botting & Conti-Ramsden, 2001; Gathercole, 2006; Gathercole & Baddeley, 1990b; for Italian: Bortolini, Arfé, Caselli, Degasperi,

Deevy, & Leonard, 2006; Casalini et al., 2007; Dispaldro et al., 2013), suggesting that they may have problems in phonological short term memory (Gathercole & Baddeley, 1990a; Montgomery, 1995). Other research has suggested a more general capacity limitation (in relation to speed of processing, working memory and attention; Leonard, 1998; Leonard, Weismer, Miller, Francis, Tomblin, & Kail, 2007). Whatever its ultimate source, an inability to maintain an accurate representation of input to which they are exposed, in ways that may impair their ability to acquire the appropriate long-term representations (i.e., linguistic knowledge), leading to fewer and imprecise representations at both the lexical and morpho-syntactic levels.

In sum, children with SLI manifest impaired ability to produce a syntactic structure that emerges early in TD children in a range of contexts, including spontaneous production and elicited production via sentence repetition. But although their poor performance in these tasks is uncontroversially indicative of difficulty in using SRc structures it is not clear whether their performance reflects an underlying representational deficit, processing deficit, or both. A number of studies have shown that children's performance in linguistic tasks may be affected by the particular task that is used (e.g., Crain & Fodor, 1993; Maratsos, Fox, Becker, & Chalkley, 1985; Messenger, Branigan, McLean, & Sorace, 2012; Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007). For example, elicited sentence repetition implicates many different cognitive components, including lexical and syntactic knowledge, the segmentation, retrieval and constructional processes that draw upon this knowledge, as well as representations and processes associated with working memory. Errors in repeating a SRc sentence might be causally associated with any of these components. In particular, it is not possible to localise the source of difficulty to underlying syntactic representation.

However, one experimental task does appear to be straightforwardly informative about syntactic representation. Substantial research over the last three decades has established that speakers have a tendency to repeat structure across otherwise unrelated sentences. For example, speakers are more likely to produce a double object sentence (e.g., *The girl is giving the man a paintbrush*) after producing or comprehending a different sentence involving a double object structure than after the equivalent prepositional object sentence (e.g., *The rock star sold the undercover agent some drugs* vs. *The rock star sold some drugs to the undercover agent*; Bock, 1986, 1989; Branigan, Pickering, & Cleland, 2000). Such *syntactic priming* effects appear to be based on facilitation of particular constituent structures through prior exposure (see Branigan, 2007; Pickering & Ferreira, 2008, for reviews). They depend on the language processor applying the same abstract representations of structure to both the *prime* and *target* sentences. As such, they provide an implicit test of syntactic representation (Branigan, Pickering, Liversedge, Stewart, & Urbach 1995): For a speaker to show syntactic priming effects for a particular structure, he or she must have an abstract representation for that structure which can be retrieved during processing of the prime sentence and then re-used in subsequent processing; the fact that priming occurs between, as well as within, comprehension and production suggests moreover that such representations must be amodal.

Syntactic priming effects have therefore been used to draw inferences about the nature of adult syntactic representation (e.g., Bock & Loebell, 1990; Branigan, Pickering, McLean, & Stewart, 2006; Cleland & Pickering, 2003; Pickering & Branigan, 1998), and more recently about the abstract nature of children's early syntax (e.g., Bencini & Valian, 2008; Huttenlocher, Vasilyeva, & Shimpi, 2004; Messenger, Branigan, & McLean, 2011; Messenger et al., 2012; Shimpi, et al., 2007). Such studies have provided striking evidence that children may draw on

abstract representations of syntactic structure during production and comprehension at an earlier age than has been demonstrated using other, more explicit tests of syntactic knowledge.

Syntactic priming effects have been explained in terms of both short-term activation of structural representations (e.g., Pickering & Branigan, 1998) and implicit learning mechanisms that yield persistent changes in the ease of use of structural representations (e.g., Chang, Dell, & Bock, 2006), with recent accounts hypothesizing a role for both kinds of mechanisms (Ferreira & Bock, 2006; Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008). Both kinds of mechanism can explain how priming facilitates the immediately subsequent use of a complex structure that the speaker does not otherwise spontaneously produce. For example, Messenger et al. (2012) found that children produced passive picture descriptions immediately after hearing another passive, despite never producing passive descriptions for the same pictures in a null context. Similarly, Hartsuiker & Kolk (1998) found that aphasic speakers were able to produce passives after hearing passives, even though they were unable to produce them spontaneously without such exposure.

In addition, an implicit learning component can explain how such effects can accumulate over exposure to multiple exemplars of a structure (e.g., Hartsuiker & Westenberg, 2000; Kaschak & Borregine, 2008); though studies of syntactic priming in children do not always find such cumulative effects, (e.g., Huttenlocher et al., 2005; Messenger et al., 2012). Some researchers have suggested that the implicit learning mechanisms that give rise to syntactic priming effects (in adults and children) are the same mechanisms that underlie language acquisition in children (e.g., Chang, Dell, & Bock, 2006). Note that such mechanisms need not be specifically linguistic in nature: Individual differences in implicit learning of visual patterns and cumulative syntactic priming effects show a positive correlation, such that children showing

the strongest implicit learning of visual patterns also show the strongest long-term priming effects (Kidd, 2012).

Syntactic priming paradigms therefore appear to offer great potential for studying language impairments in children with SLI. Most importantly, they allow an implicit test of whether children with SLI have an underlying representation for a particular syntactic structure, which appears to be sensitive to even structures that the children might not produce in spontaneous production. They also elucidate the ways in which prior exposure may facilitate such representations, and how it may relate to long-term learning in these children and TD children.

Some studies have shown that children with SLI may benefit from prior exposure to particular structures (Leonard et al., 2000, 2002; Miller & Deevy, 2006; Riches, 2012). However, such studies have tended not to address specific representational or learning questions, and the benefits that they demonstrate need not reflect syntactic priming effects. For example, Leonard and Dispaldro (2013) found that Italian children with SLI were more likely to produce descriptions of transitive events that included clitic pronouns (a clinical marker of SLI) immediately after hearing and repeating prime sentences than after counting a number of identical objects. However, Leonard and Dispaldro noted that facilitation of clitic pronoun production did not differ following prime sentences that contained clitic pronouns versus prime sentences that did not contain clitic pronouns. Facilitation was thus not contingent on the precise repetition of syntactic structure. (We note also that it could not be explained in terms of residual activation or implicit learning of particular syntactic structures.) They suggested that prior exposure to sentences involving simultaneous repetition of multiple elements of structure (in this case, repetition of lexical content between experimental items, and repetition of thematic

relations, the subject noun phrase, and verb inflection within prime-target pairs) might serve to reduce processing demands on production sufficiently to allow generation of a sentence structure with a clitic slot that would otherwise be too complex for them to generate. These effects therefore represent facilitatory effects of prior context that do not appear to constitute syntactic priming effects.

But it is possible to establish conditions under which such explanations can be excluded (e.g., where lexical content is not repeated between experimental items), in order to address issues about syntactic representation and learning in children with SLI. We now report a study that used a syntactic priming paradigm to investigate SRc structures in 4- to 6-year-old Italian-speaking children with SLI. Specifically, we examined whether these children have access to an abstract representation of SRc that they can recruit during both comprehension and production, and whose availability can be incremented through prior exposure in ways that might exert immediate and long-term effects on language use. To do this, we used a Snap priming paradigm (Branigan et al., 2005; see also Messenger et al., 2012), in which children with SLI (and a group of chronological-age-matched TD children controls) had to describe pictures as part of a picture-matching game. The game involved three elements for participants: 1) listening to the experimenter describe her picture; 2) describing the participant's own picture; and 3) deciding whether or not the two pictures matched (and if so, being first to shout 'snap!' in order to win the picture cards).

We manipulated the structure of the experimenter's *prime* descriptions and examined how this affected the structure of the child's subsequent *target* descriptions, with respect to both immediate and longer-term (cumulative) effects. Thus we examined whether children produced SRc descriptions for pictures (e.g., *La ragazza che bacia il ragazzo*, 'The girl who kisses the

boy') immediately after hearing the experimenter produce an SRc description (e.g., *Il ragazzo che mangia la banana*, 'The boy who is eating a banana'), and whether they did so more often than after hearing the experimenter produce a bare Noun description (e.g., *Sedia*; 'Chair') (*immediate priming effect*), and moreover whether children's likelihood of producing an SRc increased with cumulative exposure to SRc (*cumulative priming effect*).

Our main analyses focused on whether children with SLI would show immediate and cumulative priming effects based on the repetition of abstract syntactic structure. Thus we examined the structure of their descriptions following prime descriptions that contained distinct (open-class) lexical content (e.g., Prime: *La donna che beve l'acqua*, "The woman that is drinking water"; Target: *L'uomo che legge il libro* "The man that is reading a book"; *mismatched trials*). If children with SLI produced SRc after hearing SRc with distinct lexical content, this would suggest that comprehending the experimenter's prime description implicated retrieval and application of an abstract representation that they could reuse during their own subsequent production – in other words, that they have an abstract amodal representation for SRc. Without such an abstract representation, prior comprehension of an SRc could not facilitate subsequent production of an unrelated SRc.

The conditions under which such priming occurred would also be informative about the nature of the facilitation effect. An immediate priming effect would suggest that the relevant representations were relatively accessible, requiring only a single exposure for successful subsequent retrieval; this would be compatible with facilitation based on residual activation or implicit learning. A cumulative priming effect would suggest that the facilitatory effect of processing an SRc structure accumulated with repeated exposure to SRc, compatible with an implicit learning mechanism. If only a cumulative priming effect were found (i.e., there were no

immediate priming effect), this would suggest that the relevant representations were relatively inaccessible, requiring cumulative facilitation to accrue before they could be successfully recruited during production.

Although our main concern was whether syntactic priming effects could provide evidence for the existence of an abstract SRc structure in children with SLI, we were also interested in comparing priming effects between the SLI and TD groups. If the magnitude of immediate priming were the same in children with SLI as in TD children (as has been found in other demonstrations of syntactic priming, e.g., Miller & Deevy, 2006), this would suggest that their syntactic representations were affected by immediately prior linguistic experience in similar ways, and hence that children with SLI's difficulties in producing SRc might be associated with inaccessibility of representations during normal (unprimed) processing, rather than qualitatively degraded representations. If the magnitude of immediate priming were smaller in children with SLI than TD children, in contrast, this would suggest that their syntactic representations were affected by immediately prior linguistic experience in different ways, which would be more easily compatible with an assumption of qualitatively degraded representations. Finally, comparisons of the magnitude of cumulative priming effects could be informative about implicit learning processes in the two groups, specifically whether children with SLI and TD children both show long-term changes in the accessibility of syntactic representations based upon repeated exposure, or whether children with SLI show no or weaker long-term effects, as would be consistent with previous evidence of impaired learning mechanisms in children with SLI (e.g., Tomblin et al., 2007; Ullman & Pierpont, 2005; Windfuhr et al., 2002).

In addition to our main analyses focusing on mismatched trials, where the experimenter's and child's descriptions related to different pictures (hence had distinct lexical content), we also

analysed *matched* ('snap') trials, where the experimenter's picture and the child's picture were identical. In these trials, it was therefore possible for children to describe their own picture by repeating verbatim the experimenter's description (e.g., Prime: *Il cane che insegue il gatto* "The dog who is chasing the cat"; Target: *Il cane che insegue il gatto* "The dog who is chasing the cat"), though this was not drawn to their attention and they could of course describe the picture in any way that they chose. These matched trials therefore provided an interesting implicit sentence repetition analogue to the explicit sentence repetition task in which children with children with SLI have consistently been found to perform poorly on SRc (as in other structures; Riches, 2012). By comparing children with SLI's performance on matched trials (implicit sentence repetition) with their performance on similar materials in an explicit sentence repetition task, we were therefore able to examine further whether previous demonstrations of poor performance on SRc in explicit sentence repetition reflected an underlying deficit in syntactic representation, or a task-relevant impairment in processing.

In sum, our study set out to examine whether children with SLI have an abstract representation for SRc structures, and how such a representation might be facilitated through prior exposure; although not the main focus of our research, our data also allowed examination of how processing associated with such a representation might be affected by task demands.

Method.

Participants. 38 Italian Children (19 children with SLI and 19 TD children) participated in this study. Children with SLI (14 boys and 5 girls, age range: 51-75 months) were recruited from the IAPS (*Istituto Arcivescovile per Sordi*) Neuropsychology Language Unit in Trento, Italy, a dedicated clinical unit for children with language disorders. The TD children (chronological-age-matched controls: 9 boys and 10 girls, age range: 50-77 months) were

recruited through nurseries and primary schools in the Trento area. The children with SLI had been diagnosed with language impairment by a neuropsychologist on the basis of normal performance in measures of non-verbal IQ (>86 in the standardized Italian version of the WPPSI-3 *Wechsler Preschool and Primary Scale of Intelligence* core subtests; Sannio Fancello & Cianchetti, 2008) and performance at least -1SD below the mean on at least two measures of expressive and receptive language in the *Test Neuropsicologico Prescolare (TNP)*; Cossu, & Paris, 2007). The *TNP* is a rigorously constructed normed battery that is standardly used in Italy to assess language functions in pre-school children, including measures of expressive and receptive language at word and sentence level (sentence-level structures tested include sentential negations, dative sentences, and subject relatives).

They were all receiving intervention at the IAPS in Trento for delayed language development, and had no non-verbal learning difficulties, hearing difficulties, autism spectrum disorder, or other known syndrome, as reported by the neuropsychologist who made the diagnosis of SLI.

Although not forming part of our selection criteria, we additionally assessed both the SLI and TD groups using the standardized Italian version of the *Test for Reception of Grammar, version 2* (Suraniti, Ferri, & Neri, 2009); the standardized Italian version of the *Peabody Picture Vocabulary Test IV* (Stella, Pizzoli, & Tressoldi, 2000); a standardized Italian test of non-word repetition, the *PRCR 2: Prove di Prerequisito per la Diagnosi delle Difficoltà di Lettura e Scrittura 2* (Cornoldi, Miato, Molin, & Poli, 2009); and a story re-telling task (following Leonard, Bortolini, Caselli, McGregor, & Sabbadini, 1992) to measure MLU and narrative ability.

We assessed the TD children IQ's performance, using the standardized Italian version of the WPPSI-3 core subtests (Sannio, Fancello & Cianchetti, 2008).

TD children language's competence was also assessed with the TROG -2, PPVT-4, non-word repetition and MLU. All TD children included in the study performed within the normal range for their age group (based on standard scores) in all language tests.

See Table 1 for details of the SLI and TD groups' characteristics and performance on these tests.

The two groups did not differ in non-verbal intelligence (WPPSI-III: $t(35) = -0.57, p = 0.5$). However, children with SLI performed significantly more poorly than the TD children in receptive vocabulary (PPVT: $t(30) = -3.34, p < .002$), and receptive grammar (TROG-2: $t(30) = -11.18, p = .0001$; note that all of the SLI children scored at least -1SD below the mean, consistent with their performance in the TNP). They also performed more poorly in the non-word repetition test, correctly recalling fewer syllables (PRCR-2: $t(33) = -15.94, p = .0001$; we note that sixteen of the 19 children with SLI obtained standard scores of <14 in this test, equating to at least -1SD below the mean). Children with SLI also yielded significantly shorter mean MLUs than TD children ($t(29) = -3.64, p = .001$).

INSERT TABLE 1 HERE

Materials. *Picture-matching task.* We prepared 24 pairs of experimental pictures. Prime pictures depicted a single object (e.g., *Sedia*, “*chair*”; baseline condition) or an animate entity carrying out a non-reversible transitive action (e.g., *Il bambino che mangia la banana*, “*The boy who is eating the banana*”; SRc condition); target pictures depicted a reversible transitive action (e.g., *La donna bacia il ragazzo*, “*The woman kissing the boy*”; see Figure 1).

INSERT FIGURE 1 HERE

Each prime picture was associated with a prime description (baseline condition: a bare noun, e.g., *Sedia* ‘*chair*’; SRc condition: an SRc, e.g., *Il bambino che beve l’acqua*, “*The boy who is drinking water*”), with prime treated as a between-items factor. An experimental item

comprised a prime picture, target picture, and prime description. We also prepared eight filler items for the ‘Snap’ trials (i.e., where the experimenter’s picture and the child’s picture matched). Four of these filler items comprised a pair of identical pictures depicting a single object (e.g., *Sedia*, “*Chair*”), which were associated with a bare noun description (e.g., *una sedia*, “*a chair*”); the remaining four comprised a pair of identical pictures depicting a transitive action, which were associated with an SRc description (e.g., *La bambina che abbraccia la mamma*, “*The girl who hugs the mother*”). We constructed a list of 32 items: 12 baseline-prime experimental items; 12 SRc-prime experimental items; 4 bare-noun filler (‘snap’) items; and 4 SRc filler (‘snap’) items.

Sentence repetition task. The repetition task battery comprised 20 items and included several different sentence constructions: 4 simple declaratives (2 non reversible and 2 reversible), 2 declaratives with object coordination, 4 declaratives with verb coordination and 10 Subject Relatives (see Table 2). Overall, sentences ranged from five words (with three open-class elements) to eight words (with four open-class elements). Subject relative sentences involved six words (with three open-class elements).

INSERT TABLE 2 HERE

Procedure. Both tasks were administered in a single session. Participants undertook the picture matching task first, followed by the sentence repetition task. The experiment began with a warm-up session in which the child was asked to identify the characters (depicted on individual cards) that would appear on the target items.

Picture matching task. The task began with four practice items to ensure that the child understood the task. In both the practice session and the main experiment, the experimenter placed a set of pre-arranged picture cards face-down in front of each player (the experimenter

and the participating child). She told the participant that they would play a game in which they would take it in turns to describe pictures and look for pairs of matching pictures. The experimenter began each game by turning over the top card and describing it (following her script); this constituted the prime. The participant then took his or her top card and described it; this constituted the target response. The game continued with players alternating descriptions until all cards had been described. If the same picture appeared on both players' up-turned card, the first player to shout "Snap" would win the cards in play. The experimental sessions were audio-recorded; participants' responses were transcribed and scored according to the criteria outlined below.

Repetition task. The experimenter placed a picture on the table where both the child and the experimenter could see it. The experimenter then produced a sentential description of the picture (e.g., *Il bambino abbraccia la bambina*, "The boy hugs the girl"); the child was then asked to repeat the sentence.

Scoring. For the picture matching task, we scored a response as an SRc if it contained the following elements: a noun phrase that expressed the agent of the embedded verb, the relativizer *che*, a verb and an NP that expressed the patient/theme of that verb, a further verb and an NP that expressed the patient/theme of that verb, in that order. For the sentence repetition task, we scored as correct all sentences matching the complexity of the target sentence in terms of number of words and syntactic structures. Word substitutions across the same grammatical class were not considered as errors (see examples in 1).

- (1) Target: Il gatto che graffia il bambino "*The cat who scratches the child*"
- Nouns inversions: Il bambino che graffia il gatto "*The **child** who scratches the **cat*** "
- Verb substitution: Il gatto che fa male al bambino "*The cat who **hurts** the child* "

Noun substitution: Il gatto che graffia il ragazzo “*The cat who scratches the boy*”

We scored a response as an error if it did not match the target in terms of number of words or syntactic complexity, for example SRc that were repeated as simple declarative sentences (2) or as NPs (3).

(2) Target: Il gatto che graffia il bambino *The cat who scratches the child*

Production of a declarative: Il gatto graffia il bambino *The cat scratches the child*

(3) Production of a fragment: Il gatto *The cat*

Analysis. We compared the performance of children with SLI and TD children on the production of SRc during structural priming and sentence repetition. Our dependent measure was a binary (yes/no) response that indicated whether a child produced or not a relative clause. Our initial analysis focused on children’s production of SRc in the picture matching task, specifically whether children produced SRc after hearing the experimenter produce an SRc with different lexical content (i.e., in mismatched trials), and whether they did so to a greater extent than after hearing the experimenter produce a bare Noun. We examined whether any tendency to do so differed between children with SLI and TD children, and whether it was affected by the number of SRc that the child had previously experienced during the session (i.e., whether there was a cumulative priming effect). We also compared children's production of SRc on matched trials in the picture-matching task (i.e., Snap trials) with their production in the repetition task.

We used linear mixed effect (LME) modelling (e.g., Pinheiro and Bates, 2000). This is a hierarchical multilevel regression where the variance component of random variables (e.g., child ID) is explicitly accounted for, allowing explicit estimation of individual differences in the regression model. In LME, this variability is accounted through random slopes, where for each group of a random variable (e.g., an individual participant or an individual experimental item),

we estimate how a predictor of interest (e.g., priming) intercepts. A multitude of different models can be generated given the same set of variables. In order to decide the “best” model, we followed an information-theoretic approach and performed a step-wise, forward, best-path model selection. We compared nested models using a log-likelihood Chi-square test and retain the model that returns the best statistical fit. We started with an empty model, and built its random structure first. Then, we included the fixed effects, (i.e., experimental variables of interest, e.g., priming), and evaluated whether including random slopes would improve the fit. Each term (fixed or random) was included according to the impact on the log-likelihood, i.e., the term that gave the best improvement was entered first. The best-path model selection procedures are shown to give a level of Type-1 error, which is comparable to maximal-structure mixed models (Barr, Levy, Scheepers, & Tily, 2013).

For the first analysis, our dependent measure was the likelihood of producing an SRc on mismatched trials (i.e., a binary (1/0) variable). The predictors included in the model selection were: Primed (Primed, 0.5; Non-Primed, -0.5), Group (TD, -0.5; SLI, 0.5) and Cumulative: an incremental variable counting how many times a child had experienced (comprehended or produced) an SRc up to that trial. As control variables, we included each participant’s scores on the MLU, TROG-2 and PPTV-4 tests. Inclusion of these variables allowed us to determine more precisely how each individual child’s language ability influenced their production performance.

In the second analysis, our dependent measure was again the likelihood of producing an SRc but calculated as a proportion over trials for each participant: SRc matched trials for the picture-matching task ($n = 4$), and SRc trials in the repetition task ($n = 10$). The predictors for this analysis were Group (TD, -0.5, SLI, 0.5) and Task (Repetition, 0.5; Picture matching, -0.5).

Results.

In the picture matching task, children with SLI produced a total of 226 responses in the baseline condition (Bare noun), of which 14% were SRc, and 228 responses in the SRc condition, of which 35% were SRc (including six instances involving thematic role reversals, i.e., where the agent was expressed as the patient and vice versa; see Table 3).

TD children produced a total of 224 responses in the baseline condition (Bare noun), of which 29% were SRc, and 226 responses in the SRc condition, of which 64% were SRc. In the repetition task, children with SLI produced responses for a total of 190 declaratives, with perfect performance (i.e., no errors), and 190 SRc, with 16% SRc responses (including one instance involving thematic role reversal), 61% erroneous responses involving substitutions of declaratives and 23% erroneous responses involving NP fragments. TD children produced responses for a total of 190 declaratives, with perfect performance (i.e., no errors), and 190 SRc, with near-ceiling performance (90% correct responses, 10% erroneous responses involving substitutions of declaratives).

INSERT TABLES 3 AND 4 HERE

Table 3 shows that children with SLI spontaneously produced fewer SRcs than TD children in the picture matching task after hearing the experimenter produce a bare noun picture description (14% vs. 29%). Additionally, they showed substantially impaired performance in producing SRc during the repetition task, relative to TD children (16% vs. 90%). However, there was a striking disparity between their performance in the repetition task and their performance in the picture matching task after hearing the experimenter produce an SRc: They produced SRc on over two-thirds of matched trials (when they had heard the experimenter produce an SRc describing an identical picture to their own picture; 77%) and a third of mismatched trials (when they had heard the experimenter produce an SRc describing a different picture to their own picture; 35%).

TD children also showed an increased tendency to produce SRc after hearing the experimenter produce an SRc description (64%) than following a bare noun prime (29%). These results were inferentially confirmed in the LME analysis reported below.

Mismatched trials. The initial analysis focused on mismatched trials, i.e., likelihood of producing an SRc following a bare noun versus SRc (mismatched) prime (see Figure 2 and Table 5).

INSERT FIGURE 2 HERE

INSERT TABLE 5 HERE

The best-fit model included as a significant main effect of Prime: Participants produced more SRc when they had heard a SRc prime than when they had heard a bare noun prime. The model also included a marginal main effect of Group: TD children showed a tendency to produce more SRc than children with SLI. Crucially, however, there was not a significant interaction between Group and Prime: The effect of priming was equivalent in both groups. Thus children with SLI were affected to the same extent as TD children by the syntactic structure that they had heard in an immediately prior utterance. Additionally, the interaction of Prime and TROG-2 performance was significant; children were more likely to produce an SRc after hearing an SRc prime if they had high grammatical proficiency (but high grammatical proficiency alone was not a significant predictor of SRc production). Importantly, there was not a significant three-way interaction between TROG-2: Prime: Group, suggesting that differences in grammatical proficiency did not affect children's tendency to repeat structure differentially in the two groups.¹

Cumulative priming was a significant predictor, indicating that the number of SRc structures that participants had experienced so far increased their likelihood of producing an SRc on a subsequent trial. Both groups exhibited a cumulative priming effect, yielding a main effect;

overall, the likelihood of producing an SRc increased by approximately 1% after each exposure. However, there was an interaction between Cumulative and Group, with TD children showing a stronger tendency than SLI children to produce SRc as their experience of SRc within the experiment increased, with each exposure to an SRc increasing TDC's likelihood of producing an SRc by 1% more than SLI children. Thus, even though both groups of children manifested a cumulative priming effect, this effect was greater in TD children than in SLI children.²

To examine whether a priming effect was evident from the beginning of the experiment (i.e., on the basis of a single exposure to an SRc) and was therefore not dependent on a cumulative effect, we additionally analysed production of SRc on the first baseline prime trial and the first SRc prime trial of the experiment. Of the 19 children with SLI, none produced an SRc following the first baseline prime, whereas six produced an SRc following the first SRc prime; of the 19 TD children, none produced an SRc following the first baseline prime, whereas eight produced an SRc following the first SRc prime. This pattern was confirmed in an ANOVA, which showed a main effect of Prime ($F(2, 36) = 21.25, p < .001$), but no effect of Group, nor a Prime x Group interaction (all $F < .5$). A strong priming effect was therefore evident in both groups from the very beginning of the experiment, following a single exposure to an SRc.

Matched trials and sentence repetition. Our subsequent analysis focused on a comparison of SRc production in matched trials of the priming task and in the sentence repetition task (see Figure 3 and Table 6).

INSERT FIGURE 3 AND TABLE 6 HERE

There was a main effect of Group: Overall, TD children produced more SRc than SLI children. There was also an effect of task: Participants produced more SRc in the Repetition task than the Priming task. Crucially, there was a significant interaction between Group and Task: SLI

children produced fewer SRc in the sentence repetition task than in the picture-matching task, whereas TD children performed at the same level in both tasks.

General Discussion

A large body of research has suggested that children with SLI experience persistent difficulty in processing SRc structures, even though these structures develop early in TD children. We used a structural priming paradigm to investigate the nature of this difficulty. When Italian-speaking children with SLI (and a control group of chronologically-age-matched TD children) described pictures involving transitive actions, they were more likely to produce a description with an SRc structure when they had just heard the experimenter describe an unrelated picture using an SRc description than when they had heard the experimenter describe an unrelated picture using a bare noun phrase. Although there was a tendency for children with SLI to produce fewer SRc overall than TD children, there was no difference between groups in the extent to which immediate prior exposure to an SRc increased the likelihood of producing an SRc description. (Indeed, Bayesian classification of group performance demonstrates that immediate priming raises children with SLI's performance to a level that is indistinguishable from TD children's unprimed performance; see Coco, Garraffa, & Branigan, 2012, for details on the classification algorithm performance).

Analysis of the cumulativeness of priming showed a significant cumulative effect in both groups: The likelihood of producing SRc sentences increased for both children with SLI and TD children, the more they were exposed to them. Critically, however, the groups differed with respect to cumulative effects of exposure to SRc sentences across the experiment: Increasing exposure to SRc sentences increased the likelihood of producing SRc descriptions to a greater extent in TD children than in children with SLI. There were also differences between the same

groups' performance when spontaneously describing pictures after hearing the experimenter describe the same picture using an SRc and when asked explicitly to repeat an SRc description produced by the experimenter: Children with SLI produced more SRc structures in the picture matching task than when explicitly asked to repeat an SRc structure in the sentence repetition task.

We consider first the implications of the finding that children with SLI were able to spontaneously produce SRc after comprehending an utterance with the same structure, but different open-class lexical content (and different meaning). For this to have occurred, they must have retrieved and applied an abstract representation when comprehending the experimenter's sentence that they could also use during their own subsequent production (i.e., a representation that was not specified for open-class lexical content). In other words, the existence of structural priming effects between unrelated SRc provides evidence that children with SLI have an abstract amodal structural representation that they can use both to comprehend and to produce SRc with differing open-class lexical content. It is possible that the closed-class content of this representation is fixed (e.g., that the relativiser is specified within the representation; though see Bock (1989) and Messenger (2010) for evidence against this possibility in TD adults and children with respect to other closed-class elements); but the representation of the open-class elements must necessarily be abstract. Trivially, lexical priming of the relativiser could not explain participants' ability to produce a well-formed SRc expression involving two noun phrases and a verb in the appropriate configuration with the relativiser.

This facilitation effect occurred on a turn-by-turn basis, depending on whether the experimenter's most recent picture description (for an unrelated picture) involved a bare NP or an SRc. Reliable priming occurred following exposure to a single SRc prime in the first trial of

the experiment. Thus children with SLI did not require exposure to multiple exemplars for subsequent retrieval to be facilitated. Taken together, these results suggest that the relevant representations were sufficiently accessible that their successful retrieval could be facilitated through a single exposure. Thus, we conclude that children with SLI have an abstract representation of the SRc that they apply during both comprehension and production. Moreover, this representation is sufficiently accessible for it to be used in spontaneous production after just a single instance in prior comprehension.³

Strikingly, when we compare the performance between children with SLI and TD children on mismatched trials, there was no difference between groups in the magnitude of the immediate priming effect (over the experiment as a whole, or with respect to the first SRc trial alone; see also Miller & Deevy, 2006), despite the overall tendency for children with SLI to produce fewer SRc than TD children. That is, immediate prior syntactic experience affected the accessibility of both groups' syntactic representations in similar ways. However, we found important differences between groups in the cumulativeness of effects. Whereas both groups show the same immediate effects of prior experience, TD children showed stronger long-term changes in the accessibility of syntactic representations based upon repeated exposure. Within the course of the experiment, cumulative priming increasingly facilitated production of SRc, so that children were more likely to produce SRc the more SRc they had experienced during the session, but the magnitude of this effect was larger in TD children than in children with SLI.

Taken together, these results suggest that children with SLI do not have qualitatively degraded representations, compared to TD children. If so, we would not expect their performance to improve so markedly immediately after exposure to a single exemplar; we would also expect exposure to a single exemplar to induce differing effects in children with SLI and in

TD children. Instead, the immediate priming results seem more compatible with an account in which children with SLI have acquired the relevant representations but have difficulties in accessing them during normal production, i.e., when unsupported by prior processing.

This general pattern is compatible with other findings regarding syntactic priming effects in children with SLI and in other populations. For example, Messenger et al. (2012) showed that 3-4 year-old TD children were able to produce passive sentences to describe pictures after hearing the experimenter produce an (unrelated) passive sentence involving the same or a different event structure, even though they did not spontaneously produce passive sentences. Similarly, Hartsuiker & Kolk (1998) demonstrated that aphasic patients who were unable to produce passive sentences spontaneously were able to do so after being exposed to passive primes, but not spontaneously. In both cases, prior processing may raise to a critical level of activation those representations whose resting level is normally too low to allow retrieval.

In the same way, children with SLI may benefit from prior comprehension of an SRC because the act of parsing the prime activates the relevant SRC representation and this retains activation sufficiently for the same representation to be accessible during immediately subsequent processing. On this account, the immediate priming effect arises from residual activation of syntactic representations, which occurs in the same way and to the same extent for children with SLI and TD children. TD children's representations have a sufficiently high resting level of activation that they are accessible even without the boost conferred by prior processing of a prime, whereas children with SLI's representations are not.

The different pattern of results with respect to cumulative priming effects is suggestive about why children with SLI might have less accessible representations than their chronologically age-matched TDC controls. In the syntactic priming literature, such long-term

effects are typically characterised as an implicit learning effect (e.g., Chang et al., 2006), by which individual experiences can come to exert cumulative and long-term changes on syntactic representations. Such effects may occur in conjunction with effects of residual activation (e.g., Ferreira & Bock, 2006). Our results demonstrate such effects in TD children during the timeframe of a single experiment, but other studies suggest that they may also occur over a longer period of time, so that representations become persistently easier to access with increasing experience (e.g., Kaschak, 2002; 2004). For example, passive structures may become increasingly accessible with experience during language acquisition, moving from a state in which they are only accessible when boosted by immediately prior processing (as in Messenger et al., 2012) to a state in which they are sufficiently accessible for spontaneous production without such prior context.

Such an account is consistent with an interpretation of our findings that attributes impaired implicit learning mechanisms to children with SLI, so that experience with individual utterances does not lead over time to facilitated access to (at least some) syntactic representations in the way that it does for TD children. As such, our results show striking convergence with previous research demonstrating that children with SLI show impaired learning mechanisms, and specifically impaired implicit learning (e.g., Tomblin et al., 2007; Ullman & Pierpont, 2005; Windfuhr et al., 2002). This result has potentially important therapeutic implications, since it suggests that although children with SLI may derive short-term benefit from immediate prior exposure to a structure, they may require extensive exposure to derive any long term benefit.

Finally, we consider what the comparison of children's performance on matched trials in the picture-matching task with their performance on the elicited repetition task can further tell us about the nature of the SRc impairment in SLI. Recall that on matched trials, children saw and

described a picture that was identical to the picture that the experimenter had just described, and so could – if they wished, although this was not drawn to their attention – repeat verbatim the experimenter’s description; in the elicited repetition task, they saw the picture that the experimenter had just described, and repeated the description. In essence, then, the difference between the two cases lay in whether children implicitly or explicitly repeated the experimenter’s description. TDC performed almost at ceiling on SRc in both the picture matching task and the sentence repetition tasks (90% vs. 96%).

In contrast, children with SLI showed substantially poorer performance in the elicited repetition task than in matched trials of the picture-description task. They repeated only 16% SRc when explicitly asked to do so, compared with 77% SRc when repetition was implicit. This poor performance is particularly notable, given that the repetition task occurred at the end of the experimental session, when participants had already been exposed to 12 SRc during the priming task (8 in mismatched trials, 4 in matched [snap] trials). This suggests that their comparatively better performance on the picture-matching task than on the repetition task cannot be attributed to learning over the course of the experimental session (because this would wrongly predict better performance in elicited repetition than in picture-matching), and moreover provides further evidence that children with SLI did not benefit strongly from multiple exposures to SRc.

This disparity in performance within the SLI group on minimally distinctive tasks suggests strongly that the poor performance for SRc that has frequently been observed for children with SLI in elicited sentence repetition (e.g., Riches, 2012) may have a task-related component. We note that the SLI children also displayed poor performance in a non-word repetition task. Further research is required to identify the precise aspect(s) of the repetition task that constitute the locus of difficulty, but we speculate that the relevant task differences may lie

in the demands that the tasks place upon working memory: Whereas repetition tasks require children to generate their response whilst concurrently maintaining a representation of the whole stimulus sentence in working memory (in order to reproduce it accurately in its entirety), the picture-matching task allows children to comprehend the experimenter's description and subsequently produce their own description serially and incrementally, on a word-by-word basis (as standardly assumed for speech comprehension and production; e.g., Levelt, 1989; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). This possibility requires further investigation, but would be consistent with previous findings of working memory impairments in children with SLI (e.g., Gathercole & Baddeley, 1990a; Leonard, 1998; Montgomery, 1995; Norbury et al., 2002). More generally, our results suggest that although poor performance in repetition tasks may be a marker of SLI, such tasks may not always provide an accurate reflection of children's underlying grammatical competence.

Taken together, our results suggest that the poor performance of children with SLI on SRc reflects inaccessible (though not necessarily qualitatively degraded) syntactic representations that are resistant to long-term implicit learning, rather than the absence of a syntactic representation for SRc (i.e., a deficit in syntactic knowledge). It remains open to question whether the implicit learning impairment for which we have found evidence manifests itself in SLI only with respect to syntactic processing, or whether it may also occur for other aspects of language. We suggest that this is an interesting avenue for future research. We further suggest that the structural priming paradigm adopted in this paper has considerable potential for addressing outstanding questions about the nature of syntactic representations in children with SLI and the conditions under which such representations are acquired.

In conclusion, we used a structural priming paradigm to examine whether children with SLI may have an abstract representation for SRc that can be facilitated through prior exposure. Our results suggest that exposure leads to an immediate facilitation effect to the same extent in children with SLI as in TD children, but that this facilitation does not accumulate through time in the same way. We conclude that children with SLI have an abstract representation of SRc that they can recruit during spontaneous production when it has been facilitated through previous use. However, they show evidence for a deficit in implicit learning of syntactic structures. Furthermore, they show poor performance in explicit repetition of SRc.

Notes

¹ Note that neither PPTV-4 nor MLU scores were significant predictors in the model, neither interacted with priming.

² An additional analysis of each group individually showed exactly the same pattern: 1% increase with each exposure in the SLI group compared to a 2% increase in the TD group. Note also that for all of our analyses, there was no change in the pattern of results when the 7 SRc responses involving thematic role reversal (all produced by children with SLI; 6.1% of their responses) were excluded.

³ It is possible that we would have found even stronger priming effects if the children had repeated (i.e., produced) the primes as well as comprehending them (though note that Bock, Dell, Chang, & Onishi, 2007, found no difference in priming in adults following produced versus comprehended primes). Even with comprehended primes, however, the priming effect was very strong (21% and 35% more SRc following SRc primes than following baseline primes in children with SLI and TD children respectively). Critically, the fact that there was no difference between groups in the magnitude of the immediate priming effect suggests that the children with SLI did not experience specific difficulties in comprehending the prime that impacted upon their tendency to repeat structure in their following description. Thus they showed the same benefit from comprehending a prime as the TD children.

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Figure Captions:

Figure 1: Example target picture.



Figure 2: Interaction plots (means and standard error) for the probability of producing an SRC during the picture matching task (Mismatched trials) by group (TDC, SLIC) and Prime (Primed; Non-Primed). Asterisks indicate predicted values according to the LME model.

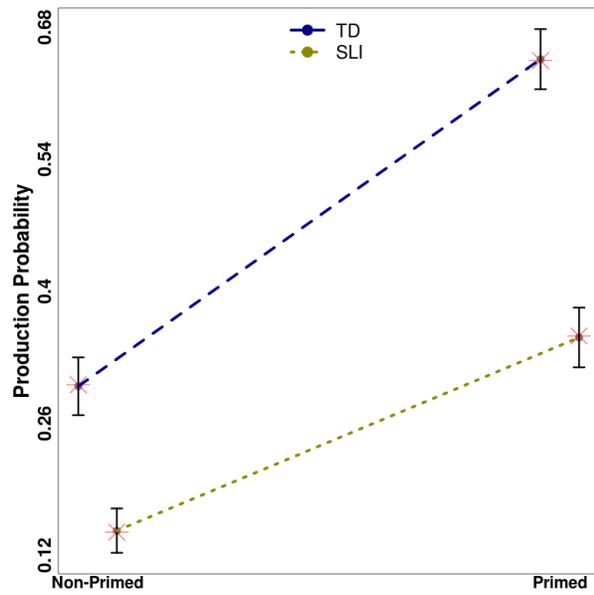


Figure 3: Interaction plots (means and standard error) for the probability of producing an SRC in the picture matching task (Matched trials) and the sentence repetition task, by group (TDC, SLIC).

Asterisks indicate predicted values according to the LME model.

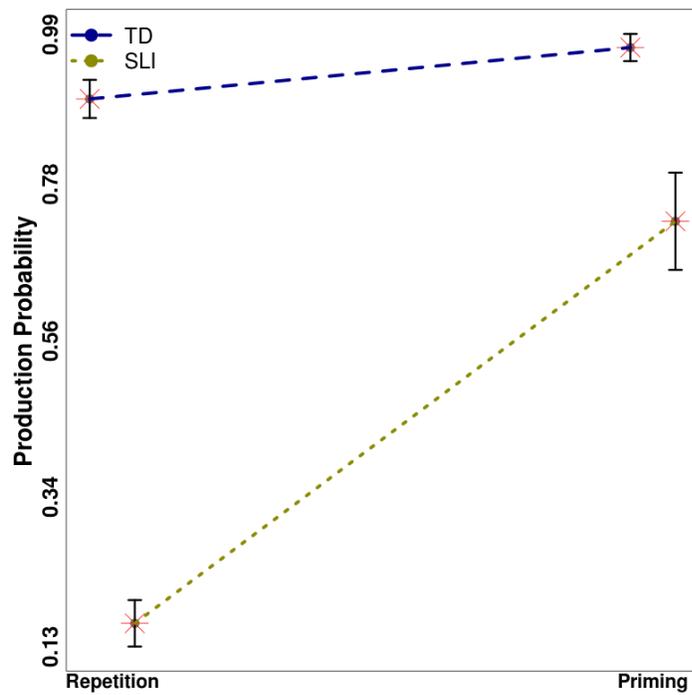


Table 1. Overview of groups: sex, age in months, WPPSI-III and performance on linguistic tasks (TNP, TROG -2, PPVT-4, non-word repetition and MLU). In the TNP, a standard score on the expressive and receptive grammar sub-tests of <4 for children younger than 6;0 and <5 for children older than 6;0 equates to -1SD below the mean; a standard score on the expressive and receptive vocabulary sub-tests of <7 for children younger than 6;0 and <10 for children older than 6;0 equates to -1SD below the mean.

GROUP	SLI	TD
Sex	5-F 14-M	10-F 9-M
Age	66.4 (SD 7.5)	61.3 (SD 8.9)
WPPSI-III	101.31 (SD 7.4)	102.57 (SD 6.1)
Expressive grammar TNP raw score	2.5 (SD 2.2)	-
Receptive grammar TNP raw score	2.9 (SD 1.55)	-
Expressive vocabulary TNP raw score	9.5 (SD 3.5)	-
Receptive vocabulary TNP raw score	9.9 (SD 2.4)	-
Receptive grammar TROG-2 blocks	5.52 (SD 1.67)	13.73 (SD 2.72)
Receptive vocabulary PPVT-4	94.84 (SD 19.65)	112.63 (SD 12.32)
Non-word repetition PRCR-2 raw score	0.33 (SD 0.08)	0.86 (SD 0.11)
MLU (in words)	4.2 (SD 0.89)	5.7 (SD 0.65)

Table 2. Example stimulus types for the repetition task.

Sentence Type	Length	Complexity	Example
Declarative	5 words	Noun-Verb-Noun	<i>Il bambino abbraccia la bambina</i> ‘The boy hugs the girl’
Object coordination	8 words	Noun-Verb-Noun1-Noun2	<i>Il bambino abbraccia la bambina e il gatto</i> ‘The boy hugs the girl and the cat’
Verb coordination	7 words	Noun –Verb1 (and) Verb2- Noun	<i>Il bambino abbraccia e bacia la bambina</i> ‘The boy hugs and kisses the girl’
SRc	6 words	Noun1 (who) Verb – Noun2	<i>Il bambino che abbraccia la bambina</i> ‘The boy who hugs the girl’

Table 3. SRc production in percentages (and raw frequencies) by group (TD children, children with SLI) on the picture matching task (Mismatched trials: Bare noun, SRc conditions; Matched trials: SRc ‘Snap’); for comparison, performance on the repetition task (SRc condition) is also shown.

Group	Bare noun prime	SRc prime	Snap prime (SRc)	Sentence Reprn SRc
SLI	14% (33/226)	35% (80/228)	77% (53/68)	16% (31/190)
TD	29% (67/224)	64% (146/226)	96% (64/66)	90% (171/190)

Table 4. Repetition performance in percentages (and raw frequencies) by group (TDC, SLIC) on the repetition task for declarative, object coordination, verb coordination and SRc stimuli.

Group	Repn Decla	Repn Object coord	Repn Verb coord	Repn SRc
SLIC	100% (76/76)	100% (38/38)	100% (76/76)	16% (31/190)
TDC	100% (76/76)	100% (38/38)	100% (76/76)	90% (171/190)

Table 5. Priming: LME coefficient estimates; Dependent measure (1/0: produced or not, SRC). Predictors: Prime (Primed = 0.5, Non-Primed = -0.5), Cumulative (number of SRC previously processed) and TROG-2 (grammatical proficiency score).

Predictor	Coefficient	p-value
Intercept	0.3561	.0001
Prime	0.2469	.0001
Cumulative	0.0173	.0001
TROG	0.0107	.1
Group	0.1139	.06
Cumulative: Group	0.0124	.02
Prime: TROG-2	0.0133	.03

Table 6. Task: LME coefficient estimates; Dependent measure (proportion of SRc produced across trials for each participant). Predictors included by the model: Group (TDC = 0.5, SLIC = -0.5), Task (Repetition = 0.5, Picture-matching = -0.5).

Predictor	Coefficient	p-value
Intercept	0.4949	.0001
Group	0.4456	.0001
Task	0.0734	.03
Group: Task	0.5824	.0001