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Phonological representations

in children with SLI: A study of French

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Abstract

The present research examined the quality of the phonological representations of French children with specific language impairment (SLI) and those with normal language development (NLD). Twenty-five children with SLI and fifty normally developing children matched on lexical age level participated in an auditory lexical decision task. The observations gathered in our study can be summarized as follows. First, children with a higher receptive lexical level performed better, and this was true both for children with NLD and children with SLI. Second, both children with NLD and SLI were more likely to reject pseudo-words resulting from a modification affecting the number of syllables of a word than pseudo-words resulting from a slight modification with the number of syllables unchanged. This difference, however, was greater for the children with SLI who appeared to have much difficulty rejecting pseudo-words resulting from slight modifications. Finally, the performance of children with SLI was particularly poor when presented with pseudo-words resulting from a slight modification at the beginning or the end of a word. These findings are interpreted as supporting the hypothesis of an underspecification of phonological representations in children with SLI.

Key words: specific language impairment, phonological representations, SLI

Phonological representations in children with SLI: A study of French

It is generally assumed that the phonological information of words is stored in an individual's lexicon in the form of phonological representations. Various studies have shown that the quality of these representations constitutes a determining factor of a child's linguistic ability; this has been clearly demonstrated, for example, in several studies devoted to language development in deaf children (Alegria, 1998). However, the construction process of these phonological representations still remains poorly understood, particularly in the case of children presenting specific language impairment (hereafter SLI).

The idea that phonological representations are progressively constructed is not accepted by all theoretical views of language development. According to more traditional views, for example, very young children are supposed to perceive, produce and represent speech in terms of phonemic categories: young children's phonological representations are supposed to be specified as early as birth and are thought to be equivalent to adults' phonemic forms. Such a view generally looks for support in the abundant literature devoted to infants' and young children's discrimination abilities (see Aslin, Jusczyk & Pisoni, 1998 for a review). However, it must be noted that important discrimination abilities, as reported in the literature, do not imply that children's early phonological representations are as well defined as those of adults. Discrimination, which essentially uses immediate memory, should not be confused with categorization, which implies storage in long-term memory. Actually, it must be kept in mind that a child might be able to differentiate between two adjacent stimuli and yet be unable to identify phoneme constancy (Bird & Bishop, 1992). On the contrary, in more recent views, the idea that phonological representations would consist of strictly segmental units from the very beginning is quite questionable; both the construction and the specification of these representations are currently conceived as progressive processes, which start in early childhood and last until explicit access to phonemic awareness is facilitated by the beginning of literacy.

Phonological representations of normal children

From birth onwards, infants are able to discriminate between almost all the consonantic contrasts of their native languages, as well as those of unfamiliar languages (Eimas, Siqueland, Jusczyk & Vigorito, 1971). As the baby grows, this equipotentiality is progressively replaced by a sensitivity to those contrasts that are relevant in the child's language environment: at 10 months, babies have already achieved a first reorganization of their phonological system (Werker & Tees, 1984). Learning their first words will induce a decrease in attention paid to the phonetic details. Stager and Werker (1997), for instance, reported that 14-month-old infants, but not 8-month-old-infants, process less phonetic detail when they are learning words than when they are simply listening to how those words sound. Similarly, in a study using a High Amplitude Sucking paradigm, Halle and de Boysson-Bardies (1996) have shown that phonemic deformations, e.g., *biberon* – *piberon* in French (approximate English equivalent: feeding-bottle – veeding-bottle), did not impair the recognition of words by children aged 11 months. When access to meaning is necessary, older children pay less attention to the phonetic details. This could reflect the fact that a fine processing of segmental information exceeds the attentional and mnemonic capacities of these children (Werker & Tees, 1999). Losing phonetic details could be considered to correspond to a second, more functional perceptual reorganization. A third developmental phase would take place after the lexical burst (i.e., around 18-20 months of age); indeed, with more and more entries in the lexicon, which enlarges very quickly, the encoding of finer representations, which allow the child to discriminate between similar words, is more and more likely to occur (Werker & Tees, 1999; see also Swingley & Aslin, 2000 for a confirmation).

Several researchers support the idea that vocabulary growth plays a determinant role in the restructuring of phonological representations (Juszyck, 1993; Metsala, 1999; Metsala & Walley 1998; Werker & Tees, 1999). With a quickly enlarging vocabulary, children are more often confronted with similar sounding words (i.e., tree and tea) that they must be able to store in long-term memory under distinguishable forms. Metsala and Walley (1998) proposed a Lexical Restructuring Model, in which vocabulary growth is responsible for the increasing specification of phonological representations. Two claims of this model are particularly important to the questions addressed in the present study: 1) young children recognize words in a more holistic manner than older children or adults because the recognition of a word is influenced by the size of the receptive lexicon; 2) the lexical restructuring is gradual and word-specific, depending both on global factors (e.g., overall vocabulary size) and local ones (e.g., familiarity or phonological similarity of words). These claims have been supported by evidence reported in several studies. For instance, the difference between the word recognition of adults and children was confirmed by a mispronunciation detection task (Walley, 1987, 1988) as well as by a gating paradigm (Walley, Michela & Wood,1995).

Phonological representations in children with SLI

In contrast to our understanding of how phonological representations are progressively elaborated by normally developing children (NLD), our comprehension of what such representations consist of in children with SLI remains quite limited. There has been considerable interest in production by those with phonological disorders (for a review see Leonard, 1998), but available data do not allow specifying the extent to which these disorders are to be attributed to poor quality phonological representations or to some deficit in the production process. Although many different factors can explain these disorders (see below), Edwards and Lahey (1998) suggest that the disorders of children with SLI could be particularly related to the quality of their phonological representations. In their study, using a repetition task, children with SLI aged 4 to 10 years appeared to have poorer phonological representations than NLD children matched on age. The authors discussed several explanations for this difference: differences in auditory discrimination, forming and holding phonological representations in working memory, or motor planning and execution. Little evidence was found to support an explanation in terms of auditory discrimination (the two groups of children did not differ on the percentage of errors for the phonemes which were expected to be difficult to discriminate) or in terms of motor planning and execution (the latency of the responses was comparable in the two groups, and there were no significant difficulties on late-learned sound classes).

The observations reported by Edwards and Lahey (1998) were, however, compatible with the idea that the difference between the two groups is due mainly to the difficulties experienced by children with SLI when forming or holding phonological representations in working memory. Indeed, the fact that children with SLI made more errors of syllable structure and produced a higher percentage of phoneme deletions than their peers can be interpreted as resulting from difficulty in forming a finely detailed representation and/or in holding this representation in working memory. According to Edwards and Lahey, these observations support the idea that the phonological representations of children with SLI could be more holistic, and therefore more similar, to younger NLD children’s representations. In reference to limited-capacity processing theories (Kail, 1994), they qualified this explanation as follows: children with SLI could have no difficulty forming appropriate phonetic representations but, under overload condition, they would revert to earlier, more holistic forms of representation. Extending this argument to include phonological representations, children with SLI would be able to form accurate phonological representations but would have to work harder to form these representations, resulting in an overload of their systems.

Another study by Edwards and Lahey (1996) examined children's recognition performances. Comparing 4- to 9-year-old SLI and normal children's performance in a lexical decision task for auditorily-presented materials, these investigators showed that children with SLI answered significantly more slowly than their normally developing peers. Edwards and Lahey's (1996) study, however, did not allow the clear identification of the source of these response latency differences; indeed, the differences could be explained by a less fine-tuned phonetic representation, affecting the speed of word recognition, but they might also be due to a generalized slowness of children with SLI particularly stressed by a task involving metalinguistic processes and phonological processing. A study by Dollaghan (1998), however, provided evidence that supports the former explanation. Using an auditory gating paradigm, the author showed that children with SLI (6- to 10-year-olds) required a significantly larger portion of the acoustic signal than their peers to recognize unfamiliar words, while the difference in performance on familiar words did not reach a significant level. Furthermore, the processing of word-initial information appeared to be globally less accurate for the SLI group. According to Dollaghan, these findings suggest that word recognition processes are vulnerable when processing demands are increased, as is the case when accessing recent representations in lexical memory or distinguishing them from previously established ones. Moreover, the fact that children with SLI also were less successful than their peers in identifying initial consonants suggests that these apparent representational deficits are accompanied by lower level speech perception deficits.

To summarize, the literature suggests that children with SLI could suffer from an underspecification of their phonological representations. However, most of the studies that led to such an assumption (except Edwards & Lahey, 1996) used control children matched on chronological age. To generalize such a conclusion, it is necessary to compare children matched on receptive lexical level. If phonological restructuring is driven by lexical development, particularly vocabulary growth (Metsala & Walley, 1998), the difference between children with SLI and children with NLD matched on receptive lexical level should disappear.

Thus, the present study aimed to investigate more precisely the quality of phonological representations in children with SLI by comparing their performances to those of children matched on vocabulary size. Unlike previous studies, which dealt mainly with children's recognition or production abilities, our study focused on the quality of their phonological representations. Secondly, a lexical decision task was used to explore phonological representations: the children were asked to decide whether or not a spoken phonetic sequence was a real word. This type of task is known to induce heavy demands on phonological processing (Edwards & Lahey, 1996). In our study, these demands were voluntarily manipulated to assess the underlying phonological representations: pseudo-words were created by making both slight and important phonological modifications to existing words. Thirdly, this task was administrated to children with SLI or NLD, distributed in different subgroups depending on their lexical age. Finally, contrary to previous studies, which were all restricted to English, our study examined native French-speaking children and took advantage of some important differences between the two languages (e.g., presence or absence of a syllabic tonic accent) to verify whether previous conclusions could be generalized.

The present study aimed at answering to the following questions:

A. Are phonological representations more holistic and less fine-tuned for children with SLI than for normally developing children matched on receptive lexical age? If the quality of phonological representations is determined by lexical development, as suggested by the

Lexical Restructuring Model (Metsala & Walley, 1998), there should not be any difference between children with SLI and NLD matched on receptive level. On the contrary, if children with SLI have less well-specified phonological representations than children with NLD, their performance on a lexical decision task should be poorer than that of NLD children.

B. Are phonological representations of children with SLI refined as a function of their lexical age as is the case for NLD children? If they are refined with age, SLI children with a higher lexical age should perform better at a later age; the same prediction holds true for children with NLD.

C. Is phonemic and syllabic information similarly encoded in the phonological representations of both populations? If syllabic information is better encoded, modifications of words affecting the number of syllables should be better detected than modifications that preserve the number of syllables.

D. Is there any part of the phonological representations where the information would be better defined?

Method

Participants

Seventy-six school-age children participated in this study, including 25 children with SLI and 51 NLD control children.

Children with NLD. All control participants were recruited from schools in the French-speaking part of Belgium. These children were learning French as native language and none were experiencing substantial exposure (more than 7 hours per week) to a second language (criteria adopted from Marchman, Wulfeck & Ellis Weismer, 1999). According to the teacher's report and background information supplied by parents, they had no history of speech, language or hearing problems, nor any exceptional needs. They were between the ages of 4;4 and 7;3 (years; months) and were in kindergarten or 1st grade.

*Children with SLI***.** These children were recruited from special education language classes for children with SLI in the French-speaking part of Belgium. All children had been previously diagnosed as language impaired by a multidisciplinary team. The diagnosis included a medical exam (audition and vision), as well as neuropsychological and speech-language investigations. They scored in the average range on either the Leiter International Performance Scale (Roid & Miller, 1993) or the non-verbal scale of the Weschler Intelligence Scale for Children (WISC III, Weschler, 1996). The children also demonstrated hearing and oral motor functioning within normal limits and showed no signs of emotional disturbance. At the time of the study, these children ranged in age from 6;4 to 12;3 were administrated a large set of norm-referenced tests and experimental tasks investigating spontaneous language, phonology, vocabulary, morphosyntax and verbal memory. According to the classification of Evans (1996), all the children of this study can be considered as ER-SLI, i.e., they presented both expressive and receptive impairment. They performed under **–**1.5 SD from the mean on the French version of Test of Reception of Grammar (ECOSSE, Lecocq, 1996), and they presented important expressive disorders.

Lexical subgroups. Both SLI and NLD children were distributed into different subgroups on the basis of their receptive vocabulary level, which was assessed with the French version of the Peabody Picture Vocabulary Test-Revised (Dunn, Thériault-Whalen & Dunn, 1993). Both SLI and NLD participants were subdivided into three subgroups according to whether their lexical age was 5, 6 or 7 years (hereafter NLD5 or SLI5 refers to NLD and SLI children with a 5-year-old lexical age, respectively and so forth). This repartition was submitted to an analysis of variance, with raw score on PPVT-R as the dependant variable, to check the group matching. As expected, an effect for vocabulary was observed, F (1, 72) = 85.89, $p < .001$, but the effect of group, F (1, 72) < 1, and the interaction between group and vocabulary, F (2, 72) = 1.07, $p < .34$, did not reach the level of significance. Moreover, a signal detection analysis (Macmillan, 1993) was applied in order to detect children who might have showed a tendency to answer “yes” or “no” to all items, regardless of the stimuli. With this criterion, 3 children with NLD were excluded but none of the children with SLI were excluded. In summary, 73 children matched on lexical level were selected for participating in this analysis (n= 25 SLI and 48 NLD). Table 1 displays more details about the participants.

Table 1 about here

Materials

Forty-eight very frequent multisyllabic words were selected from the Novlex database, which reports the frequency of French words normally encountered by school-aged children (see Lambert & Chesnet, 2001); the mean frequency of these words was 40.37 per million. The words were separated into two sets in such a way that each word of the first set matched a word of the second set in regard to both its frequency and phonemic structure. For example, “*pantalon*” (trousers), freq. = 64.26 per million, phonemic structure of CVCVCV was matched with “*magasin*” (shop), freq. = 61.88 per million, CVCVCV. The words of the first set were used without modification, while the words from the second set were manipulated to obtain pseudo-words. Three independent variables were examined: 1) *size of the modification*: in half the pseudo-words, the number of syllables in the original word was retained (slight modification, e.g., pseudo-word *antalon* from the word *pantalon*). In the other half, this number was not retained (important modification, e.g., pseudo-word *mino* from the word *domino*); 2) *position of the modification*: the position of the modification was counterbalanced: 1/3 in initial position, 1/3 in medial and 1/3 in final position; 3) *type of modification*: half the pseudo-words were constructed by adding elements (phoneme or syllables) to the original words, while the other half were constructed by deleting elements from the original words. This control variable was added to avoid easy detection of the nature of the modification. All pseudo-words followed French phonotactic constraints and were controlled for phonological neighborhood. In addition, all pseudo-words were presented to independent adults who were then asked to guess from which words the pseudo-words arose, with the intend of avoiding pseudo-words too distant from the target word. Examples of the materials are presented in Table 2. The full set of materials can be requested from the first author.

Table 2 about here

Procedure

The experimental task and assessment measures used in the present study were completed within two sessions, each lasting approximately thirty minutes. Every child was tested individually, both at school and in a quiet room. The participants were told that they would be presented with vocal items and were instructed to say “yes” when they heard a real word and “no” when they heard a pseudo-word. No temporal constraints were imposed, and twelve practice items were presented to familiarize the children with the task. Feedback was given during training, but not during experimental tasks. The 48 stimuli were randomly presented, but the same random order was used for every child. The only restriction to this random presentation was the avoidance of four successive matching answers. At the beginning of the task, the instructor said, “You are going to listen to somebody who says some words. Sometimes, he makes a joke. He says words that do not exist in French. Each time you hear a real word – a word that you know- you say ‘yes’. If it is an invented word, you say ‘no’. For instance, if you hear ‘*chaise*’ (chair), you say ‘yes’ because it is a word that you know, but if you hear ‘*festoule*’, you say “no”. Do you understand? Let’s try again. If you hear ‘*balançoire*’ (swing), what do you say?”.

Initially, we wanted to use computerized stimuli in order to standardize the conditions of presentation. However, a pretest with 5 children with NLD and 2 children with SLI, who were not included in the current study, showed that children rejected more words in a computer presentation than they did when the materials were presented orally by an experimentor. This could be due to the absence of lip-reading in a computer presentation condition; the use of visual cues to aid discrimination is well documented (e.g., Bishop, Byers Brown & Robson, 1990), especially in children with SLI whose fine auditory difficulties are established (Tallal et al., 1996). It was therefore decided to allow children to use lip-reading in the present study; test items were presented orally by an experimentor who was trained to pronounce the stimuli in a constant way, which is fairly simple in oral French because there is no tonic accent.

Results

The analysis followed the logic of signal detection theory. For words, any “*yes*” answer was considered as a *hit* and any “*no*” answer a *miss*. For pseudo-words, any “yes” answer was considered a *false alarm* and any “no” answer as a *correct rejection*. Participants’ performance can be described completely by two values (Macmillan, 1993): the hit rate (hereafter HIT) and the false-alarm rate (hereafter FA). A sensitivity index (*d*') was calculated by subtracting the Z-score of FA from the Z-score of HIT. Figure 1 presents an illustration of the data as a sensitivity index for children with SLI and children with NLD as a function of their lexical age.

Figure 1 about here

Participants' performances on the lexical decision task were globally assessed; the respective contributions of real and pseudo-words were assessed, as were the contributions of lexical and chronological age. Further analyses focused on the participants' performance on pseudo-words, as the modifications that are accepted or rejected should provide interesting information about the quality of phonological representations of the children with SLI and NLD.

General analysis

After being assured that the GLM assumptions were met –homogeneity of variances revealed no significant differences across the different subgroups, F (5, 67) = 2.31, $p < .06$)–, an analysis of variance was performed on the *d*' values, with group (NLD vs. SLI) and lexical age (5,6, or 7) as between-subjects independent variables. An effect of group was observed, F (1, 72) = 8.34, $p < .01$, $\eta^2 = .10$; the performances were higher in the NLD group (M = 2.76; SD = 1.11) compared to the SLI group (M = 2.27; SD = 0.6). There was also a significant effect of lexical age level, F (2, 72) = 14.43, $p < .001$, $\eta^2 = .29$; post hoc analyses revealed that 6- and 7-year-olds (lexical age) performed better than 5-year-olds, but that 6- and 7-year-olds did not differ. The group by lexical age level interaction was marginally significant, F (1, 72) = 2.98, $p < .06$, $\eta^2 = .03$. The effect of lexical age level was also highly significant in the NLD group, F (2, 47) = 18.49, $p < .001$, $\eta^2 = .44$, but failed to reach significance in the SLI group, F (2, 24) = 3.17, $p < .06$, (see

Figure 1). However, post hoc contrasts revealed a significant difference between SLI5 and SLI7, $F(1, 14) = 7.51$, $p < .05$. The lack of significance of the global effect for the SLI group was probably due to the low statistical power resulting from the small sample size.

To check that the observed lexical age effect was not due only to a chronological age effect, the respective contributions of lexical and chronological age to *d'* performances were tested. Considering the two groups as a whole, there was a significant correlation between lexical and chronological ages, $r = .434$, $p < .001$. However, only the correlation between d' and lexical age was significant, $r = .498$, $p < .001$. Nonetheless, if one considers the two groups separately, different patterns of data can be observed. For children with NLD, lexical and chronological age are unsurprisingly highly correlated, $r = .707$, $p < .001$, and *d'* scores are highly correlated to both chronological age, $r = .560$, $p < .001$, and lexical age, $r = .569$, $p < .001$. But, when the contribution of chronological age is accounted for (Pearson correlation partialized for chronological age), the correlation between *d'* and lexical age was not significant. For the children with SLI, lexical and chronological age are also highly intercorrelated, $r = .635$, $p < .001$; *d'* and lexical age are correlated, $r = .513$, $p < .001$, but there is no correlation between *d'* and chronological age, $r = .268$, $p < .19$. Contrary to what is observed with NLD children, the correlation between *d'* and lexical age in children with SLI remains significant even when the contribution of chronological age is neutralized by partial correlation ($r = .46$, $p < .05$).

Another analysis of the same data aimed at separating out word types to specify the respective contribution of real and pseudo-words to *d'* performances. This contribution was assessed in a variance analysis of word type (real vs. pseudo words) as a within-subject variable, group and lexical age level as between-subject variables and the arcsine transformed percentage of correct responses as the dependent variable. A similar picture was obtained for the between-subject effects. The group effect was F (1, 67) = 8.21, $p < .001$, $\eta^2 = .11$, with a mean of 81.9% (SD=8.6) for the children with SLI and 87.8% (SD=12.4) for children with NLD. The lexical age level effect was F (2,67)= 13.77, $p < .001$, $\eta^2 = .29$, with a mean of 76.9% (SD=11.2) for the NLD/SLI5, 88.5% (SD=9.9) for the NLD/SLI6, and 91.9% (SD=7.5) for the NLD/SLI7. There was also a significant interaction between group and lexical age level, F (2, 67) = 3.17, $p < .05$, $\eta^2 = .08$. Further post-hoc tests revealed that this interaction was due to the fact that the performances of children with SLI and NLD were different for the two highest lexical age levels, but were similar for the lowest one. There was also a significant effect of word type on lexical decision accuracy; with the participants responded better to real words than to pseudo-words, F (1, 67) = 62.98, $p <$ .001, $\eta^2 = .48$. However, as suggested by the group by word type interaction, F (1, 67) = 22.41, $p <$ .001, $\eta^2 = .25$, children with SLI presented more difficulties in rejecting a pseudo-word (M = 68 %, SD = 17.7) than did children with NLD (M = 83.5 %, SD = 19.7), while the two groups did not differ in making a lexical decision on words (M= 92.4 % and 95.5%, SD = 8.3 and 4.6, respectively). Finally, there were no significant interactions between word type and lexical level nor between word type, lexical level and group.

Analyses of the responses to pseudo-words

A preliminary analysis was used to check that the type of modification (addition or deletion), used to avoid any biased systematic answer, had no particular effect. A variance analysis of the percentages of correct responses revealed no significant main effect of this manipulation, F (1, 67) = 3.6, $p < .07$, and no significant interaction of manipulation with either the lexical age level, F (2, 67) < 1, or group, F (1, 67) < 1. Therefore, this variable will be omitted from the following analyses.

Table 3 about here

Table 3 provides the percentages of correct responses for pseudo-words (i.e., correct rejections) for each lexical age level, for both NLD and SLI groups. These percentages were submitted to a variance analysis (mixed GLM design) using group (SLI vs. NLD) and lexical age (5, 6, 7) as between-subject variables and the size of modification (slight vs. important) and the position of the modification (initial–medial-final) as within-subject variables. The effects of group and lexical age on responses to pseudo-words were similar to those previously observed, with better performance in the NLD group than in the SLI group, F (2, 67) = 17.39, $p < .001$, $\eta^2 = .34$, better performance in children with higher lexical levels, F (1, 67) = 9.46, $p < .001$, $\eta^2 = .12$, and no lexical age level by group interaction, F (2, 67) = 1.72, $p < .19$. On the other hand, the analysis revealed a highly significant effect of modification size, F (1, 67) = 69.93, $p < .001$, $\eta^2 = .51$; modifications that affected the number of syllables were better detected (M = 83.9%, SD = 18.9) than the ones that did not affect the number of syllables (M = 72.14 %, SD = 24). There were also two significant interactions: (a) between the size of modification and lexical age level, F (2, 67) = 3.47, $p < .05$, $\eta^2 = .09$, and (b) between the size of modification and group, F (1, 67) = 19.99, $p < .001$, $\eta^2 = .23$. The analysis also revealed a marginally significant effect of the position of the modification, F (2, 67) = 2.82, $p < .06$. Post hoc analyses revealed that the modifications in initial (M = 76.8 %; SD = 24.2) and final positions (M = 76.4 %, SD = 20.2) were significantly less well detected than modifications in medial position (M = 80.8%, SD = 21.9), but detection of modifications in initial and final positions did not differ.

There were also significant interactions between position and group, F (2, 67) = 4.21, $p < .05$, $\eta^2 = .11$, between position and size, F (2, 134) = 7.65, $p < .001$, $\eta^2 = .10$, and among group, size, and position, F (2, 134) = 4.88, $p < .001$, $\eta^2 = .07$. This three-way interaction was further investigated to compare position and size effects within each group (see Figure 2). For the children with NLD, the position effect, F (2, 94) = 2.52, $p < .08$, and the size by position interaction, F (2, 94) = 2.63, $p < .08$, did not reach significance. In contrast, the size effect, F (1, 47) = 11.4, $p < .001$, $\eta^2 = .19$, was significant. For the children with SLI, both position effect, F (2, 48) = 4, $p < .05$, $\eta^2 = .14$, and size effect, F (1, 24) = 51.79, $p < .001$, $\eta^2 = .68$, were considerable, as was size by position interaction, F (2, 48) = 7.57, $p < .01$, $\eta^2 = .24$. In others words, the children with SLI, unlike the NLD children, performed more poorly on slight modifications in initial and final position than they did in medial position.

Figure 2 about here

Discussion

Children's abilities to distinguish words from pseudo-words in a lexical decision task, based on the observations gathered in our study, can be summarized as follows. First, children with a higher receptive lexical level perform better; this was true both for children with NLD and children with SLI. Second, both children with NLD and SLI were more likely to reject pseudo-words resulting from an important modification of a word than pseudo-words resulting from a slight modification. However, children with SLI appeared to have greater difficulty rejecting pseudo-words resulting from slight modifications than did their NLD peers. Finally, the performance of children with SLI was particularly poor when they were presented with pseudo-words resulting from a slight modification at the beginning or the end of a word.

The effect of lexical age supports the view in which phonological representations refine progressively while the receptive lexicon increases. The reported observations support the conclusions drawn by previous studies, which suggest that the progressive refinement of the phonological representations is linked to vocabulary growth (Kuhl, 1993; Jusczyk, 1993; Metsala & Walley, 1998). In this respect, our data is in accordance with emergent phonology theory. This is not to say, however, that receptive and productive lexicons growth is the only factor responsible for the progressive refinement of the phonological representations. Among other factors that might contribute to such refinement, the beginning of literacy is not to be underestimated. In the present study, all of the youngest children with NLD (i.e., NLD5) attended kindergarten, but none of them had started to learn to read. Although NLD6 children were also attending kindergarten and, strictly speaking, had not yet begun to learn to read, most of them were aware of some phoneme-grapheme conversions (through, for example, early learning of some vowels or consonants); it is therefore reasonable to assume that most of these NLD6 children had already developed some preliminary literacy abilities. This might explain why there was not a significant difference between the NLD6 and NLD7 children’s performance on the lexical decision task, but there was a highly significant difference between those children and NLD5. This could be due to the fact that the former had already acquired literacy abilities, entailing some refinement of their phonological representations.

At present, it is unclear how various factors affect the progressive elaboration of phonological representations; no clear answer can be proposed that would lead to a deep understanding of the mechanisms involved. Actually, it may even be the case that all the components involved in the development of phonological representations have not been identified. We have just mentioned the role of vocabulary growth and literacy, but these might not be sufficient to explain the emergence and refinement of phonological representations, even for normally developing children. Other components, as diverse as perceptual processes, morphosyntactic pressures, or even the learning of motor programs, are likely to intervene. In a recent connectionist model by Plaut and Kello (1999), the feedback between the acoustic and articulatory representations – sustained by early babbling or other vocal imitations – is hypothesized to play an important role in the development of phonological representations. This variety of components could be related to the rather well documented “associated difficulties” frequently experienced by children with SLI. Sequential difficulties (Fazio, 1998), slow processing of information (Kail, 1994), working memory weakness (Gathercole & Baddeley, 1990), and motor coordination (Hill, 2001) might also affect the development of phonological representations in children with SLI. Therefore, further research is needed to determine whether and how the links between lexical age and quality of phonological representations are mediated by such variables.

With regard to the nature of the information encoded in representations, our data suggest that the phonemic and the syllabic information are not similarly encoded in the phonological representations of children with NLD and children with SLI. On one hand, both groups were better at rejecting pseudo-words that were obtained by altering the number of syllables of existing words. Both groups appear to begin at the earliest lexical level with a good representation of the number of syllables of which a word is comprised. This is in accordance with other experimental studies showing that children are able to detect word structure very early (e.g., Bijeljac-Babic, Bertonincini & Mehler, 1993), or that they respect the syllabic pattern in their very first verbal productions (Boysson-Bardies, 1996). This syllabic effect is particularly noticeable in French-speaking children because the rhythm of French is largely dictated by syllables (Segui, Dupoux & Mehler, 1990). On the other hand, with regard to the encoding of phonemic information, our data indicate that the children with SLI at all lexical ages performed more poorly than the children with NLD. This observation alone, however, does not allow us to specify the reasons for which children with SLI would have particular difficulties in reorganizing their initial representations to incorporate finer phonemic information.

Actually, the fact that children with SLI judged pseudo-words according to whether these pseudo-words did or did not preserve the number of syllables of the original words lends strong support to the idea that the phonological representations of those children are more holistic and less fine-tuned than the representations of normally developing children at the same lexical level. To grasp the importance of this observation, it must be kept in mind that there was no difference between children with SLI and children with NLD when they were presented with real words: for such items, their performance appeared to be very high (more than 90% of accuracy) in both groups. This finding is, of course, not surprising since the two groups were matched on receptive lexical level. More importantly, however, it allows ruling out any explanation of the SLI children's performance in terms of deficits in vocabulary size. What our results suggest is that the phonological representations of frequently used words stored in the children's mental lexicon are in a less defined form for children with SLI; the underspecification of their representations is such that it is sufficient for recognizing words, but insufficient for detecting slight alterations resulting in pseudo-words.

To further characterize such insufficient representations in children with SLI, it would be relevant to know whether every part of a word (beginning, middle or end) is likely to receive an underspecified phonological representation. Our findings show that children with SLI were particularly deficient in detecting small changes at the beginning and end of pseudo-words. The difficulty participants had with changes in initial position accords well with findings obtained in other studies. In a spoken word recognition task, for example, Dollaghan (1998) showed that children with SLI were less likely than age-matched controls to respond with correct initial consonants at the earliest gate interval. Similarly, Criddle and Durkin (2001) showed that children with SLI were less able than typically developing children to detect phonemic changes from a target morpheme, especially when the initial phoneme was changed. These observations further confirm the idea that children with SLI have a more holistic processing strategy, but also suggest, as Dollaghan (1998, p.203) pointed out, that their representational deficits are accompanied by "lower level speech perception deficits that impede the analysis of isolated phonetic information at the earliest stages of processing".

In our study, children with SLI also appeared to have much difficulty detecting small phonemic changes in final position. This finding suggests that their representational and / or speech perception deficits are not restricted to the initial segment of a word or to the first stages of processing. Yet, this observation disagrees with the findings reported in a recent study by Criddle and Durkin (2001) who showed that children with SLI were as skilled as normally developing children in detecting phonemic changes from a target morpheme when the change occurred in final position. The discrepancy between the two studies may be accounted for by an important difference between the materials used as stimuli. Criddle and Durkin used monosyllabic pseudo-words (e.g., *zeeb* with *weeb* or *zeek*), while we only used multisyllabic pseudo-words (e.g., *salopette* or *cigarette*). To understand how this might have affected the performance of children with SLI, it must be remembered that in oral French rhythmic constraints impose a particular prosodic cutting of any utterance. An utterance in French is normally made of a succession of rhythmic units, the mean length of which is about 2.5 syllables in spontaneous conversation (Wioland, 1991). A direct consequence of this is that, when a rhythmic unit consists of vocal material that is longer than 2.5 syllables, it tends to be uttered more quickly (see Park, 1989). It can be inferred from this observation that most French multisyllabic words are likely to be uttered more quickly in normal discourse than mono or bisyllabic ones. On the other hand, the quality of the acoustic signal, particularly at the end of a multisyllabic word, is likely to be poorer when the speed of utterance increases. For children with SLI, a direct consequence of such a subtle speed difference could be a larger representational deficit for multisyllabic words than for monosyllabic ones. Poor signal quality at the end of words, along with possible speech perception deficits, could account for the difficulty that the children with SLI had in detecting small changes in final position of multisyllabic pseudo-words. At present, this explanation remains highly speculative; further research should thus be planned to allow a systematic comparison of performances for mono-, bi- and multisyllabic words, as well as a controlled manipulation of the speed of utterance of multisyllabic items. Even if it seems speculative, it is worth noting that an explanation in terms of auditory perception deficits would be in accordance with findings reported by Wright et al. (1997), showing that there is massively enhanced backward and forward masking in children with SLI. According to Wright and colleagues, these auditory perception deficits could clearly degrade the perception of the acoustic elements of speech. Our findings suggest that the effects of such perceptual deficits might be particularly important for multisyllabic words.

In summary, this study provided further evidence supporting the view that children with SLI have underspecified phonological representations. This conclusion in itself is not entirely original. In recent years, several studies have suggested such an account of the difficulties that children with SLI experience in language learning. Our study, however, has several original features that give weight to this general conclusion.

First, a vast majority, if not all, of the previous researchs concerned with the phonological representations of children with SLI studied only native English-speaking children. By examining native French-speaking children, our study allows us to generalize previous conclusions despite important differences between the two languages. Nearly all the previous observations with English-native children are based on monosyllabic words. The choice of such words is particularly appropriate in English since it allows escaping problems associated with the tonic accent. Indeed, even when uttered in isolation, as is the case in these experimental studies, every English word of two or more syllables is characterized by a tonic accent: the syllable on which this accent is placed receives particular prominence. Therefore, using multisyllabic materials would have complicated the interpretation of the position effects (i.e., causing less fine-grained representation of some parts of a word). On the other hand, monosyllabic words have many more neighbors than multisyllabic ones. Thus, the possibility that at least part of the difficulties experienced by children with SLI could be due to this neighbourhood co-variable cannot be excluded. In French, on the contrary, there is no tonic accent; we were thus able to use multisyllabic words chosen among the most frequent in the repertory of words known by school-aged children. In addition, since such multisyllabic words have no neighbors, the differences that are characteristic of the children with SLI cannot be explained by a neighborhood effect.

Second, contrary to many previous studies in which children with SLI are compared to normally developing children of the same chronological age, our study compared children with the same lexical age, this rejecting the idea that differences can be entirely explained in terms of vocabulary size. On average, the children with SLI in our study were 3.5 years older (chronological age) than normally developing children of the same lexical age; it is likely that the difference between the performances of the two groups would have been larger if we had compared children with SLI to NLD children of the same chronological age.

Third, in comparing three groups of differing lexical age in both children with SLI and in normally developing children –instead of analyzing pairs of children with SLI and NLD, as in most previous studies–, our study allowed us to be more specific about the developmental course of restructuring phonological representations. The significant interaction between group and lexical age level, essentially due to the absence of any significant difference between SLI and NLD children of the lowest lexical age, makes it difficult to argue that children with SLI simply present a delayed pattern of development. On the other had, our findings do not suggest that children with SLI will never catch up children with NLD, an indication of deviant development. Research comparing SLI and NLD children of greater lexical ages is needed to further outline this finding.

It should be noted that the way in which materials were presented could be regarded as a methodological weakness or limitation. We chose to utter the stimuli as naturally as possible to make the children feel at ease and to allow, particularly the children with SLI, to take advantage of lip-reading. It is our feeling that suppressing lip-reading or using computerized stimuli would increase the number of erroneous answers. Future researches should clarify how the underspecification of phonological representations and /or the limited processing capacities contribute to difficulties experienced by children with SLI.

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Table 1. *Raw scores on PPVT and chronological age (with standard deviations in parentheses) by lexical subgroups for SLI and NLD children*

Lexical age	5	6	7
NLD Children	N=16	N=21	N=11
Raw scores	46.18 (4.6)	60.61 (3.51)	93.36 (18.0)
(PPVT)	[40-52]	[55-67]	[70-114]
Range			
Chronological Age			
(in months)	61.06 (7.98)	65.38 (6.43)	81.09 (6.59)
Children with SLI	N=7	N=10	N=8
Raw scores (PPVT	48.42 (4.31)	63.2 (5.2)	87.5 (20.62)
Range	[40-53]	[54-68]	[69-122]
Chronological Age			
(in months)	92.42 (9.67)	109.7 (12.62)	114.75 (16.18)

Table 2. Examples of stimuli for the auditory lexical decision task

target word	*Pseudo-word*	*Nature of the process*
/□□□□□□/	/□□□□□□□/	addition - initial position - maintaining syllable number
/p□□□□□□/	/□□□□□□/□	deletion - initial position - maintaining syllable number
/□□□□□/□	/□□□□□□□/	addition - initial position – changing syllable number
/d□□□□□/	/□□□□/	deletion - initial position – changing syllable number

Table 3. Percentage of correct responses (correct rejection) on pseudo-words by group and lexical level for each effect separately (standard deviation in parentheses)

	SLI5 (n=7)	SLI6 (n=10)	SLI7 (n=8)	NLD5 (n= 16)	NLD6 (n=21)	NLD7 (n=11)
Size of modification						
Important (n=12)	75 (16.6)	75 (21.1)	86.4 (16)	73.9 (21.9)	90.8 (15.5)	96.9 (5.6)
Slight (n=12)	47.6 (17)	63.3 (22.9)	60.41 (15.2)	60.4 (22.6)	85.3 (18.8)	96.2 (5.7)
Position of modification						
Initial (n=8)	55.35 (23.7)	63.75 (27.3)	68.75 (18.8)	67.9 (23.7)	89.2 (16.9)	97.72 (7.5)
Medial (n=8)	64.2 (15.1)	78.75 (21.2)	78.12 (20.8)	68.7 (24.5)	89.3 (20.2)	96.5 (5.8)
Final (n=8)	64.3 (15.2)	65 (21)	73.4 (16.9)	64.8 (17.8)	85.7 (17.3)	95.4 (8.4)

Figure Caption

Figure 1. Index of sensitivity (d') for NLD and SLI children, grouped according to lexical age.

Figure 2. Results for SLI and NLD children by size and position of modifications. Error bars indicate plus one standard error.

Figure 1

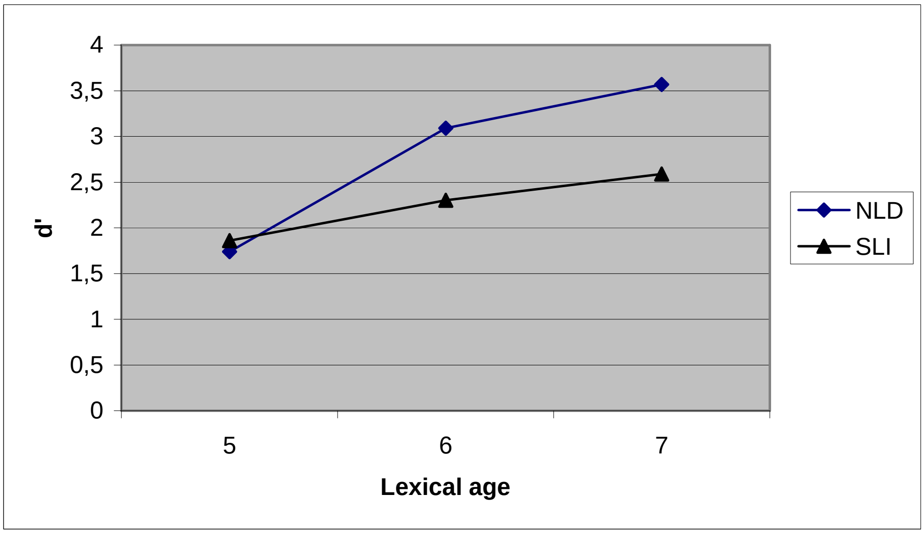
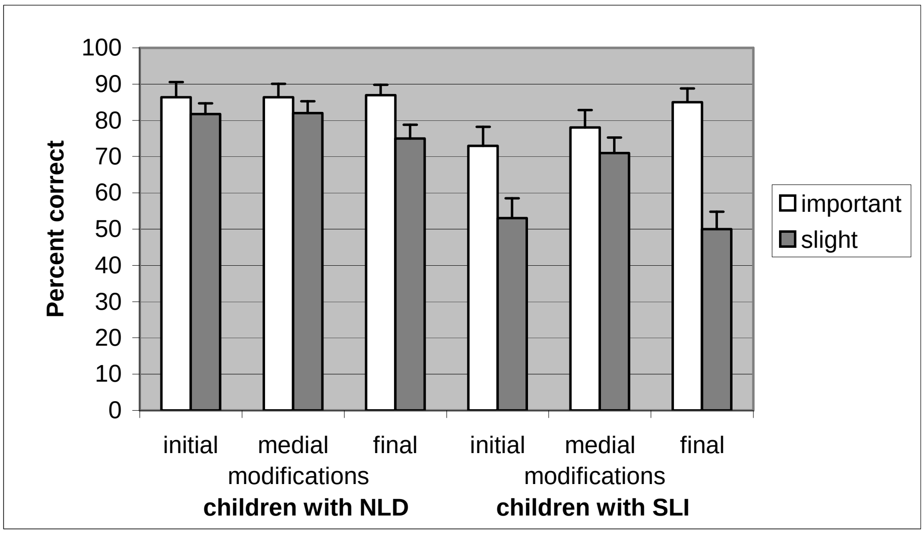


Figure 2


100
90
80
70
60
50
40
30
20
10
0
Percent correct
initial
medial
final
modifications
children with NLD
initial
medial
final
modifications
children with SLI
important
slight