The Impact of Lexical Frequency on Sentence Comprehension in Children with Specific Language Impairment

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**Abstract**

Children with SLI generally exhibit poor sentence comprehension skills. We examined the specific impact of grammatical complexity and lexical frequency on comprehension performance, yielding contrasting results. The present study sheds new light on sentence comprehension in children with SLI by investigating a linguistic factor which has attracted little research interest: the impact of the lexical frequency of known words on sentence comprehension. In addition, we conducted a parallel study of the impact of grammatical complexity and sentence length on sentence comprehension by manipulating these two variables independently. Fifteen children with SLI, 15 age- and IQ-matched controls, and 15 controls matched on lexical and grammatical skills, performed sentence comprehension tasks in which three linguistic factors were manipulated: lexical frequency (sentences containing words of either low or high lexical frequency), grammatical complexity (sentence containing either a subject relative clause or an object relative clause) and sentence length (either short or long sentences). Results indicated that children with SLI performed more poorly overall compared to age- and IQ-matched children and to lexical and morphosyntactic age-matched children. However, their performance was not more affected by either sentence length or clause type than that of control children. Only lexical frequency affected sentence comprehension to a greater extent in children with SLI relative to the control groups, revealing that SLI children’s sentence comprehension abilities are particularly affected by the presence of low-frequency but familiar words.

**Keywords**: sentence comprehension, specific language impairment, lexical frequency, vocabulary, processing resources

1. **Introduction**

Children with SLI exhibit major morphosyntactic deficits, which have led to the hypothesis that grammatical impairments are the core deficit in SLI(e.g., van der Lely, 2005). . In recent years, sentence comprehension has emerged as a topic of increasing research interest. Two potential causal factors have been adduced in an effort to explain comprehension problems in children with SLI: grammatical complexity and sentence length. However, surprisingly few studies have dealt with the impact of lexical processing on sentence comprehension in children with SLI, despite the lexical problems often seen in this patient population (McGregor, 1997). The aim of the present study is to provide a detailed analysis of sentence comprehension deficits in children with SLI by assessing the impact of three linguistic factors on sentence comprehension: sentence length, grammatical complexity (as assessed by clause type) and the lexical frequency of constituent words.

* 1. **Sentence comprehension in children with SLI: Where do we stand?**

Children with SLI consistently show deficiencies in the comprehension of transitive sentences. They exhibit difficulties in interpreting reversible transitive passive and active sentences, especially in instances when semantic or pragmatic knowledge cannot guide them (Bishop, Bright, James, Bishop, & van der Lely, 2000; van der Lely, 1998; van der Lely & Harris, 1990). Short passive sentences also appear to be particularly difficult to process for SLI children, insofar as they exhibit a strong preference for adjectival passive interpretations (Norbury, Bishop, & Briscoe, 2002; van der Lely, 1996). Difficulties in assigning reference to pronouns and reflexives have also been reported (Bishop, et al., 2000; van der Lely, 1998; van der Lely & Stollwerck, 1997). Van der Lely and Stollwerk (1997) showed that when ascribing a pronoun to its antecedent, children with SLI were especially sensitive to semantic-conceptual lexical knowledge.

Studies with Hebrew-speaking children have shown that children with SLI manifest specific impairments in processing sentences that contain an object relative clause (Friedmann & Novogrodsky, 2004, 2007). The impairments underlying their difficulties in processing subject relative clauses are less clear. Friedmann and Novogrodsky (2004) (see also Levy & Friedmann, 2009) found that children with SLI did as well on processing subject relative clauses as they did on processing simple SVO sentences. However, Stavrakaki’s (2001) study of SLI Greek-speaking children showed that this patient population sometimes performed at the same level as, and sometimes worse than, language-matched children on sentences with a subject relative clause. Davies (2002) also found that English-speaking children with SLI show deficits in judging the grammaticality of a range of negative constructions, in comparison to both language-matched and age-matched control children. This was true both for declarative sentences and subject questions, but the deficit was particularly marked for object questions. Finally, Levy and Friedmann (2009) observed that comprehension over a wider range of reversible sentences, i.e., sentences in which the canonical order of arguments is not maintained;, may also be impaired in children with SLI.

These various sentence comprehension difficulties have generally been explained in terms of a selective impairment of the grammatical system. It has been further proposed that children with SLI have specific difficulties in building hierarchical grammatical structures when nonlocal syntactic dependencies have to be computed and no semantic or pragmatic cue is available (van der Lely, 2005; van der Lely & Harris, 1990). Others have proposed that the assignment of thematic roles itself, rather than the ability to construct a given grammatical structure, is impaired in children with SLI. This hypothesis would account for specific problems observed when the argument order is non-canonical, as in object relative clauses (Friedmann & Novogrodsky, 2004, 2007; Levy & Friedmann, 2009).

* 1. **The impact of sentence length on sentence comprehension in SLI**

 Other authors suggest that children with SLI suffer from difficulties in processing complex information rather than from a core impairment at the level of grammatical structures. Studies that pursue this line of argument have explored factors affecting sentence complexity, such as sentence length, and their impact on sentence comprehension abilities in children with SLI. A number of studies have revealed that children with SLI have specific difficulties in comprehending long sentences relative to age- and vocabulary-matched control children. Montgomery (1995, 2000a,b) showed that children with SLI are particularly poor at comprehending long redundant sentences, i. e. , sentences containing elements which are nonessential to sentence interpretation. However, in these studies, sentence length might have been confounded with grammatical complexity. Montgomery lengthened the sentences in various ways, most notably through the addition of a single embedded subject relative clause and the addition of a double embedded subject-and-object relative clause. It would be difficult to assert that comprehension deficits in children with SLI are to be explained exclusively in terms of increased sentence length, given that, in the Montgomery study, longer sentences were also of greater grammatical complexity. This is further corroborated by previous studies which have shown that children with SLI have problems in processing relative clauses (Friedmann & Novogrodsky, 2004; Stavrakaki, 2001). Other studies have demonstrated that syntactic complexity (presence/absence of a relative clause; subject/object relative clause) rather than sentence length might account for SLI children’s poor performance in the comprehension of long sentences (Marton & Schwartz, 2003; Montgomery, Evans, & Gillam, 2009; Robertson & Joanisse, 2010). Moreover, Marton, Schwartz, Farkas and Katsnelson (2006) have observed that the lengthening of sentences in some languages may be associated with an increase in morphological complexity, which can explain difficulties in processing long sentences. A more recent study assessed how a specific increase in sentence length, without modifying sentence structure, affects SLI children’s sentence comprehension (Leonard, Deevy, Fey, & Bredin-Oja, 2013). No significant impact of increased sentence length on performance in children with SLI was observed when the added adjectives were semantically superfluous; however, a significant impact was noted when the added adjectives had to be retained in order to provide the correct response. The impact of sentence length on sentence comprehension in children with SLI thus remains unclear.

* 1. **The impact of lexical frequency on sentence comprehension**

Various studies have revealed the significant impact of lexical variables on sentence processing (MacDonald, 1997). Adults are generally slower at reading sentences containing words of low lexical frequency than sentences containing words of high lexical frequency (Keller, Carpenter, & Just, 2001; Prat, Keller, & Just, 2007). This effect has also been observed in spoken-language comprehension: adults are slower at processing sentences containing low- rather than high-frequency words (Ferreira, Henderson, Anes, Weeks, & McFarlane, 1996; Henderson & Ferreira, 1990). Significant interaction effects have also been observed between lexical frequency and grammatical complexity. Whereas Keller and colleagues (2001) demonstrated the greater impact of lexical frequency on performance in the comprehension of active-conjoined sentences as compared to object-relative sentences, Johnson, Lowder, and Gordon (2011) noted that lexical frequency has a greater impact on processing object relative clauses than it does on processing subject relative clauses. A previous study has also shown interaction effects between lexical factors, syntactic factors and sentence length, in sentence comprehension performance, revealing that lexical factors are less vulnerable to increases in sentence length than are syntactic factors (Fortuno-Tavares et al., 2012). As far as we know, no study has directly assessed the impact of lexical frequency on sentence comprehension in children with SLI, despite the fact that these children show lexical processing deficits (for a review, McGregor, 2009). They also exhibit problems with lexical access (Seiger-Gardner &Schwartz, 2008), delays in receptive vocabulary (Clarke & Leonard, 1996), sparse lexical-semantic representations (McGregor, Newman, Reilly, & Capone, 2002), and slower response times in a lexical-decision task (Pizzioli & Schelstraete, 2007). Presentation frequency has been shown to interfere with vocabulary acquisition in children with SLI. Riches and colleagues (Riches, Tomasello, & Conti-Ramsden, 2005) have compared performance on the comprehension of newly learned words according to the frequency with which these new words had been presented. Whereas younger, typically developing controls showed good comprehension of the newly learned words in the low frequency condition, increasing the number of presentations improved SLI children's performance on the comprehension of newly learned words. Previous studies have shown that lexical and grammatical processes interact in children with SLI. Montgomery (2006) demonstrated that children with SLI were slower than typically developing children in identifying target words in a sentence context, whereas this was not the case when the words were presented in isolation. Moreover, in previous studies, children with SLI exhibited an increased sensitivity to semantic conceptual lexical knowledge when interpreting sentences (Lum & Bavin, 2007; van der Lely & Stollwerck, 1997). Finally, one study investigated whether SLI children's difficulties in syntactic comprehension could be linked to lexical processing and integration problems (Pizzioli & Schelstraete, 2013). In a primed auditory lexical decision task where children had to judge whether the last word of a sentence was a real word or not, children with SLI appeared to rely on both word knowledge and lexico-semantic associations more than controls, and to use these cues independently of syntactic information. However, the impact of lexical factors on sentence comprehension abilities in children with SLI remains to be investigated more directly.

* 1. **Aim**

The aim of the present study was to explore the impact of three linguistic factors on sentence comprehension in children with SLI: grammatical complexity, sentence length and lexical frequency. First, we explored the impact of lexical frequency on sentence comprehension by presenting sentences containing verbs and nouns of either high or low lexical frequency. This study is the first to directly assess the impact of the frequency of known words on sentence comprehension abilities in children with SLI. If increased demands on lexical processing affect sentence comprehension in children with SLI to a greater extent than in controls, we should observe a proportionally greater decrease in SLI children’s performance in processing sentences containing lower-frequency vocabulary relative to their typically developing peers. We also manipulated grammatical structure by presenting both sentences with right branching subject relative clauses and sentences with center-embedded object relative clauses. Difficulties in processing object relative clauses as compared to subject relative clauses have often been explained in terms of a core grammatical deficit (Friedmann & Novogrodsky, 2004, 2007; van der Lely, 2005). However, lower performance in processing center-embedded object relative clauses can also be explained in terms of memory: given that the embedded clause interrupts the main clause, it requires the unattached representation of the subject of the main clause to be maintained in memory before it can be integrated with the verb of the main clause (Gibson, 1998; Just & Carpenter, 1992). We therefore decided to further manipulate memory load independently of grammatical complexity by lengthening sentences without modifying the core syntactic structures. Lengthening the sentences increases the number of elements that have to be processed and/or maintained before their integration. If SLI involves a core grammatical deficit, then children with SLI should exhibit a greater performance decrement than typically developing peers on object relative clause sentences, regardless of sentence length. On the other hand, if their sentence processing abilities are to be explained in terms of reduced working memory abilities (Just & Carpenter, 1992), then their performance should be disproportionately affected by sentence length, for both types of sentence structures.

1. **Methods**

**2.1. Participants**

Fifteen French-speaking children with SLI aged 7 - 12 years (4 girls and 11 boys; mean age = 10;0 years; *SD* = 1;5; range = 7;9 – 12;7), 15 typically developing children matched for chronological age and nonverbal reasoning (6 girls and 9 boys; mean age = 10;2 years; *SD* = 1;7; range = 7;1 – 12;4), and 15 younger typically developing children matched for receptive vocabulary (5 girls and 10 boys; mean age = 6;11 years ; *SD* = 1;1; range: 5;6 – 9;2) participated in the study. The SLI group and the age control (AC) group were comparable in age, *t* (28) < 1, *n.s.*, and non-verbal reasoning (Raven, Raven, & Court, 1998), *t* (28) < 1, *n.s*. They differed in their phonological abilities (*t*(28) = 3.98, *p < .*001) as measured by the word repetition task of the *Evaluation du Langage Oral*,which measures repetition performance for later-acquired phonemes, complex phonological patterns and multisyllabic words (Khomsi, 2001) in their lexical abilities (*t*(28) = 3.08, *p < .*01) as measured by the French adaptation of the Peabody Picture Vocabulary Test (*Echelle de Vocabulaire en Images Peabody*: Dunn, Thériault-Whalen, & Dunn, 1993), in their receptive grammatical abilities (*t*(28) = 4.96, *p < .*001) as measured by the French adaptation of the TROG (*Epreuve de compréhension syntaxico-sémantique,* or E.CO.S.SE: Lecocq, 1996) and in their productive grammatical abilities (*t*(28) = 7.85, *p < .*001) as measured by the sentence production task of the *Evaluation du Langage Oral* (Khomsi, 2001). The SLI and language control (LC) groups had the same level of receptive vocabulary (*t* (28) <1, *n.s.*). A comparison of morphosyntactic abilities between the two groups revealed that they also had the same level of receptive grammar (*t* (28) = 1.03, *p* = .31) and productive grammar (*t* (28) = 1.31, *p* = .20). However, the two groups significantly differed in their phonological abilities (*t* (28) = 2.76, *p < .*05), children with SLI performing worse than control children.

Children were recruited from schools located in the French-speaking part of Belgium in a neighbourhood in the city of Liège. Informed consent was obtained from the parents of all participating children.All children came from families with low- or middle-class socioeconomic backgrounds as determined by their parents’ profession. The parents completed a medical history questionnaire which verified that all children were French native speakers, had no history of psychiatric or neurological disorders, and suffered no neurodevelopmental delay or sensory impairment. Children with SLI were recruited from specific language classes in special needs schools. They were diagnosed with SLI by speech-language pathologists prior to the study. Moreover, we used standard clinical tests to ensure that all of the children with SLI met the following criteria: scoring more than 1.25 SD below expected normative performance in 2 language areas (according to SLI criteria adopted by Leonard et al., 2007) based on the language tasks described above. The children also demonstrated normal-range nonverbal IQ (≥80) on the WISC-IV (Wechsler, 2005; see Table 1). Hearing thresholds were determined by audiometric pure-tone screening at 20dB HL at 500, 1000, 2000 and 4000 Hz. All children displayed normal-range hearing thresholds. Control children scored in the normal range on all language tests.

**2.2. Materials and Procedure**

**2.2.1. Sentence comprehension task**

A hundred and twenty active sentences with relative clauses were created. Three factors were manipulated: the lexical frequency of the constituent words, sentence length, and the type of relative clause. Each factor had two levels: sentences were either short or long, contained either a subject or an object relative clause, and contained words of either high or low lexical frequency, yielding 8 sentence types in all (2 × 2 × 2). Fifteen sentences were created for each sentence type (examples are given in the Appendix*)*. The 120 sentences were divided into three parallel sets containing 5 sentences of each sentence type. The order of presentation of the different sets was counterbalanced across participants.

The sentences were recorded by a female speaker in an isolated acoustic booth using a high-quality microphone connected to a MiniDisc® digital recorder. Sentences were read at normal rate and prosodic variation. Sentences were digitized at 44 kHz, and edited to eliminate any noise at the beginning or the end of the sound file. They were presented binaurally through high-quality headphones at a comfortable listening level.

The task was presented using E-Prime 1.0 Psychology Software (Schneider, Eschmann, & Zuccolotto, 2002). Before beginning the experiment, the children’s knowledge of the nouns used in the sentences was assessed using a picture-pointing task. Children were presented with a picture including five or six toy figures and were asked to point to a specific figure. The examiner told the child: "*Find out which of these is the X"* (e.g., "*the grandmother*" or "*the policeman"*). The same procedure was used to assess the children’s knowledge of the verbs used in the study. The examiner told the child: *"Find out which of these figures is X"* (e.g., "*drinking*" or "*cooking*"). For the experimental task, the children were told that they would have to help a writer choose the right pictures to illustrate his imaginary story. The children were instructed to listen carefully to the sentences which they would hear through the headphones, and told that after each sentence, they would have to choose the correct picture from among the four which would appear on the computer screen. The pictures appeared immediately after the end of the presentation of the stimulus sentence. The pictures depicted the target situation conveyed by the sentence and 3 foil situations corresponding to the incorrect syntactic parsing of the sentence, i.e., confounding the subject and object of the main clause, and ascribing the relative clause to the wrong antecedent. For example, for the sentence "*La madame voit le garçon qui glisse*." ("*The woman sees the boy who is sliding*."), the foils would correspond to the following sentences (1) "*The woman who is sliding sees the boy,*" (2) "*The boy sees the woman who is sliding*," and (3) "*The boy who is sliding sees the woman*." The children were instructed to point to the correct picture. A touchscreen recorded response accuracy. Four practice items were used to familiarize the child with the task, and feedback was provided during the practice trials but not during the experimental trials. Across the practice and experimental trials, the target picture appeared equally often at the top left, top right, bottom left and bottom right of the screen.

***2.2.1.1. Sentence length***

Short sentences contained 7 words and 9 syllables; for example: "*La madame voit le garçon qui glisse.*" ("*The woman sees the boy who is sliding*.") Long sentences contained 15 words and 17 syllables, for example: "*Ce soir la belle dame noire appelle la petite fille qui lit dans le pré."* ("*This evening, the beautiful black lady calls the little girl who is reading in the meadow.*") The added elements in long sentences were redundant, i.e., not essential to the understanding of the sentences’ meaning. The added elements consisted of adjectives, adverbs and time and location complements. None of these added elements facilitated the children’s decision-making when matching the sentence to one of the four presented pictures.

***2.2.1.2. Relative clauses***

Two types of relative clauses were presented: subject relative clauses and object relative clauses. Both sentence types contained a two-argument predicate and an intransitive verb. In the sentences containing a right-branching subject relative clause, the main clause contained a two-argument predicate and the verb of the relative clause was intransitive. The antecedent of the subject relative clause was the object of the matrix clause. They were thus composed of the subject of the matrix clause, the main verb, the object of the matrix clause, and the relative clause that contained the relative pronoun and the verb of the relative clause. For example, "*Le monsieur montre la madame qui roule.*" ("*The man shows the woman who is driving*."). In the sentences with a center-embedded object relative clause, the main clause verb was intransitive and the relative clause contained a two-argument predicate. They were composed of the subject of the matrix clause, the relative clause (containing the relative pronoun, the subject of the relative clause and the verb of the relative clause) and the verb of the matrix clause. The antecedent of the relative clause was the subject of the matrix clause. For example, "*Le monsieur que la madame voit, roule.*" ("*The man who the woman is seeing, drives*.").

***2.2.1.3. Lexical frequency***

The sentences were created by using words of either high or low lexical frequency, based on the Novlex French Database (Lambert & Chesnet, 2001). Only the verbs and the core of their arguments varied in lexical frequency, as these elements were the target words that needed to be processed in order to understand the sentence. The four target words which varied in frequency therefore included the verb, the subject and the object of the main clause, as well as the verb of the relative clause. Sentences with low lexical frequency contained target words with low lexical frequency (Lambert & Chesnet, 2001), such as "*Le policier filme l’apache qui skie."* ("*The policeman films the Apache who is skiing*."), while sentences with high lexical frequency contained target words with high lexical frequency (Lambert & Chesnet, 2001), such as "*La madame voit le garcon qui mange*." ("*The woman sees the boy who is eating*."). As these sentences also varied in semantic plausibility, we presented the images as part of a picture book describing an imaginary land where everything is possible. However, the nouns did not differ in animacy, so that children could not rely on animacy cues to process the sentences (Evans & MacWhinney, 1999). Given these were fully reversible active sentences, children had to use grammatical information to interpret sentences correctly. Moreover, as described in the procedure below, we ensured that all children knew the lexical units before presenting the sentences. This is especially important in order to ensure that any effect of lexical frequency on performance accuracy cannot be explained in terms of a lack of vocabulary knowledge. Each and every noun that was used in the sentences was known to the children, enabling us to specifically address the question of the impact of lexical *frequency,* rather than lexical *knowledge* impact on sentence comprehension performance.

1. **Results**

**3.1. Descriptive Statistics**

Descriptive statistics are shown in Table 2. Long sentences with object relative clauses were particularly difficult to process for all groups, as revealed by very low performance levels, especially in SLI children. Skewness and kurtosis estimates on scores nevertheless remained within the recommended two standard error range (Tabachnick & Fidell, 1996) for each group in every sentence type.

**3.2. Analysis of Variance**

Response accuracy for all sentence types was subjected to a mixed ANOVA. The between-subjects factor was the participant group (children with SLI, language-controls or age-controls), and the within-subjects factors were sentence length (short or long sentences), relative clause (subject or object relative clause), and lexical frequency (sentence with low or high lexical frequency). We will present the group effect first, before separately presenting the impact of length, grammatical complexity and lexical frequency on sentence comprehension according to group.

**3.2.1. Group effect**

 Results revealed a main effect of group (*F*(2,42) = 25.40, *p < .*001, partial η² = .547). Newman-Keuls post hoc analyses revealed that the SLI group performed significantly worse than the LC group (*p < .*001) and the AC group (*p < .*001), and that the LC group performed significantly worse than the AC group (*p* = .002; see Table 3).

**3.2.2. Sentence length effect**

A main effect of sentence length was found, performance was better for short rather than long sentences (*F*(1,42) = 46.29, *p < .*001, partial η² = .524, see Table 3). The group-by-length interaction effect was not significant (*F*(2,42) = 0.52, *p* = .60, partial η² = .024).

**3.2.3. Clause effect**

A main effect of clause type was observed, performance was better for sentences with a subject relative clause rather than an object relative clause (*F*(1,42) = 198.37, *p*< .001, partial η² = .825, see Table 3). The group-by-clause interaction effect was not significant (*F*(2,42) = 0.36, *p* = .69*,* partial η² = .017).

**3.2.4. Lexical frequency effect**

The lexical frequency effect was non significant (*F*(1,42) = 1.21, *p =*.28, partial η² = .028, see Table 3). Importantly, a group-by-lexical frequency interaction effect was observed (*F*(2,42) = 4.03, *p* = .02, partial η² = .161; see Figure 1). Newman-Keuls post hoc analyses revealed that only children with SLI showed a performance decrement for sentences with low lexical frequency (*p* = .005); Age Controls (*p* = .43), Language Controls (*p* = .82). Furthermore, a significant group-by-length-by-frequency interaction effect was observed (*F*(2,42) = 4.47, *p* = .002, partial η² = .175). Newman-Keuls post hoc analyses revealed that length affected the performance of SLI group only for sentences with high-frequency vocabulary (*p* = .004; sentences with low-frequency vocabulary: *p* = .11), while length affected age controls only in comprehending sentences with low-frequency vocabulary (*p < .*001; sentences with high-frequency vocabulary: *p* = .54); and language controls in both conditions (sentences with high-frequency vocabulary: *p =*.001; sentences with low-frequency vocabulary: *p* = .003).

**3.2.5. Interaction effects for between-subject factors**

This section presents all remaining two-way and three-way interaction effects in which the group factor played no role. A significant length-by-clause type interaction effect was found (*F*(1,42) = 17.46, *p < .*001; partial η² = .294). Newman-Keuls post hoc analyses revealed that performance was only affected by sentence length for sentences with a subject relative clause (*p < .*001); this was not the case for sentences with an object relative clause (*p* = .22). This result is not surprising given the observation of a similar interaction effect between sentence length and relative clause type by Robertson and Joanisse (2010).

A significant frequency-by-clause type effect was also observed (*F*(1,42) = 33.23, *p < .*001, partial η² = .442). Newman-Keuls post hoc analyses showed that the lexical frequency effect was significant on both sentences containing subject- (*p < .*001) and object relative clauses (*p =*.002) respectively. At the same time, the lexical frequency effect was greater for sentences containing subject relative clauses (partial η² = .331) than object relative clauses (partial η² = .192), as assessed by planned comparisons. Keller and colleagues (2001) also observed a lower impact of lexical frequency on performance in comprehending object-relative sentences (as compared to active-conjoined sentences) in adults.

Finally, the length-by-frequency-by clause type effect was also significant (*F*(1,42) = 15.62, *p < .*001, partial η² = .271). Firstly, Newman-Keuls post hoc analyses revealed that, in long sentences, performance on object relative clauses did not interact with lexical frequency (*p* = .72), whereas the interaction effect was significant for subject relative clauses (*p =*.027) as well as for both clause types in short sentences (*p*< .001 for both sentence types). Secondly, the three-way interaction effect reveals that, in sentences containing high-frequency words, performance on object relative clauses did not interact with sentence length (*p* = .33), whereas the interaction effect was significant for subject relative clauses (*p < .*001), as well as for both clause types in sentences containing low-frequency words (subject relative, *p < .*001; object relative, *p* = .001). These results are congruent with previous studies which highlight the reduced impact of lexical frequency on object relative clauses (Keller et al., 2001) as well as interaction effects between lexical factors, syntactic factors, and sentence length, with syntactic factors more vulnerable to sentence length increase (Fortunato-Tavares et al., 2012). No other effect was significant.

**4. Discussion**

Our study was directly aimed at both exploring the impact of lexical frequency on sentence comprehension in children with SLI and further investigating the separate effects of grammatical complexity and sentence length on comprehension. Results showed a main effect of group: children with SLI performed worse than language-matched and age-matched control groups. Main effects of relative clause type and sentence length were also found, exhibiting improved performance overall for sentences with a subject relative clause rather than an object relative clause, and for short rather than long sentences. The SLI group was affected to the same extent by these variables as the control groups; nevertheless, a significant group-by-frequency interaction effect was found, revealing that only the SLI group displayed poorer sentence comprehension performance for sentences containing low-frequency words.

In keeping with previous studies (e.g., Bishop et al., 2000; Norbury et al., 2002), we observed that SLI children"s sentence comprehension performance is worse than that of age-matched typically developing children, but also younger children of the same morphosyntactic age. These data confirm the severity and specificity of sentence comprehension difficulties in children with SLI (e.g., van der Lely & Harris, 1990). Given that our SLI group exhibited impaired sentence comprehension performance relative to younger children performing at the same level on a standardized test of grammatical comprehension, it appears that processing full reversible relative clauses, and even subject clauses, is especially difficult for children with specific language impairment (SLI). This is true even for the short sentences containing only two noun clauses used in the present study, while Stavrakaki (2001) observed similar results with respect to more complex sentences containing three noun clauses.

**4.1. The impact of relative clause type on sentence comprehension**

Given that children with SLI are particularly poor at processing fully reversible sentences, our results may be taken to support the grammatical deficit hypothesis, i.e., specific difficulties in assigning theta-roles when no semantic cue is available (e.g., van der Lely & Harris, 1990). However, in this case, we would also expect larger impairment in SLI for the most complex grammatical structures, i.e., object-relativized sentences (Friedmann & Novogrodsky, 2004). A general relative clause effect was observed in all children, corroborating previous studies which demonstrate that object relative clauses are more difficult to process than subject relative clauses (King & Just, 1991). However, no group-by-relative clause interaction effect was observed. Consequently, our results do not confirm the hypothesis of a specific and permanent impairment in processing object relative clauses, as proposed in a study with Hebrew-speaking children with SLI (Friedmann & Novogrodsky, 2004, 2007). Syntactic complexity, as assessed by comparison between the processing of object relative clauses and subject relative clauses, does not specifically affect sentence comprehension in French children with SLI. These varying results could be attributed *inter alia* to differences in the sentence material used. The sentences used in the present study were more complex than those in Friedmann and Novogrodsky's study ("*This is the grandmother that the girl is kissing.*") in that they contained two verbs ("*The man whom the boy sees is reading*."). It therefore follows that, notwithstanding the possibility of error in assigning an antecedent to the relative clause, there exists an additional possibility for error, in attributing the correct subject to the main verb. Friedmann and Novogrodsky showed that typically developing children increase their understanding of object relative clauses between four and six years of age. Our results in age controls show that this object-relative syntactic structure is not fully mastered at school age, and that the accurate attribution of two subjects to their respective verbs is more difficult in object relative clauses than in subject relative clauses for both SLI children and controls.

**4.2. The impact of sentence length on sentence comprehension**

We manipulated sentence length in order to increase processing load without modifying sentence structure. In keeping with the capacity limitation hypothesis, we expected a greater impact of sentence length on performance in children with SLI as compared to typically developing children. The results indicated that all children performed better on short than on long sentences. Importantly, sentence length affected performance to the same extent in each group. This result does not support the capacity limitation hypothesis. We should note that the elements added to lengthen the sentences in this study were not required in order to process the semantic content of the sentence: the elements added were redundant adjectival and adverbial material modifying the nouns. These elements were not critical for achieving a correct interpretation of the sentences in relation to the four probe scenes that were presented. It would thus appear that processing long sentences, without any change in syntactic structure, is not more complex for children with SLI than it is for children without language problems. Our results are congruent with a recent study by Leonard and colleagues (2013). The authors manipulated sentence length by adding adjectives that were either semantically superfluous or essential to accurately interpret the sentence. When processing long sentences with superfluous material, the performance of children with SLI did not differ from the performance of their language-age matched peers. Moreover, in children with SLI, the results demonstrated no statistical difference in performance when comprehending long sentences with superfluous material; however, a significant performance decrease was observed with long sentences containing supplementary adjectives that had to be processed and stored in order to comprehend the sentence. In the present study, although a main effect of sentence length was observed in all groups, comprehension performance in children with SLI was no more affected than that of controls by the need to process supplementary material that did not have to be integrated into the sentence meaning. This result also corroborates the proposal that length in itself does not specifically impair the performance of children with SLI (Marton & Schwartz, 2003; Marton, Schwartz, Farkas & Katsnelson, 2006; Montgomery et al., 2009).

**4.3. The impact of lexical frequency on sentence comprehension**

The only variable that affected SLI children’s sentence comprehension performance disproportionally in this study was lexical frequency. Contrary to previous studies, our results showed no main effect of lexical frequency on sentence comprehension performance (Ferreira et al., 1996; Henderson & Ferreira, 1990; Keller et al., 2001; Prat et al., 2007). However, this effect has usually been observed on response speed, whereas in the present study response accuracy was analysed. Our results showed that response accuracy was not affected by the need to process less frequently occurring known words in typically developing children, nor even in younger children matched on lexical and grammatical abilities. Children with SLI, in contrast, were particularly sensitive to the lexical frequency of constituent words in the sentence material as compared to the control groups. It could be argued that poor vocabulary knowledge might have been at the root of this difficulty. However, the language-control group was matched for vocabulary knowledge to the SLI group. Furthermore, lexical comprehension abilities for each individual target word had been checked in each participant before the start of the experiment. We thus ensured that every child, including children with SLI, knew every target word used in the sentence material. It would therefore appear that children with SLI show greater difficulty in processing low-frequency words in a sentence context where semantic representations of individual words have to be integrated with the syntactic analysis in order to construct a unified meaning at the sentence level.

This effect has often been explained in terms of processing resources required to activate the lexical content (Keller, et al., 2001; Prat, et al., 2007). However, our results do not corroborate an interpretation in terms of limited processing resources, since children with SLI were not disproportionately affected by other processing factors such as sentence length. Our discovery of increased sensitivity to lexical frequency in a sentence comprehension context corroborates previous findings demonstrating increased sensitivity to semantic-conceptual lexical knowledge when interpreting sentences (Pizzioli & Schestraete, 2011; van der Lely & Stollwerck, 1997). It is possible that slowed lexical access underlies this increased impact of lexical frequency on sentence comprehension: children with SLI may not be able to fully access the semantic content of all the words before the end of the sentence. A previous study also showed that children with SLI are especially hindered when processing words embedded in a sentence context, while they exhibit comparable reaction times in an isolated lexical decision task (Montgomery, 2006). Following Montgomery, problems in processing words in a sentence context are likely attributable to problems in computing the multiple higher-order linguistic processes involved in sentence comprehension. This is what was observed by Pizzioli and Schelstraete (2011), who suggested that problems emerge in post-lexical processing, when various lexical and semantic elements have to be integrated to construct sentence meaning. Although the present study was not designed to distinguish between these different accounts, the results hint at difficulties in co-activating and/or integrating lexical and semantic information when processing sentences.

More generally, our results show that lexical and syntactic processing levels are highly interconnected. Verifying lexical knowledge before assessing sentence comprehension is probably not sufficient to rule out a deleterious impact of lexical knowledge on performance, even for known words. Future studies should clarify the mechanisms at work during lexical processing (i.e., lexical access or integration into sentence meaning) that affect sentence comprehension.

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**Table 1**

*Descriptive Summary Data for Children with Specific Language Impairment (SLI), Age Control Children (AC) and Language Control Children (LC)*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Age (months) | PIQ | VIQ | RCPM | EVIP | E.CO.S.SE  | ELO Words repetition | ELO Sentence production  |
| SLI |  |  |  |  |  |  |  |  |
| Mean | 120.4 | 92.6 | 70.93 | 28.87 | 91.2 | 76.93 | 23.67 | 13.5 |
| SD | 19.2 | 9.70 | 10.67 | 3.98 | 21.56 | 6.52 | 8.11 | 3.99 |
| Range | 93-151 | 79-111 | 53-84 | 19-34 | 43-122 | 65-86 | 6-32 | 6-18 |
| AC |  |  |  |  |  |  |  |  |
| Mean | 122.53 | - | - | 29.8 | 113.53 | 85.67 | 32 | 22.67 |
| SD | 19.31 | - | - | 3.51 | 17.96 | 2.02 | 0 | 2.06 |
| Range | 85-148 | - | - | 22-35 | 73-131 | 81-89 | 32-32 | 17-25 |
| LC |  |  |  |  |  |  |  |  |
| Mean | 83.27 | - | - | 21.53 | 90.33 | 79.33 | 29.8 | 15.6 |
| SD | 13.91 | - | - | 4.97 | 20.81 | 6.29 | 2.88 | 4.59 |
| Range | 66-110 | - | - | 15-31 | 50-120 | 69-90 | 21-32 | 8-22 |

*Note.* PIQ, WISC-IV performance IQ; VIQ, WISC-IV verbal IQ; RCPM, Raven’s colored progressive matrices; EVIP, French version of the Peabody Picture Vocabulary Test; E.CO.S.SE, French version of the Test for the Reception of Grammar; ELO, Évaluation du Langage Oral Test.

**Table 2**

*Descriptive Statistics for Response Accuracy for Each Experimental Condition, as a Function of Participant Group for Children with Specific Language Impairment (SLI), Age Controls (AC) and Language Controls (LC)*

|  |  |
| --- | --- |
|  | Condition |
|  | Relative |  | Subject |  | Object |
|  | Length |  | Short |  | Long |  | Short |  | Long |
|  | Frequency |  | High |  | Low |  | High |  | Low |  | High |  | Low |  | High |  | Low |
|  |  |  | (max : 15) |  | (max : 15) |  | (max : 15) |  | (max : 15) |  | (max : 15) |  | (max : 15) |  | (max : 15) |  | (max : 15) |
| SLI |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Mean |  |  | 11.8 |  | 8.27 |  | 8.4 |  | 7.53 |  | 4.93 |  | 5.6 |  | 4.8 |  | 4.33 |
| SD |  |  | 2.31 |  | 2.99 |  | 2.32 |  | 3.07 |  | 1.53 |  | 2.03 |  | 2.14 |  | 1.59 |
| AC |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Mean |  |  | 14.47 |  | 14.2 |  | 12.27 |  | 11.27 |  | 8.07 |  | 11 |  | 9.67 |  | 9.13 |
| SD |  |  | 0.74 |  | 0.74 |  | 1.71 |  | 2.19 |  | 3.24 |  | 2.98 |  | 2.89 |  | 3.14 |
| LC |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Mean |  |  | 13.47 |  | 11.93 |  | 9.87 |  | 9.2 |  | 6.8 |  | 8.73 |  | 6.93 |  | 7.53 |
| SD |  |  | 2.07 |  | 3.2 |  | 2.92 |  | 2.51 |  | 3.36 |  | 2.76 |  | 3.35 |  | 2.92 |

**Table 3**

*Descriptive Statistics (Raw Data, Maximum Score: 15) for Response Accuracy Regrouped by Experimental Variables as a Function of Participant Group: Children with Specific Language Impairment (SLI), Age Controls (AC) and Language Controls (LC)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | SLI | AC | LC | TOTAL |
| Relative | Subject | 8.85 (3.11) | 13.05 (1.99) | 11.12 (3.14) | 11.06 (3.24) |
|  | Object | 4.92 (1.85) | 9.31 (3.17) | 7.5 (3.13) | 7.29 (3.34) |
| Length | Short | 7.65 (3.51) | 11.93 (3.44) | 10.23 (3.86) | 9.94 (4.00) |
|  | Long | 6.27 (2.88) | 10.58 (2.78) | 8.38 (3.11) | 8.41 (3.4) |
| Frequency | High | 7.48 (3.55) | 11.12 (3.38) | 9.27 (3.99) | 9.29 (3.92) |
|  | Low | 6.43 (2.89) | 11.4 (3.01) | 9.35 (3.23) | 9.06 (3.66) |
| TOTAL |  | 6.96 (1.24) | 11.26 (1.61) | 9.31 (2.02) |  |