Early identification of dyslexia and preventive training of children at risk
Results of 10 year follow-up of children with familial risk for dyslexia from birth to school age
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• Finnish – phonemic
  – 24 phonemes, 24 graphemes (+6 letters used in loan words)
  – single letter graphemes (+ng for /ŋ:/)
  – bidirectionally regular G-P correspondences

  – simple syllable structure; few consonant clusters
  – loan words (and spellings) adapted into Finnish
    eg. pankki, muki, traktori,
    eg. pizza → pitsa

Aro et al., 2005
Development of Nonword Reading accuracy during 1st Grade (Scottish data up to 2nd grade)

Results from COST A8, Seymour, et al. 2003

The goals of the JLD

Jyväskylä Longitudinal study of Dyslexia: from birth to school age
to identify

• precursors of dyslexia
• predictors of dyslexia
• developmental paths leading to dyslexia

The next step: the development of preventive measures

For recent review of the results, see: Lyytinen et al., Merrill-Palmer Quarterly, 2007
DEFINING RISK IN THE JLD

SELECTION CRITERIA FOR THE AT-RISK FAMILIES: parents

- At least one parent with diagnosed dyslexia from multiple criteria
- Reported dyslexia among at least one of the first degree relatives
- IQ at least 85 (Raven matrices)
- No reported language problems in childhood or later
- No neurological or psychiatric symptoms
- No hearing problems

For details, see Leinonen et al. Reading and Writing, 2001
The reading status of children born at familial risk for dyslexia at school age

- Expectation of the genetic influences
  - > 1/2 would be affected (due to dyslexia of one of the parents and of his/her relative(s))

- The observed result (at the end of the 2. gr.):
  - reading acquisition was compromised among almost 1/2 ie. 48 of 107, persistently 37, +11 initially

Differences between children with and without familial risk of dyslexia and predictive correlations to reading

<table>
<thead>
<tr>
<th>Age</th>
<th>Variable</th>
<th>P = Predictors</th>
<th>D = Differences between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 yrs</td>
<td>Reading accuracy &amp; speed</td>
<td></td>
<td>D</td>
</tr>
<tr>
<td>5 yrs</td>
<td>Naming speed</td>
<td>P &amp; D</td>
<td></td>
</tr>
<tr>
<td>4 yrs</td>
<td>Phonological manipulation</td>
<td>P &amp; D</td>
<td></td>
</tr>
<tr>
<td>4 yrs</td>
<td>Letter knowledge</td>
<td>P &amp; D</td>
<td></td>
</tr>
<tr>
<td>5 yrs</td>
<td>Verbal memory</td>
<td>P &amp; D</td>
<td></td>
</tr>
<tr>
<td>3 yrs</td>
<td>Phonological sensitivity</td>
<td>P &amp; D</td>
<td></td>
</tr>
<tr>
<td>3 yrs</td>
<td>Inflectional skills</td>
<td>P &amp; D</td>
<td></td>
</tr>
<tr>
<td>2 yrs</td>
<td>Articulation accuracy</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>2 yrs</td>
<td>Maximum sentence length</td>
<td>P &amp; D</td>
<td></td>
</tr>
<tr>
<td>6 mth</td>
<td>Speech/processing/percep.</td>
<td>P &amp; D</td>
<td></td>
</tr>
<tr>
<td>Birth ERP to sound differences</td>
<td>P &amp; D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lyytinen et al., Annals of Dyslexia, 2004, and Dyslexia, 2004
ERP recording from newborns in the JLD

From: F3, F4, C3, C4, P3, P4 (Ag/AgCl-electrodes), referred to ipsilateral mastoid; bandpass: 0.5-35 Hz, sampling rate 200 Hz

Responses to /ba/ /da/ /ga/ syllables at age 3-5 days
Predictions on the basis of the differential feature(s) of the ERP between the groups

Guttorm et al., 2005

Correlations of the 3-5 days olds’ ERPs in the at-risk group

Guttorn, et al., Cortex, 2005
ERP difference waves between responses to repeated standard and infrequently presented deviant /ata/s. Note that the deflection of negative polarity called mismatch negativity (MMN?) is present in both groups in the right hemisphere but is clearly smaller in the left hemisphere among at-risk children (see Leppänen & Lyytinen, 1997; Leppänen et al. 2002).

Scatterplot: 6-mo ERP amplitude and early reading before school start

Standard-N400 amplitude at right frontal area

At-risk group (N=25)  Control group (N=27)
Development of language skills and late-talking ... worth attention among children with familial risk for dyslexia

![Graph showing mean z-score composite for receptive and expressive language development across different age groups.](image)

- Late talkers1 at risk group (expressive delayed, N=10)
- Late talkers1 control group (expressive delayed, N=10)
- Late talkers2 at risk group (receptive and expressive delayed, N=12)
- Late talkers2 control group (receptive and expressive delayed, N=3)


Reading accuracy and speed by groups at the end of the first grade

![Bar chart showing mean z-score composite for reading accuracy and speed across different groups.](image)

- Remainder of the groups
- Control group
- At-risk group

Environment

- affects language development in multiple ways but:
  - maternal behavior is connected to the language development of at risk children less explicitly than to that of nonrisk children during early years (Laakso et al., 1999 Infant & Child Development, 8,79-95)¹
  - home literacy environment is associated with phonological development during ages 3-6 years more among at risk children (Torppa et al., Developmental Psychology, 2006, 42,6, 1128-1142)

  .. but the group differences continue to increase..

¹ but see also Lyytinen P. et al. J. Learning Disabilities, 36, 74-86.
Correlates of reading at reading age: speech perception plays still a role!

<table>
<thead>
<tr>
<th></th>
<th>Reading nonwords accuracy</th>
<th>Reading nonwords speed</th>
<th>Text reading accuracy</th>
<th>Text reading speed</th>
<th>Spelling accuracy</th>
<th>Single word reading accuracy &amp; speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd gr. June RAN object time</td>
<td>.312*</td>
<td>.186</td>
<td>.402**</td>
<td>.366*</td>
<td>.258</td>
<td>.263</td>
</tr>
<tr>
<td>2nd gr. June RAS/time</td>
<td>.422**</td>
<td>.328*</td>
<td>.322*</td>
<td>.510***</td>
<td>.392**</td>
<td>.423**</td>
</tr>
<tr>
<td>2nd gr June Speech perc. accuracy</td>
<td>.332*</td>
<td>.113</td>
<td>.465**</td>
<td>.401**</td>
<td>.511***</td>
<td>.327*</td>
</tr>
<tr>
<td>1st gr Aug Phonol. awareness accuracy</td>
<td>.289</td>
<td>.108</td>
<td>.417**</td>
<td>.552***</td>
<td>.410**</td>
<td>.402**</td>
</tr>
</tbody>
</table>
But could poor acquisition of the reading skill be based on compromised auditory perception?

Saturated path model of the associations among auditory perception (2-ramp rise time discrimination), speech perception (phoneme duration discrimination) and spelling accuracy in the JLD children with reading disability (N=30).

The effect of auditory perception on spelling accuracy is mediated through speech perception (Hämäläinen et al., submitted).

Assessments of interest here

<table>
<thead>
<tr>
<th>Predictive domains</th>
<th>Ages of the assessments</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receptive language</td>
<td>12, 14, 18 mo, 2.5, 3.5, 5 y</td>
<td>.78</td>
</tr>
<tr>
<td>Expressive language</td>
<td>12, 14, 18 mo, 2.0, 2.5, 3.5, 5 y</td>
<td>.93</td>
</tr>
<tr>
<td>Morphology</td>
<td>2.5, 3.5, 5.0 y</td>
<td>.76</td>
</tr>
<tr>
<td>Verbal short term memory</td>
<td>3.5, 5.0, 5.5, 6.5 y</td>
<td>.75</td>
</tr>
<tr>
<td>Rapid serial naming</td>
<td>3.5, 5.5, 6.5 y</td>
<td>.89</td>
</tr>
<tr>
<td>Letter knowledge</td>
<td>3.5, 4.5, 5.0, 6.5 y</td>
<td>.72</td>
</tr>
<tr>
<td>Phonological skills</td>
<td>3.5, 4.5, 5.5, 6.5 y</td>
<td>.82</td>
</tr>
<tr>
<td>IQ</td>
<td>5.0</td>
<td></td>
</tr>
</tbody>
</table>

Outcome measure based on a composite of scores of:

- Reading accuracy - 1., 6. and 10. month of the 1.grade
- Fluency 1., 6 and 10. month of the 1. grade and 4. month of the 2. grade
- Spelling 1., 6 and 10. month of the 1. grade and 4. month of the 2. grade
- Comprehension 10, month of the 1 grade and 4. of the 2 grade

For details, see Lyytinen et al., Merrill-Palmer Quarterly, 2006
Profiling of the subgroups of the reading related developmental differences

- Method: Latent profile analysis – variances set as equal between groups
- Program: MPLUS (including imputing the missing data)
- Estimation method: Maximum likelihood parameters estimates with robust standard error
- Criterion: Bayesian information criterion
- N=199

For details, see Lyytinen et al., Merrill-Palmer Quarterly, 2006

Subgroup members’ average performance across ages 1-6 years in the seven skill domains. Phonological impairment N=35 (11r+3c); Typical N=85 (11r+4c); Naming dysfluency N=12 (8r+1c); Unexpected N=67 (14r+8c).

For details, see Lyytinen et al., Merrill-Palmer Quarterly, 2006, 52, 3, 514-546.
Individual profiles of the prediction measures of the JLD children whose reading acquisition was most severely compromised

Figure 1 The age-specific probability curves illustrating the risk of reading disability by variation in key predictors

Puolakanaho et al., Journal of Child Psychology and Psychiatry, 48, 9, 923-931.
The numbers (%) of children according to the relatively **most compromised** pre-reading skill domain among the JLD children with significantly delayed acquisition of reading (N = 44)

- **RAN**: 19 children (43.2%)
- **Phonology**: 5 children (11.4%)
- **Memory**: 4 children (9.1%)
- **Letter Naming**: 12 children (27.3%)
- **None**: 4 children (9.1%)

Let's denote:

- **RAN**: Rapid Accurate Naming
- **Phonology**: Phonological processing
- **Memory**: Working memory
- **Letter Naming**: Letter naming
- **Language production**: Language production
- **Language comprehension**: Language comprehension

**Statistical Analysis**

\[ X^2 (65) = 66.41, \ p = .43, \ CFI = 1, \ TLI = 1, \ RMSEA = .01 \]

Included: standardized coefficients \( \leq .05 \)

Lyttinen et al., in press
### Developmental differences between at-risk children with (N=37) and without (N=66) severe reading impairment

<table>
<thead>
<tr>
<th>Developmental skill</th>
<th>Observed p’s and powers of the differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expressive language 1.5y</td>
<td>.001 .78</td>
</tr>
<tr>
<td>Expressive language 2.5y</td>
<td>.027 .61</td>
</tr>
<tr>
<td>Verbal short-term memory 3.5y</td>
<td>.010 .74</td>
</tr>
<tr>
<td>Verbal short-term memory 5.0y</td>
<td>.016 .68</td>
</tr>
<tr>
<td>Verbal short-term memory 6.5y</td>
<td>.001 .92</td>
</tr>
<tr>
<td>Morphology 5.0y</td>
<td>.024 .62</td>
</tr>
<tr>
<td>Phonology 4.5y</td>
<td>.006 .80</td>
</tr>
<tr>
<td>Phonology 5.5y</td>
<td>.001 .93</td>
</tr>
<tr>
<td>Phonology 6.5y</td>
<td>.002 .88</td>
</tr>
<tr>
<td>Letter knowledge 4.5y</td>
<td>.003 .85</td>
</tr>
<tr>
<td>Letter knowledge 5.0y</td>
<td>.000 .98</td>
</tr>
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<td>.003 .85</td>
</tr>
<tr>
<td>Letter knowledge 6.5</td>
<td>.000 .98</td>
</tr>
<tr>
<td>Rapid naming 5.5y</td>
<td>.000 .97</td>
</tr>
<tr>
<td>Rapid naming 6.5y</td>
<td>.000 .99</td>
</tr>
<tr>
<td>Verbal IQ 8.5y</td>
<td>.004 .83</td>
</tr>
</tbody>
</table>

Lyytinen et al., in press, Sage Handbook of Dyslexia

### Implications for preventive interventions

Compromised development of **expressive and receptive** language characterizes many children at familial risk for dyslexia at early age.

The challenges associated with reading acquisition are reflected in:
- poor readiness to store letter names to memory (from age 3 years),
- fuzzy representations of speech items (and therefore),
- slow learning of grapheme-phoneme connections (at the age of school entry) and

Many of the children who have mentioned difficulties fail to automatize reading comparably with their agemates. This is associated with slow retrieval of spoken responses on the basis of visual input (reflected e.g. in poor RAN scores).

Preventive training should thus help
1) in differentiation of the phonemic space to make the connection building between phonemes and graphemes easier,
2) in storing the connections written and spoken units of language and
3) in the automatization of the identification of written words.

Concluding remarks

- Familial background increases the risk of dyslexia substantially – relatively the more severe reading difficulties are attended
- Very early language delays can be very informative, both in the expressive and receptive language domains
- Poor letter name learning predicts without false negatives (false positives should be accepted)
- Dysfluent naming predicts the most persistent difficulties
- Speech perception is predictive from 6 months and does so at school age still after controlling for other known predictors
- ERPs to changes in speech and nonspeech sounds comprise the earliest significant predictors


Reprints from heikki.lyytinen@psyka.jyu.fi
Preventive training to
decrease the fuzziness of phonological representations and
increase the automaticity of the interplay between spoken
and written language

By motivating children to play an enjoyable game to learn to
identify written units among alternatives which correspond
given phonemic sound unit.
> helps making the phonemic space more differentiated.
Repetition of playing this connection building game
> helps increasing the speed of retrieval from the memory
Massed practice of a few hours' playing helps - also most of
the severely compromised early readers


Literate game
The task: Catch the letter that matches the sound you hear!
Expected conditions for success

- Sufficiently accurate, intensive and long lasting exposure
  - By using high quality sounds with emphasis (when required on an individual basis) on features which are difficult to master
  - Optimal adaptation of the training on an individual basis
  - Maximizing enjoyment (experienced success and appropriate level of challenge) to maintain the player’s interest to continue to be fully involved in training and to sustain training until the goal is achieved

Exemplary learning curves of 4-8 year olds (N=726)

The cumulative number of learned items

Modeling: Janne Kujala
Challenges

• Works without complications in consistent (gr>=<ph) orthographies
  – Warning: may "condition" the connections too deeply to allow easy re-learning of different associations required by English if items with small units size are used.
  – Therefore, only consistent connections (mostly large units) can be drilled without risk of losing the necessary flexibility (alternation of associations) typical of inconsistent orthographies.

Early identification and prevention of dyslexia

Supported by The Academy of Finland via CoE, University of Jyväskylä, Niilo Mäki Foundation and EU Marie Curie Excellence Grants

The Jyväskylä Longitudinal study of Dyslexia (JLD)
Prospective follow-up of children at familial risk for dyslexia from birth to school age

> Early identification
Timo Ahonen, Mikko Aro, Kenneth Eklund, Jane Erskine, Tomi Guttorm, Jarmo Hämäläinen, Ritva Ketonen, Marja-Leena Laakso, Matti Leiwo, Paavo Leppänen, Paula Lyytinen, Anna-Maija Poikkeus, Anne Puolakanaho, Ulla Richardson, Paula Salmi, Minna Torppa, Helena Viholainen

> Studying with prevention methods
Reading game: Ulla Richardson, Jane Erskine, Janne Kujala, Anne Alanko, Sani Hintikka
Learning game programmer: Tuomo Hokkanen, Ville Mönkkönen, Miika Pekkarinen
Thank you!

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