Early identification and prevention of difficulties in learning to read – a global perspective

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& the Jyväskylä Longitudinal study of Dyslexia (JLD) and Graphogame teams

Content: basic facts about reading acquisition, acquisition of reading skill among readers of fully transparent Finnish, associated cultural factors, bottlenecks compromising their reading, ways to preventively help them and how a follow-up from birth of children with and without familial risk of dyslexia has helped us to develop effective learning environment for all

For more including publications, see heikki.lyytinen.info and graphogame.info

Important facts about reading acquisition

• Reading acquisition = learning to connect items of spoken language to its written forms

• Written languages vary in terms of how this connection-building can be made

• Alphabetic orthographies such as Finnish, German, Spanish and African local languages are relatively consistent at grapheme-phoneme level >no challenges associated with choosing the items which had to be connected from spoken to written – >>very different in English where none of its letters represents the same phoneme in all contexts of written English

• Nonalphabetic scripts – the main challenge: large number of connections to be stored for acquiring the reading skill
Reading acquisition and the consistency of the connections between spoken and written

- If the reading instruction is organized optimally the time child needs for the acquisition of the basic reading skill is the shorter
  - the more consistent the connections are - when only few (if any) complexities/alternatives need to be learned
  - the smaller the number of connections one has to learn

Thus the learning loads differ widely between transparent e.g. Finnish & African. ~30 and English >1000 and between Alphabetic and Chinese writings:

Alphabetic no more than 1000 but in Chinese >10 000
Compromised reading skill

Biological reasons (% of population)
» Global  > 5%
» Finland > 3% (and other transparent languages)

Educational reasons
» Global - up to 90% (in developing countries)
» Finland – 0%

» >500 million compromised readers!
Early identification - Jyväskylä Longitudinal study of Dyslexia (JLD) & Graphogame – our tool for the prevention of RDs

The Jyväskylä Longitudinal study of Dyslexia (JLD):
An intensive follow-up of children at familial risk for dyslexia from birth

> JLD 1994-

> Graphogame (Ekapeli in Finland, 2004-), the Finnish participants
Learning game programmers: livo Kapanen, Ville Mönkkönen, Miika Pekkarinen

Supported by EU, Niilo Mäki Foundation, Academy of Finland, Univ. of Jyväskylä, Tekes, RAY, Ministries of Education & Foreign Affairs Finland, Kela, Finnish Cultural Funds, Nokia Oy, Kone Oy, Wärtsilä Oy.
The goals of the JLD following children with familial risk for dyslexia from birth to identify (from children at familial risk for dyslexia)

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

The last step: the development of preventive measures
I Screening

Short questionnaire administered at the maternity clinics
N=8427 parents

II Screening

Comprehensive questionnaire
N=3146 parents

Assessment of parents’ reading and spelling skills
N=410 parents

III Screening

AT-RISK GROUP
N=117 infants

CONTROL GROUP
N=105 infants

Number of children who have attended the last originally agreed assessment phase in Grade 3

AT-RISK GROUP
N=108 children

CONTROL GROUP
N=92 children

Born at the hospitals of Central Finland during 01.04.93-31.07.96
N=9368 infants
**PHASES OF ASSESSMENTS**

**AT-RISK GROUP**
- N=108 children
- 18 months: N = 107
- 14 months: N = 108
- 6 months: N = 112

**CONTROL GROUP**
- N=92 children
- 18 months: N = 96
- 14 months: N = 94
- 6 months: N = 96

**Primary school**
- I grade: AT-RISK GROUP N = 107, CONTROL GROUP N = 92, CLASSMATES N = 1549
- II grade: AT-RISK GROUP N = 108, CONTROL GROUP N = 92, CLASSMATES N = 1756
- III grade: AT-RISK GROUP N = 108, CONTROL GROUP N = 92, CLASSMATES N = 2641

**Secondary school**
- VII grade: AT-RISK GROUP N = 85, CONTROL GROUP N = 66, CLASSMATES N = 1452
- VIII grade: AT-RISK GROUP N = 101, CONTROL GROUP N = 81, CLASSMATES N = 1705
- IX grade: AT-RISK GROUP N = 88, CONTROL GROUP N = 76, CLASSMATES N = 204

**Adulthood**
- 20 years: AT-RISK GROUP N = 27
- 5½ years: CONTROL GROUP N = 16

Data gathering continues.
IDENTIFYING & PREDICTING RISK
significant predictors found in the follow-up from birth of children at familial risk for dyslexia (Jyväskylä Longitudinal study of Dyslexia)

Age | Variable
--- | ---
7 - yrs | Reading accuracy & speed | D
5 - yrs | Naming speed | P & D
4 - 6 yrs | Phonological manipulation | P & D
5 - 6 yrs | Letter knowledge | P & D
5 - yrs | Verbal memory | P & D
3 - 6 yrs | Phonological sensitivity | P & D
3 - 5 yrs | Inflectional skills | P & D
2 - 3 yrs | Articulation accuracy | P
2 yrs | Maximum sentence length | P & D
6 mth | Speech perception | P & D
3-5 days ERP to speech sound | P & D
3-5 days ERP to sinusoidal sound/pitch | reading acquisition


P = Predictors
D = Differences between groups
Reading acquisition/dyslexia among readers of fully transparent alphabetic writing - Finnish

Learners of Finnish have to
1) store the sounds of the < 30 letters and
2) invent that just pronouncing those sounds in the order of letters makes one able to read whatever pronounceable known or unknown written item

Struggling readers of Finnish face difficulties in differentiating sounds from each others – those of e.g. N and M letters are difficult – to be able to store the sounds of those letters.

The final problem occurs in learning to master the lengths of the phoneme which can be short or long (last marked by repeating the letter) - thus the main problem is in speech perception and as we have observed compromised sensitivity to sounds in general soon after birth.
Individual profiles of the prediction measures of the JLD children whose reading acquisition was most severely compromised

Predicting reading fluency

- **Letter knowledge**: 4.5 to 6.6 years
- **Rapid Naming**: 5 to 6.5 years
- **Phonological awareness**: 1st Grade, 7.5 years
- **Reading accuracy**: 1st to 3rd Grade, 7 to 9 years
- **Reading fluency**: 8th Grade, 15 years

CFI = 0.98, TLI = 0.98
RMSEA = 0.043, SRMR = 0.036
chi = 112.063 (df = 82), p = 0.004
N = 200

R² = 49.5%
### Observing developmental routes to dyslexia

- **Predictive domains, assessment ages from 1-6.5 y**
  - Receptive lang. 12,14,18 mo, 2.5, 3.5, 5.0 y, .78
  - Expressive lang. 12,14,18 mo, 2.0, 2.5, 3.5, 5.5 y, .93
  - Morphology, 2.5, 3.5, 5.0 y, .76
  - Verbal short term memory, 3.5, 5.0, 5.5, 6.5 y, .75
  - Rapid serial naming, 3.5, 5.5, 6.5 y, .89
  - Letter knowledge, 3.5, 4.5, 5.0, 6.5 y, .72
  - Phonological skills, 3.5, 4.5, 5.5, 6.5 y, .82
  - IQ, 5.0

- **Outcome measures used as a composite of the following measures:**
  - Reading accuracy (Aug., Jan., May), Fluency (Aug., Dec., April, May/1 gr, Nov/2. gr), Spelling (Dec., Apr./1.gr Nov/2. gr) and Comprehension (Apr./1gr. And Nov/2. gr)

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
Profiles of early cognitive skills for different subgroups across ages 1 to 6.5 years, their average performance in reading and writing composite score across Grade 1 and 2, and PISA reading composite at 15 years of age. (Modified from Figure 1 in Lyytinen et al., Merrill-Palmer Quarterly, 2006)
Learning game and research environment for the acquisition of the basic reading skill:

Graphogame helps learning the connections between spoken and written language
Graphogame – an enjoyable mobile or computer game for learning to read: How it helps at risk children to overcome the fuzziness of the phonemic representations with letters

Description. In the game (left) the learner is choosing (in its classical version) from the falling balls the corresponding letter of the one s/he hears from headphones. The illustration (right) shows an example of how results can be followed. Here we follow how /N/ sound (in the centre) which learner has heard in the game more than 100 trials at the moment this picture is printed from the game logs has made him/her to choose incorrect alternative letters (shown with the number of times these have occurred with the correct N-letter). The red distributions reveal that the learner has had difficulties in not to choose R and M during the first fourth of such trials, but became able to learn during the last fourth (with green distribution) that e.g. R does not represent the /N/ sound. For this learner acquiring that the /N/ sound is not represented by M-letter has been a real challenge as shown by the red and darker green distributions which reveal that most of the choices during the first and second fourths of trials (respectively) have ended up to this mistake. The learner has failed to learn to identify the correspondence of the /N/ sound during the whole session in trials where M has occurred (7 times) as an alternative. On the other hand s/he has not chosen e.g. S to represent the /N/ sound any more during the last fourth of the trials (no misidentifications during the 9 last of the 34 trials with S as an alternative). For more details, see Lyytinen et al., Scand.J.Psychol., 2009, 50, 668-675 and for documentation of the efficiency of the game in supporting learning among at risk children, see eg. Saine et.al., Child Development, 82,3,1013-1028.
Exemplary learning curves of children at risk showing the time needed for learning the sounds of the letters among Finnish children (N=726)

4–8 (RGBMC) vuotiaat (N=726)

The cumulative number of the acquired connections between sounds and letters

Hours of playing

Modelling: Janne Kujala
CARRI group = Computer assisted remedial reading intervention group who played the GG 1/4 of the remediation time
Mainstream group = Mainstream reading instruction group
RRI group = Remedial reading intervention group – face-to-face remediation all the time

At the end of the 1.gr.
Brain changes resulting from the use of the Graphogame
GG training of <5 hours affects brain

Pre-Post GG: Children (n=15) before and after playing with Graphogame

Post-pre interaction between groups playing Graphogame vs Mathgame (same with numbers): $p<0.005$

Brem et al., PNAS, 2010, 107(17), 7939-7944.
Successful preventive practice

Massed practice using the Graphogame following optimal phonics strategy helps at risk children when

* started at >6.5y of age

* played >1 x per day in subsequent days until the goal is reached
  – motivated to be used in an as “active” sounding form as possible
  – motivation to continue is guaranteed by rewarding via experience of success (~80% correct trials)

– the role of parents: they show they very much like child plays GG

See: [www.lukimat.fi](http://www.lukimat.fi) (where Finnish children play) or [graphogame.com](http://graphogame.com) for description and demo in English
Challenges

• Works without complications in consistent (gr>=<ph) orthographies
  – Warning: may ”condition” the stimulus-response connections too deeply to allow easy relearning of different associations when there are alternative connections.
  – Therefore, only consistent relations can be drilled without any risk of losing the necessary flexibility (alternation of associations) typical of inconsistent orthographies.
An example of the statistical approach to illustrate the problems associated with consistency (or the paucity of it)

A mimimun set of single letter-sounds selected to a version of the game – list of their sounds present in > 5% of the occurrence of the letter in English text (Cedex databasis, among 17 million words)

<table>
<thead>
<tr>
<th>Letter</th>
<th>% of different / all words</th>
<th>Letter</th>
<th>% of different / all words</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>62.3</td>
<td>l</td>
<td>95.4</td>
</tr>
<tr>
<td></td>
<td>24076</td>
<td></td>
<td>22272</td>
</tr>
<tr>
<td></td>
<td>3471217 l (in)</td>
<td></td>
<td>2934160 l (all)</td>
</tr>
<tr>
<td>19.4</td>
<td>4386</td>
<td>al</td>
<td>94.4</td>
</tr>
<tr>
<td></td>
<td>1083446 al (i)</td>
<td></td>
<td>14990</td>
</tr>
<tr>
<td>5.1</td>
<td>2519</td>
<td></td>
<td>2844232 d (and)</td>
</tr>
<tr>
<td></td>
<td>283459 (social)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>95.4</td>
<td></td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>22272</td>
<td>m</td>
<td>11176</td>
</tr>
<tr>
<td></td>
<td>2934160 l (all)</td>
<td></td>
<td>1817206 m (from)</td>
</tr>
<tr>
<td>d</td>
<td>94.4</td>
<td>b</td>
<td>99.0</td>
</tr>
<tr>
<td></td>
<td>14990</td>
<td></td>
<td>7726</td>
</tr>
<tr>
<td></td>
<td>2844232 d (and)</td>
<td></td>
<td>1169525 b (be)</td>
</tr>
</tbody>
</table>

Computation: J.Kujala
Connection building of written and spoken units of English

Alternative approaches:

• Small unit game: teaches graphemes of the most prototypical vowels, blends of CV and VC digraphs and combines into CVC words etc.

• Larger unit game: phoneme approach+large rime units, blends learned small set of ph/gr in CV rime units starting from most dense neighbourhoods with consistent spelling etc.
Introducing connections between spoken and written in English in the GG

One example of a game level: a frog hunting bugs. Player hears the target word and selects the written counterpart for the frog to catch.
Results of the English Graphogame
with Usha Goswami and Fiona Kyle, Cambridge University

• Reading gains in standard scores (SS) per hour of playing:
  – Phoneme game 0.47 SS points
  – Rime game 0.68 SS points

Note: ~0.3 in the most promising earlier interventions (Hatcher et al. 2006)

Only rime game elevated significantly the spelling skill

Kyle, Goswami et al., Reading Res. Q. 2012, 48, 61-76
Grapho Learning Initiative

Our vision: will help millions of learners, who otherwise would not have access to learn **basic skills**, such as **reading**, and be able to launch themselves to a sustainable **learning** curve and a **road to prosperity**.

我們的願景: 幫助成千上萬的沒有機會學習各種基本技能（例如閱讀）的孩子，讓他們走上可持續發展的學習之路，通向成功。

www.graphogame.com
Research Evidence

• we have gained research evidence on the efficacy of GraphoGame™ training.
  – from transparent writing environments
  – to some degree also from more non-transparent orthographies including English.

• Our partner network is tackling global challenges
  – Biological factors (dyslexia)
  – Insufficient teaching
  – Lack of social support
Evidence-based Educational Game

GraphoGame™ is

• Theoretically sound, & empirically validated with behavioral and brain measures

• Documented in publication forums, such as Child Development and Proceedings of National Academy of Sciences (PNAS)
The basic principles of Graphogame development for a new writing system

- Careful study of the written language environment with local experts for developing appropriate content
- Evidence based documentation of the efficiency of the game after a new implementation of content for a new context
- Distribution and use under the responsibility of the local Ministry of Education after research has shown its efficiency in an orthographic environment
The solutions offered by our GraphoWorld Initiative

Children are helped to acquire functional reading skills by

- 1. supporting the learning of basic reading skill via our training tool – Graphogame - to be used e.g. in Africa by
  - elementary school teachers for learning the sounds of letters and
  - children to practice basic reading skill, starting from the letter-sound learning

- 2. finding ways to create and distribute exciting reading material for children to be used at the time they have just learned to read for supporting the acquisition of the functional skill for knowledge acquisition

- 3. supporting the acquisition of the skill to read L2, such as English, via the Graphogame
Objectives

Training literacy skills: basic skill, automatisation and reading comprehension

1. Global distribution and service
2. GraphoGame™ in local language
3. Non-profit business model
Examples

Low cost solution for developing countries

• The GG works in low cost tablet and smart phone devices.
• The mobile games are likely reaching the homes also in Africa within next not so many years.
  • Ministries of Education: training, learning, analytics.

For learning the results of our GG-studies in Africa, (-2015), see Ojanen et al., 2015

**How Graphogame helps in Zambia**

*Estimated Marginal Means of spelling Test*

![Graph showing Estimated Marginal Means of spelling Test over different conditions: Controls (C), Teachers informed about phonics instr. (TG), Teachers informed about phonics + children play (TG&TG), Teachers informed about phonics + also teachers play (TG&LG), and Teachers informed about phonics + also teachers play (TG&LG). The graph shows an upward trend in Estimated Marginal Means as more conditions are included.*
Practical facts about the game

• Available for free (from 2007) to all Finnish children
  – Playing via net with up-to-date information for teachers and parents about learning difficulties
• Very easy to use – children learn within minutes and can use without adults
  – 4-10 hours of playing helps most at risk for dyslexia
• Works also in Android, Apple, MS mobile phones
• Used in Finland via a state procurement (made by the Ministry of Education - at best >20 000 daily users – from the age cohort of 60 000)
GraphoGame® as a Service

Learning

GraphoGame® as download and/or online

Online learning material, videos, ebooks and guides

Teacher training, Classroom and/or GraphoGame® Club support.

GraphoGame® Cloud

Analytics

Dynamic assessment, analysis and adaptation to learners skills.

Gamelogs Database

Big Data

Training
GraphoGame™
Pre-releases, for testing

• Studies initiated in Europe (outside Finland)
  – Austria, Cyprus, Denmark, Estonia, **Finland, France**, Greenland, Hungary, Ireland, Island, Israel, Netherlands, Norway, Poland, Portugal, **Sweden**, Switzerland and UK

• Studies running in Africa
  – Erithrea, Kenya, **Namibia**, South Africa, Tanzania and **Zambia**

• Elsewhere
  – Brazil, Canada, **Chile, China**, Indonesia, Mexico, Taiwan and US
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• Call: +358 50 552 4892
• Have a look of our research: heikki.lyytinen.info
• Ask for reprint(s): heikki.lyytinen@psyka.jyu.fi
• The game pages in Finnish: http://www.lukimat.fi/
• ..in English: http://www.graphogame.com
• See also grapholearn.info for the whole approach
• The most recent summary of main results of the JLD: https://link.springer.com/article/10.1007/s40474-015-0067-1
• The most detailed recent description of the Graphogame:
  • http://www.humantechnology.jyu.fi/articles/volume10/2014/Richardson_Lyytinen.pdf
• If you are interested in joining us, please, contact Ulla.a.Richardson@jyu.fi

Thank you for attention!