GraphoGame –
A learning environment for literacy acquisition:
On the route to helping compromised readers across the globe

Professor Heikki Lyytinen & the GraphoGame team

Please, have a look of the present slides (and some more) from info.graphogame.com

22. Annual meeting of the Society for the Scientific Study of Reading,
Globally
780 000 000 people are illiterate

• Biologic, educational and social problems
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%
Development of Nonword Reading accuracy during 1st Grade

(Scottish data up to 2nd grade)

COST A8 results, 1998
The development of reading accuracy (% correct) during the 1. grade in Finland

The average development

Individual development

Aro et al., 2004
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

III Screening

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

AT-RISK GROUP

- N=117 infants

CONTROL GROUP

- N=105 infants

Born at the hospitals of Central Finland during 01.04.93-31.07.96

N= 9368 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
### Phases of Assessments

<table>
<thead>
<tr>
<th>Phase</th>
<th>Age (years)</th>
<th>AT-Risk Group N</th>
<th>Control Group N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neo-natal</td>
<td>6 months</td>
<td>108</td>
<td>92</td>
</tr>
<tr>
<td>14 months</td>
<td>108</td>
<td>96</td>
<td>94</td>
</tr>
<tr>
<td>18 months</td>
<td>107</td>
<td>96</td>
<td>94</td>
</tr>
<tr>
<td>2 years</td>
<td>108</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>2½ years</td>
<td>107</td>
<td>95</td>
<td>94</td>
</tr>
<tr>
<td>3½ years</td>
<td>107</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td>4½ years</td>
<td>107</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td>5 years</td>
<td>107</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td>5½ years</td>
<td>107</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td>6½ years</td>
<td>107</td>
<td>93</td>
<td>93</td>
</tr>
</tbody>
</table>

#### Primary School

<table>
<thead>
<tr>
<th>Grade</th>
<th>AT-Risk Group N</th>
<th>Control Group N</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>107</td>
<td>92</td>
</tr>
<tr>
<td>II</td>
<td>108</td>
<td>92</td>
</tr>
<tr>
<td>III</td>
<td>108</td>
<td>92</td>
</tr>
</tbody>
</table>

#### Secondary School

<table>
<thead>
<tr>
<th>Grade</th>
<th>AT-Risk Group N</th>
<th>Control Group N</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII</td>
<td>85</td>
<td>66</td>
</tr>
<tr>
<td>VIII</td>
<td>101</td>
<td>81</td>
</tr>
<tr>
<td>IX</td>
<td>88</td>
<td>76</td>
</tr>
</tbody>
</table>

#### Adulthood

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>AT-Risk Group N</th>
<th>Control Group N</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>27</td>
<td>16</td>
</tr>
</tbody>
</table>

Data gathering continues.

School entry at the age of 7 years.
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
Birth | ERP to speech sound | P & D

<table>
<thead>
<tr>
<th></th>
<th>At-risk with dyslexia</th>
<th>At-risk with NO dyslexia</th>
<th>Controls with NO dyslexia</th>
<th>F</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expressive language 1.5 y</td>
<td>-.26 (.58)</td>
<td>.03 (.90)</td>
<td>.05 (.96)</td>
<td>1.49</td>
<td>.32</td>
</tr>
<tr>
<td>Expressive language 2.5 y</td>
<td>.03 (.90)</td>
<td>-.05 (.94)</td>
<td>.09 (.78)</td>
<td>.44</td>
<td>.12</td>
</tr>
<tr>
<td>Morphology 5 y</td>
<td>-.66 (.89)</td>
<td>-.33 (1.17)</td>
<td>.01 (.99)</td>
<td>4.56*</td>
<td>.77</td>
</tr>
<tr>
<td>Verbal short-term memory 5 y</td>
<td>-.42 (1.04)</td>
<td>-.36 (1.08)</td>
<td>.06 (1.01)</td>
<td>3.88*</td>
<td>.70</td>
</tr>
<tr>
<td>Verbal short-term memory 6.5 y</td>
<td>-.18 (1.26)</td>
<td>.01 (1.07)</td>
<td>.11 (.98)</td>
<td>.83</td>
<td>.19</td>
</tr>
<tr>
<td>Phonology 5.5 y</td>
<td>-.76 (.70)</td>
<td>-.31 (1.02)</td>
<td>.03 (.90)</td>
<td>9.89***</td>
<td>.98</td>
</tr>
<tr>
<td>Phonology 6.5 y</td>
<td>-.61 (.85)</td>
<td>-.26 (.97)</td>
<td>.04 (.89)</td>
<td>6.78**</td>
<td>.92</td>
</tr>
<tr>
<td>Letter knowledge 5-5.5 y</td>
<td>-.91 (.85)</td>
<td>-.26 (1.11)</td>
<td>.15 (.92)</td>
<td>12.28***</td>
<td>1.00</td>
</tr>
<tr>
<td>Letter knowledge 6.5 y</td>
<td>-.89 (.91)</td>
<td>-.34 (1.20)</td>
<td>.20 (.82)</td>
<td>13.58***</td>
<td>1.00</td>
</tr>
<tr>
<td>Rapid naming 5.5 y</td>
<td>-1.47 (2.02)</td>
<td>-.36 (1.48)</td>
<td>.08 (.87)</td>
<td>13.78***</td>
<td>1.00</td>
</tr>
<tr>
<td>Rapid naming 6.5 y</td>
<td>-1.29 (1.52)</td>
<td>-.37 (1.71)</td>
<td>.13 (.86)</td>
<td>13.13***</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Individual profiles of the prediction measures of the JLD children whose reading acquisition was most severely compromised

Important facts about reading acquisition

• Reading acquisition = learning to connect a spoken language to its written forms
• Written languages (orthographies) vary in terms of how this connection-building can be made
• Alphabetic orthographies such as Finnish, Spanish and most African languages are **consistent** at grapheme-phoneme level
• There are no challenges associated with choosing the items which had to be connected from spoken to written
Predicting reading fluency

- **Rapid Naming**
  - 5 to 6.5 years

- **Letter knowledge**
  - 4.5 to 6.6 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%
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.
Illustration of the feedback the game provides to teachers about the present status of the differentiation of the phonemic space of the learner at any stage of one’s training

Illustration developed by Janne Kujala
..continuation of the feedback about learning of different letter-sound connections
Illustration of the game developed by Janne Kujala
Illustration of the game developed by Janne Kujala
Graphogame as an assessment tool

• Dynamic assessment:
  – Online follow-up of the results of learning connections between spoken and written items
  – Immediate application of the observed results to guiding the training to bottleneck areas
  i.e. integrating assessment and intervention as made in the response-to-intervention model with the exception that the cycle of refocussing intervention can happen in seconds
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
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 following optimal phonics strategy helps at risk children when started at $>6.5$y of age

$>1$ x per day in subsequent days until the goal is reached

– motivated to be used in an as ”active” form as possible

– motivation to continue is guaranteed by rewarding via experience of success ($\sim 80\%$ 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 mimimum 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>(exemplary word)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>62.3</td>
<td>3471217 l (in)</td>
</tr>
<tr>
<td></td>
<td>19.4</td>
<td>1083446 al (i)</td>
</tr>
<tr>
<td></td>
<td>5.1</td>
<td>283459 (social)</td>
</tr>
<tr>
<td>l</td>
<td>95.4</td>
<td>2934160 l (all)</td>
</tr>
<tr>
<td>d</td>
<td>94.4</td>
<td>2844232 d (and)</td>
</tr>
<tr>
<td>m</td>
<td>100.0</td>
<td>1817206 m (from)</td>
</tr>
<tr>
<td>b</td>
<td>99.0</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.
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
Introducing connections between spoken and written in English in the GG

Word "jet" is the target item, frog has to catch all "jet" words on the screen.

Green bar is showing the time left in the level, one level is approximately 30 seconds.

Other words on the screen are distractors. If the player selects the wrong word, the game shows the correct one.

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.
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.

**How Graphogame helps in Zambia**

![Graph](image-url)
Practical facts about the game

• Available for free 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 Symbian & Android 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.

Analytics

Dynamic assessment, analysis and adaptation to learners skills.

Gamelogs Database
Big Data

Training
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
Global Network
Research And Development Partners
GraphoWorld Network of Excellence
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 (in Finland)
Learning game programmers: Iivo 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.
For more.., please,

- Call: +358 50 552 4892
- See for Unesco Chair: www.jyu.fi/unescochair
- 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 info.graphogame.com for the whole approach
- Open access summary: Human Technology, May 2014

Thank you for attention!