Speech perception of young children at risk for dyslexia and children with specific language impairment

Ellen Gerrits
University Hospital Maastricht, The Netherlands
E-mail: egerr@skno.azm.nl

ABSTRACT

The present study investigated the relationship between dyslexia and specific language impairment (SLI) by comparing the speech perception of 3-year-old children with a genetic risk for developing dyslexia and children with SLI. Speech perception was studied with two listening tasks, a phoneme identification task with minimally differing word pairs, and a categorical perception task with a stimulus continuum between a stop-consonant contrast and a vowel contrast. Results demonstrated that both the at-risk group en SLI group had more difficulty with the identification and categorisation of speech sounds than the control group. The findings support the view that dyslexia and SLI might be caused by the same underlying speech perception deficit. This study further shows that the perceptual performance of the at-risk children is highly similar to that of older dyslexic children and adults and therefore might be an early sign of the inherited disorder.

1. INTRODUCTION

The development of reading is one of the major achievements of the early school years. For most children learning to read is an enjoyable experience. However, some children struggle for years with written language because they suffer from developmental dyslexia. Developmental dyslexia is a language-based disorder characterised by a failure in reading and spelling despite conventional instruction, adequate intelligence, visual perception and sociocultural opportunity. It affects around 3.6 percent of the Dutch primary school population [1]. Although there is not yet consensus about the cause(s) of dyslexia, the most widely accepted cognitive explanation is that it stems from an underlying phonological processing deficit [1,2,4,6,9]. A poor analysis of words into sequences of phonemes (phoneme awareness) has been shown to be one of the most consistent deficits in persons with dyslexia, whether children or adults. This begs the question what the causes are of this phonological processing deficit. There is growing evidence that the poor phoneme awareness skills in poor readers are associated with problems in speech perception [4,6]. It is suggested that poor speech perception gives rise to ‘fuzzy’ or ‘underspecified’ lexical representations, to weak verbal short-term memory and ultimately to poor metaphonological abilities.

In the current study, speech perception was studied in children with a genetic risk for developing dyslexia. These children had at least one parent with dyslexia. According to the Dutch study by Blomert [1], the dyslexia risk for children with one dyslexic parent is 20 to 47%. The selection of at-risk children creates the opportunity to study speech perception at a much younger age, during early language development and long before the children start to read and write, than in previous reports. Moreover, it makes it possible to investigate early signs or risk factors of the familial disorder. Previous at-risk studies with 5-year-old children have shown delays in oral language development, such as a delay in vocabulary development or grammatical expression [9]. In addition, retrospective studies have suggested that many dyslexic children show a history of language impairment in their pre-school years. From the perspective of SLI, it has been shown that many children with early oral language problems develop reading problems when they start to read and write [5,7,9]. Such findings have led to the formulation of several assumptions about the relationship between SLI and dyslexia in terms of links between language and literacy development [2,7,9]. It is hypothesised that dyslexia and specific language impairment might simply represent different manifestations of the same underlying speech perception disorder [9]. This hypothesis is supported by several reports showing that SLI children, as well as children with dyslexia, are impaired in their identification, discrimination and categorisation of speech sounds [4,5,6,10,11].

The aim of the present study was to collect further evidence for the relationship between dyslexia and SLI and the underlying speech perception deficit. The research questions were: 1) Do young children at-risk for dyslexia have problems with the perception of speech sounds? 2) Is their speech perception performance similar to that of children with specific language impairment? These questions were addressed with two listening tasks, reported as Experiment I and Experiment II. Experiment I was conducted to gain insight in the children’s identification of words that differed only in one phoneme or even only one phonetic feature. In Experiment II, the categorisation of speech stimuli on an acoustic continuum was investigated.

2. EXPERIMENT I

Experiment I tested the identification of words in minimally differing word pairs by three groups of 3-year old children: at-risk children, SLI children and controls.

ISBN 1-876346-48-5

2.1. Stimuli. The stimulus material of the phoneme identification task consisted of 20 items, all minimally differing monosyllabic Dutch word pairs. The meaningful words in the word pairs differed only in one single phoneme or phonetic feature like in 'pear-'bear' and 'sock'-'rock'. The items were a selection (most vowel contrasts were excluded) of a 30 item standardised Dutch test of auditory discrimination for children of age 4 to 6. Eleven different phoneme contrasts were presented in total.

2.2. Subjects. A total of 125 children participated in the experiment (see details in table 1). The at-risk children were recruited via calls in newspapers and parental magazines. The SLI-children were recruited from Language Development Centres that provide full-time specialised teaching to children with SLI from 3 to 12 years. These children had been classified as language impaired after extensive assessment of their verbal and nonverbal abilities. The control children were matched in terms of chronological age and were recruited via day-care centres.

2.3. Procedure. The children responded by pointing at one of two pictures that represented the words in a pair, after they had heard one of the words by an audio recorder.

2.4. Results. The results in Table 1 show that all children had relatively high scores; between 80 and 91% correct word identification. The mean score of the at-risk group appears to be in between those of the SLI and control group.

Table 1. Mean proportion correct identification for the three groups of children. Their mean age is presented in years; months.

Group	Mean prop. Correct	SD	N	Mean age
At-risk	.84	.37	58	3;2
SLI	.80	.40	25	3;5
Control	.91	.28	42	3;2

An univariate analysis of variance with fixed factors Group (3 levels), and factor Item (20 levels) and covariate Age revealed a significant effect of all variables (resp. F=4.27, p=0.014; F=9.56, p<0.01, and F=10.72, p<0.01). There was an Age*Group interaction (F=3.13, p=0.04) showing that the SLI children were significantly older. However, their performance was still poorer than that of the younger control children. Tukey's post-hoc comparison of Group showed that only performance of the control group was significantly higher than that of the at-risk and SLI group; there was no significant difference between the identification scores of the at-risk and the SLI group. A Tukey post-hoc test with factor Item revealed that all children made more errors on certain items. It is not clear why those items were more difficult to identify: there was no effect of a certain phoneme contrast or of familiarity of the words. In several other studies it has been suggested that children with dyslexia or SLI mainly have difficulty with the identification of phonetically less salient contrasts, such as stop-consonant voicing or place-of-articulation [4,6,10,11]. However, the children in our study had no apparent difficulty with word pairs that were differentiated by stop-consonants, at least no more than the controls did (there was no Group by Item interaction). Yet, the relatively high scores, almost at ceiling level, of all children, might obscure this effect. Therefore a more sensitive perception task was used when the children were slightly older. This study is described in the following section. To summarise, the findings of Experiment I indicate that, as early as age 3, at-risk children have subtle speech perception problems, comparable to those of young SLI children.

3. EXPERIMENT II

The findings in Experiment I showed that children with a familial risk for dyslexia and SLI children make a larger number of errors than controls when presented with minimal pairs of words, which only differed by one phoneme. To further investigate the speech perception of these children, the categorical perception paradigm was used. This test, in which a speech continuum is presented, is a highly sensitive test to investigate speech perception processes. Previous studies with dyslexic adults and children (8 to 11 years old) suggest that their phoneme categorisation is less consistent, and therefore less categorical, than that of average readers [6]. Similar results have been found for older children with SLI [10]. In one study, speech perception of at-risk children has been reported [8]. Richardson et al. showed that speech sound discrimination of six-months-old at-risk infants deviated from age-matched controls. In the selection of speech stimuli, most studies have focused on the perception of stop-consonant voicing or place-of-articulation contrasts. In the present study, speech sounds from two different classes were selected, stop-consonants and vowels, in order to test the hypothesis that speech perception might be impaired in general or be affected selectively, i.e. only affecting perception of certain speech sounds.

3.1. Stimuli. In the present experiment two stimulus continua with seven stimuli each were presented to the children in two separate test conditions. The stimuli consisted of a six-step continuum between the /p/ and /k/ in the words /pɔp/ and /kɔp/ ('doll' and 'cup') and a six-step continuum between the vowels /a/ and /ɑ/ in the words /zak/ and /zɑk/ ('shop' and 'bag'). The continua were generated by interpolation between the relative amplitudes of the spectral envelopes of the original words. In the vowel continuum, vowel duration was also manipulated by decreasing it in equal steps of 15 ms.

3.2. Subjects. The subjects of this experiment were the same children as in Experiment I, with as main difference that all children were nine months older. The mean age of the at-risk children was 3;11 (N=15), The SLI children

ISBN 1-876346-48-5 © 2003 UAB

were again slightly older, 4,4 years old (N=8), and the controls were on average 3;11 years old (N=19). It has to be noted that the number of subjects per group was much less in Experiment II compared to Experiment I, due to relatively strict criteria. Children were excluded from data analysis if they failed to pass the training criterion, did not complete both the stop-consonant and the vowel task or did not remain concentrated. In the present data analysis only those children were included who completed both tasks in order to be able to investigate the effect of the phoneme contrast. A relatively high attrition rate was expected since this task was more difficult and lasted longer than the one chosen in Experiment I.

3.3. Procedure. The categorisation task contained training and a test phase. In the test phase each stimulus was presented six times. The children were tested in the language acquisition lab of the Utrecht Institute of Linguistics OTS. They heard one stimulus at a time and had to respond by pointing at one of two pictures that represented the endpoints of the continuum. The stimuli were presented via headphones connected to a speaker and laptop computer.

3.4. Results. The categorisation performance of the three groups of children is presented in figures 1 and 2. Figure 1 shows the percentage /kɔp/ responses of the three subject groups at each stimulus level. Firstly, it can be seen that the slope of the categorisation functions of the at-risk group and the SLI group is less steep than the function gradient of the control group. The slope is the reciprocal of the standard deviation and indicates the range of uncertainty distinguishing one phoneme category from another. A steep slope indicates a small uncertainty range and suggests highly consistent ability to categorise a speech contrast; whereas a shallow slope indicates a large range of uncertainty and suggests difficulties in identifying the speech stimuli. Secondly, the data show that the at-risk and SLI children also had more difficulty with categorising the (unambiguous) endpoint stimuli, which is in line with the findings of Experiment I. The difference between groups was confirmed by the statistical analysis. A repeated measurement analysis was performed with percent /kɔp/ response as the dependent or outcome variable for each of the seven levels of stimulus. All possible interactions between group, stimulus level, and age were considered as potential terms. The final model includes Group (at-risk and SLI), Stimulus, and the interaction between Group and Stimulus as statistically significant ($p<0.01$) parameters for phoneme categorisation. The model obtained was: %/kɔp/= -20.77 + 23.75*at-risk + 26.41*SLI + 17.46*stimulus – 5.47*at-risk*stimulus – 5.85*SLI*stimulus. The SLI group was older than the two other groups. Nevertheless, after controlling for age the SLI group still performed more poorly.

The results of /zak/-/zɑk/ categorisation are presented in figure 2. The categorisation functions indicate that the three groups do not differ in their categorisation responses, as was the case with the stop-consonant contrast. The statistical analysis confirms that there is no difference between the groups. A repeated measurement analysis was conducted with percent /zɑk/ response as the dependent variable for each of the seven levels of stimulus. All possible interactions between group, stimulus level, and age were considered as potential terms. The final model includes only Stimulus as statistically significant ($p<0.01$) parameter for phoneme categorisation. The model obtained was: %/zɑk/= -5.99 + 1.73*at-risk + 2.3*SLI + 15.51*stimulus.

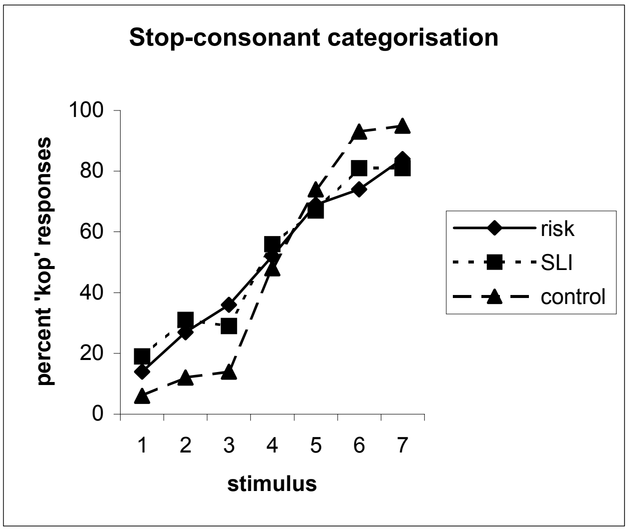

Figure 1. Mean percent /kɔp/ identification per stimulus per group.

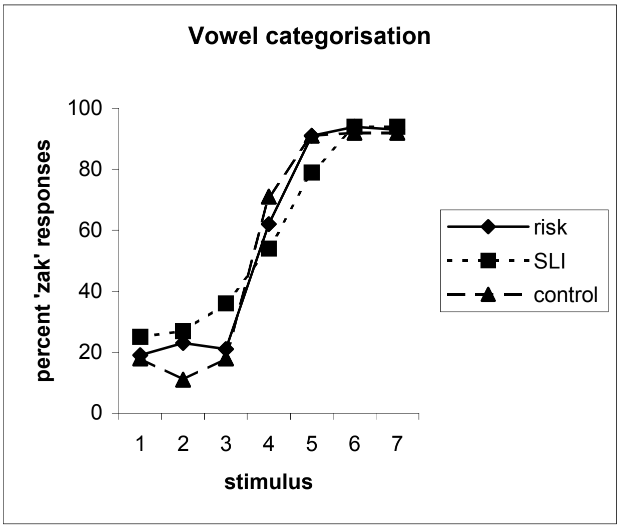

Figure 2. Mean percent /zɑk/ identification per stimulus per group.

Taken together, the results of Experiment II reveal that children at risk for dyslexia and SLI children are less consistent in their categorisation of stop consonants than normally developing children and do not have such a clear phoneme boundary. The difference between groups does not hold for the vowel contrast. This contrast effect was also demonstrated in the study of Tallal and Stark [11], who showed that SLI and control children of 5;6 to 8 years old

ISBN 1-876346-48-5 © 2003 UAB

only differed in their consonant perception, but not in their vowel perception. They explain this difference by the nature of the acoustic cues of the two classes of speech sounds: brief and transitional formant spectra for stop consonant, but relatively long and steady-state formant spectra for vowels. This implies that, for all listeners, stop consonant will be perceptually less salient than vowels. Although little has been reported with respect to the development of vowel perception, it is generally agreed that the perceptual vowel system is fully acquired long before the consonant system. In Gerrits [3], it was found that in normal developing children the weighting of acoustic cues for vowel categorisation was adult-like at age 6. However, the weighting of cues for stop-consonant categorisation was not fully acquired yet at age 9. The present categorical perception task will be repeated with the at-risk and SLI children when they are six months older to see whether the stop-consonant results are presenting a delay or deficiency of their speech perception skills.

4. EXPERIMENT I AND II

The results of Experiment I and II demonstrate that at-risk and SLI children are impaired in their perception of subtle changes in speech sounds, which may not surface when standardised language tests are used. However, in an experimental setting the perception performance of these children clearly deviates from normally developing controls. The clinical relevance of the phoneme categorisation paradigm has already been demonstrated by Maassen et al. [6] in a study with dyslexic children of 8 years old. They found a negative correlation between reading performance and identification and discrimination of a voice and place-of-articulation contrast. A follow up study with the children in the present study is needed to fully understand the relationship between early speech perception and later developing reading and writing skills.

5. CONCLUSIONS

The findings of the present study show that young children (age 3) with a genetic risk for developing dyslexia have subtle speech perception deficits. Their perceptual performance is highly similar to that of young language impaired children and much older dyslexic children and adults with impaired phonological processing. The results of this study confirm the hypothesis that perceptual deficits might be the underlying cause of dyslexia as well as specific language impairment and imply that dyslexia and SLI might be merely two conditions on a phonological processing continuum rather than represent two "specific" language disabilities. Furthermore, the findings suggest that an impaired speech sound categorisation may be a precursor of dyslexia, present early in life.

ACKNOWLEDGEMENTS

The present study is part of a larger ongoing Dutch research project, "Early language development in SLI and dyslexia: a prospective and comparative study", headed by Frank Wijnen from the Utrecht Institute of Linguistics OTS. I would like to thank my collaborators Elise de Bree, Carien Wilsenach, Jan de Jong and Frank Wijnen. Special thanks are also for Mickey Chenault for her help on statistics. The project was supported by grant nr. 360-70-030 from the Netherlands Organisation for Scientific Research (NWO), and by the Utrecht Institute of Linguistics OTS at Utrecht University, the Netherlands.

REFERENCES

[1] L. Blomert. Stand van zaken dyslexie. In: R. Reij, *Dyslexie, naar een vergoedingsregeling*, Rapport nr. 144 College voor Zorgverzekeringen, 2003.

[2] H.W. Catts, The relationship between speech-language impairments and reading disabilities, *Journal of Speech and Hearing Research*, 36, 948-958, 1993.

[3] E. Gerrits, The categorisation of speech sounds by adults and children, Doctoral Thesis, Utrecht University, the Netherlands, 2001.

[4] M.F. Joanisse, F.R. Manis, P. Keating and M.S. Seidenberg, Language Deficits in Dyslexic Children: Speech Perception, Phonology, and Morphology. *Journal of Experimental Child Psychology*, 77, 30-60, 2000.

[5] M.F. Joanisse, and M.S. Seidenberg, Specific Language Impairment: A Deficit in Grammar or Processing? *Trends in Cognitive Sciences,* 2, 240-247, 1998.

[6] B. Maassen, P. Groenen, Th. Crul, et al., Identification and discrimination of voicing and place-of-articulation in developmental dyslexia, *Clinical Linguistics and Phonetics,* 15, 319-339, 2001.

[7] G.M. McArthur, J.H. Hogben, V.T. Edwards, et al., On the "specifics" of specific reading disability and specific language impairment, *Journal of Child Psychology and Psychiatry,* 41, 869-874, 2000.

[8] U. Richardson, M. Leiwo, P. H.T. Leppänen and H. Lyytinen, Perception of duration in infants with high genetic risk for dyslexia, *Proceedings of the 14th International Congress of Phonetic Sciences in San Francisco,* 1909-1912, 1999.

[9] M. Snowling, D.V.M. Bishop and S.E. Stothard, Is preschool language impairment a risk factor for dyslexia in adolescence?, *Journal of Child Psychology and Psychiatry*, 41, 587-600, 2000.

[10] J.E. Sussman, Perception of Formant Transition Cues to Place of Articulation in Children With Language Impairments. *Journal of Speech and Hearing Research*, 36, 1286-1299, 1993.

[11] P. Tallal and R.E. Stark, Speech acoustic-cue discrimination abilities of normally developing and language-impaired children, *Journal of the Acoustical Society of America,* 69, 568-574, 1981.