Early signs of dyslexia from the speech and language processing of children

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Abstract
The Jyväskylä Longitudinal Study of Dyslexia project (JLD) has followed the development of 200 children from birth until 10 years of age. Half the children are from families in which at least one of the parents has dyslexia, thus the child has a high risk of becoming dyslexic, and half have no such risk. Here the main findings of four studies in linguistics from the JLD project are reviewed. The speech processing skills were studied in 6, 18, 24 and 30-month-old children. The findings show that early signs of dyslexia can be detected in speech processing both phonologically and morphosyntactically. These precursors can be seen in perception or production of duration, in the prosody and phonotactics of word production attempts and word structures, as well as in the complexity of morphosyntactic features of expressions. This information can be useful in practice to provide early and appropriate assistance for those children who most likely will face difficulties in learning to read and write at school.

Keywords: Dyslexia, reading, early language development, phonological processing, morphosyntactic processing.

Introduction
In several studies of dyslexia, attempts have been made to show that the quality of phonological representations is closely associated with the child’s reading skills. Indeed, many studies involving both typically (e.g., Bradley & Bryant, 1983; Hoen, Lundberg, Stanovich, & Bjaalid, 1995; Siok & Fletcher, 2001) and atypically developing children (e.g., Bradley & Bryant, 1983; Bruck, 1992; Landerl, Wimmer, & Frith, 1997; Porpodas, 1999) from across languages demonstrate the importance of the aforementioned relationship. According to the phonological deficit theory (Stanovich, 1988) children with dyslexia have difficulties forming accurate and detailed phonological representations from spoken words. However, the reasons behind qualitative differences or accessibility issues of phonological representations are not well understood.

Here we review the main findings of four studies in linguistics, all of which are aimed at finding early signs of dyslexia in language development. Recognition of early signs of dyslexia is important, since up to now the earliest dyslexia can be diagnosed in children is around the second or third year of school by which time children have already struggled for several years from inability to master technical as well as fluency aspects of reading. With early discovery of signs of dyslexia, appropriate tasks and training programs can be developed for children before they enter school. Children would have a better opportunity to start their school career on an even ground with their peers and concentrate on learning rather than using all their efforts in mastering the basic tools of learning in the school environment. The search for early precursors is possible since dyslexia is familially aggregated. In fact, the research findings are very straightforward showing that from 35–50% of children with at least one parent with dyslexia will also have dyslexia (e.g., Pennington, 1995). Thus, the genetic or familiarity aspect enables study designs in which early signs of dyslexia can be searched long before the actual evidence can be seen from children’s failing attempts to learn to read and write. For such endeavours longitudinal study designs are ideal.

This paper reviews four studies from the same longitudinal study on dyslexia, the Jyväskylä Longitudinal Study on Dyslexia (JLD (see Table I). Altogether 200 children from Finland have been followed from birth until 10 years of age and the data collection still continues (see e.g., Lyytinen et al.,
features of the Finnish language

Before we continue to the description of the individual studies, a few words of the main characteristics of the Finnish language are in order (see also Kunnari & Savinainen-Makkonen, 2007). Phonologically the main characteristics of Finnish are vowel harmony as well as quantity in both vowels and consonants. The main stress is always on the first syllable, secondary stress on the third and every other syllable after that, with the last syllable never being stressed. Stress is not usually quantity sensitive. Unlike in English, stress does not cause any noticeable modifications to vowel quality. Orthographically Finnish has an extremely consistent grapheme-phoneme correspondence: each phoneme is represented by exactly one grapheme and vice versa. The long quantity of sounds is marked with two identical letters. Typologically Finnish is an agglutinative language although morphophonology adds many fusional features to the inflections. Apart from the 15 cases of nouns, signs, suffixes, and affixes can be added to noun stems, and therefore Finnish words can often be long. In addition, one form of a word can have many different semantic meanings. On the other hand, morphophonological features allow word order to be flexible: the syntactic functions of the words are expressed with inflections and it is not necessary to use word order for this purpose. Verb conjugations have finite forms, signs of tempus, modus and voice as well as various affixes. In addition Finnish has a rich derivation system in both verbs and nouns. Typically to the Finno-Ugric languages Finnish also has a declinable negative auxiliary and not just a negative particle. In comparison to English (which is the language of most of the dyslexia studies) which has minimal inflection, and almost no cases, Finnish is drastically different since a noun in Finnish can have over 20,000 different forms, and a verb up to 12,000 different inflections (e.g., koti “home”, koteissa “in homes”, kotetiet “into homes”, kotiisi “your home”, etc.; pesen “I wash”, pememme “we wash”, pesetkö “do you wash?”, pesivätkö “did they wash”, et pese “you don’t wash”, eivä pesesse “they did not wash”, etc.).
Study 1: Processing of speech sound duration in dyslexia (Richardson, 1998)

Study 1a: Categorization skills in 6-month-old infants and their parents (Richardson, 1998)

Richardson’s (1998) study was centred around the question of how speech sound duration affects the way in which sounds are categorized in adults with dyslexia as well as their 6-month-old children. The interest in the linguistic function of duration stems from the fact that one of the most distinctive features of the Finnish language is phonological quantity, and a determining factor in Finnish quantity is duration. In other words, in Finnish phonology the meaning of the word changes merely according to the length of the phoneme, and the decisive factor for the categorization of length phonemically (either short or long) is the duration of the sound. It is important to note that it is not the absolute duration of speech sound alone that determines the quantity of the sound but it is also the relative, proportional duration of the sound in the context of other sound durations within the word that determines if a sound is long or short. For instance, a sound that we categorize as short can be over twice as long in absolute (measurably) duration in the word final position in CVCV structures in comparison to a sound in the same word position but in CVCCV word structures and yet they both are still categorized as short. Thus, there can be almost an endless amount of variation in speech sound durations but quantity categories or degrees into which all the different physical durations are linguistically placed, are limited to two (short and long). Apart from the physical and relative aspects of quantity, it should be noted that quantity categorization is also subjective to a certain extent, since speakers’ experience with the language affects their linguistic judgements and, thus, durational differences are interpreted according to a subjective reference code. In addition, it should be noted that quantity is not only a feature of the spoken language but in Finnish the two quantity degrees are also explicitly marked in writing. The sounds that are perceived and categorized as long are written with two identical letters whereas short quantity is written with one letter (e.g., kisa “cat” vs. kisa “competition”). It is precisely in the quantity aspect of written language that dyslexics make most of their reading and spelling errors in Finnish (Lyytinen, Leinonen, Nikula, Aro, & Leivo, 1995).

A further impetus for Richardson (1998) to focus on the durational aspect of speech came from the evidence that school-aged children with language disorders, including individuals with dyslexia, have an auditory temporal deficit in perceiving speech as well as non-speech sounds. Some of this evidence has been obtained from a temporal order judgment task in which individuals with dyslexia performed significantly poorer than non-dyslexics when the rate of stimulus presentation was fast (Tallal, 1980). Apart from this and other similar evidence (see for example, Farmer & Klein, 1995), there is also contradictory evidence (e.g., Mody, Studdert-Kennedy, & Brady, 1997), emphasizing the speech-specificity of the possible differences or that dyslexia does not involve temporal processing deficiencies at all. In Richardson’s study (1998) several experimental investigations were conducted in order to test the temporal processing skills in both infants and adults.

Participants

In the Richardson (1998) study adults with dyslexia who also had at least one first- or second-degree relative with dyslexia, as well as their children when they were 6 months and 18 months of age, served as participants in the experiments. The control groups (CG) were formed from adults who themselves did not have problems in reading or writing and their children.

Procedure

Previous studies on infants have indicated that infants as young as 6 months of age have the ability to categorize speech sounds (see Eimas, 1996, for review). Yet, there is little information on infants’ ability to categorize sounds according to their prosodical features, and especially according to duration. In Richardson’s study auditory perception experiments were devised using a stimulus continuum in which the only parameter that changed in the pseudoword context was the duration of the stop sound (the occlusion part). The eight stimuli were constructed by adding 20-msec increments of silence to the middle of the t-sound. According to the pilot studies on adult listeners, perception and categorization changes sharply at some point in the stimulus continuum from ata to atta (Richardson, 1998).

The categorization abilities of the infants were assessed using a modified procedure of Kuhl’s (1985) conditioned head-turn procedure. This relied on infants’ instinct to turn their heads toward the most interesting stimulus. Infants were conditioned to turn their heads toward a visual reinforcer whenever they perceived a change within the auditory sequence from ata to atta. The experiment on adults was exactly the same except the required response was made by pressing a button when they heard atta (Richardson, 1998).

Results

The data consisted of 133 adults’ and 105 infants’ performance in the categorization tasks. Results showed that already at the age of 6 months infants were able to categorize speech sounds according to duration in similar fashion to adults (see Figure 1). However, the data also showed that as a group in
comparison to controls both dyslexic adults as well as their infants require longer duration in order to change their perception from short to long quantity category (Richardson, 1998; Richardson, Leppänen, Leiwo, & Lyytinen, 2003). It should be noted, however, that the data from adults clearly showed that not all the responses of parents with dyslexia differed significantly from the controls but the group-level differences were due to the performance of particular individuals. This uncertainty shown in the categorization functions was reinforced also by the reaction time data. All in all, the data point to the conclusion that individuals with dyslexia can differ from those with no dyslexia in processing temporal auditory information of speech and these differences in processing abilities can be present already at a very early stage in development (Richardson, 1998).

**Study 1b: Duration in the speech productions of 18-month-old children (Richardson, 1998)**

In addition to studying durational aspect in speech perception, Richardson (1998) studied whether adults with dyslexia and their children differ from those individuals with no background of dyslexia in the durational aspects of speech production.

**Method**

The task of the 18-month-old children was to imitate the image of a woman in a video recording who produced the pseudowords *ata* and *atta* as well as the words *mato* (“worm”) and *matto* (“carpet”). The parents’ productions of the words *mato* and *matto* were studied from the situation in which they tried to make their own children imitate the words after them. The absolute as well as proportional durations of the sounds were measured from the production data. A total of 118 acceptable imitations from children were included in the results (58 from the at-risk for dyslexia group and 60 from the control group). The adult data consisted of 104 words (44 words produced by individuals with dyslexia and 60 by control adults).

**Results**

The results showed that although the absolute durations were relatively longer in the infants’ productions in comparison to those of the adults, overall the proportional durations of the children’s productions were similar to those of adults. This can be taken to show that Finnish-speaking children as young as 18 months of age can use and control durations in speech production almost in the same way as adults do. However, in some instances there were significant differences. Although at the group-level the children with a dyslexia background managed to make clear durational differences in their CVCCV and CVCCV word structures similarly to control children and adults, they did not manage to do the same when they produced the pseudowords *ata* and *atta* (see Table II). This finding suggests that infants at-risk for dyslexia may indeed be unable to use durational cues for quantity oppositions in producing new words (here they were pseudowords) indicating that they may have problems either perceiving or paying attention or when utilizing...
temporal features in speech productions when they do not yet have an existing representation of a word. In addition, the children with a dyslexia background produced durations which differed from the adult productions more than those of the children with no dyslexia background (see Figure 2). The data on the adults’ naming task (see Table III) indicated that in CVCV words the proportional measurements of durations of both the first and the word-final vowel in individuals with dyslexia differed from those of adults without dyslexia (ANOVA, $F_{6,46} = 6.46, p = .014$; $F_{7.53} = 7.53, p = .008$, respectively). This result could be at least partly due to dialectical differences since earlier findings have shown that there can be great differences of durations in the word final vowel in this particular word structure (Wiik, 1985). Alternatively, it could be speculated that these adults with dyslexia are able to produce or concentrate on producing an adequate difference in the place of the major cue for the quantity distinction but do not notice or cannot make the important durational relationship adequately on the slightly subtler durational cue. Also it should be pointed out that since the data were collected in the situation in which the adult speakers used a typical child-directed naming style including emphasized durational cues, the way

Table II. Descriptive data in milliseconds and in percentages of the average (C)VCV and (C)VCCV imitations produced by at-risk for dyslexia children and children with no such risk. The produced target words were mato and matto and the pseudowords ata and atta (Richardson, 1998, pp. 164–166).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>(C)VCV</th>
<th></th>
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<th>(C)VCCV</th>
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<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>SD</td>
<td>vs.</td>
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<td>Mean</td>
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<tr>
<td>M:ms</td>
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<td>48</td>
<td>27</td>
<td>16</td>
<td>69</td>
<td>36</td>
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<tr>
<td>A:ms</td>
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<td>50</td>
<td>128</td>
<td>120</td>
<td>30</td>
<td>122</td>
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<td>T:ms</td>
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<td>106</td>
<td>195</td>
<td>110</td>
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<tr>
<td>O:ms</td>
<td>209</td>
<td>5</td>
<td>10</td>
<td>4</td>
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<td></td>
</tr>
<tr>
<td>M:%</td>
<td>8</td>
<td>5</td>
<td>10</td>
<td>4</td>
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<tr>
<td>A:%</td>
<td>21</td>
<td>8</td>
<td>17</td>
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<td>T:%</td>
<td>34</td>
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<td>O:%</td>
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<td>12</td>
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<tr>
<td>A:ms</td>
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<td>104</td>
<td>34</td>
<td>14</td>
<td>138</td>
<td>44</td>
</tr>
<tr>
<td>T:ms</td>
<td>233</td>
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<td>264</td>
<td>137</td>
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<td>A:ms</td>
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<td>184</td>
<td>59</td>
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<tr>
<td>A:%</td>
<td>21</td>
<td>9</td>
<td>24</td>
<td>7</td>
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<tr>
<td>T:%</td>
<td>46</td>
<td>18</td>
<td>45</td>
<td>15</td>
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</tr>
<tr>
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<td>13</td>
<td>31</td>
<td>9</td>
<td>n.s.</td>
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<tr>
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<td>12</td>
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<td>25</td>
</tr>
<tr>
<td>A:ms</td>
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<td>38</td>
<td>100</td>
<td>32</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>T:ms</td>
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<td>19</td>
<td>352</td>
<td>41</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>O:ms</td>
<td>222</td>
<td>85</td>
<td>136</td>
<td>78</td>
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<tr>
<td>M:%</td>
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<td>5</td>
<td>8</td>
<td>6</td>
<td>n.s.</td>
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<tr>
<td>A:%</td>
<td>18</td>
<td>7</td>
<td>16</td>
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<td>T:%</td>
<td>31</td>
<td>11</td>
<td>55</td>
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<tr>
<td>O:%</td>
<td>42</td>
<td>13</td>
<td>21</td>
<td>5</td>
<td>***</td>
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</tr>
<tr>
<td>A:ms</td>
<td>17</td>
<td>111</td>
<td>58</td>
<td>17</td>
<td>107</td>
<td>39</td>
</tr>
<tr>
<td>T:ms</td>
<td>137</td>
<td>59</td>
<td>310</td>
<td>163</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>A:ms</td>
<td>177</td>
<td>83</td>
<td>138</td>
<td>49</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>A:%</td>
<td>26</td>
<td>8</td>
<td>19</td>
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<td>T:%</td>
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<td>56</td>
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<tr>
<td>A:%</td>
<td>42</td>
<td>12</td>
<td>25</td>
<td>9</td>
<td>n.s.</td>
<td></td>
</tr>
</tbody>
</table>

Key: ms = milliseconds, C = consonant, V = vowel. T-tests for paired samples were used for the calculations of statistical differences (*p < .05, **p < .01, ***p < .001).
in which these adults considered the importance of the cues should be reflected in the data. When the production data of parents and infants from the same families with dyslexia were compared (see Figure 2), it is interesting to note that there are similarities within families in the temporal aspects of the productions, and as a whole the durational differences between segments were similar between the parents and their children. These observations could be interpreted as showing that there is a connection between the productions within families. Since speech communication is by nature social it is believed that parental input has an effect on infants’ speech. The question whether the suggested relationship between parents and infants is due to some biological factor about muscular control or perceptual categorization skills or both, or whether this relationship is due to the fact that parents provide a strong model for infants at this age and the interaction or negotiation of some aspects of speech like temporality evolves in the particular social contact between parents and infants, or whether both genetic and social aspects affect the proposed relationship remains to be answered in future research.

Study 2: Phonological features in the speech of 24-month-old children at risk for dyslexia (Torvelainen, 2007)

From the same JLD longitudinal study, Torvelainen (2007) investigated variation in the phonological development of the children when they were 24-months-old (n = 39). Nineteen of the children belonged to the at-risk group (RG) and all of them had weaker phonological abilities at the age of 3.5 years. Of the 19 children 6 had significant problems in literacy skills at the age of 8 (Torvelainen, 2007).

Method

The phonological development of the 24-month-old children was studied from the spontaneous speech data. These data were evaluated from three aspects: from the point of view of the amount of the unintelligible speech, attempted and produced words of different length, and phonotactics (restricted to C1VCVC, CV1CV1, C1VC1V, CV1CV1 and complex C1VC1V, CVC2VC2).1 A mean of the most advanced and the weakest fifth (n = 8) was identified in each type of evaluation (Torvelainen, 2007). The stage of the children’s morphological development was measured by the Mean Length of Utterance (MLU), and the syntactical development with the total score of the Finnish version of the Index of Productive Syntax (IPS) (Nieminin & Torvelainen, 2003). The estimate of the size of the child’s lexicon provided by the children’s parents in the Finnish-language MacArthur Communicative Development Inventory (MCDI) (Lyytinen, 1999) was used as the size of the child’s lexicon (Torvelainen, 2007).

For the intelligibility measure, the data were analysed for the number of intelligible and unintelligible utterances. An utterance was considered as unintelligible when it contained at least one word for which an adult who did not know the child could not define the target. For the measure of attempted words, the length of the words the children attempted to produce as well as the phonotactic complexity of these words were analysed. More specifically, the data were analysed for the length of the words that the children attempted to produce
and the number of the attempted words which consisted of only one consonant and one vowel. For the measure of produced words, the number of words produced which were different from the targets in length as well as how these words were different from the targets were analysed. In addition, the produced words were analysed to ascertain how many of them were produced in a phonotactically simplified form having only one consonant and a vowel (Torvelainen, 2007).

**Results**

The results showed that the variation in phonological development is considerable at age two in general. In the most advanced fifth, the children’s speech was highly intelligible (96%), whereas in the weakest fifth 75% of the speech was intelligible. The most advanced children attempted both short and long words, whereas the weakest fifth only attempted words with one or two syllables. Of the targets, 35% were phonotactically restricted in the most advanced fifth, whereas 69% of the targets were restricted in the weakest fifth. The most advanced children had errors in the length of trisyllabic words (3%), whereas the weakest fifth had errors in both short and long words (10%). Three percent of words produced in the most advanced fifth were phonotactically restricted, compared with 26% in the weakest fifth. The correlations between the different areas of grammar indicated that in some respects the level of phonological development predicts the level of morphological and syntactical development (attempted words and syntactic development (Pearson’s correlation was .895***, attempted words and syntactic development .871***).

The evaluation of phonological development was based on the supposition that children’s words develop from forms that are restricted in length in prosodic minimal words (e.g., Pater, 1997; Kehoe, 2000) (mono- and disyllables) and phonotactics (C1V1C1V1, C1VC1V, CV1CV1) into adult forms, in which, for example extrametric syllables and the combination of various consonants and vowels (e.g., C1V1C1V1) take place. In such cases the most restricted forms (mono- or disyllables and words adhering to complete consonant and vowel harmony) could be unintelligible. The analyses showed that at-risk children’s phonological skills were less advanced than those of the control group children in all the different aspects analysed in Torvelainen’s (2007) study, but not all the differences were statistically significant (see Table IV).

**Phonological development of control children and at-risk children**

The amount of unintelligible speech and the amount of unintelligible phonotactically restricted words were significantly larger and the amount of attempted mono- as well as trisyllabic words was significantly smaller in the at-risk children’s productions. Although the differences were quite clear at the group level, in terms of individuals there were also at-risk children among both the most and least advanced fifths. Since the individual variation is large at this early age, it is not feasible to predict individual children’s language development based on

<table>
<thead>
<tr>
<th>Control Children (CG) (n = 20)</th>
<th>At-risk Children (RG) (n = 19)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of unintelligible speech (CG f = 1461, RG f = 1331)</td>
<td>9.6% (3.3)</td>
<td>14.1% (5.9)</td>
</tr>
<tr>
<td>Amount of attempted words of different length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foursyllables (CG f = 2277, RG f = 1758):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0% (4.0)</td>
<td>2.5% (2.8)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Trisyllables</td>
<td>11.5% (11.2)</td>
<td>5.5% (4.6)</td>
</tr>
<tr>
<td>Disyllables</td>
<td>53.9% (27.4)</td>
<td>66.6% (23.6)</td>
</tr>
<tr>
<td>Monosyllables</td>
<td>30.8% (20.0)</td>
<td>25.3% (11.6)</td>
</tr>
<tr>
<td>Amount of words altered in length:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foursyllables (CG f = 68, RG f = 44)</td>
<td>13.2% (1.4)</td>
<td>31.8% (2.1)</td>
</tr>
<tr>
<td>Trisyllables (CG f = 262, RG f = 97)</td>
<td>8.8% (1.3)</td>
<td>16.5% (1.4)</td>
</tr>
<tr>
<td>Disyllables (CG f = 1228, RG f = 1171)</td>
<td>2.0% (3.3)</td>
<td>2.0% (1.3)</td>
</tr>
<tr>
<td>Monosyllables (CG f = 2277, RG f = 1758)</td>
<td>0.0% (0)</td>
<td>7.6% (3.5)</td>
</tr>
<tr>
<td>Amount of phonotactically restricted attempted words (CG f = 2277, RG f = 1758)</td>
<td>50.6% (12.6)</td>
<td>53.5% (11.7)</td>
</tr>
<tr>
<td>Amount of phonotactically restricted unintelligible words (CG f = 109, RG f = 178)</td>
<td>63.3% (3.0)</td>
<td>65.2% (4.5)</td>
</tr>
<tr>
<td>Amount of phonotactically restricted words (CG f = 2277, RG f = 1758)</td>
<td>10.8% (10.0)</td>
<td>11.3% (6.2)</td>
</tr>
</tbody>
</table>

1 Longer words than foursyllables (f = 19) were rare and therefore excluded from analyses.
2(C1V1C1V1, C1VC1V, CV1CV1).
3 Standard deviations in parentheses.
4 Independent T-tests were used for the calculations of statistical differences (*p < .05, **p < .01, ***p < .001).
merely one or two measures on phonological features. However, the measures undertaken at the early stages of language development can be considered as indicative but wider scope (i.e., more features and follow up from a longer period of time) is needed in order to gain a more reliable understanding of the development. In fact, the preliminary analyses of the data when the same children were older show that the large number of phonotactically restricted unintelligible words at the age of 2 was a precursor of poor reading skills at the age 8 in six of nine individuals. The phonological development of two of these six children showed surprisingly individual paths, from which there was disproportion between different levels of grammar, particularly since the size of these children’s lexicon was large. In other words, they had advanced in the lexical level, but not in phonotactical level of words. However, in terms of the whole group (n = 39) the results indicate that there may be a link between lexicon and the children’s phonological/phonetic development (for similar conclusions see Smith, McGregor, & Demille, 2006). In Torvelainen’s study there were statistically significant positive correlations between the size of the lexicon and the attempted words of different lengths (Pearson’s correlation .639**) and a significant negative correlation between the size of the lexicon, number of phonotactically restricted target forms (−.470**) and the number of phonotactically restricted unintelligible forms (−.459**). Typically, therefore, children with a small lexicon attempted short and phonotactically simple words. These results indicated that a long-term assessment comparing phonological development with the size of the lexicon as opposed to the age of the child is needed in order to determine early precursors of difficulties in phonological development of dyslexia. Torvelainen (2007) concludes that in particular in the case of at-risk children it is advisable to pay attention to language development if the child’s vocabulary is large but the word forms are phonotactically restricted and if the child does not even attempt to produce longer and phonotactically more complex word forms in spontaneous speech. It has been noticed also in experimental settings that if a child does not produce or even attempt to produce words this can be a sign of deviant language development (Leiwo & Kulju, 2003; Leiwo, Turunen, & Koivisto, 2002).

Study 3: Phonological features in the speech of 30-month-old children at risk for dyslexia (Turunen, 2003)

Method

The relationship between early phonological skills and later reading skills was also studied by Turunen (2003, currently Kulju), but when the children were slightly older. In her retrospective study of 30-month-old at-risk (n = 105) and control children (n = 91) the focus was on the hierarchical aspect of word structure: children’s word structures were analysed within an autosegmental framework (Goldsmith, 1976) by applying prosodic hierarchy (Selkirk, 1980). Thus, in addition to the analysis of individual phonemes in children’s word productions, also phonotactical elements, (e.g., consonant sequences) as well as syllable and word length were taken into account.

The data were collected from a picture-naming task which comprised altogether 33 objects. Children named each object twice, first, using a picture book and, secondly, using stickers. Nineteen words with varying word structures were selected to be transcribed for further analyses from almost 200 children. Phonological scores of the children’s productions were calculated and the overall transcription reliability score was 89.9%. In the following, we will briefly describe a hypothetical model on the acquisition of word structures in Finnish-speaking children. This model served as a basis for phonological scoring and group comparisons. As an example, the following illustrates the hypothetical acquisition path of a trisyllabic word *porkkana* “carrot”, in the productions of one child:

1. **Word level (syllable number)** *pokka*
   - not complete:
2. **Syllable level (syllable heaviness)** *pokkana*
   - not complete:
3. **Phonotactics (cons. sequence)** *poikkana*
   - not complete:
4. **Phoneme level (/r/)** *polkkana*
   - not complete:
5. **A target-like word structure:** *porkkana*

According to this model, it is assumed that prosodic elements govern the phonotactical and phoneme level in the acquisition of word structures. In the above example this means that at first the child should overcome the constraints preventing trisyllabic word structure producing instead a trochaic, bisyllabic structure. As the word length in the number of syllables is acquired, the child proceeds to a syllable level in which the acquired syllable length serves as a basis for more complex phonotactical elements (e.g., diphthongs and complex consonant sequences). The last stage concerns the finalization of a phoneme inventory, which in the above example means the acquisition of the trilled /r/-phoneme. As mentioned above, the acquisition path can also be illustrated within a constraint-based account, such as by using the constraint definitions of Optimality Theory (see Bernhardt & Stemberger, 1998; Kager, 1999; Turunen, 2003).

The cross-sectional data of 30-month-old Finnish-speaking children supported this hypothetical view...
since the presented word types were common in the data, and also the subgroup of late talkers produced the less advanced word structures. Thus, when investigating phonological acquisition, the interplay of phonemes, phonotactics and syllables should be taken into account (Turunen, 2003, see also Kulju & Savinainen-Makkonen, 2008; Savinainen-Makkonen, 1996).

In studying the at-risk and control children, the following phonological parameters were used: production of three and four syllabic words, heavy unstressed syllables, consonant sequences and diphthongs, and the individual phonemes /s/ and /r/. Production skills of long words were studied because they are common in Finnish due to inflection (morphemes are added into a word stem), but they may be prosodically challenging in early stages of phonological development for which it is typical for Finnish children to truncate them. In addition to the above mentioned Finnish children to truncate them. In addition to the phonological development for which it is typical for children may be prosodically challenging in early stages of

production (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common in Finnish due to inflection (morphemes are added into a word stem), but they are common


Results

Against expectations, no clear differences were found between the at-risk and control children at this age in the phonological quality of their word productions. It should be noted, however, that only about half or fewer of the children in the at-risk group were expected to show deficits in their later reading performance. In addition, it may be that the familiarity of the words used in the naming task affected the results. Even though the task did reveal differences in the phonological development of these children, it may be, that it was not demanding enough to reveal possible group differences. As seen earlier in this paper, the more demanding experimental methods (e.g., a head-turn paradigm) were able to reveal both group differences and significant predictions to later language skills at a very early age (see Lyttinen et al., 2004; Turunen, 2003, for discussion.)

At the current point of the longitudinal data collection, it is possible to identify those at-risk children who actually have reading difficulties. The preliminary results show that, indeed, children with dyslexia were not as advanced at the age of 30 months as those children with no reading/writing problems in the production of some prosodic aspects of a word structure, such as in producing four syllable words (Kulju, 2007).

Phonological features in the speech of poor, intermediate and good readers at the age of 30 months

The relationship between early phonological ability and later reading skills was further examined in a retrospective analysis of poor (n = 38), intermediate (n = 36) and good readers (n = 40) who were identified at school entry based on Lindeman’s (2000) test measuring word recognition skills. A comparison of the three groups revealed significant differences in early phonological skills: children who were identified as good readers at school entry had been more advanced than intermediate or poor readers especially in their production of word length and syllable structures at the age of 30 months. On average, poor readers produced 4.1 four syllable target words out of the maximum 8, and 3.2 of these were realized as four syllables (78%). Good readers produced 5.5 four syllable targets out of which 4.8 were realized as four syllables (87%). Respectively, poor readers produced 6.6 out of the 12 target words with heavy unstressed syllable, and on average in 4.3 (65%) of these productions the heavy unstressed syllable was realized as heavy. Good readers produced 8.4 of this type of targets and 6.5 (77%) included a heavy unstressed syllable. In both parameters the results of intermediate readers were placed in between the poor and good readers. These results indicate a correlation between early reading skills and the acquisition pace of phonological structures (for details, see Turunen, 2003; Kulju, 2003).

Overall the results of Turunen’s (2003) study showed that at age of 30 months 61% of the nearly 200 Finnish children managed to produce all four syllable-words as four syllables whereas 9% of the children were not able to produce four syllable structures at all. Similarly, trisyllabicity was correct in 60% of the children’s productions whereas 5% did not produce any trisyllabic structures in the naming task. All in all, heavy unstressed syllables were always correctly produced by 35% of the children while only 5% never produced them (for more details see Turunen, 2003). It seems that especially these features may be more problematic for children with dyslexia in their early phonological acquisition.
The above results were based on large cross-sectional data with a large number of children. These types of data reveal the high variation of phonological stages at the age of 30 months. However, the amount of data from individual children is limited. In further studies our aim is to investigate phonological acquisition from an intra-individual aspect by comparing different types of data. One goal is to attempt to define normal and abnormal variation in word production. For example, as the child corrects his/her word structure spontaneously, (e.g., [ovava, orava] /orava/ orava “squirrel” in a naming task, this can be taken as showing typical variation. In this specific example the child is proceeding to produce the /r/-phoneme instead of substituting it by assimilation. It may be that if a child with dyslexia has problems in perceiving the exact form of word structure; this results in a high level of variation in his/her output. The following examples illustrate this type of abnormal variation (examples are from two 30-month-old children who were later identified as dyslexic):

[puleli] [puleli] (high intonation) [pole:le] /puhelin/ puhelin “telephone”
[hap:le], [api:ta] /lapio/ lapio “shovel”
[u:hto], [po?:hto:] /juusto/juustoo “cheese + PART”
[ousut soustu tossa] /housut housut tos:a:/ housut housut tossa “trousers trousers there”

It is evident that the definition of abnormal variation in intraindividual speech production is demanding, but by focusing on this we may be able to find out more about early precursors of dyslexia and the hypothesis concerning fuzzy phonological representations.

Study 4: Morphosyntactic features in verbal productions of 30-month-old children at risk for dyslexia (Nieminen, 2007)

Although problems in phonological processing have been strongly emphasized in many studies on dyslexia, there are also several occasions where morphological and syntactic skills are considered as potential areas for precursors of dyslexia to appear. In her retrospective study on spontaneous speech produced by individuals with dyslexia and their controls (typically reading individuals), Scarborough (1990a; 1991) discovered that at 30–48 months of age control children produced longer utterances than children with dyslexia. In addition, their utterances were syntactically more complex in terms of IPSyn analysis. Also studies concerning inflectional (Joanisse, Manis, Keating, & Seidenberg, 2000) and derivational processes (Leong & Parkinson, 1995) have shown that there are some differences in morphological processing between individuals with dyslexia and control subjects.

There are at least three different hypotheses which attempt to explain the connections between syntactic skills and dyslexia. One of these hypotheses claims that there are deficiencies in basic syntactic skills which are due to either (a) delayed language development or (b) a structural deviation in the linguistic system. A second hypothesis presumes that dyslexic and non-dyslexic people have similar syntactic skills but production differences found in several investigations are due to limitations in the capacity of short term memory which are caused by problems in phonological processing (cf. Deutch & Bentin, 1996; Leikin & Assayag-Bouskila, 2004). The third view claims that both individuals with dyslexia and their controls have similar basic syntactic skills, but people with dyslexia are not able to use these skills as efficiently as the controls. Phonological processing abilities can not explain this alone. Instead, the underlying deficiency must be a broader problem of metalinguistic skills (Deutch & Bentin, 1996).

Method

In Nieminen’s (2007) study spontaneous speech performances of 20 risk group (RG) children and 20 control (CG) children were compared at the age of 30 months. The main focus of the comparison was in morphosyntactic complexity of the children’s utterances. Following Scarborough’s (1990a) methods Nieminen used the Mean Length of Utterance (MLU; Brown, 1973) and Index of Productive Syntax (IPSyn; Nieminen & Torvelainen, 2003; Scarborough, 1990b) as a preliminary measure of complexity. MLU measures the linear length of utterances using a morpheme as a unit of measurement whereas IPSyn credits with points different morphosyntactic structures used by a child. Both MLU and IPSyn were compatible with the view of absolute complexity (cf. Dahl, 2004; Miestamo, 2006) based on information theory, since both of them measure the number of units in a system (Nieminen 2007; Nieminen, submitted). In Nieminen’s study, the 80 longest intelligible utterances produced by each child were analysed with MLU and IPSyn.

Results

Both MLU and IPSyn showed parallel results in both groups. The control group performed better than the risk group. This was shown by group mean values in Table V. Although the mean differences were clearly different it is important to pay attention to standard deviations in both groups. It is the high standard deviations that prevent the differences in group comparison from becoming statistically significant. When individuals in the RG were compared to individuals in the CG the similarity of children in both groups is emphasized (Figures 3 and 4). It can
be stated that in both groups utterances of the same length are produced and that children in both groups use a similar number of different morphosyntactic structures to build utterances. The group differences seen in average values (Table IV) can be explained by the performance of seven children in the RG whose performance show clearly lower skills than other children in this study (Nieminen, 2007).

MLU and IPSyn enable analysis of children’s spontaneous speech productions from two different points of view. However, neither of them is capable of detecting the whole morphosyntactic structure of any individual utterance. In languages such as Finnish which are morphosyntactically rich and versatile, the evaluation of the absolute complexity of utterances requires that the morphosyntactic complexity is considered as a multidimensional property of the language. Therefore, relying on either the linear length of utterances like in MLU or the inventory of different structures used in utterances like in IPSyn is not enough. In Nieminen’s study (2007) the multidimensional analysis of utterances was executed by Utterance Analysis (UA).

In Utterance Analysis each utterance is divided into components and each component further into smaller morphosyntactic parts like words and grammatical morphemes. An example of UA and its use in analysing a single utterance is provided in Figure 5. In UA a component is a linguistic unit which consists of related parts such as a word stem and an ending or a head word and a modifier. The inner structure of components and especially elaboration devices that are utilized to construct the utterance are important factors in evaluating the structural complexity of an entire utterance. The two basic elaboration devices which can be utilized are morphological and syntactic elaboration. Morphological elaboration includes the use of suffixes and syntactic elaboration refers to structures where a head word occurs together with a modifier or determiner, an auxiliary co-occurs with the main verb, or a noun and an adposition (i.e., prepositions or postpositions) coexist. A syntactic component can be an unelaborated, single uninflected word with no modifiers or determiners. Syntactic and morphological elaboration can also both exist in the same

| Table V. MLU-values and IPSyn-scores in the control (CG) and risk groups (RG) (Nieminen, 2007, pp. 64, 67). |
|-----------------|-----------------|
| **MLU**         | **IPSyn**       |
| **CG**          | **RG**          |
| **n**           | **Mean**        | **SD** | **n**           | **Mean**        | **SD** |
| All             | 20              | 5.09   | 1.53          | 20              | 4.40   | 1.75 |
| Girls           | 8               | 5.30   | 1.91          | 10              | 4.84   | 2.03 |
| Boys            | 12              | 4.69   | 1.29          | 10              | 3.96   | 1.39 |
| **n**           | **Mean**        | **SD** | **n**           | **Mean**        | **SD** |
| All             | 20              | 63.80  | 16.86         | 20              | 57.50  | 18.32 |
| Girls           | 8               | 63.25  | 24.41         | 10              | 59.90  | 20.58 |
| Boys            | 12              | 64.17  | 10.56         | 10              | 55.10  | 16.50 |

Figure 3. The MLU values according to the 80 longest intelligible utterances produced by children in the risk (RG) and control groups (CG) (Nieminen, 2007, p. 63).
syntactic component. On the other hand, components with no elaboration are very common as well. Each morphological or syntactic addition creates a new elaboration layer. The more there are elaboration layers the more complex the component is structurally (Nieminen, 2007).

When the syntactic components produced by children in the RG and in the CG were compared, it was found that the groups are very similar. Children in the CG produced 24 different component types and in the RG produced 25 of different types. In both groups the component types represented similar levels of structural complexity. The only difference was that in the CG there were four different types of component each consisting of five elaboration layers whereas in the RG there was only one component type consisting of five layers (Nieminen, 2007). Based on these findings it can be claimed that children in RG and CG have similar morphosyntactic skills, if the skills were evaluated in terms of structural complexity of individual component types. These results support the two hypotheses mentioned earlier which claim that dyslexic and non-dyslexic individuals have similar syntactic skills. However, these results do not yet give any clarification of how these skills are used and, therefore, it can not be concluded which one of the hypothesis candidates is more accurate. To investigate this, the whole utterance structure must be considered.

In order to find out the structural complexity of the entire utterances the composition of the utterances produced by the RG and the CG children were analysed in terms of different component types. The analysis showed that children in the CG combined elaborated components more in their utterances than the RG children. For example, 14.8% of utterances which consisted of two components were unelaborated in the RG whereas in the CG the proportion of unelaborated 2-component utterances was only 6.5%. Risk Group children seemed to prefer also 2-component utterances with one elaborated component. The proportion of these utterances was 62.4% of all 2-component utterances in the RG and 53.7% in the CG. The CG's emphasis on combining several elaborated components within the same utterance was seen also in 3- and 4-component utterances, although the difference between the groups became greater when the number of components increased (Nieminen, 2007). However, the only statistically significant difference between the productions of the two groups was in 3-component utterances in which all three components were elaborated ($U = 36.5$ ($z = -2.03$), $p = .042$). Thus, it seems that the difference between the CG and the RG lies in the structural complexity of the entire utterances, that is, in how many elaborated components can be
combined together in an utterance. This result supports the hypothesis by Deutch and Bentin (1996). This hypothesis suggested that the basic syntactic skills of dyslexic and non-dyslexic children do not differ from each other but the group differences are due to varying abilities to use these skills.

The results from the Utterance Analysis reported here are compatible with the MLU and IPSyn results presented earlier (Nieminen, 2007). Except for the results from the seven children with the lowest performance in the RG, the children in the RG and CG proved to be very similar in terms of IPSyn results. This implies that the children have structures of similar complexity especially on the component level. However, the MLU results showed that children in the RG produced utterances that have fewer morphemes than utterances of the CG children. The RG children’s shorter utterances are a corollary of the lower number of elaborated components when compared to the utterances produced by the CG children.

Conclusion

The studies reviewed here on early language development and dyslexia have been made possible only with a large amount of longitudinal data from different stages of language development as well as with further development of research methods. Besides collecting data from experiments employing typical experimental methods including a head-turning experiment, data have also been collected from picture-book naming and structured play situations. By having different types of data we have been able to gather more comprehensive information on the speech and language development of children with and without risk for dyslexia. Until recently, much of the existing information on dyslexia is based on data and methods used in psychology, and most often the information comes from the English language context. Here we developed linguistic models and methods for analyses in order to study and recognize early signs of dyslexia from Finnish-speaking children. Apart from group comparisons on quantified data, early language development has been analysed qualitatively according to linguistic theories, especially on the phonological and morphosyntactical levels. At the same time as we have more information on possible early signs of dyslexia we also have gained a better understanding of the typical language development of children during the first years of life. In addition, we have created methods for analyses that can be used in other language studies, not only in studies of language development and dyslexia have been made possible only with a large amount of longitudinal data from different stages of language development as well as with further development of research methods. Besides collecting data from experiments employing typical experimental methods including a head-turning experiment, data have also been collected from picture-book naming and structured play situations. By having different types of data we have been able to gather more comprehensive information on the speech and language development of children with and without risk for dyslexia. Until recently, much of the existing information on dyslexia is based on data and methods used in psychology, and most often the information comes from the English language context. Here we developed linguistic models and methods for analyses in order to study and recognize early signs of dyslexia from Finnish-speaking children. Apart from group comparisons on quantified data, early language development has been analysed qualitatively according to linguistic theories, especially on the phonological and morphosyntactical levels. At the same time as we have more information on possible early signs of dyslexia we also have gained a better understanding of the typical language development of children during the first years of life. In addition, we have created methods for analyses that can be used in other language studies, not only in studies of language development (see Nieminen & Torvelainen, 2003).

The reviewed main findings of the four studies (Richardson, 1998; Torvelainen, 2007; Turunen, 2003; Nieminen, 2007), provide us with grounds for stating that possible signs of dyslexia can be detected already in the very early stages of phonological and morphosyntactical development. These signs can be seen in perception or production of duration in speech, in intelligibility of utterances, in the prosody and phonotactics of attempted words and word structures, and the morphosyntactical complexity of utterances. All these linguistic research findings support the theory according to which individuals with dyslexia can have difficulties in creating accurate representations from spoken words. In addition, such individuals might not be able to utilize their syntactical skills as well as individuals without such a risk for dyslexia.

The finding of group differences in different linguistic features is a significant discovery that can also be utilized in practice. This type of information is vital in order to create effective training programs with appropriate linguistic content for assisting very young children who most likely will encounter difficulties in reading and spelling at school. It is possible that these very young children would benefit already before entering school from training with the specific language features included in the analysis of the reviewed studies. However, it is vital to note that children with a family history of dyslexia did not differ even in the group level from the control children on all of the analysed speech and language features (no differences in phonological quality of the produced words, and no differences in MLU and IPSyn measures separately). At the same time it is as important to recognize that all in all there was wide individual variation within the data which is very typical of the early stages of language development (see e.g., McIntosh & Dodd, 2008; McLeod & Hewett, 2008). Therefore, we believe that it is not possible to draw far-reaching conclusions according to a single research finding, for example, that making errors in durational aspects of speech according to the standard view of language would be a certain sign of dyslexia. Or vice-versa, it would not be well founded to state that if a child manages to produce correct word structures and utterances in early language development that this particular child would not have problems in reading and writing in the future. Further investigation of individual children’s performances is needed before such far-reaching conclusions can be made.

The studies reviewed here suggest that prosodic features, phonotactics and complexity of morphosyntactic features in language development in dyslexia should be examined in more detail in the future at least in languages such as Finnish, but these could also be key elements in language development in general. For instance, there is evidence that a prosodic feature such as the perception of duration (using similar speech stimuli as was used here in the perception experiments) is different in children with dyslexia and that this skill predicts reading and spelling skills in English (Richardson, Thomson, Scott, & Goswami, 2004). Our intention is to continue to examine speech and language-specific...
skills of these children in various tasks on an individual level from different stages of development as well as to connect these to the other skills that the children have. In this way, we hope to gain an overall picture of possible individual paths and the skills that are either critical for achieving or hindering good reading and spelling skills. For all this, the JLD project provides an excellent opportunity to explicate dyslexia since over 10 years the same children’s skills have been studied in many different types of tasks.

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Notes

1 The CVCV structures form prototypical Finnish words. Here the same subscript indicates that the phonemes are exactly the same. In cases where there is no subscript the phonemes are different. Thus, CV1CVC1V1 refers to a structure with complete harmony, as in the word pupu “bunny”. CV1VC1V1 refers to a form with consonant harmony, as in the word mummo “granny“. CV1CV1V1 refers to a form with vowel harmony, as in the word vene “boat“. The complex CV1V1CV1V1 refers to a structure which has no harmony, as in the word kupu “cup“.

2 The size of lexicon of these two children was 103 and 241. Despite large lexicons, these children produced phonotactically restricted word forms.

References


