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[AQ1]

Nonword Repetition Problems in Children With SLI

A Deficit in Accessing Long-Term Linguistic Representations?

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Children with specific language impairment (SLI) consistently show poor nonword repetition (NWR) performance. However, the reason for these difficulties remains a matter of intensive debate. Nonword repetition is a complex psycholinguistic task that heavily relies upon phonological segmentation and phonological knowledge, and even lexical knowledge. This study aims at investigating various linguistic factors that can be at the root of difficulties in children with SLI when repeating nonwords, with the goal of achieving a better understanding of the linguistic processes supporting nonword processing. Linguistic complexity was assessed by manipulating lexicality, syllabic complexity, and perceptual difficulty in NWR tasks. Fifteen children with SLI, 15 typically developing controls matched on both age and performance IQ, and 15 typically developing children matched on lexical knowledge participated in this study. Children with SLI performed overall more poorly than age- and IQ-matched children and lexical age–matched children. Importantly, children with SLI showed lower lexicality and syllabic complexity effects in their NWR performances. These results are compatible with difficulties to retrieve lexical and sublexical phonological knowledge in the context of NWR tasks. **Key words:** *nonword repetition*, *specific language impairment*, *verbal short-term memory*

CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT (SLI) consistently show poor nonword repetition (NWR) performance. Researchers have suggested that this task could be a useful tool for identifying children with SLI (Bishop, North, & Donlan, 1996; Conti-Ramsden, Botting, & Faragher, 2001; Dollaghan & Campbell, 1998; Gathercole, 2006; Weismer et al., 2000). Indeed, this deficit appears to be very robust, as it is observed from preschool years (Gray, 2003) to adolescence and adulthood (Poll, Betz, & Miller, 2010; Whitehouse, Line, Watt, & Bishop, 2009) even when language deficits have resolved (Bishop et al., 1996; Conti-Ramsden et al., 2001). However, the reason for these difficulties remains a matter of intensive debate. Nonword repetition was first assumed to provide a pure measure of phonological short-term memory (STM; Gathercole & Baddeley, 1990; Gathercole, Willis, Emslie, & Baddeley, 1992), but many studies have demonstrated the significant association of linguistic knowledge with NWR performance (e.g., Coady & Aslin, 2004; Messer, Leseman, Boom, & Mayo, 2010). By definition, children with SLI experience difficulties in processing and acquiring language. Hence, it is likely that linguistic complexity is an important source of difficulty for children with SLI when performing an NWR task. The aim of this study

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was to achieve a better understanding of the factors that impair NWR performance in French-speaking children with SLI by systematically exploring the impact of three linguistic factors on NWR performance. First, lexicality is manipulated by comparing nonwords composed of either word or nonword syllables. Second, syllabic complexity is manipulated by presenting syllables with either single or cluster consonants. Third, perceptual complexity is manipulated by presenting the same syllables either in a concatenated form, leading to multisyllabic nonwords (containing either word or nonword syllables), or in a segregated form, leading to serial recall of monosyllabic word or nonword lists. The underlying logic was that for serial recall of monosyllabic nonword lists, the syllables are separated by a temporal interval and hence phonological input is already partially segmented. On the contrary, when repeating single multisyllabic nonwords, which is the most frequent procedure used for NWR tasks in children, fast and detailed segmentation processes are required for efficient identification and encoding of individual syllables, thereby leading to higher perceptual load. Also, because of coarticulatory processes, syllable boundary consonants in multisyllabic nonwords will have a shorter duration, further increasing perceptual load (Umeda, 1977).

A further originality of this study is the use of French as study language. Studying NWR in French is of particular interest in assessing phoneme-level perceptual complexity, given that it allows avoiding any confound by prosodic cues. Stress patterns in French are far less important in speech processing and have less acoustic substance than in English (Nazzi, Iakimova, Bertoncini, Frédonie, & Alcantara, 2006). The use of French thus enabled us to directly assess the impact of phoneme-level segmentation processes on NWR, independently of the impact of prosodic cues.

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WHAT DOES NWR ACTUALLY MEASURE?

Nonword repetition is a complex psycholinguistic task that requires perceiving and segmenting the input signal, matching the signal with phonological representations in long-term memory, maintaining them activated as well as their sequential order, and planning speech motor programs. Hence, NWR not only involves short-term maintenance processes but also heavily recruits phonological segmentation processes and phonological knowledge. This study focuses specifically on these linguistic parameters as potential predictors of poor NWR performance in children with SLI. Before examining more closely the role of linguistic parameters in NWR performance in children with SLI, we first examine their general influence on NWR performance in typically developing children and adults.

Previous studies demonstrated that NWR is influenced by sublexical and lexical phonological knowledge. Lexical influences on NWR are reflected by the fact that children and adults repeat more accurately nonwords in which constituent syllables are real words or nonwords that have a high wordlikeness (Gathercole, 1995; Munson, Kurtz, & Windsor, 2005). Sublexical influences on NWR are reflected by the impact of phonotactic knowledge, which refers to knowledge about the frequency of phoneme cooccurrences in a given language. Children and adults usually are better at repeating nonwords containing frequent rather than rare phoneme associations, reflecting their ability to match the acoustic input to previously encoded phonological sequences (Coady & Aslin, 2004; Majerus & van der Linden, 2003; Messer et al., 2010). An effect of syllabic patterns and frequency has also been observed. Long nonwords containing frequent syllable patterns are repeated more accurately than nonwords containing syllables that are less frequent (Nimmo & Roodenrys, 2002).

Perceptual segmentation cues also influence NWR performance. Archibald and Gathercole (2007a) showed that typically developing children are better at repeating single multisyllabic nonwords than the same syllables presented in a serial list with short pauses between them. They proposed that perceptual suprasegmental factors, such as coarticulatory and prosodic cues, may support retention for nonword syllables in an NWR task using multisyllabic nonwords. However, these authors also showed that this benefit was less marked for children with SLI (Archibald & Gathercole, 2007b). As already noted, although coarticulatory and prosodic cues may support multisyllabic NWR, these cues may also be more difficult to process in the context of multisyllabic nonwords where these cues have a more variable and shorter acoustic reality, making them more difficult to process in children presenting difficulties at the level of perceptual and phonological segmentation processes. In sum, these studies highlight the impact of various perceptual, sublexical, and lexical factors on NWR performance, disconfirming the view that NWR is a pure measure of phonological STM. One of the key issues of this article is to better understand the linguistic factors that may explain why children with SLI process nonword stimuli differently than typically developing children.

NONWORD REPETITION IN CHILDREN WITH SLI

Many studies have shown that children with SLI are poor at repeating nonwords as compared with typically developing children and younger, language-matched children (e.g., Archibald & Gathercole, 2006; Girbau & Schwartz, 2008; Marton & Schwartz, 2003). Whereas some authors proposed that poor NWR in SLI reflects a basic impairment in phonological STM capacity (Gathercole & Baddeley, 1990; Montgomery, 1995), others argue that poor performance reflects their underlying phonological processing ability (Bowey, 2006; Chiat, 2006). In support of the phonological STM deficit hypothesis, children with SLI generally show poorer performance than their age-matched peers even when performing other STM tasks, such as digit span (e.g., Hick, Botting, & Conti-Ramsden, 2005). At the same time, they generally perform particularly poor when repeating nonwords (Alloway & Archibald, 2008; Majerus et al., 2009). Because children with SLI often experience poor phonological segmentation abilities and phonological knowledge difficulties (i.e., Chiat, 2001; Maillart & Parisse, 2006), it is likely that the linguistic complexity of NWR will be associated with poorer performances in this task than among children without language impairment, especially given the large range of phonological processes involved in NWR. To date, only a few studies have systematically addressed this issue (Archibald & Gathercole, 2007b; Ebbels, Dockrell, & van der Lely, 2012; Jones, Tamburelli, Watson, Gobet, & Pine, 2010) and none of them were conducted with French-speaking children.

Previous studies have shown that children with SLI encounter difficulties in accurately perceiving nonword syllables, supporting a phonological segmentation deficit hypothesis (Coady, Evans, Mainela-Arnold, & Kluender, 2007; Coady, Kluender, & Evans, 2005). Moreover, a previous review has shown that their difficulties increase when nonwords are embedded in long phonological strings (Coady & Evans, 2008). If difficulties in segmenting and identifying the phonological input are to explain NWR impairments in SLI, then children with SLI should show larger deficits if the same syllables are presented in a concatenated form (i.e., as a multisyllabic nonword) and not individually presented in a list interposed by pauses of approximately 1 s. Partial evidence for this hypothesis stems from a study by Archibald and Gathercole (2007b). These authors showed that impairment in NWR performance is larger in children with SLI when the syllables are presented in a concatenated form (as a multisyllabic nonword) rather than temporally separated by intersyllabic pauses introduced electronically.

In line with a phonological knowledge deficit hypothesis, previous studies have assessed the ability of children with SLI to rely on stored lexical knowledge in the context of immediate serial recall tasks, showing comparable lexicality effects in both SLI and control groups as reflected by higher recall performance for lists of real words relative to lists of nonwords (Majerus, Vrancken, & van der Linden, 2003; van der Lely & Howard, 1993). This indicates that children can use lexical knowledge in STM tasks where phonological units are easily identifiable, as is the case for the short familiar and clearly separated stimuli used in these studies.

However, to achieve a better understanding of the linguistic factors that impair NWR in children with SLI, a manipulation of lexicality within nonwords has to be conducted. This can be done by comparing multisyllabic nonwords composed of syllables that vary relative to lexical content (i.e., nonwords containing real-word syllables such as *bain-joue-nid* [*bath-cheek-nest*] or containing only nonword syllables */bZ Fa nS/*). Also controversial are results for a related factor, phonotactic knowledge (i.e., knowledge related to the frequency of phoneme sequences in a language). Importantly, phonotacic knowledge may support retention of nonwords that vary in the relative frequency of phoneme sequences. Although some studies have shown standard effects of phonotactic knowledge on NWR performance in SLI (Coady, Evans, & Kluender, 2010; Majerus et al., 2003), other studies have shown a larger impact of phonotactic probability on NWR in children with
[AQ6] SLI than in their age controls (AC; Munson et al., 2005). This latter finding may suggest that children with SLI show a differential sensitivity to phonotatic patterns in the language.

The literature also shows conflicting results regarding the impact of syllabic complexity (e.g., consonant clusters) on NWR. Whereas some authors have shown that NWR in children with SLI is affected by the presence of consonant clusters to a greater extent than in typically developing children (Bishop et al., 1996; Briscoe, Bishop, & Norbury, 2001; Gallon, Harris, & van der Lely, 2007; Marshall & van der Lely, 2009), others have observed no selective impairment in the repetition of nonwords containing clustered rather than single consonants (Gathercole & Baddeley, 1990).

AIM

The aim of this study was to achieve a better understanding of the linguistic factors that impair NWR performances in children with SLI. We also aimed to achieve a better understanding of the linguistic aspects that are especially problematic to children with SLI during nonword processing. We manipulated three main aspects of phonological complexity: lexicosemantic support; syllabic complexity; and perceptual load.

First, the impact of syllable lexicality on NWR performance was assessed by using nonwords composed of real-word syllables or nonword syllables. If children with SLI encounter difficulties in matching the phonological input with stored lexical phonological patterns, either because of less developed lexical representations or because of difficulties in accessing these representations (the phonological *knowledge* deficit hypothesis), then we should observe a lower influence of lexicality on NWR in SLI than in typically developing peers. This would be observed as a proportionally smaller increment in the repetition of nonwords containing word syllables versus nonword syllables relative to typically developing children. On the contrary, if poor performance in NWR results from basic limitations in phonological STM capacity (the phonological STM deficit hypothesis), we might expect a significantly increased lexicality effect in children with SLI, which would be observed as a proportionally larger decrement in the recall of nonwords containing nonword than word syllables, compared with typically developing children. This second outcome would be consistent with lexical knowledge being recruited to a greater extent to support the quickly decaying phonological STM traces in case of phonological STM impairment (e.g., Freedman & Martin, 2001; Martin, Shelton, & Yaffee, 1994).

Second, syllable complexity was manipulated by using either consonant–vowel (CV) or consonant–consonant–vowel (CCV) phonological structure within syllables. This manipulation allowed us to distinguish between phonological segmentation difficulties and difficulties stemming from poor sublexical phonological knowledge. If poor NWR performance in children with SLI is to be explained by impaired phonological segmentation processes (the phonological *segmentation* deficit hypothesis), then a larger structural complexity effect due to impaired perceptual and segmentation processes is observed. At the same time, CV and CCV structures differ by their relative frequency in French: Whereas the CV structure characterizes 55% of all syllables, the CCV structure represents only 14% (Béland, 2001). If children with SLI encounter difficulties in matching the input with stored sublexical phonological patterns or if they have less developed sublexical representations (the phonological *knowledge* deficit hypothesis), there would not be as much of an advantage for simpler forms that are also more frequent in French. We should thus observe a smaller syllabic complexity effect in these children, which would be observed as a proportionally smaller decrement in the recall of structurally more complex nonwords than less complex nonwords, than in typically developing children.

Third, the impact of perceptual load was assessed by presenting the same syllable stimuli either in a concatenated manner (multisyllabic NWR task) or in a temporally segregated manner (serial syllables). Typical NWR tasks have a high perceptual load, because they require fast and detailed segmentation processes. Although the additional coarticulatory and suprasegmental cues may benefit recall of multisyllabic nonwords in typically developing children, processing of these cues may be more difficult in children experiencing phonological identification and segmentation deficits. In a serial syllables recall task, where monosyllabic stimuli are presented with an interstimulus interval, the acoustic signal is segmented at the between-syllable level and more time is available to process the acoustic signal at the phonological and lexical levels. If poor NWR in children with SLI stems from a reduced capacity to process the perceptual load of the task (the phonological *segmentation* deficit hypothesis), then they should be less impaired when processing the same syllables in a serial recall task. At the same time, presentation time is longer in the serial syllables condition, increasing retention demands in STM. If poor NWR in children with SLI stems from a reduced STM capacity (the phonological STM deficit hypothesis), then they should be more impaired when processing the same syllables in a serial recall task.

In sum, if NWR performance in children with SLI suffers from STM limitations (the phonological STM deficit hypothesis), then children with SLI should show a larger impact of lexicality and a lower impact of perceptual load. If NWR performance in children with SLI suffers from phonological identification and segmentation deficits (the phonological *segmentation* deficit hypothesis), then children with SLI should show a larger impact of perceptual load and of syllabic complexity. Finally, if NWR performance is impacted by an inability to access lexical and sublexical phonological knowledge, then a reduced impact of lexicality and syllabic complexity should be observed, consistent with the phonological *knowledge* deficit hypothesis. Each factor had two levels of complexity: lexicality (word syllables vs. nonword syllables), syllabic complexity (CV vs. CCV), and perceptual load (high vs. low perceptual load). A cross-factorial design was used, yielding eight task conditions. **[AQ7]**

Finally, prosodic factors (intonational contour) were held constant. In English, prosodic factors are known to influence performance in NWR: More errors are generally found on unstressed than stressed syllables and especially on unstressed syllables preceding stressed syllables (e.g., Roy & Chiat, 2004). English is a stressed language: Speech is punctuated by trochaic patterns that facilitate segmentation of the acoustic input. On the contrary, the rhythmic unit of French—the language of the participants of this study—is the syllable (Nazzi, 2008). Stress patterns in French are far less important in speech processing than they are in English (Nazzi et al., 2006), which has even led some authors to consider French speakers as being "stress deaf" (Dupoux, Sebastian-Galles, Navarrete, & Peperkamp, 2008). Therefore, in this study, all the syllables were pronounced with an identical monotonous prosodic contour (i.e., we used the same monotonous contour that also characterizes spoken French).

METHODS

Participants

Fifteen French-speaking children with SLI, aged 7–12 years (4 girls and 11 boys; mean age = 10 years 1 month [10;1 years]; *SD* = 1;6 years; range: 7;9–12;7 years); 15 typically developing children matched for chronological age, sex, and nonverbal reasoning (4 girls and 11 boys; mean age = 10;2 years; *SD* = 1;6 years; range: 7;7–12;7 years); and 15 typically developing children matched for receptive vocabulary (7 girls and 8 boys; mean age = 8;1 years; *SD* = 1;0 years; range: 6;0–10;1 years) participated in the study. The SLI group and the AC group were comparable in age, $t(28) = -0.21$, $p = .84$, and nonverbal reasoning, $t(28) = -0.21$, $p = .84$. They differed in their phonological, $t(28) = -3.48$, $p = .001$, and lexical abilities, $t(28) = -2.68$, $p = .01$. The SLI group and the language control (LC) group had the same level of receptive vocabulary, $t(28) = -0.20$, $p = .84$. However, they significantly differed in their phonological abilities, $t(28) = -3.01$, $p = .005$
[T1] (Table 1).

Children were recruited in schools in the city of Liege. Informed consent was obtained from the parents. All children came from families with low- or middle-class socioeconomic background, as determined by their parents' profession. All of the children were French native speakers, had no history of psychiatric or neurological disorders, and had no neurodevelopmental delay or sensory impairment. Children with SLI were recruited from language classes in special needs schools. They received a diagnosis of SLI by certified speech–language pathologists. Moreover, by using standard clinical tests, we ensured that all of the children with SLI met the following criteria. (1) They scored more than −1.25 *SD* below expected normative performance in two language areas (according to SLI criteria adopted by Leonard et al., 2007). Their phonological abilities were assessed using the word repetition task of the *Evaluation du Langage Oral*, which measures repetition performance for late acquired phonemes, complex phonological patterns, and multisyllabic words (Khomsi, 2001); their lexical abilities were measured by the French adaptation of the Peabody Picture Vocabulary Test (*Echelle de Vocabulaire en Images Peabody*; Dunn, Thériault-Whalen, & Dunn, 1993); their receptive grammatical abilities were measured by the French adaptation of the Test for Reception of Grammar (*Epreuve* [AQ8]
de COmpréhension Syntaxico-SEmantique; Lecocq, 1996); and their productive grammatical abilities were measured by the sentence production task of the *Evaluation du Langage Oral*, which measures production performance for complex grammatical forms such as auxiliary, verbal subject and tense agreement, or passive sentences (Khomsi, 2001). (2) The children demonstrated normal range nonverbal IQ (≥80) on the Wechsler In- [AQ9]
telligence Scale for Children–Fourth Edition (Wechsler, 2005; see Table 1). (3) All children showed normal range hearing thresholds, as determined by audiometric pure-tone screening at 20 dB HL at 500, 1,000, 2,000, [AQ10]
and 4,000 Hz. Control children scored in the normal range on all language tests. Moreover, all children demonstrated accurate phonological discrimination performances, as assessed by the French Phonemic Discrimination Task EDP 4–8 (Autesserre, Deltour, & Lacert, 1989). Finally we ensured that even if having significantly weaker phonological abilities as demonstrated by phoneme substitutions or omissions in the word repetition task, no children demonstrated articulatory problems. This was assessed by an inventory of phonemes where children had to repeat all French vowels, all French consonants followed by the vowel /a/ and French consonant clusters followed by the vowel /a/.

Table 1. Descriptive summary data for children with specific language impairment, age controls, and lexical controls [AQ11]

	Age (months)	PIQ	Phonemic Discrimination	EVIP	Word Repetition
Children with specific language impairment					
M	121	93.46	30.73	91.13	24.07
SD	18	8.95	1.16	21.59	8.12
Range	93–151	82–111	29–32	43–122	6–32
Age controls					
M	122	94.13	31.47	110.8	31.4
SD	18	8.72	0.74	18.53	0.74
Range	91–151	82–111	30–32	84–136	30–32
Lexical controls					
M	96	98.73	31.87	92.67	30.6
SD	13	14.98	0.35	19.91	2.23
Range	72–121	73–119	31–32	53–121	24–32

Note. EVIP = *Echelle de Vocabulaire en Images Peabody* (French version of Peabody Picture Vocabulary Test); PIQ = Wechsler Intelligence Scale for Children–Fourth Edition performance IQ.

Materials and procedure

Children performed eight STM conditions, varying lexicality, syllabic complexity, and perceptual load. Order of presentation of the tasks was counterbalanced within each group. Items varied in length from two to seven syllables, four items at each syllable length. Each task was split into two equal parts (each containing two items at each syllable length), to optimize the reliability of the estimate of a given child's performance level and to confirm the psychometric stability of the measures.

The following sections describe the syllabic material: 27 nonword syllables of the CV structure, 27 nonword syllables of the CCV structure, 27 word syllables of the CV structure, and 27 word syllables of the CCV structure (see the Appendix). The same syllables are used for the low and the high perceptual load conditions. For the low perceptual load condition (the serial syllable task, i.e., separate syllables presented serially), each syllable was recorded separately, with an equal neutral intonation across syllables, by a female speaker in an isolated acoustic booth using a high-quality microphone connected to a MiniDisc digital recorder. Syllables were then recombined electronically at the rate of 1 per second to create stimuli containing two to seven syllables and presented at the rate of 1 per second. For the high perceptual load condition (the multisyllabic task), each multisyllabic stimulus was recorded separately using an equal neutral intonation across syllables, resulting in stimuli containing concatenated syllables with intersyllable coarticulation effects, as is the case for typical NWR stimuli. No phoneme was repeated within a sequence.

Nonword syllables

Syllables were of the CV or CCV structure. Consonant–vowel stimuli respected French phonotactic rules, but diphone combinations were of relatively low familiarity relative to the phonological structure of French (mean diphone frequency: 261; range: 7–1,447; Tubach & Boë, 1990) in order to minimize the possibility of relying on lexical knowledge (frequent diphones typically have a higher lexical neighborhood; Vitevitch & Luce, 1999). Twenty-seven syllables were created, each syllable being presented equally often at each session. Twenty-seven CCV stimuli were also characterized by diphone combinations of relatively low familiarity (mean diphone frequency of the consonant–consonant (CC) segment: 809; range: 78–3,083; mean diphone frequency of the CV segment: 724; range: 33–2,292; Tubach & Boë, 1990). However, when treating each syllable as a unit, the mean frequency of the CV syllables (mean CV-diphone frequency: 1,456; range: 78–7,645; Gendrot, Adda-Decker, & Schmid, 2012) was higher than the mean frequency of the CCV syllables (mean CCV-triphone frequency: 152; range: 1–965; Gendrot et al., 2012), as expected.

Word syllables

Word syllables were also of CV or CCV structure. Twenty-seven CV words were of high lexical frequency (mean: 23 978; range: 2,856–90,926; Novlex French Database, Lambert & Chesnet, 2001) to ensure that they were familiar to every child. Second, they were matched on diphone frequency to the nonword syllables (mean diphone frequency: 260; range: 2–1,320; Tubach & Boë, 1990), $t(52) = 0.008$, $p = .99$, to ensure that lexicality rather than sublexical phonological knowledge explains the difference between performance in recalling word and nonword syllables. Third, consonant and vowels composing the word syllables were matched to those of the created nonword syllables in order to ensure that nonword syllables were not more phonologically/articulatory complex than word syllables. Twenty-seven CCV word syllables met the same criteria: They were of high lexical frequency (mean: 24,831, range: 1,666–94,497; Novlex French Database, Lambert & Chesnet, 2001), and were matched on diphone frequency to the nonword syllables (mean diphone frequency of the CC segment = 809, range = 78–3,083; mean diphone frequency of the CV segment = 751; range = 19–2,655; Tubach & Boë, 1990; for CC segment: $t(52) = 0.00$, $p = 1.00$; for CV segment: $t(52) = -0.12$, $p = .90$). Moreover, the cluster consonants were the same for word as for nonword syllables, and the vowels composing the word syllables were matched to those of the nonword syllables. Finally, the CV and CCV words were matched on lexical frequency, $t(52) = 0.14$, $p = .89$.

Procedure

The task was presented using E-Prime 1.0 Psychology Software (Schneider, Eschmann, & Zuccolotto, 2002). The 27 word-CV syllables, nonword-CV syllables, word-CCV syllables and nonword-CCV syllables were first presented separately to the child in order to ensure that each syllable was accurately repeated in isolation. To ensure that the child was aware of the lexical status of the stimuli to repeat, four different stories were created. For the word low perceptual load condition, the child was told that he or she had to help a parrot to learn to speak French and to become a real grownup parrot by repeating the different French words it had to learn. For nonword low perceptual load condition, the child was told that an extraterrestrial had lost his friends. The child was asked to repeat the extraterrestrial words to help it to call his friends. For the word high perceptual load condition, the child was told that he or she was a spy on a top-secret mission. He or she had to give secret messages containing words stuck together to his spy-friend. Finally, for the nonword high perceptual load condition, the child was told that he or she was an adventurer who had to open multiple castle doors to deliver a princess and that each door opens with a new magical password. In each task, the child was informed when stimulus length increased. The same stories were used for CV and CCV syllables. The child completed first the tasks with CV syllables and then the tasks with CCV syllables. Each task was split into two equal parts (each containing two trials for each sequence length), administered in two different sessions over a 1-week period in order to confirm the psychometric stability of the measures.

Responses were transcribed online, tape recorded, and later transcribed and scored for accuracy. Recall accuracy was scored at the syllable level, using a strict serial order criterion. Fifteen protocols were transcribed phonetically by a second listener. Interrater reliability yielded 96% agreement.

RESULTS

Each task showed moderate to high test-retest reliability estimates, as reflected by the correlation of each participant's score on its first and second administration (Table 2).

[T2] The number of syllables accurately repeated for each task, by pooling over the different list lengths, was subjected to a mixed analysis of variance to answer the primary questions about the impact of three linguistic factors on performance. The between-subjects factor was participant group (children with SLI, lexical controls, or age controls); the within-subjects factors were syllabic complexity (CV or CCV), lexicality (words or nonwords), and perceptual load (multisyllabic [high load] or serial syllables [low load]).

Group effect

Results revealed a main effect of group, $F(2, 42) = 15.25$, $p < .001$, partial $\eta^2 = .42$. Newman-Keuls post hoc analyses revealed that the SLI group performed significantly worse than the LC group ($p < .001$) and the AC group ($p < .001$); the LC and AC groups did not differ ($p = .68$).

Syllabic complexity effect

A main effect of syllabic complexity was found, performance being higher for CV syllables than for CCV syllables, $F(1, 42) = 328.53$, $p < .001$, partial $\eta^2 = .87$ (see Table 2). Furthermore, the Group × Syllabic Complexity effect was significant, $F(2, 42) = 8.37$, $p < .001$, partial $\eta^2 = .28$. Newman-Keuls post hoc analyses showed that syllabic complexity influenced performance in all groups (SLI, $p < .001$; LC, $p < .001$; AC, $p < .001$). At the same time, the effect of syllabic complexity was smaller in children with SLI (partial $\eta^2 = .55$) than in the LC (partial $\eta^2 = .79$) and AC (partial $\eta^2 = .75$) groups (Figure 1). [AQ12] [F1]

Lexicality effect

A main effect of lexicality was found, performance being higher for real-word than nonword syllables, $F(1, 42) = 124.82$, $p < .001$, partial $\eta^2 = .75$ (see Table 2). The Group × Lexicality Effect was not significant, $F(2, 42) =$

Table 2. Descriptive statistics and test–retest reliability estimates for response accuracy for each experimental condition as a function of participant group for children with specific language impairment, age controls, and lexical controls

			M (SD)			
Syllabic Structure	**Lexicality**	**Perceptual Load**	**Children With Specific Language Impairment**	**Age Controls**	**Lexical Controls**	**Internal Reliability**
CV	Word	Low	39.73 (15.99)	61.13 (9.41)	57.53 (16.82)	$r = .75$
		High	51.07 (14.18)	73.3 (11.41)	76.13 (14.6)	$r = .89$
	Nonword	Low	32 (16.48)	52.67 (9.98)	51.2 (14.18)	$r = .78$
		High	49.87 (16.25)	76.67 (13.05)	78.8 (14.45)	$r = .89$
CCV	Word	Low	31.93 (11.37)	47.07 (13.47)	40.27 (12.36)	$r = .79$
		High	32.6 (12.09)	52.67 (9.02)	48.87 (16.44)	$r = .87$
	Nonword	Low	20.8 (6.78)	31.6 (7.45)	29.53 (9.69)	$r = .56$
		High	27.33 (9.8)	38.33 (9.19)	38.73 (9.14)	$r = .73$

Note. CCV = consonant–consonant-vowel; CV = consonant–vowel.

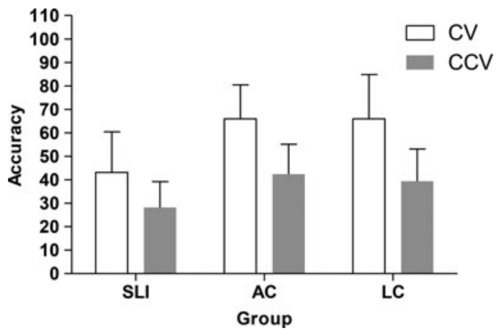

Figure 1. Syllables accurately repeated in each group as a function of syllabic complexity. AC = age controls; CCV = consonant–consonant-vowel; CV = consonant–vowel; LC = lexical controls; SLI = children with specific language impairment.

1.76, p = .18, partial η^2 = .08. The Group × Syllabic Complexity × Lexicality Effect, however, was significant, $F(2, 42) = 4.21$, p = .022, partial η^2 = .17 (Figure 2). Tukey post hoc analyses revealed that for CV syllables, performance was not significantly affected by lexicality (SLI, p = .14, partial η^2 = .19; LC, p = .98, partial η^2 = .04; AC, p = .83, partial η^2 = .07). For CCV syllables, performance was affected by lexicality in all groups ($p < .001$): At the same time, the effect of lexicality was less important in children with SLI (partial η^2 = .38) than in the LC (partial η^2 = .49) and especially the AC (partial η^2 = .67) groups.

[F2]

Perceptual load effect

A main effect of perceptual load was found, performance being higher for the high per-

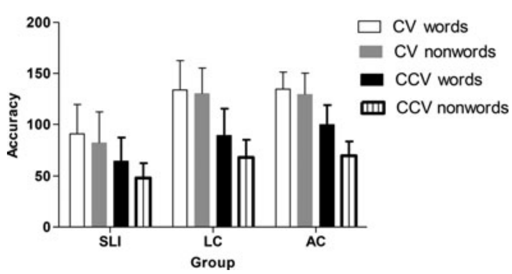

Figure 2. Syllables accurately repeated in each group as a function of syllabic complexity and lexicality. AC = age controls; CCV = consonant–consonant-vowel; CV = consonant–vowel; LC = lexical controls; SLI = children with specific language impairment.

ceptual load condition (mutlisyllabic nonword) versus the low perceptual load condition (serial syllables), $F(1, 42) = 95.43$, p < .001, partial η^2 = .69 (see Table 2). The Group × Perceptual Load interaction effect was not significant, $F(2, 42) = 2.47$, p = .09, partial η^2 = .11.

In sum, children with SLI performed overall worse than their lexical- and age-matched controls. They showed lower effects of syllabic complexity and lower effect of lexicality when syllabic complexity was high, but comparable perceptual load effects, than their typically developing peers.

Interaction effects for between-subject factors

The following section presents all remaining two-way and three-way interaction effects in which the group factor had no role.

A significant Lexicality × Perceptual Load interaction effect was found, $F(1, 42) = 26.55$, $p < .001$, partial η^2 = .39. Newman-Keuls post hoc analyses showed that lexicality affected both multisyllabic nonword ($p < .001$) and serial syllables ($p < .001$) whereas the lexicality effect was more important in serial syllables (i.e., the low perceptual load, partial η^2 = .76) than in multisyllabic nonwords (i.e., the high perceptual load condition, partial η^2 = .36). This effect was expected, because the phonological information is already partially segmented in serial syllabic condition, facilitating the matching of perceived units and lexical representations.

A significant Syllabic Complexity × Lexicality Interaction effect was also found, $F(1, 42) = 46.10$, $p < .001$, partial η^2 = .52. Newman-Keuls post hoc analyses showed that CV (p = .001) and CCV syllables ($p < .001$) were both affected by lexicality. At the same time, CCV syllables (partial η^2 = .77) were affected to a greater extent than CV syllables (partial η^2 = .24). It appears that lexicality especially supports the retention of complex syllabic structures.

Furthermore, a significant Syllabic Complexity × Lexicality × Perceptual Load interaction effect was found, $F(1, 42) = 9.19$,

p = .004, partial η^2 = .18 (Figure 3). Tukey post hoc analysis revealed that for the high perceptual load condition, CV syllable performance did not interact with lexicality (p = .82) whereas the interaction effect was significant for CCV syllables (p < .001). This effect was not expected. Again, it seems that lexicality significantly improves repetition when complex structures are being retained.

[F3]

Finally, a significant Syllabic Complexity × Perceptual Load interaction effect was found, F(1, 42) = 86.51, p < .001; partial η^2 = .67. Newman-Keuls post hoc analyses showed that syllabic complexity interacted with perceptual load in both high (p < .001) and low (p < .001) perceptual conditions. At the same time, the interaction effect was more important in the high perceptual condition (multisyllabic nonword, partial η^2 = .98) than in the low perceptual load condition (serial syllables, partial η^2 = .79). Because consonants are harder to perceive and harder to articulate in consonant clusters, this syllable complexity effect was especially expected for multisyllabic nonwords where segmentation processes are already heavily solicited at the nonword level. The remaining effects (the Group × Condition × Syllabic Complexity effect, the Group × Condition × Lexicality Effect, and the four-way interaction effect) were not significant. However, these null effects need to be considered with caution, given the moderate sample size and ensuing limited statistical power for high-level interactions.

In sum, the between-subjects factors interaction effects show a larger lexicality effect in the low than high perceptual load conditions, no association of lexicality with performance on CV syllables in the high perceptual load condition, and a larger association of syllabic complexity with performance in the high perceptual load condition.

DISCUSSION

Our study aimed at providing a detailed exploration of the association of linguistic factors with performance in verbal repetition and maintenance tasks in children with SLI. We manipulated lexicality, syllabic complexity, and perceptual load in verbal repetition tasks. We observed that overall children with SLI performed worse than the lexical- and age-matched groups. Following the phonological STM deficit hypothesis, we expected a lower impact of perceptual load and a larger impact of lexicality. However, the SLI group was affected by perceptual load to the same extent whereas the lexicality effect was diminished as compared with control groups. Following the phonological segmentation deficit hypothesis, we expected both a larger perceptual load effect and a larger syllabic complexity effect than their typically developing peers. However, the SLI group was affected by perceptual load to the same extent whereas the syllabic complexity effect was diminished as compared with control groups. Following

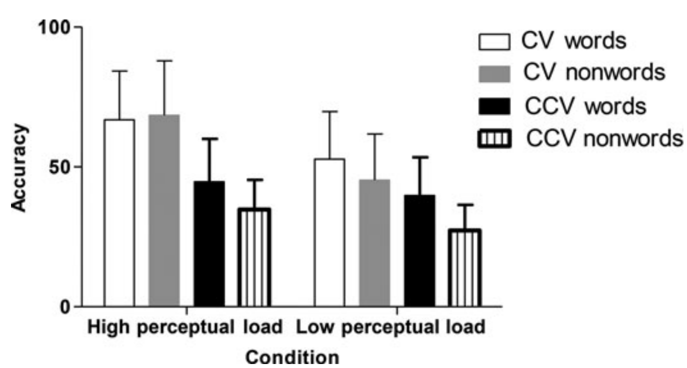

Figure 3. Syllables accurately repeated (all groups collapsed) as a function of condition, syllabic complexity, and lexicality. CCV = consonant–consonant-vowel; CV = consonant–vowel.

the phonological knowledge deficit hypothesis, we expected a lower impact of lexicality and syllabic complexity in the SLI group than the control groups. This is what we observed: Children with SLI showed diminished lexicality and syllabic complexity effects on performance.

The impact of syllabic complexity on NWR in SLI

Syllabic complexity affected children with SLI to a lesser extent than control children. Note that this was not due to floor effects, performance for CCV syllable stimuli in SLI children being normally distributed and showing similar variance as in the control groups. The fact that they are less affected by syllabic complexity suggests more poorly developed knowledge of the statistical properties of French syllables, and thus more poorly developed phonotactic knowledge, or their poorer ability to access this knowledge.

This is, however, in contrast with previous studies that showed that NWR in children with SLI varies with the presence of consonant clusters to a greater extent than in typically developing children (Bishop et al., 1996; Briscoe et al., 2001; Gallon et al., 2007; Marshall & van der Lely, 2009). These discrepant findings may be related to differences in stimulus design. In the studies by van der Lely and colleagues (Gallon et al., 2007; Marshall & van der Lely, 2009), the syllable complexity manipulation concerned both the syllabic complexity and the metrical complexity of the nonwords and hence metrical complexity rather than syllable complexity may explain the pattern of results observed in these studies. As explained in the "Introduction" section, we decided not to manipulate prosody because stress patterns are far less important for speech processing in French than in English (Dupoux et al., 2008). Furthermore, in the studies by Bishop and colleagues (Bishop et al., 1996; Briscoe et al., 2001), both CV and CCV syllables varied in wordlikeness. Wordlikeness is related to phonotactic probability (e.g., Munson, 2001): Nonwords whose constituent syllables are more frequent are rated as more wordlike than nonwords whose constituent syllables are less frequent. Consequently, the differences in performance between the CV and CCV syllables in Bishop and colleagues' studies do not reflect differences in phonotactic frequency as is the case in the present study.

The impact of lexicality on NWR in SLI

We observed a main effect of lexicality in all three groups for repeating CCV syllable stimuli. On the one hand, these results confirm that lexicosemantic representations support performance in phonological tasks for children with SLI as they do in typically developing children (Majerus et al., 2003; van der Lely & Howard, 1993). At the same time, the lexicality effect, even if present, was reduced in children with SLI, especially for repeating CCV syllables. These results do not support a problem in phonological STM capacity per se as underlying poor NWR performances in children with SLI because an increased lexicality effect had been expected in that case. The decreased impact of lexicality rather indicates difficulties in matching the acoustic input to phonological patterns in long-term memory, either because of access difficulties or because of less developed lexical long-term memory representations. Given that this effect of lexicality was lower in younger children matched on receptive lexical knowledge than in children of the SLI group, our results are most compatible with access difficulties rather than reduced lexical knowledge. This interpretation is also congruent with Service's (2006) proposal that noisy representations in STM are a sign of inadequate mapping with stored phonological knowledge.

The impact of perceptual load on NWR in SLI

Children with SLI were affected to the same extent by perceptual load as control children: The stimuli that were most difficult to process (multisyllabic nonwords) at the level of perceptual segmentation and identification did not lead to a proportionally lower performance on nonwords in SLI children than in control children. Like in Archibald and Gathercole (2007b), children with SLI benefited from the coarticulatory cues that characterize multisyllabic nonwords, although this advantage was reduced relative to the control children in the Archibald and Gathercole study but not in the present study. A possible explanation for this difference in results may be related to differences in stimulus construction: Archibald and Gathercole exclusively used CV syllables, and only stimuli with three and four syllables were included in the analyses. To check for the impact of these differences in stimulus design and analysis, we performed the same analyses as Archibald and Gathercole, by restricting our analyses to stimuli containing three or four CV nonword syllables. However, we still did not observe a disproportionate impairment in the high perceptual load condition for our SLI group (Group × Perceptual Load interaction effect): $F(2, 42) = 0.28$, $p = .76$. Thus, in the present study and for the present sample of French-speaking children, difficulties in dealing with perceptual load does not seem to lie at the root of poor NWR in children with SLI. These contrasting results may also be related to the larger dependency upon prosodic cues during speech segmentation in English than in French. Archibald and Gathercole suggested that children with SLI were less able to process the prosodic cues associated with concatenated nonword syllable stimuli. As we know, these cues play no role during segmentation processes in French (Nazzi et al., 2006). In any case, the present data show that the French-speaking SLI children in this study did not have any difficulties in identifying and using the coarticulatory cues associated with multisyllabic NWR.

CLINICAL IMPLICATIONS

The present data have interesting implications for the training of verbal repetition and STM capacity in children with SLI. To date, the strategy typically proposed to enhance phonological STM capacity in children with SLI is the training of verbal rehearsal and hence the stimulation of maintenance processes per se (e.g., Montgomery, Magimairaj, & Finney, 2010). Only few studies have addressed the question of the efficacy of such a strategy (Gill, Klecan-Aker, Roberts, & Fredenburg, 2003). The present findings, highlighting difficulties in accessing lexical and sublexical knowledge that normally supports maintenance and repetition performance during NWR tasks, suggest that a more appropriate strategy may be the consolidation of lexical and sublexical phonological knowledge and the training of fast access to this information when processing complex novel verbal material. For example, this could be done by helping children to identify the similarities and dissimilarities between novel words and already known words. Future studies will need to compare traditional STM drill techniques with consolidation/access of phonological knowledge training procedures when trying to stimulate phonological STM performances.

CONCLUSION

Overall, our results show two main findings in children with SLI: A lower impact of lexicality and a lower impact of syllabic complexity on verbal repetition performance, which, in the present case, actually reflects a syllable frequency effect. These results are compatible with difficulties in accessing lexical and sublexical phonological representations stored in long-term memory to support short-term storage of verbal information. Hence, poor NWR performance in SLI may actually reflect long-term memory access deficits in the context of a highly challenging cognitive task such as NWR rather than a basic phonological STM impairment. Also, our results discard perceptual and segmentation deficits as underlying poor NWR performance. However, these findings may be restricted to nonstress languages such as French and stress-based languages such as English may lead to different findings, calling for multilinguistic studies of SLI.

The present results show that minor differences in accessing lexical information may interfere with short-term storage of new phonological sequences. More generally, they also support the proposal that there is a specific link between lexical access difficulties and difficulties in processing new phonological sequences (i.e., McGregor, 1997). Consequently, language therapies targeting repetition and learning of phonological information could benefit from optimizing access to existing lexical structures, which then, can be used more efficiently to support processing of novel phonological structures, at least for those structures where such a support is possible.

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