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Elicited production of relative clauses in German: Evidence from typically developing children and children with specific language impairment

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Abstract

We elicited the production of various types of relative clauses in a group of German-speaking children with specific language impairment (SLI) and typically developing controls in order to test the movement optionality account of grammatical difficulty in SLI. The results show that German-speaking children with SLI are impaired in relative clause production compared to typically developing children. The alternative structures that they produce consist of simple main clauses, as well as nominal and prepositional phrases produced in isolation, sometimes contextually appropriate, and sometimes not. Crucially for evaluating the movement optionality account, children with SLI produce very few instances of embedded clauses where the relative clause head noun is pronounced in situ; in fact, such responses are more common among the typically developing child controls. These results underscore the difficulty German-speaking children with SLI have with structures involving movement, but provide no specific support for the movement optionality account.

Keywords

Elicited production, first language acquisition, German, relative clauses, specific language impairment

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Introduction

In her seminal 1998 work, Heather van der Lely proposed, for the first time, the existence of a direct link between the performance deficit that is observed in children affected by Grammatical Specific Language Impairment (G-SLI) and how this deficit can be related to the computation and representation of certain linguistic operations (van der Lely, 1998, 2005). The novelty of van der Lely's proposal was to explain the poor performance on various sentence types by children with G-SLI as due to their inability to process syntactic movement in the same way as Typically Developing (TD) children do. Furthermore, van der Lely argued that children with G-SLI do not treat movement operations as obligatory (as the unimpaired grammar would do) but rather as optional (van der Lely, 1998; van der Lely & Battell, 2003). In the case of wh-movement, it is shown that children with G-SLI perform generally very poorly on object wh-questions and produce instances of them with a filled object gap (examples from van der Lely & Battell, 2003):

1. Who Mrs Peacock saw *somebody*?

2. What did Colonel Mustard had *something* in his pocket?

3. Which one did Mrs. White wore *a hat*?

Atypical processing of object wh-questions in children with G-SLI was also found using cross-modal priming (Marinis & van der Lely, 2007), event-related potentials (Fonteneau & van der Lely, 2008) and grammaticality judgments (van der Lely, Jones, & Marshall, 2011).

Moreover, the original proposal that movement operations might develop atypically in G-SLI has inspired a lot of cross-linguistic research and this proposal has been extended to the broader SLI population in different languages (Friedmann & Novogrodsky, 2004, 2011; Jakubowicz, 2011; Jakubowicz & Tuller, 2008; Levy & Friedmann, 2009; Novogrodsky & Friedmann, 2006; Stavrakaki, 2001, 2002, 2006; Stavrakaki & van der Lely, 2010).

There is quite substantial consensus that syntactically complex sentences are often poorly understood and rarely produced in children with SLI, but the source of this difficulty is still a matter of debate. Is there really a selective deficit in the computation of syntactic movement, as van der Lely originally proposed (van der Lely, 1998)? And if so, is it really the case that wh-movement is optional in SLI (van der Lely & Battell, 2003)? Or, rather, are children with SLI globally slower than their typical peers, but qualitatively similar – employing developmentally typical processing mechanisms and grammatical rules (e.g., Deevy & Leonard, 2004; Leonard, Deevy, Fey, & Bredin-Oja, 2013)? Solving this debate goes, of course, beyond the scope of this article. Rather, we aim to broaden the empirical base of information with a new set of data from German-speaking children that were collected using an elicited production task (Zukowski, 2009) designed to offer many contextually felicitous opportunities for the production of both subject-extracted and object-extracted restrictive relative clauses (RCs). This rich set of data will be analyzed to determine whether wh-movement is optional in German-speaking children with SLI or whether a generalized difficulty with the more complex structures is observed instead.

Restrictive RCs are argued to be derived via wh-movement (Chomsky, 1995; Rizzi, 2013), where the RC head noun (*the girl* in the examples below) moves to the left periphery of the sentence, namely to the Specifier position of the Complementizer Phrase (CP). Specifically, the two RC types that are relevant for our study distinguish themselves on the basis of which grammatical role the RC head noun occupies within the embedded clause:

4. The girl [that __ is kissing the boy] is blonde.

5. The girl [that the boy is kissing __] is blonde.

In both examples, the noun phrase *the girl* is pronounced in a position that is different from the one where this noun phrase is interpreted with respect to the embedded clause. *The girl* is interpreted as the subject of *is kissing* in (4) and as the object of *is kissing* in (5) (the interpretative position is indicated in (4) and (5) with '__'). Throughout this article, the clause *The girl is blonde* will be labelled as the matrix clause and the one in between squared brackets will be called the RC or the embedded clause. Importantly for the argument developed in the present article, it is generally assumed that wh-movement makes possible the connection between the position where the RC head noun is interpreted and the one where it is pronounced (Chomsky, 2001).

The current study examines the responses of German-speaking children when they are tested in a controlled experimental situation designed to elicit sentences such as (4) and (5), which contain center-embedded RCs, and also right-branching RCs and RCs modifying an isolated noun phrase. The type of embedding (center-embedded vs. right-branching) refers to the position of the embedded clause (i.e., the RC) with respect to the matrix clause. The whole experimental design is illustrated in Table 1.

In center-embedded RCs, the embedded clause appears within the matrix clause (cf. 6,7,8c) whereas in right-branching RCs, the embedded clause attaches at the end of the matrix clause (cf. 6,7,8b). Center-embedded RCs have been repeatedly shown to be more difficult to process than right-branching RCs in adults (Warren & Gibson, 2002, among many others). Crucially, the type of embedding can be manipulated independently of the extraction type: this means that center-embedded and right-branching RCs can be both subject- and object-extracted.

We manipulated three experimental conditions: contexts designed to elicit subject RCs with one animate noun (SRC1, 6 in Table 1), subject RCs with two animate nouns (SRC2, 7) and object RCs with two animate nouns (ORC2, 8).

The task was a German adaptation of Zukowski (2009). It was chosen for several reasons. First, while several studies have looked at the production of RCs in children with SLI, including children acquiring Hebrew (Novogrodsky & Friedmann, 2006), Italian (Contemori & Garraffa, 2010), Danish (Jensen de López, Sundhal Olsen, & Chondrogianni, 2014), English (Hesketh, 2006; Schuele & Nicholls, 2000) and Swedish (Håkansson & Hansson, 2000), not much work has been published on German. At the time of writing, only Koch, Schuler, Friedmann, and Schulz (2013) have investigated the production of subject and object RCs in a group of German-speaking children with SLI. For now, we would like to point out that our study distinguishes itself from that of Koch

Table 1. Experimental condition and examples of tested structures.

Condition	Expected response
SRC1	6a. Der Junge der winkt.
Isolated noun	The boy who$_{NOM}$ waves
	'The boy that is waving'
Right-branching	6b. Max fotografiert den Jungen der winkt.
	Max photographs the$_{ACC}$ boy$_{ACC}$ who$_{NOM}$ waves
	'Max photographs the boy that is waving'
Center-embedded	6c. Der Junge der winkt ist jetzt blau.
	The boy who$_{NOM}$ waves is now blue
	'The boy that is waving is now blue'
SRC2	7a. Der Junge der die Kuh berührt.
Isolated noun	The boy who$_{NOM}$ the cow touches
	'The boy that is touching the cow'
Right-branching	7b. Max fotografiert den Jungen der die Kuh berührt.
	Max photographs the boy who$_{NOM}$ the cow touches
	'Max photographs the boy that is touching the cow'
Center-embedded	7c. Der Junge der die Kuh berührt ist jetzt blau.
	The boy who$_{NOM}$ the cow touches is now blue
	'The boy that is touching the cow is now blue'
ORC2	8a. Die Kuh die der Junge berührt.
Isolated noun	The cow that the$_{NOM}$ boy touches
	'The cow that the boy is touching'
Right-branching	8b. Max fotografiert die Kuh die der Junge berührt.
	Max photographs the cow that the$_{NOM}$ boy touches
	'Max photographs the cow that the boy is touching'
Center-embedded	8c. Die Kuh die der Junge berührt ist jetzt gelb.
	The cow that the$_{NOM}$ boy touches is now yellow
	'The cow that the boy is touching is now yellow'

Note. SRC1 = Subject RC with one animate noun; SRC2 = Subject RCs with two animate nouns; ORC2 = Object RCs with two animate nouns.

et al. (2013) in at least two dimensions. First, they tested only right-branching RCs. The animacy of the arguments was not systematically controlled, in the sense that in some trials two animate nouns were used (e.g., 9) while in other trials only one animate noun was used, as in (10):

9. I'd rather be the boy that is kissing the father

10. I'd rather be the boy that is drinking Coke

As Table 1 shows, in the present study, we elicit both right-branching and center-embedded RCs and we control for the animacy properties of nouns used as subject and object of the verb. Moreover, we also report cross-sectional data of TD children whose ages range from 4 to 9 years, in order to provide insight into the development of RCs in German.

A second reason for the current study is the methodology itself, elicited production. This method gives participants considerable freedom in how to shape their responses. This may result in the production of the targeted responses, but it could also include other grammatically correct and contextually appropriate sentences, which are not necessarily the targeted ones. Thus, elicited production opens the possibility to explore children's response *preferences* that they might apply because of a language deficit. Hence, the information that one can obtain in elicited production studies is an innovative and important contribution to the information that can be obtained with other tasks, such as sentence repetition (Frizelle & Fletcher, 2014; Riches, 2016; Riches, Loucas, Baird, Charman, & Simonoff, 2010). While it is established that difficulties with sentence repetition are a clinical marker for SLI in English (e.g., Riches, 2012, among many others), it is also the case that the participant's success rate heavily depends on memory capacities. This aspect can be particularly detrimental in children with SLI given their severe difficulties in building and maintaining the representation of an entire sentence. Moreover, successful comprehension of the sentence may be a prerequisite of successful repetition, thus making the cause of impaired repetition difficult to discern (cf. Coco, Garraffa, & Branigan, 2012, and Zukowski, 2009 for a discussion on these two aspects). In contrast, by providing a supportive visual context, elicited production burdens the participants' memory capacities to a lesser extent and, therefore, it optimizes the chance for participants to utter a complex sentence, if their system allows them to.

Although children with SLI are the focus of this article, a third motivation for the current study is to provide a trajectory of how RC production develops during childhood in typically developing German-speaking children. So far, a few studies (Adani, Sehm, & Zukowski, 2012; Diessel & Tomasello, 2005; Kidd, Brandt, Lieven, & Tomasello, 2007; Koch et al., 2013) have studied the production of RCs in German-speaking children but none of them covers the wide age range that is the focus of the present study. The analysis presented in this article allows us to observe that certain abilities may emerge stepwise over development and that certain non-adult productions decrease over time, until they finally disappear. Unfortunately, our sample of children with SLI was not large enough to warrant a similar developmental analysis for our affected population. Therefore, the data collected from children with SLI were analyzed as a single group. As a point of comparison for this study, the next section reviews results from previous studies that have investigated the production of RCs in children with SLI.

Cross-linguistic production of RCs in children with SLI

One of the hallmarks of SLI is the struggle with various aspects in the expression and reception of grammatical information encoded in linguistic stimuli (Bishop, 1997; Leonard, 1998) and, as reviewed earlier, movement-derived sentences are one particular area of weakness. Because of their complexity, RCs are often included in standardized assessments of grammatical abilities (e.g., Siegmüller, Kauschke, van Minnen, & Bittner, 2011). There is now a fair amount of data amassed cross-linguistically on RC production and comprehension by children with SLI. Focusing on production, all published studies point towards a generalized greater difficulty with object RCs (5) rather than subject RCs (4), but they also show some specific differences in terms of which alternative strategies are used when the target sentence cannot be produced. Schuele and Nicholls (2000) report that the most typical error in English-speaking children with SLI is the omission of obligatory relativized markers (relative pronouns, complementizers) in subject RCs (e.g., *Where's that ice cream (that) was there?*, where the omitted complementizer is reported in parentheses). This error is observed in the elicited production of three 6-year-old children with SLI acquiring English and of 4- to 6-year-olds acquiring Swedish (Håkansson & Hansson, 2000). However, the type of odd answers that children with SLI give appear to change over time. In a subsequent study (Hesketh, 2006), English-speaking 6- to 11-year-olds rarely omitted relative markers. Rather, Hesketh reports that children with SLI make frequent use of reduced relatives (e.g., *One day there was a monkey hanging on the tree branch*), something that the TD children did not produce so often.

Using an act-out task, Stavrakaki (2002) tested Greek-speaking 5- to 9-year-olds and a group of Language Age (LA) matched controls. The children with SLI were overall less accurate than TD children and the overwhelming majority of their errors were simple declarative sentences, coordinated structures and RCs with missing heads. For example, an English RC with a missing head would be *that is chasing the elephant* instead of *The one that is chasing the elephant*. Only the last structure was not attested in the productions of TD children. Stavrakaki argues that RCs with missing heads show the absence of operator movement in SLI and that the few target-like RCs that were produced cannot be taken to indicate the use of a relativization strategy.

Novogrodsky and Friedmann (2006) designed a preference task and a picture description task to elicit the production of right-branching RCs, which were translated into a number of languages. Novogrodsky and Friedmann (2006) tested Hebrew-speaking 9- to 14-year-olds with SLI and found impaired production of both subject and object RCs, with the latter being especially affected. Instead of producing the targeted object-extracted structures, children with SLI either turned them into simple declaratives or they produced subject-extracted RCs, RCs with reversed theta-roles or RCs with a reduced number of arguments. Except for the simple declaratives, it should be noted that the other options consist of structures that include the so-called Complementizer Phrase (CP), hence demonstrating a quite advanced ability to generate the syntactic structure itself, but failure specific to movement and/or to the interpretation of moved elements, especially when they cross another argument.

Contemori and Garraffa (2010) adapted Novogrodsky and Friedmann's tasks to test Italian-speaking 4- to 5-year-olds with SLI, compared with Chronological Age (CA) and Language Age (LA) matched controls. The most widely attested atypical production (virtually absent in TD controls) was the omission of the complementizer *che* 'that', which is obligatory in RCs, e.g., *il soldato (che) il dottore spinge* lit. the soldier (that) the doctor pushes.

Turning to a typologically different language, Jensen de López et al. (2014) also used Novogrodsky and Friedmann's tasks to test Danish-speaking 5- to 8-year-olds with SLI, compared with two groups of CA- and LA-matched controls. The results did not reveal strong asymmetries between the TD and SLI groups but the latter performed more poorly in the production of both subject and object RCs. Moreover, children with SLI were able to produce subject RCs with passive voice when object RCs were targeted. In line with

Novogrodsky and Friedmann (2006), Jensen de López and colleagues conclude that Danish-speaking children with SLI do not have problems with RC structure building, but rather tend to produce structures that simplify the assignment of theta-roles in production.

Turning to German, Koch et al. (2013) report on a study conducted with German-speaking 4- to 9-year-olds with SLI and one group of younger TD children. Besides producing many fewer responses with RCs than TD children, the children with SLI produced a higher rate of simple declarative sentences. Relative pronoun omissions were overall very rare.

In summary, the existing studies that have used an elicited production paradigm with children with SLI of different ages and language backgrounds point towards the existence of significant difficulties in producing RCs at age 4 or 5. This difficulty is manifested in the omission of the relative marker (in languages where this marker is obligatory), the omission of the RC head noun, and/or the use of simple declarative sentences in contexts that heavily bias the production of RCs. These results suggest a genuine difficulty with the projection of a fully-fledged RC that involves the CP layer. In later years, these children are better able to produce fully-fledged RCs that involve a CP, but when they do so, they demonstrate clear problems with theta-role assignment and in the production of all obligatory verb arguments. Moreover, they also resort to using other grammatical alternatives (e.g., subject RCs with passive voice) when object RCs are targeted, an alternative that is also observed less frequently in TD children.

The debate as to whether children with SLI have a deficit in wh-movement or not hinges directly on the ability to represent and use the CP layer. Based on existing accounts of the difficulty children with SLI have with RCs and complex syntax more generally, we formulate the following four predictions:

(P1) *General processing deficit*: a generalized impairment in processing sentence structure, with no impairment to specific linguistic operations, predicts an overall lower production of well-formed embedded structures in the center-embedded condition, given that center-embedded RCs are more demanding to process although not necessarily more syntactically complex than right-branching RCs;

(P2) *Movement is absent*: a specific impairment in the representation/derivation of wh-movement would predict that children with SLI produce no or very few target-like RCs in general and that they resort to the production of ungrammatical sentences most of the times;

(P3) *Movement is hard*: if children with SLI have a difficulty with wh-movement but they are still able to process correctly the events that are prompted by the experimental task, they are expected to produce fewer fully-fledged RCs and rather opt for structurally simpler yet contextually appropriate structures;

(P4) *Movement is optional*: if the ability to produce sentences that are derived by wh-movement is optionally operative in the grammar of children with SLI, their most natural 'compensating' strategy would be producing at least some fully-fledged RCs where the relative pronoun or the RC head noun are left in situ.

In our study, the responses of children with SLI are compared to those of two groups of TD children in two steps. First, we perform a comparison based on CA: here the age of the TD children is centered with the CA of the children with SLI. A second comparison is based on the LA: here the age of the TD children is centered with the LA of the children with SLI, which is lower than their CA because of their language impairment. Because of their language deficit, children with SLI are expected to perform more poorly than TD children in the CA comparison. However, if language is only delayed in SLI but not qualitatively different (Deevy & Leonard, 2004), we predict children with SLI to perform similarly to TD children in the LA comparison. If the performance of children with SLI differs also from TD children in the LA comparison, this would be consistent with the existence of deficient, qualitatively different grammars in SLI and TD.

Method

Participants

Eighty-four monolingual native speakers of German participated in the study. The TD children ($N = 72$) were recruited in day care centers and primary schools in the area of Potsdam; the children with SLI ($N = 12$) were recruited in speech and language therapy centers and day care centers with language-focused programs in the area of Potsdam and Berlin.

For all TD children, we asked the parents to give their consent for the participation and we also asked them to fill in a written questionnaire to ensure that their child neither had a language disorder nor had familial risk for one. The age of the TD children ranged from 4;0 to 9;8 and they were divided into the following age groups: 4-year-olds ($N = 18$), 5-year-olds ($N = 7$), 6-year-olds ($N = 19$), 7-year-olds ($N = 13$), 8-year-olds ($N = 7$) and 9-year-olds ($N = 8$). The age of the children with SLI ranged from 4;7 to 10;11. They were assessed with a battery of standardized tests focusing on language and cognitive abilities. The individual scores for each child with SLI on each of these tests are reported in Table 2.

For the SLI group, only children whose performance fell 1 SD or more below the mean for their age on at least two of the standardized tests reported in Table 2 were included in the sample. All children had non-verbal cognitive abilities within the normal range, with no socio-emotional problems reported by their therapists or teachers. In order to determine the language age of the SLI group, an individual language age was obtained for each child averaging over the age-corrected scores of three subtests of the TSVK (Siegmüller et al., 2011), one subtest of the SET (Petermann, Fröhlich, & Metz, 2010) and the phonological memory subtest of the IDS (Grob, Meyer, & Hagmann-von Arx, 2009). In order to be able to compare the children with SLI to the TD children on the basis of their language age, we computed the average language age of the children with SLI (mean language age SLI: 5.166 years) and set it to zero to be able to use it as a baseline, to which we compare TD children. Next, we subtracted the average language age of the children with SLI from the individual age of each TD child. Likewise, to compare children with SLI with children with the same chronological age, we computed the average age of the children with SLI (mean chronological age SLI: 6.416 years) and set it as

Table 2. Standardized test scores for children with SLI.

Child ID	Age		IDS-IQ	IDS-SVM	IDS-PM	TSVK3	TSVK5	TSVK6	SET9	WWT/PDSS	LA
	y	m	IQ	S	S	T	T	T	p	T	years
SLI01	8	8	91	11	6	47[a]	20[a]	46[a]	3	0	7
SLI02	8	1	86	11	7	32[a]	37[a]	38[a]	1	0	5
SLI03	10	11	115	10	12	54[a]	37[a]	46[a]	7	58[a]	9
SLI04	5	7	112	17	6	47	54	22	82	45	5
SLI05	5	3	104	8	10	34	55	38	85	39[b]	4
SLI06	4	7	101	13	2	44	70	81	0	32[b]	4
SLI07	6	3	96	9	6	43	54	33	54	41	5
SLI08	6	5	92	7	6	36	50	39	38	42	5
SLI09	9	0	106	9	9	41[a]	37	34	4	30	6
SLI10	5	8	98	9	12	62	59	30	100	32[b]	4
SLI11	5	2	87	7	8	27	51	38	9	17[b]	4
SLI12	6	3	115	7	11	50	54	39	7	53	5

Note. The grey shading highlights a score of at least −1 SD below the mean or lower. IQ = Intelligent quotient score; s = standard score; T = T score; p = percentile score; IDS-IQ = Intelligence quotient from the Intelligence and Developmental Scales (Grob, Meyer, & Hagmann-von Arx, 2009 – cognitive part); IDS-SVM = spatial-visual memory of the IDS; IDS-PM = phonological memory of the IDS; TSVK3 = word order subtest of the Test zum Satzverstehen von Kindern (Siegmüller, Kauschke, van Minnen, & Bittner, 2011); TSVK5 = binding principles subtest of the TSVK; TSVK6 = relative clause subtest of the TSVK; SET9 = correction of incorrect sentences of the Sprachstandserhebungstest für Kinder im Alter zwischen 5 und 10 Jahren (Petermann, Fröhlich, & Metz, 2010); WWT = expressive subtest of the Wortschatz- und Wortfindungstest für 6- bis 10-Jährige test (Glück, 2007); LA: language age.

[a]Score refers to the oldest age group for which a standard score is provided (when the age of the child is actually older).

[b]Score obtained with the expressive verb vocabulary subtest of the Patholinguistische Diagnostik bei Sprachentwicklungsstörungen (PDSS; Kauschke & Siegmüller, 2002).

a baseline. Next, we subtracted the average chronological age of children with SLI from the individual age of each TD child. Doing so, we obtain all children's ages centered on the age of the children with SLI.

Material

The visual stimuli from Zukowski (2009) were used and adapted into German. The following modifications were made: first, we omitted most trials that involved a verb particle construction (e.g., 'fly over') as embedded verb, where the direct object appears as an object of a preposition rather than a verb. In German, these prepositions split from the verb in embedded clauses and, therefore, may create an additional complexity compared to bare lexical verbs. Where possible, we substituted the prepositional verb with a transitive verb without a preposition, e.g., from *point to* to *berühen* (to touch). This verb substitution was pragmatically appropriate in the context of the pictures used. Second, the action performed by the two little animals was changed from *look at* to *fotografieren* (to photograph) in the current study; again, this was done to avoid the use of a verb particle construction. Finally, all stimuli were pre-recorded by a female native speaker of German and they were played to the participant using a laptop computer. In order to motivate the participant to produce contextually appropriate answers for a potential hearer blind to the visual scene, we introduced a snail puppet (see Procedure). The material consisted of computerized images that satisfy all requirements that are known in the existing literature to facilitate the production of restrictive RCs (Zukowski, 2009). The reader should refer to Zukowski (2009) and to our Appendix A in the online supplement, for a detailed explanation of the procedure.

The experiment targeted 24 subject RCs with one animate noun (SRC1), 18 subject RCs with two animate nouns (SRC2) and 18 object RCs with two animate nouns (ORC2). The production of RCs was prompted using questions that refer to one or more characters depicted in a visual display. Single question trials (e.g., which x turned blue?) required only an isolated NP response (e.g., the one who threw the ball, cf. (b) and (c) in Appendix A). Double question trials (which x turned blue and which x turned red?) required two coordinated answers, with each modified NP embedded within the appropriate matrix clause, either a center-embedded or a right-branching one (cf. (d) and (e) in Appendix A). This means that the same visual display in (d) and (e) prompted two coordinated RCs. These are analyzed separately. Most 4-year-olds were tested with a shorter version of the experiment, using 30 trials (14 SRC1; 8 SRC2; 8 ORC2). The visual stimuli were presented on a computer screen in a pseudo-randomized order.

Procedure

Participants were tested either in a quiet room of their day care center or school, or at home or at their language therapy center. The task was introduced to each participant as a game that s/he and the researcher would play with a snail puppet, Betty, in order to teach Betty some new words and sentences in German. As a start, the experimenter showed the participant that Betty is not able to pronounce words correctly. Hence, the help of the participant is needed to improve her speaking skills. Afterwards, Betty was placed next to the participant but in a position where she could not see the computer screen completely. Therefore, the participant was motivated to produce a description of the scene using a full sentence. At the beginning of each trial, the two events depicted in the base picture (cf. Appendix A) were described using simple active declarative sentences. This means that the experimenter did not produce any examples of relative clause syntax in the immediately preceding context available to the participant. The full test took between 25 and 35 minutes to complete. If the experimenter considered this necessary, the testing session was divided over two separate visits.

Data coding

All testing sessions were auditorily recorded. Two independent coders transcribed 71% of the produced utterances, ranging from 50% to 100% for each participant. Each pair of transcripts was then compared and their agreement was 95%. Disagreements that would change the interpretation of the sentence were resolved by listening to the audio recordings. Further, two trained coders categorized all responses according to their grammaticality (well-formed in the adult grammar vs. ill-formed in the adult grammar) and contextual appropriateness. A verbal utterance was considered as contextually appropriate if it was a correct answer to the preceding question and if it uniquely identified the correct referent in the visual display. Additionally, the coders categorized each utterance based on a range of specific features (or their combination), which yielded the response categories reported in Tables 3–5. The reader should refer to Appendix B in the online supplement for real examples of utterances produced in each response category.

Results

Tables 3–5 show a detailed categorization of responses in the three experimental conditions.

In order to investigate our four predictions (reported at the end of the literature review), all responses (with exception of the ones classified as 'Other' or 'Not analyzed') were merged into the following four larger categories that are used in the statistical analysis. Tables 3–5 show which detailed responses were included in the larger categories. In the discussion, however, we also refer to the more detailed categories shown in Tables 3–5 to provide a finer characterization of the results.

An utterance was coded as:

a. Appropriate Embedded: when the participant produced a grammatically correct and contextually appropriate sentence, consisting of an RC embedded in a matrix clause. The produced utterance was not necessarily the targeted one: for example, well-formed subject-extracted RCs with passive voice that were produced when object-extracted RCs were targeted were included in this category (see Appendix B for more response types that were included).

b. Appropriate Matrix: when the participant produced a grammatically correct and contextually appropriate sentence which consisted of a simpler structure, for example, a declarative clause or a noun phrase or a prepositional phrase.

Table 3. Response percentages in condition SRC1, in each participant group.

Group	Appropriate Embedded		Appropriate Matrix		Inappropriate Embedded				Inappropriate Matrix		Other responses	Not analyzed
	Correct gap	Passive	Correct SVO	Correct DP/PP	Wrong head	Wrong gap	Filled object gap	Pronoun wrong gender	Wrong SVO	Wrong DP/PP		
4	80.9	0	6.6	0.9	0	0	0.3	0.3	3.8	0.3	0	6.9
5	76.8	0	1.2	1.8	0.6	0	0	0.6	2.4	0	0.6	16[a]
6	95.8	0	0.7	1.3	0	0.7	0	0.2	0	0	0.7	0.6
7	90.1	0.3	6.7	0.3	0.3	0.3	0	0	0.3	0	0.6	1.1
8	92.3	0	5.4	1.2	0	0.6	0	0	0	0	0.5	0
9	98.4	0	1.6	0	0	0	0	0	0	0	0	0
SLI	65	0	7.9	8.2	0	0.7	0	0	10.7	0.7	1.1	5.7

Note. For an example of each category, see Appendix B (online supplement); 4 = 4-year-olds; 5 = 5-year-olds; 6 = 6-year-olds; 7 = 7-year-olds; 8 = 8-year-olds; 9 = 9-year-olds; SLI = group of children with SLI.

[a]The unexpected high occurrences in 5-year-olds is predominantly driven by three children in the group.

Table 4. Response percentages in condition SRC2, in each participant group.

Group	Appropriate Embedded		Appropriate Matrix		Inappropriate Embedded				Inappropriate Matrix		Other responses	Not analyzed
	Correct gap	Passive	Correct SVO	Correct DP/PP	Wrong head	Wrong gap	Filled object gap	Pronoun wrong gender	Wrong SVO	Wrong DP/PP		
4	75	0	4.2	1.4	0	0.9	0.5	3.8	5.7	0.5	0.5	7.5
5	77.8	0	1.6	0	2.4	2.4	0	0.8	2.4	0	0	12.6[a]
6	88.9	0.9	2.3	2.3	0	1.5	1.5	1.2	0.3	0	0.6	0.5
7	86.3	0	7.3	0	0.4	1.7	0	2.6	0.9	0	0.8	0
8	90.5	0	7.9	0	0	0.8	0	0	0	0	0.8	0
9	94.4	0	1.4	0	0	0.7	0	2.8	0	0	0	0.7
SLI	51.9	1	10.6	7.2	0	5.3	0	5.3	11.5	1.4	1.9	3.9

Note. For an example of each category, see Appendix B (online supplement); 4 = 4-year-olds; 5 = 5-year-olds; 6 = 6-year-olds; 7 = 7-year-olds; 8 = 8-year-olds; 9 = 9-year-olds; SLI = group of children with SLI.

[a]The unexpected high occurrences in 5-year-olds is predominantly driven by three children in the group.

Table 5. Response percentages in condition ORC2, in each participant group.

Group	Appropriate Embedded		Appropriate Matrix		Inappropriate Embedded				Inappropriate Matrix		Other responses	Not analyzed
	Correct gap	Passive	Correct SVO	Correct DP/PP	Wrong head	Wrong gap	Filled object gap	Pronoun wrong gender	Wrong SVO	Wrong DP/PP		
4	27.5	10.5	12.5	2	9	6	6.5	4	11	1.5	0	9.5
5	30.5	6.7	4.8	1.9	6.7	6.7	5.7	6.7	5.7	0	0	24.6[a]
6	39.3	15.8	7.7	2.8	3.2	6.3	15.4	2.5	1.4	0	0.4	5.2
7	43.6	24.6	5.1	1	3.6	6.2	7.2	3.1	3.1	0	1	1.5
8	24.8	42.9	14.3	0	4.8	2.9	5.7	2.9	1	0	0	0.7
9	30	45.8	2.5	0.8	5.8	5.8	5	0.8	0	0	0.8	2.7
SLI	17.7	10.3	10.3	8	6.9	6.9	1.1	5.1	22.3	2.9	1.1	7.4

Note. For an example of each category, see Appendix B (online supplement); 4 = 4-year-olds; 5 = 5-year-olds; 6 = 6-year-olds; 7 = 7-year-olds; 8 = 8-year-olds; 9 = 9-year-olds; SLI = group of children with SLI.

[a]The unexpected high occurrences in 5-year-olds is predominantly driven by three children in the group.

c. Inappropriate Embedded: when the participant produced either an ungrammatical sentence and/or a contextually inappropriate sentence which consisted of an RC embedded into a matrix clause. Therefore, this category includes sentences that were structurally grammatical but inappropriate to describe the scene (cf. for instance, the subcategory 'wrong head' or 'wrong gap' in Appendix B), as well as sentences that attempted to describe the scene correctly but resulted in an ungrammatical sentence (cf. 'filled object gap' and 'wrong gender of relative pronoun' in Appendix B). Although we acknowledge that the underlying problem that distinguishes an ungrammatical sentence from a contextually inappropriate sentence may be very different in nature, this broad categorization will suffice to keep these instances separate from the well-formed sentences included in (a).

d. Inappropriate Matrix: when the participant produced either an ungrammatical sentence and/or a contextually inappropriate sentence which consisted of a simple, non-embedded structure, for example, a declarative clause or a noun phrase or a prepositional phrase.

Data analysis

We analyzed the data using the *lme4* package (version 1.1-7; Bates, Maechler, & Bolker, 2011) in the R environment (R Development Core Team, 2014), specifying the optimizer 'bobyqa' for our models.

For each of our dependent variables (Appropriate Embedded, Appropriate Matrix, Inappropriate Embedded, Inappropriate Matrix) we have fitted two generalized linear mixed models: one using the centered CA as covariate and the other using the centered LA. The two models, however, did not differ with respect to the fixed factors (Group: TD vs. SLI and Sentence Type: SRC1 vs. SRC2 vs. ORC2) and the random factors (Subject and Item). For dependent variables Appropriate Matrix, Inappropriate Embedded, Inappropriate Matrix, the three main effects of Group, Sentence Type, Age and the interaction Group:Sentence Type were fitted into the model. More complex models would fail to converge, with the exception of Inappropriate Matrix, where we could also specify the interaction Age:Sentence Type. Only for the dependent variable Appropriate Embedded, have we also included the fixed factor Embedding Type (NP vs. RB vs. CE) and all possible two-way interactions between the fixed factors. Each level of the factors Group (SLI-TD), Sentence Type (SRC1-SRC2-ORC2) and Embedding Type (NP-RB-CE) was compared to the following levels (in the order given in brackets).

The outcome of each model is presented accompanied by a plot that visually depicts how the rate of production of the different response types (Appropriate Embedded, Appropriate Matrix, Inappropriate Embedded, Inappropriate Matrix) develops as a function of age (from 4 to 9 years) in TD children in each of the three experimental conditions (SRC1, SRC2, ORC2). The corresponding mean rate of production for the children with SLI in each condition is represented by two points: one is centered around the age of 6 years (mean CA) while the other is centered around the age of 5 years (mean LA). In reporting the statistical results comparing the SLI and TD children, we always first report the comparison of the SLI group according to their CA. The results of the comparison

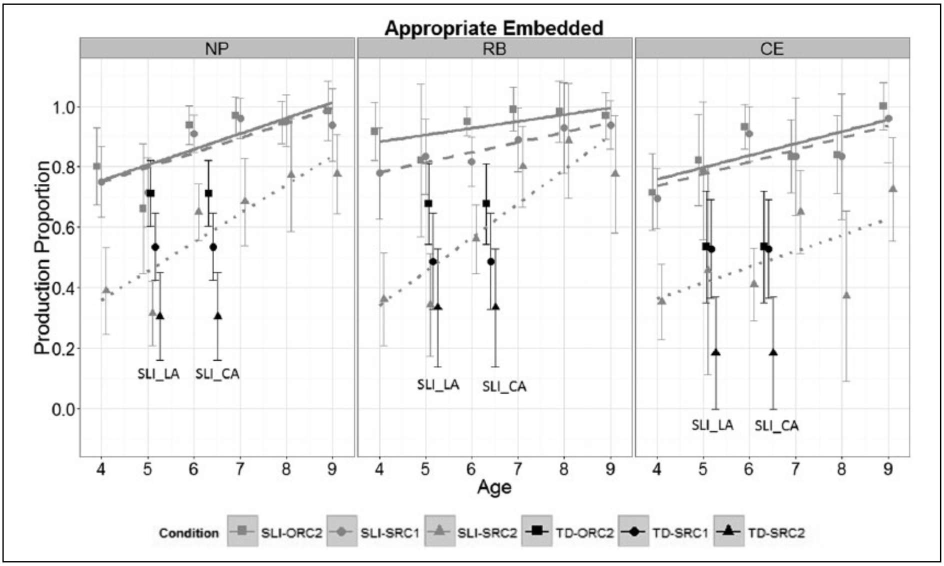

Figure 1. Mean production proportion (95% confidence interval) of Appropriate Embedded responses as a function of age in years.

Note. NP = targeted relative clauses attached to an isolated noun phrase; RB = targeted right-branching relative clauses; CE = targeted center-embedded relative clauses; TD = typically developing children; SLI_CA = children with SLI centered on Chronological Age; SLI_LA = children with SLI centered on Language Age; SRC1 = subject RCs with one animate noun; SRC2 = subject RCs with two animate nouns; ORC2 = object RCs with two animate nouns.

with the SLI group according to their LA are only reported when the results differ from the previous comparison.

Appropriate Embedded responses. The mean proportion of Appropriate Embedded responses separated by targeted Embedding Type (NP: isolated NP; RB: right-branching; CE: center-embedded) is reported in Figure 1.

The statistical analysis revealed a main effect of Group (coef. = 2.09, SE = 0.36, z = 5.8, $p < 0.001$). Overall, children with SLI produced significantly fewer appropriate embedded responses compared to TD children. The analysis also revealed a significant difference between SRC2-SRC1 (coef. = −0.7, SE = 0.2, $z = -3.7$, $p < 0.001$) and ORC2-SRC2 (coef. = −1.66, SE = 0.2, $z = -8.03$, $p < 0.001$). Appropriate Embedded structures were most frequent in the SRC1 condition, followed by SRC2 and, last, ORC2. A main effect was also observed between CE and RB (coef. = −0.62, SE = 0.2, $z = -3.2$, p = 0.002). Appropriate Embedded structures were more frequent in the RB condition than the CE condition.

The analysis also demonstrated a main effect of CA among the TD children (coef. = 0.48, SE = 0.09, $z = 5.5$, $p < 0.001$). Appropriate Embedded responses increased as a function of age in TD children. Finally, the SRC2-SRC1 × CE-RB interaction was significant (coef. = 1.02, SE = 0.43, $z = -2.4$, $p = 0.02$). In the RB condition, Appropriate Embedded

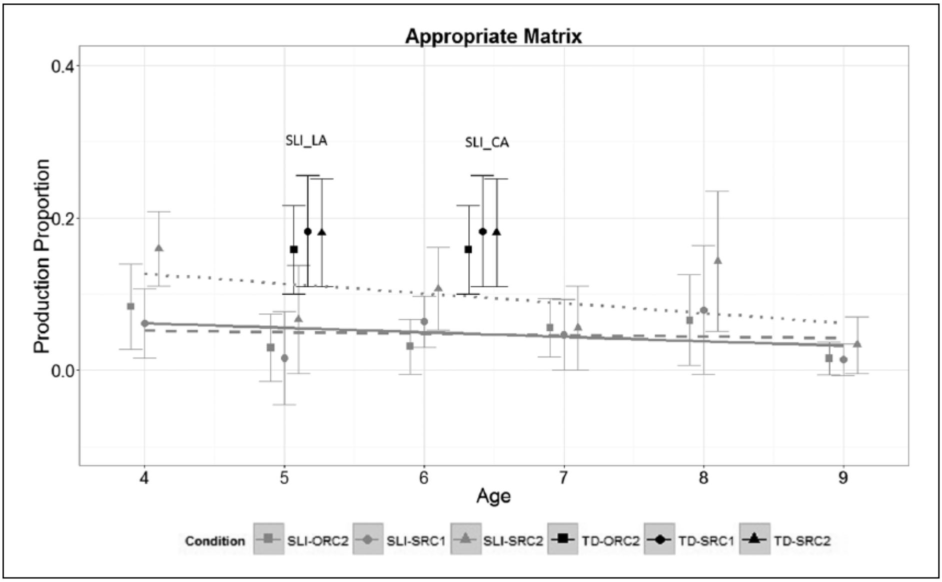

Figure 2. Mean production proportion (95% confidence interval) of Appropriate Matrix responses as a function of age in years.

Note. NP = targeted relative clauses attached to an isolated noun phrase; RB = targeted right-branching relative clauses; CE = targeted center-embedded relative clauses; TD = typically developing children; SLI_CA = children with SLI centered on Chronological Age; SLI_LA = children with SLI centered on Language Age; SRC1 = subject RCs with one animate noun; SRC2 = subject RCs with two animate nouns; ORC2 = object RCs with two animate nouns.

responses were less frequent in the SRC2 condition, which involved two animate arguments, than in the SRC1 condition, which involved only one animate argument, but this difference among the two SRC conditions did not hold in the CE condition.

Appropriate Matrix responses. The mean proportion of Appropriate Matrix responses is reported in Figure 2.

The statistical analysis revealed a main effect of Group (coef. = −1.79, SE = 0.6, $z = -2.97$, $p = 0.003$). This means that, overall, children with SLI produced significantly more grammatical and contextually appropriate matrix utterances than TD children do.

Inappropriate Embedded responses. The mean proportion of Inappropriate Embedded responses is reported in Figure 3.

The statistical analysis revealed a significant difference between SRC2 and SRC1 (coef. = 2.08, SE = 0.53, $z = 3.9$, $p < 0.001$) and between SRC2 and ORC2 (coef. = 2.85, SE = 0.52, $z = 5.47$, $p < 0.001$). This means that ungrammatical and/or contextually inappropriate utterances were most common in the ORC2 condition, less common in the SRC2 condition, and even less common in the SRC1 condition. There was no difference between the participant groups on this measure.

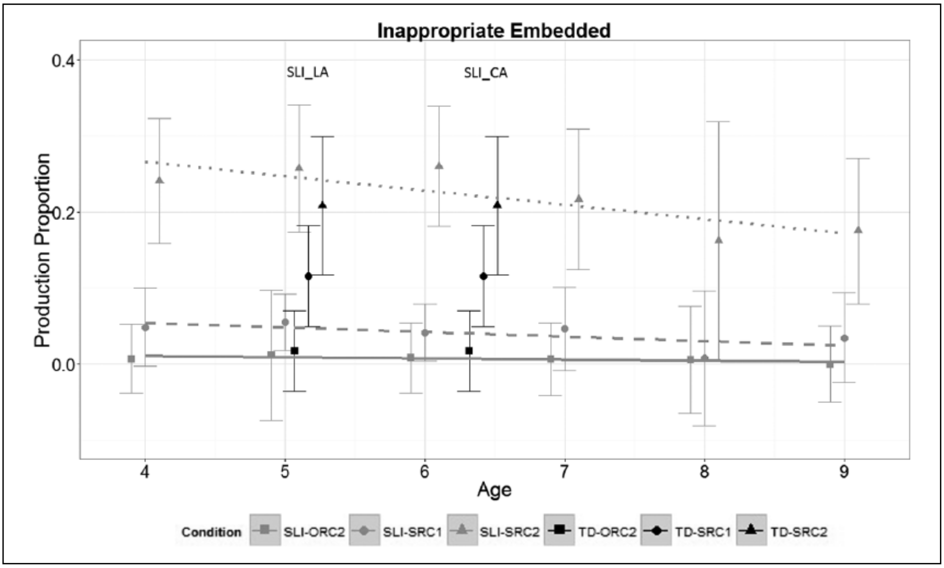

Figure 3. Mean production proportion (95% confidence interval) of Inappropriate Embedded responses as a function of age in years.
Note. CE = targeted center-embedded relative clauses; RB = targeted right-branching relative clauses; NP = targeted relative clauses attached to an isolated noun phrase; TD = typically developing children; SLI_CA = children with SLI centered on Chronological Age; SLI_LA = children with SLI centered on Language Age; SRC1 = subject RCs with one animate noun; SRC2 = subject RCs with two animate nouns; ORC2 = object RCs with two animate nouns.

Inappropriate Matrix responses. The mean proportion of Inappropriate Matrix responses is reported in Figure 4.

The statistical analysis revealed a main effect of group (coef. = −4.65, SE = 1.07, z = −4.3, $p < 0.001$). Children with SLI produced significantly more Inappropriate Matrix sentences overall than TD children. There was also a significant difference between ORC2-SRC2 (coef. = 1.59, SE = 0.4, $z = 4.1$, $p < 0.001$; overall, participants produced more Inappropriate Matrix sentences in the ORC2 condition than in either of the SRC conditions, which do not differ from each other. Finally, there was a main effect of CA (coef. = −1.63, SE = 0.43, $z = -3.77$, $p < 0.001$); older TD children produced fewer ungrammatical and/or contextually Inappropriate Matrix sentences.

Discussion

The first aim of our study was to provide novel empirical evidence on how the production of RCs in German develops in typical children during childhood. We have presented cross-sectional data from TD children whose ages range from 4;0 to 9;8 years. These data provide a developmental trajectory of responses from a task designed to elicit RCs. To the best of our knowledge, this is the first study that provides an analysis of how the production of center-embedded and right-branching RCs develops in

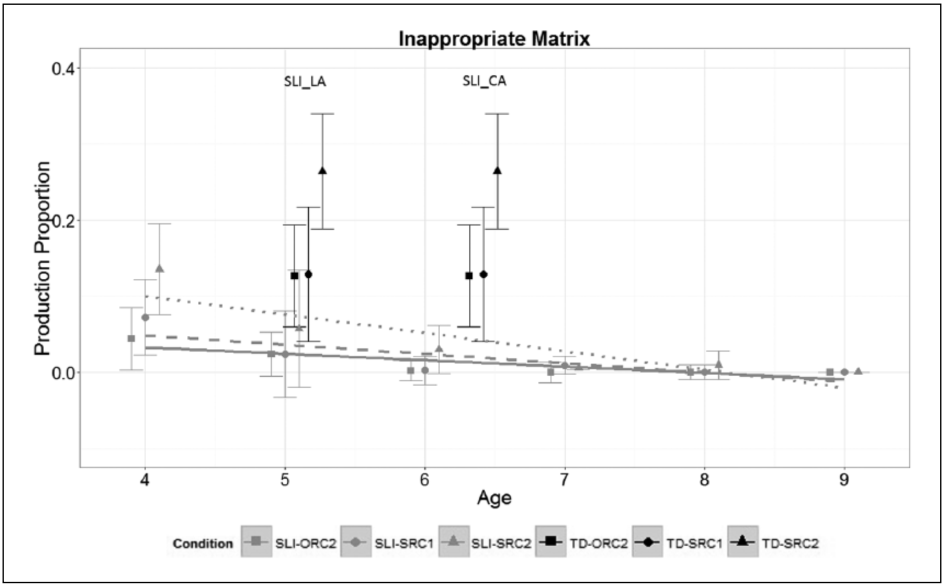

Figure 4. Mean production proportion (95% confidence interval) of Inappropriate Matrix responses as a function of age in years.

Note. NP = targeted relative clauses attached to an isolated noun phrase; RB = targeted right-branching relative clauses; CE = targeted center-embedded relative clauses; TD = typically developing children; SLI_CA = children with SLI centered on Chronological Age; SLI_LA = children with SLI centered on Language Age; SRC1 = subject RCs with one animate noun; SRC2 = subject RCs with two animate nouns; ORC2 = object RCs with two animate nouns.

pre-schoolers to school-age children at intervals of one year. For each age tested, we found that trials designed to elicit object-extracted RCs yielded fewer appropriate and grammatically correct RCs of any kind than trials designed to elicit subject-extracted RCs. It is important to emphasize that one of the novelties of our analysis was to include not only the targeted structures but any instance of grammatical and contextually appropriate embedded RC structures. It is therefore shown that, when the to-be-picked-out referent is a theme/patient (rather than an agent), the production of any appropriate embedded RC structure is more challenging. Interestingly, we did not observe a steady increase over age in children's production of object-extracted RCs (cf. Table 5). Rather, overall rates of appropriate RCs increased in the ORC condition specifically because children were more likely, over development, to produce higher rates of passive RCs (with increasing age, we observed a gradual increase from 10% to 45% of subject-extracted passive RCs, in line with Contemori & Belletti, 2014). Whatever factors are responsible for the low rate of production of object RCs during the pre-school years, those factors apparently continue to hold back the production of these structures even up through age 9.

Another interesting response pattern that is particularly relevant for the TD children involves inappropriate embedded structures. Wrong head (i.e., RC where the extraction type is correct but the head noun is not the targeted one) and wrong gap (i.e., active subject RCs with the expected RC head noun but the wrong assignment of thematic roles) responses are error types that were largely confined to the ORC condition. Interestingly, the rates of these errors barely changed from age 4 to 9 years, accounting collectively for some 8–15% of responses in the ORC condition. Thus, whatever is responsible for these two errors, they account in part for the low rate of production of object-extracted RCs throughout the age range we examined. Among the ungrammatical utterances, we observe filled object gaps, which represent a kind of resumptive strategy (5–15%). Object-extracted RCs with filled object gaps are often produced by child speakers tested experimentally (e.g., Contemori & Belletti, 2014; Diessel & Tomasello, 2005), even when this is not a well-formed option of the target language. Interestingly, filled object gaps were predicted to be produced by children with SLI under the optional movement account.

Our analysis of results from the TD children also revealed that not all subject-extracted RCs are equally easy: those with one animate noun were significantly easier than the ones with two animate nouns, but only in the right-branching condition. Therefore, when RCs are produced, there seems to be a challenge for the language system not only with the extraction site of the RC itself (whether it is a subject- or object-extracted) but also with the number of verbal arguments, their animacy properties and the type of embedding (e.g., Goodluck & Tavakolian, 1982). When the embedded verb requires two animate nouns as arguments, this operation requires more processing cost than when only one thematic role needs to be filled with an animate argument. Animacy effects on RC production have been observed before (Kidd et al., 2007). Future research should focus on whether this difference also holds for an elicited production task and considering all well-formed alternatives that participants decide to produce.

The second aim of the study was to investigate the abilities of German-speaking children with SLI to produce RCs and compare them to TD children in order to shed more light on the nature of the SLI impairment. Our results reveal that young German-speaking children with SLI have substantial difficulty with the production of RCs in general and they perform more poorly even than children matched to their language age. Based on the existing cross-linguistic literature, we formulated four predictions, which are discussed now in turn:

(P1) *General processing deficit*: We found no evidence that children with SLI have a stronger disadvantage with center-embedding than TD children. As previously discussed, we found that center-embedded RCs are overall less accurate than right-branching RCs but this pattern held for both participant groups. This finding appears to be in contrast with accounts that attempt to explain the source of the impairment in SLI uniquely in terms of slower processing (e.g., Deevy & Leonard, 2004) or restricted cognitive capacities (Leonard et al., 2013).

(P2) *Movement is absent*: Our results do not support the claim that movement is absent from the grammars of children with SLI. Although it is true that the children with SLI in our study produced many fewer RCs than TD children of the same language age, they nevertheless did produce RCs representing movement (they produced more than 50% subject-extracted RCs in the SRC conditions and around 18% object-extracted RCs in the ORC condition). It is worth noting that producing subject-extracted RCs correctly cannot be explained in terms of using a default SVO strategy since, in German, the verb is in final position in both RC types. Therefore, the children with SLI tested in our study did show some ability to produce adult-like embedded sentences, also derived by wh-movement.

(P3) *Movement is hard*: We found ample evidence in this study that wh-movement is hard for children with SLI. Even though these participants were able to produce both subject-extracted and object-extracted RCs, the rate of production of these structures is significantly lower in children with SLI than in TD children. Children with SLI have a greater tendency than TD children to use simple sentences that do not require wh-movement (cf. examples in Appendix B, in the online supplement). The production of monoclausal declarative sentences and simple nominal phrases (either AP or PP) when RCs are targeted is often reported in the literature, both for TD children and for children with SLI (Contemori & Garraffa, 2010; Courtney, 2006; Håkansson & Hansson, 2000; Koch et al., 2013; Novogrodsky & Friedmann, 2006; Schuele & Nicholls, 2000; Stavrakaki, 2002; Zukowski, 2009). Our TD children also produce such sentences to some extent, but only in the object-extracted RC condition. In contrast, the response rate of children with SLI in this response category always ranges around 7–11%, even in the subject-extracted conditions. Crucially, we can safely assume that these simpler sentences are genuine matrix clauses (rather than attempted RCs with a missing relative marker), for two reasons: first, the children with SLI never omitted the relative marker in their embedded RCs (as reported in Koch et al., 2013) and second, we have only coded sentences with the matrix verb in second position as matrix clauses. This means that, when the children in our study produce an appropriate matrix response, they encode the visual event/s and associated linguistic stimuli correctly, but opt for a structurally simpler response than the one that was targeted.

(P4) *Movement is optional*: A natural prediction of the movement optionality account would be to find at least some instances of RC head nouns in situ, in line with what van der Lely and colleagues have found for object wh-questions in children with G-SLI. An inspection of Table 5 reveals that the group of children with SLI produce very few instances of filled object gap structures and, in fact, considerably fewer than the TD children at any tested age. Thus, our study provides no support for the claim that wh-movement is optional. We argue that the lack of in situ heads/filled object gaps points towards a difficulty with wh-movement (and/or with the construction of the CP layer that is necessary to produce RCs correctly) that is less selective than the one documented in children with G-SLI by van der Lely and colleagues. One could argue that the elicitation of RCs allows appropriate matrix responses as an alternative to well-formed responses. This could explain the lack of in-situ constructions in our data: in situ/filled object gap responses may only occur in structures that do not allow an alternative appropriate structure to be used, such as object wh-questions. Interestingly, it appears that TD children do produce RC with filled object gaps more often than children with SLI, at any tested age showing that TD children do not avoid movement and are less likely than children with SLI to use the appropriate matrix response.

Summing up the evaluation of the predictions of these four accounts, the evidence from this study does not support the claim that children with SLI have a general processing deficit that affects their language development. Our study most strongly supports the idea that wh-movement is hard for children with SLI, but neither absent nor incorrectly marked in the grammar as being optional.

In conclusion, the results presentend in this article reveal that, in our elicited production task, TD children attempt to produce an embedded clause most of the time, and only rarely opt for simpler structures. We can therefore conclude that the ability to produce well-formed RCs is already active by at least 4 years of age, although this ability becomes more robust and less prone to errors as children grow older. In contrast, German-speaking children with SLI are impaired in RC production compared to TD children. Almost half of the utterances produced by children with SLI were grammatical and contextually appropriate, thus revealing that these children are able to encode the visual event they are exposed to and they are also able to process the prompt question. However, they produce many more simple structures than TD children in contexts designed to facilitate RCs, possibly reflecting avoidance of these structures. These results, taken together with virtually no examples of object-extracted RCs with filled object gaps, are consistent with the claim that wh-movement is very challenging for children with SLI, but it is not specified as optional in their grammars.

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