Breaking the reading code, reading comprhension and reading skill

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Lecture in Iceland, 21.10.2022

Literacy acquisition – what are the present challenges?

This is a summary of our knowledge collected during the more than 30 years of intensive research of literacy acquisition and ways of

*how we have applied the results in Finland during last 20 years and

*how we plan to proceed to overcame the present challenges globally

The actual goal now is to invent ways to stop the observed fall of the PISA results

seen in many countries including Finland and Iceland although Finnish girls are still at the top level

PISA literacy results have been declining during 3 assessment points especially among *boys whose readiness to learn knowledge is at risk of declining in unacceptable ways*

How we have proceeded in Finland and influenced globally?

- About 20 years ago Finland ordered from my group (which had run the Jyväskylä Longitudinal study of Dyslexia (JLD)) a digital learning environment to stops problems related to acquisition of the basic reading skills, including children at risk for dyslexia

- We developed a digital learning game called Ekapeli (First Game) for helping all

- The results have been dramatic

- Every Finnish child has used it with good results when starting her/his literacy career

- We can say that there are **no learner with dyslexia anymore in Finland** among those who have playd the game following the way we have recommended it to be used

- After seeing the excellent results tens of countries have wanted to follow our solution which is why this product is now distributed globally with the name GraphoGame.

* It is based on the same GraphoLearn technology which runs Ekapeli

- During last years it has been used eg. in France and USA by millions of children
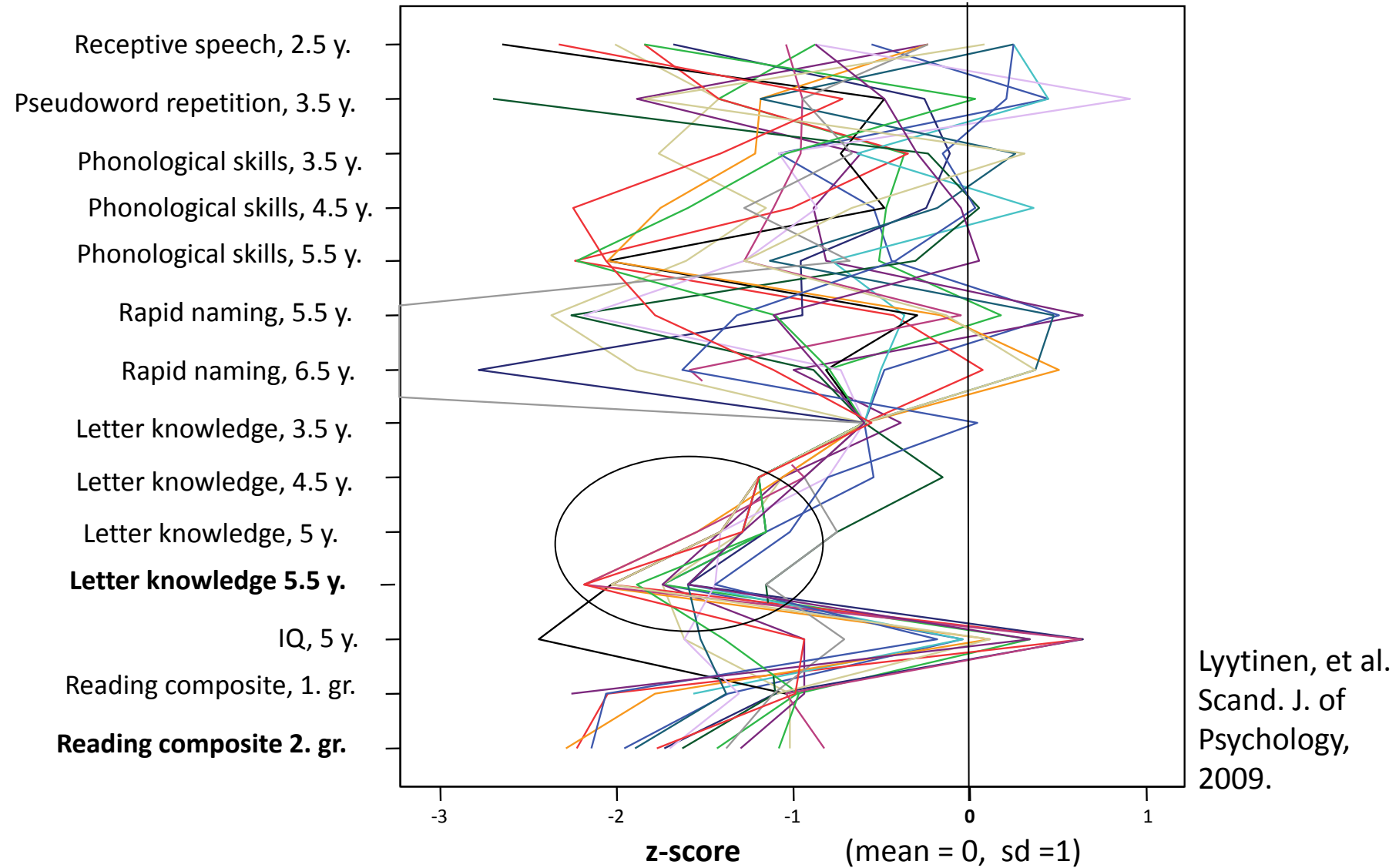
Important facts about reading acquisition

- Reading acquisition = **learning to connect items of spoken language to their written** forms – is based on associative learning principles which is applied in Graphogame

- 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 written items which one had to be able to connect to its spoken form**

- >>very different in English in which none of its letters represents the same phoneme in all contexts of written English – especially difficult to master are the vowel items

- Icelandic is between fully consistent orthographies and that of English and is open to be implemented in the GraphoGame

- Icelandic is among the few countries which has not developed it (with us) first for empirical validation and then for the use of all Icelandic children

# Prevention of learning problems (LDs) is import

- Overcoming LDs defines childrens' success in the school and then also in life
- **Prevention is most often the only way to overcome LDs successfully**
- The most central learning problems are hindering reaching full literacy
- This is why we had to consider how to divide the available resources to
  - spend them optimally, ie. prevention of most challenging reading problems
  - focus on opening the most damaging bottlenecks
  - make our best to use scientific knowledge to achieve confirmed results
  - means which are most cost-effective
  - keep learners **engaged long enough to repeat the training f**or reaching the goals
  - confirm that the results have been achieved by using appropriate methods
  - apply dynamic assessment for doing that most optimally
- Successful revention is possible if we identify children with risk before school

The JLD-follow-up from birth to school age of reading-related development

Receptive speech, 2.5 y.
Pseudoword repetition, 3.5 y.
Phonological skills, 3.5 y.
Phonological skills, 4.5 y.
Phonological skills, 5.5 y.
Rapid naming, 5.5 y.
Rapid naming, 6.5 y.
Letter knowledge, 3.5 y.
Letter knowledge, 4.5 y.
Letter knowledge, 5 y.
Letter knowledge 5.5 y.
IQ, 5 y.
Reading composite, 1. gr.
Reading composite 2. gr.

-3   -2   -1   0   1

z-score   (mean = 0, sd =1)

Lyytinen, et al. Scand. J. of Psychology, 2009.

Individual profiles of the prediction measures of the JLD **children whose reading acquisition was most severely compromised**

Illustration of the traditional version of the GraphoGame (GG) – an enjoyable digital game (Android/Apple/MS) training the basic reading skills :
How it helps in overcoming the fuzziness of the phonemic representations of written items
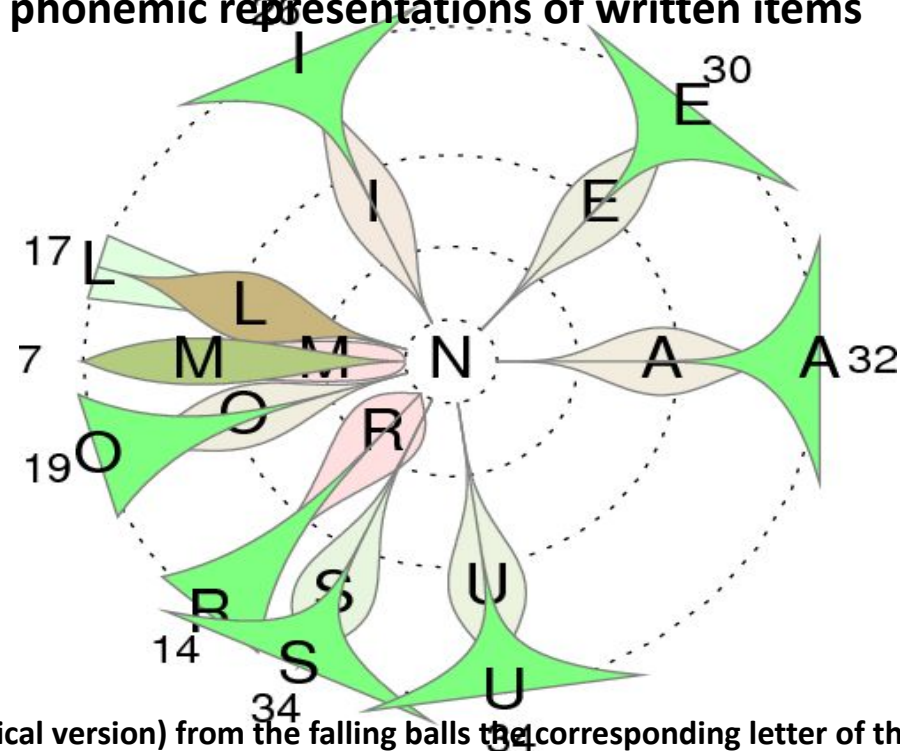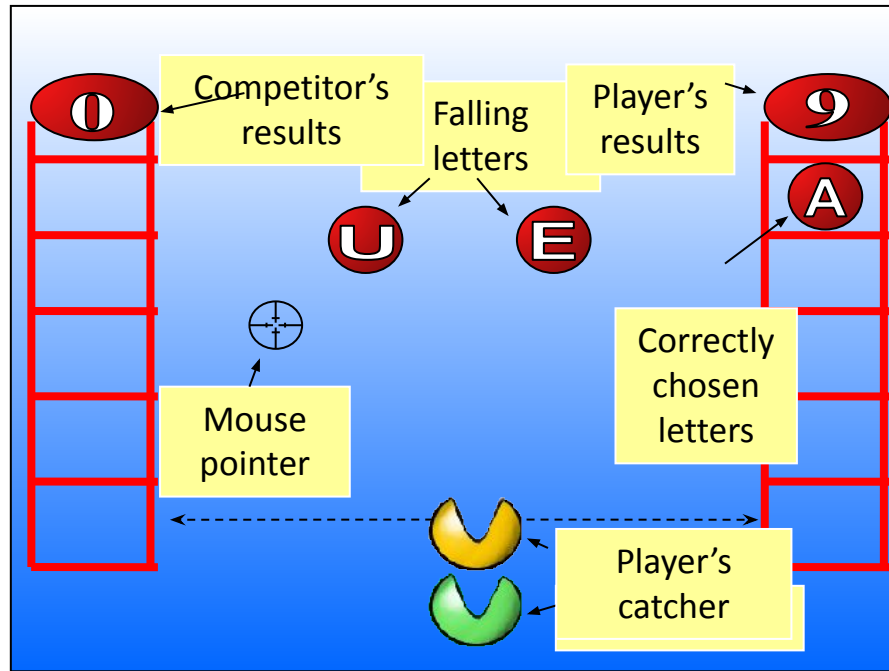

Description. In the game (left) the learner is choosing (in its classical version) from the falling balls the corresponding letter of the one s/he hears from headphones. The illustration (right) shows an example of how results can be followed. Here we follow how /N/ sound (in the centre) which learner 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**.
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Exemplary learning curves of GG players showing the time needed for storing the sounds of the letters among Finnish at risk children
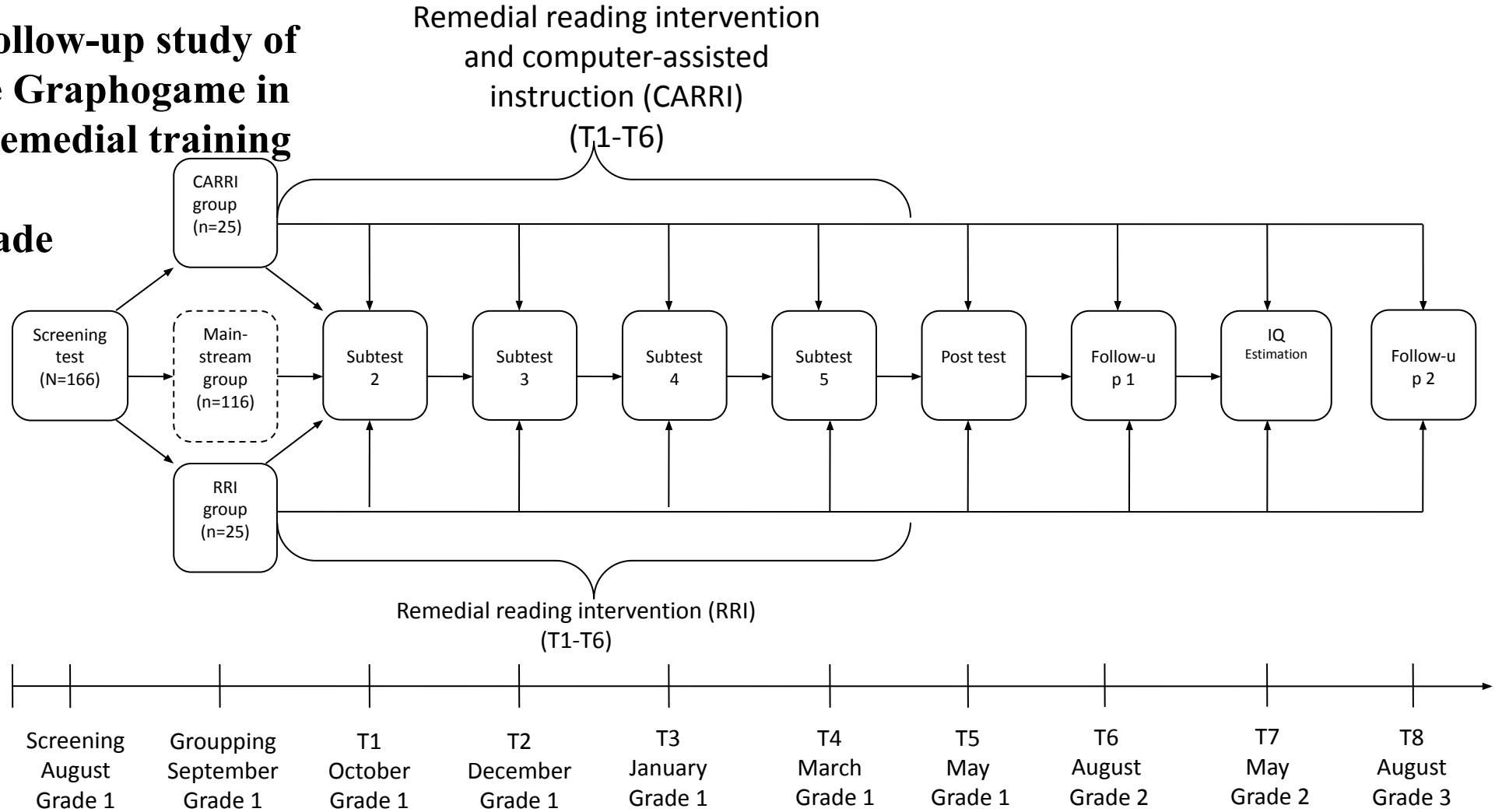

4–8 (RGBMC) vuotiaat (N=726)

osattujen kirjaimien lkm

peliaika (h)

The cumulative number of the acquired connections between sounds and letters
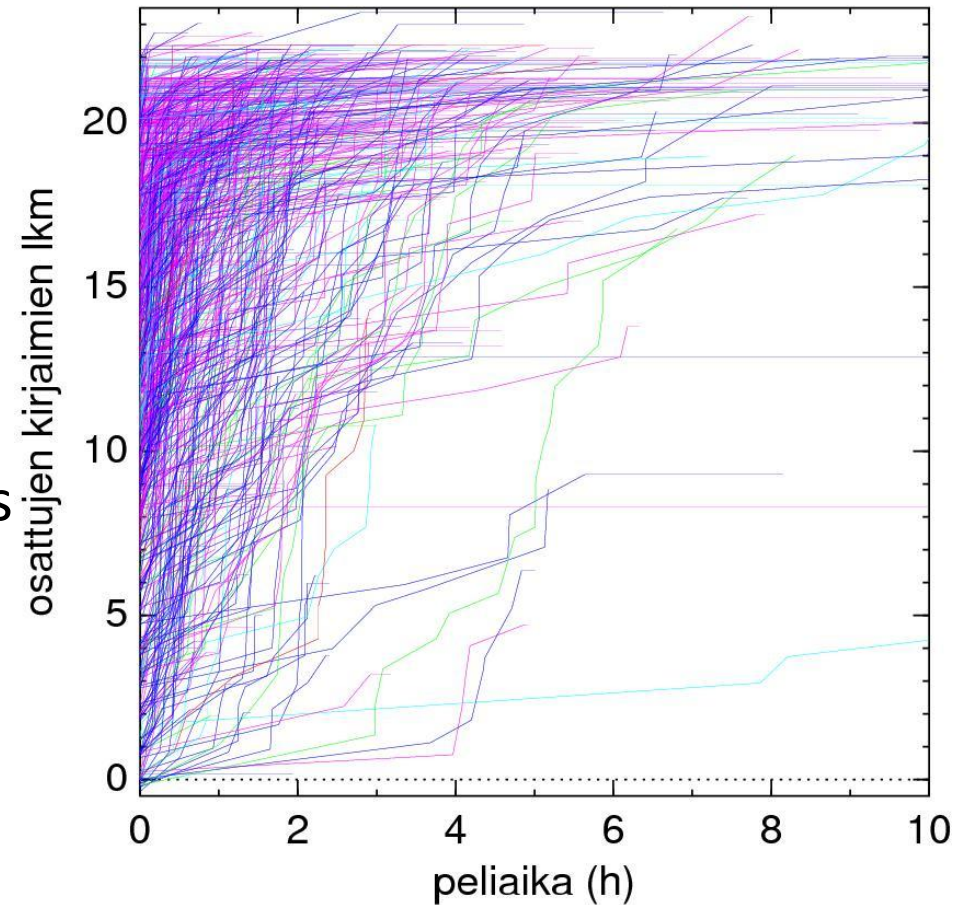
Hours of playing

Modelling: Janne Kujala

Examplary follow-up study of the use of the Graphogame in the schools' remedial training context from the 1. to 3.grade among poor readers

Remedial reading intervention and computer-assisted instruction (CARRI) (T1-T6)

CARRI group (n=25)

Screening test (N=166)

Main-stream group (n=116)

RRI group (n=25)

Subtest 2

Subtest 3

Subtest 4

Subtest 5

Post test

Follow-up 1

IQ Estimation

Follow-up 2

Remedial reading intervention (RRI) (T1-T6)

Screening	Groupping	T1	T2	T3	T4	T5	T6	T7	T8
August	September	October	December	January	March	May	August	May	August
Grade 1	Grade 1	Grade 1	Grade 1	Grade 1	Grade 1	Grade 1	Grade 2	Grade 2	Grade 3

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

Saine et al., (2011) Child Development, 2011, 82, 1013-1028.

Spelling results of the GG- intervention-based learners as compared to to the learners of the intervention given using traditional remedial teaching and those of the mainstream children

Saine et al., Child Development, 2011, 82, 1013-1028
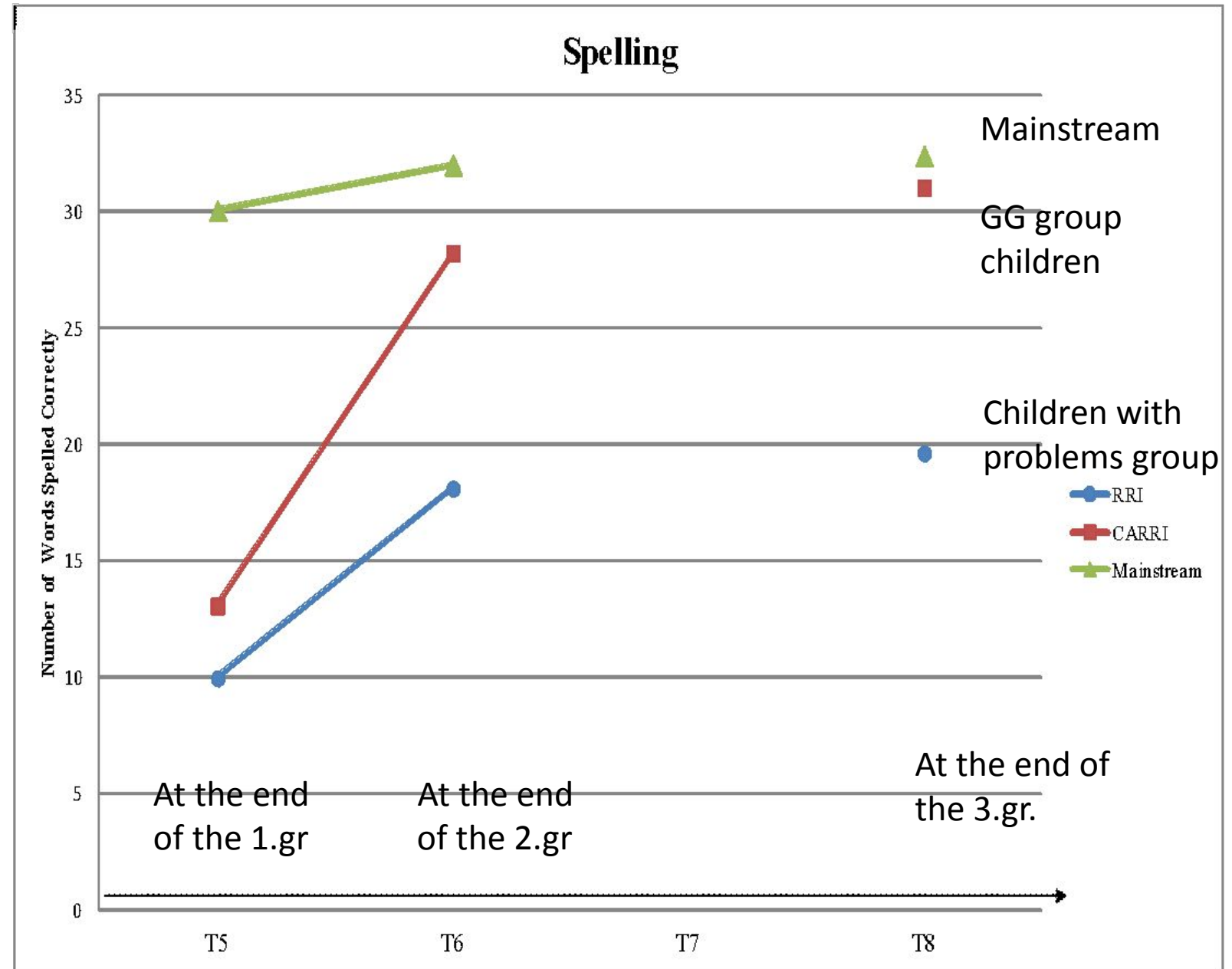
The goal of reading is mediating the messages texts convey

- Cracking the code=basic reading skills is **not** enough.
- The goal of reading is the mediation of the message text conveys
- This goal is mostly reached fully not much earlier than at the PISA-age
- ..and **requires a lot of reading activity without special support**
- **More and more boys are not reaching this goal due to reading less and less**
- Only those who start reading soon after learning the basic reading skill
  - can reach the mentioned basic goal of reading
  - they should also learn effective ways to read to achieve well in the school and in their lifes
  - they should today learn to be more and more critical what they believe from the text
  - they can save a lot of time by learning correct strategies to approach written knowledge
  - **all such readinesses can be trained using available tools to reach all the goals effectively**
  - See: grapholearn.info and comprehension.info

Today the ways to understand reading need updating

- Terms most widely used, such as phonological processing/skills
    - are not understood well enough by almost anybody who uses these
    - are not enough for helping anybody to instruct reading well enough

- *Reading skill means that one has learned the connections between spoken and written language*
- The appropriate connections should be learned by using appropriate unit sizes
- The size of the unit is important because it has to make the connections learnable=consistent
- The size is the smaller the more consistently the writing behaves
- Consistent writings are fastest to learn because the connections to-be-learned are easy to know
- This all means that **learning the basic reading skill (BRS) follows association learning principles**
- After storing the to-be-learned connections and inventing their assembly one masters the BRS
- *But this same does not work in taking steps needed for full literacty, reaching the goal of reading*
- The last steps may be the most difficult which is why these deserve most resources & teaching
- **Reaching the main goal of reading requires a lot of time of explicit and repeated training**
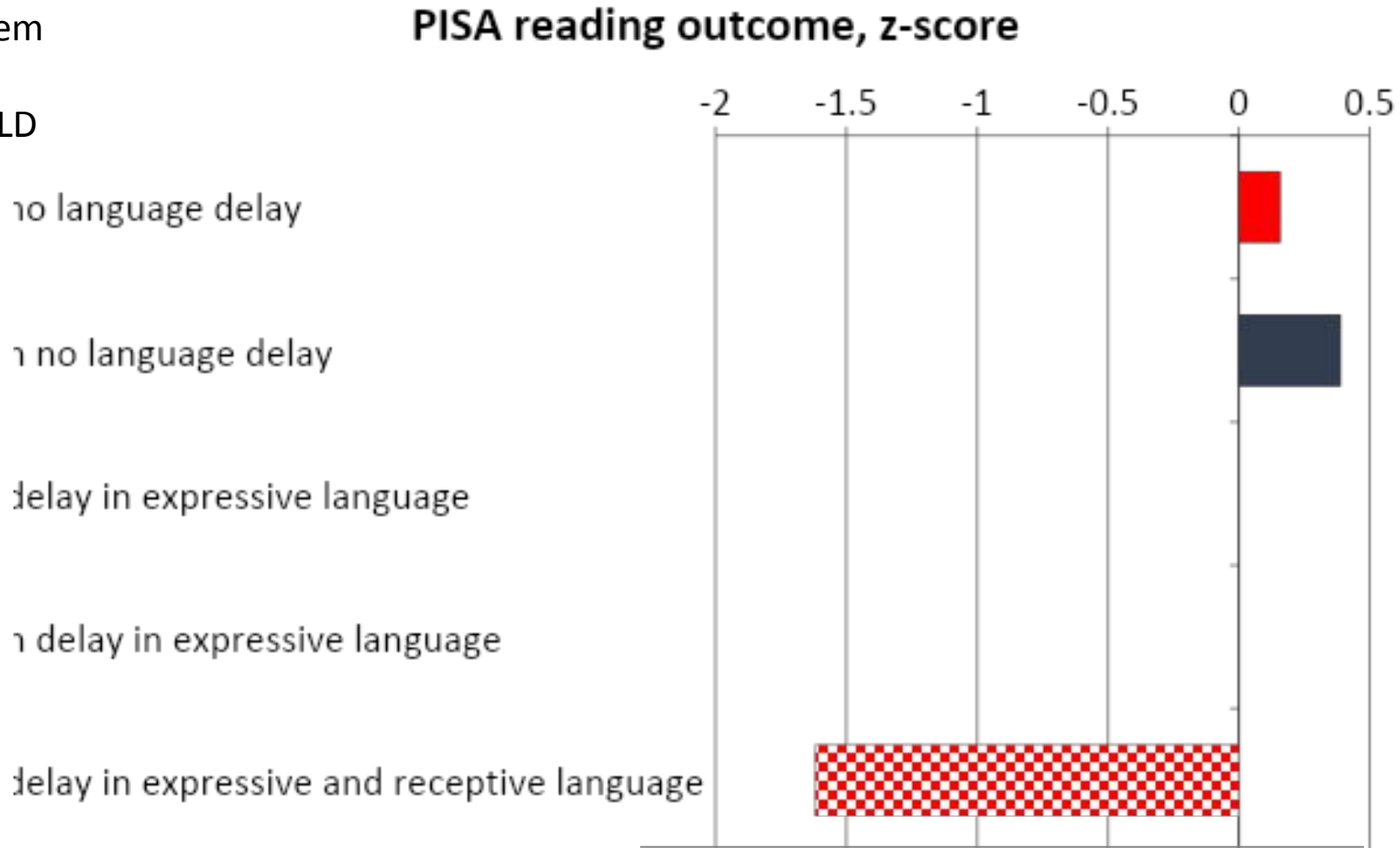
Situation in Finland?

The ways followed until now:

- The state strategy has been to make eventhing to motivate children to read
- It has affected girls but also their PISA-results have been declining
- But it has totally failed to affect reading activity of boys
- Especially the reading activity among men has ended up elevating the percentage of **adult men to not comprehend written material to >10%**
- This is surprising among most active readers of newpapers in the world!
- How comprehension of written knowledge could be better in other countries?
- Some **new strategies are needed for changing the situation among boys/men**

Planned solution in Finland

- It seems that the reasons to problems is the change in the time especially boys have been spending for computer playing instead of reading
- Thus a potential way to influence is to rely on the game strategy used earlier:
  - **motivate the boys to read via a second computer game!**
    - by adding second game = Comprehension Game (CG) to follow the first game (Graphogame) we are now intending to change the situation starting now with a ready to use version of the CG
- **Especially the rural people who do not have books / libraries for finding interesting books for reading are in problems**
- Thus the game has to work like GraphoGame via net, to be available everywhere
- **And it has to be immersed in the school activities to become in wide use under sufficient control and responsibility, ie. helping teachers in their heavy duty**
- We are starting to distribute the CG first to teachers and then also children

PISA READING PERFORMANCE (age: 15 y) OF
"Late talkers" at the age of 2.5y

Some children need support because the present methods have not helped them enough, see here a main result of the JLD

PISA reading outcome, z-score

no language delay

no language delay

delay in expressive language

delay in expressive language

delay in expressive and receptive language

Lyytinen, et al. 2015 Current Developmental Disorders Reports, 2, 4, 330-338.

The steps towards full literacy (=what PISA shows)

- The step towards reading skills start from the
- 1. *basic reading skill* ie. accurate oral reading (decoding)
- and continue to
- 2. *automatized reading*, allowing to
- a) remember the beginning of a sentence when reaching its end and
- b) reserve cognitive capacity for processing the content of the text
- and either by reading enough or using the Comprehension Game to learn
- 3. *full literacy* which PISA results are reflecting
- *Note: "reading enough" is not enough for acquiring critical reading skills*
- *for that only the ComprehensionGame kind of training provides help*

Learning knowledge via reading

- Today's way to consider it is to anticipate that it occurs via spontanous learning - ie. by not letting it to get any special attention or support in school

- This results to problems which are most common reading problems

- In a most literate country, Finland, 3-5% of children need and get support for learning the basic reading skill, but >10% end up failing to comprehend even one's work agreement

- But althought this is necessary - it is not sufficient

What it means to learn the basic reading skills?

- For learning to sound out written language one has to store the connections between spoken and written units – ie. apply association learning principle

- (see Lyytinen, et al. 2021, doi: 10.3389/fpsyg.2021.566220)

- In severe dyslexia which is a genetic disorder half of those born to a parent whose pedigree contains people with dyslexia the likelihood of facing dyslexia is about fifty-fifty

- The half of children born to such a family can be identified at age of 3-5 days by observing brain event-related potentials (ERP), more specifically Mismatch Negativity (MMN) e.g. to pitch changes (1000Hz-1100Hz) of sinusoidal sound.

- The cause of dyslexia can thus be defined to be auditory insensitivy which differentiates the halves. The lack of MMN makes it difficult for the learner to perceive the smallest differenes between speech sound to be able to connect these to their written representations (e.g. l m and n), see Fig.

Newborn ERPs to tone frequency change differ between 2nd grade typical control and dyslexic at-risk readers
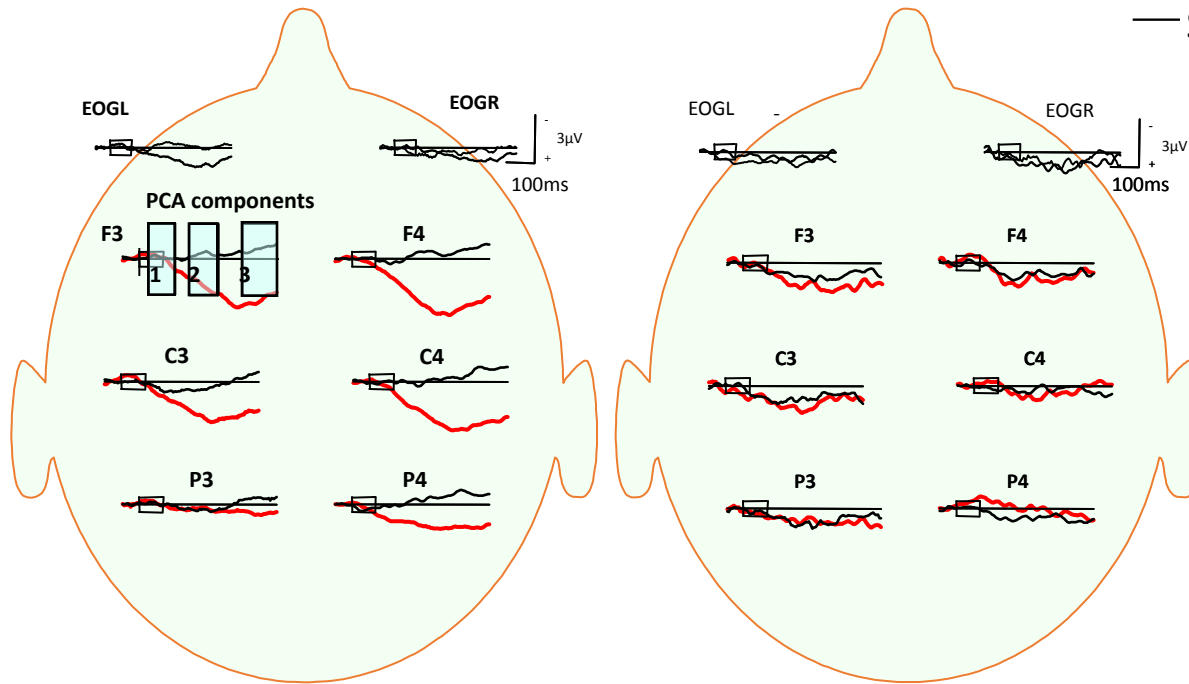
在二年级，有阅读障碍风险的高危儿童与没有阅读障碍的控制组儿童在刚出生时对音频的ERPs的反应是不同的

MMN-paradigm MMN范式

Standard标准刺激

Deviant变异刺激

— Dev 1100Hz, 12 %, SOA 425 ms
— Std 1000Hz

EOGL EOGR 3µV 100ms

PCA components

F3 1 2 3 F4

C3 C4

P3 P4

Control typical readers (TRC, N=25)

EOGL EOGR 3µV 100ms

F3 F4

C3 C4

P3 P4

At-risk dyslexic readers (RDFR, N=8)

1994-07-21 20:07:16 S:14105 I:855 7:ka110 ISI/ 1 0:00:04
EXP: TR: 18 Std: 53 Dev: 6

Quiet sleep

Leppänen et al, *2010, Cortex*

Further steps towards full literacy

- After learning the basic reading skill one has to
- read a lot for

      a) automatizing one's reading skill for being able to
      -remember the end of the sentence when one reaches its end
      -make sufficient cognitive capacity free for comprehending the content of the text

      b) concentrate on training the comprehension of the text via reading

      c) learning to read critically which is a new need everybody had to master

      And all these are main goals of the Comprehension Game –based training

Why Comprehension Game (CG) is needed

- Both research and practice tend to undermine this stage of training needed for becoming fully literate

- Its training is studied much less compred to that of the basic reading skill - less than half as many research papers focus on comprehension

- School learning seems to not focus specifically and sufficiently on supporting

- a) acquisition of the reading comprehension and even less

- b) critical reading skills needed in today's world

How Comprehension Game (CG) offers its support

- Training is offered in the context of learning the lessons from the school books

- During going trough a number of school books via lessons pupils learn better ways to approach written knowledge with comprehension and to apply critical evaluation of the given content by using CG on the side of the schoolbooks

- This all is possible independent of the readers's age, language, level of knowledge and place of living because the content is given by the local teachers after they are trained to use the CG for that purpose

- CG is is available via net to all, including people living in Africa

Summary of the goals of the Comprehension Game

1. Guide teachers to instruct knowledge effectively and successfully

2. Guide learners to acquire effective and critical ways to read by
   a) helping them to focus on the identification of the key contents from texts by summarizing these to claims chosen from school books which are learned in reading lessons using CG
   b) conditioning learners to critical reading by forcing them to judge the claims as true or not (where the "trues" summarize the key contents of the section one is learning as a lessons and "not-trues" are typical misunderstandings children tend to have (to get rid of these))

3. Activate CG users to start to use optimal, more effective reading stategies
   c) Learn their school lesssons more realiably and with learning better results by using the CG on the side of schoolbooks
   d) Help teachers to save time when CG instructs the knowledge and informs teachers which are the results of each pupil (thus saving one from making eg. exams)

   See: comprehensiongame.info

Which are CG's means to reach these goals?

- The training occurs in the context of reading school books

- Repeating a number of subsequent books the goal will be reached before PISA
   if the material chosen from the books to do that is well made

- A good material comprises sentences (claims) which represent the key and most important contents of the book to form a model for the learner how to focus on the central information the book is helping the learner to understand

- And this all is made by motivating the learners to judge each sentence/claim by telling is it true or not (the last being typical misunderstandings)

How to make learning most effective

- The game applies so called dynamic assessment, ie. concomitant training and assessment

- Immediately when a bottleneck is observed in learning the game starts focussing on opening this bottleneck

- Also other adaptation methods are applied

- The game tries to guarantee engagement which can be made using different ways to motivate children to compete either between each other or by using the change in ones learning as the criterion of success

If we ask
what is **the most important doable duty to do for making the world better?**

How many is not agreeing that it is:

- Helping children to learn knowledge by reading and to do it with full comprehension and critics
- This may be the most realistic way to help making to future generations better able to guide the development of their world and take care of themselves

The lesson we learned: a summary

- The goal of reading is to mediate meanings of the text to the use of the readers
- All can reach this goal after acquiring the basic reading skill eg. by using empirically validated GraphoGame which is available for implementation to whatever language
- The main goal of reading – reading comprehension – is observed via PISA studies
- This, reading comprehension, can be learned naturally by reading enough
- PISA results from the few last runs of the assessment are alarming:
  - **The results are falling especially among boys**
- **Thus boys had to-be-motivated to read or trained to reach the goal otherwise**
- Such countermeasures are needed because reading is the main source of our learning of knowledge in the world where wellbeing is based on knowledge
- Todays a **new skill** is becoming more and more important: **critical reading**
- One way to elevate both reading comprehension and critical reading is to use countermeasures which have now becoming available to respond to those needs:

Comprehension Game to-be-used on the side of reading schoolbooks to learn lessons

For more.., please,

- Have a look of our research: heikki.lyytinen.info
- Ask for reprint(s): heikki.j.lyytinen@jyu.fi
- For international operations, see grapholearn.info
- The most recent summary of main results of the JLD:
  https://link.springer.com/article/10.1007/s40474-015-0067-1
- A most relevant articles for learning how to use GraphoGame published in Child Development:
  DOI: 10.1111/j.1467-8624.2011.01580.x
- To have an access to GraphoGames: www.graphogame.com
- If you are interested in joining to running validation research for GraphoLearn technology for Iceland please, contact ulla.a.richardson@jyu.fi

For learning about ways to train reading comprehension and critical reading, please, see

Comprehensiongame.info

Thank you for your attention!