Full title: Resolving Reading Disability – Childhood Predictors and Adult-Age Outcomes

Short title: Resolving Reading Disability

Authors: Anna-Kaija Eloranta, MA, Vesa M. Närhi, PhD, Kenneth M. Eklund, PhD, Timo P. S. Ahonen, PhD, and Tuija I. Aro, PhD

Affiliations:

Anna-Kaija Eloranta, Niilo Mäki Institute & University of Jyväskylä

Vesa M. Närhi, Niilo Mäki Institute & University of Jyväskylä

Kenneth M. Eklund, University of Jyväskylä

Timo P.S. Ahonen, Niilo Mäki Institute & University of Jyväskylä

Tuija I. Aro, Niilo Mäki Institute & University of Jyväskylä

Corresponding author: Anna-Kaija Eloranta, Department of Psychology, PO Box 35, FI-40014 University of Jyväskylä, Finland. Email: akeloranta@nmi.fi Telephone: +35850 377 3906.

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Abstract

We examined frequency of adult-age reading disability (RD) and its childhood predictors among 48 adults (20 to 39 years) with documented childhood RD, and contrasted their cognitive skills, education, and employment with 37 matched controls. Among individuals with childhood RD, more than half had improved in their reading fluency to the level where the set criterion for adult-age RD was not met anymore. More fluent rapid naming, less severe childhood RD, and multiple support providers in childhood together predicted improvement of reading fluency. More fluent naming differentiated the childhood RD participants whose reading fluency had improved by adult-age from those participants whose RD persisted to adult-age. All the individuals with childhood RD performed weaker than the controls in adult-age working memory, processing speed, and verbal skills. Educational level among both RD groups was lower than that among the controls. Unemployment of individuals with persistent adult-age RD (31.6%) was higher than that of individuals with improved adult-age RD (13.8%) or that of the controls (8.1%). According to our findings, rapid naming is one evident factor differentiating individuals with persisted RD from those with ameliorated reading fluency. Also, better adult-age reading fluency has significance for adult-age employment among individuals with childhood RD.

Longitudinal research has shown that developmental reading disability (RD) is a persistent deficit that impacts adult life (for reviews see Gerber, 2012; Swanson, 2012). However, follow-up studies have continued mostly up to adolescence or the early twenties (e.g., Landerl & Wimmer, 2008; Torppa, Eklund, van Bergen, & Lyytinen, 2015), with few studies extending beyond emerging adulthood (e.g., McLaughlin, Spears, & Shenassa, 2009; Maughan et al., 2009). Furthermore, although studies have shown continuity of RD on a group level, developmentally distinguishable subtypes of RD have also been detected, such as a group of individuals with RD who improve in their reading skill over time to the level where RD criteria are no longer fulfilled (e.g., Ferrer, Shaywitz, Holahan, Marchione, & Shaywitz, 2010; Torppa et al., 2015). However, factors contributing to whether RD persists or not are not yet known. In the present study, we aimed to provide more insight into RD continuing to adult-age (adult-age RD) and into the factors related to it using follow-up data of individuals with documented childhood RD.

Earlier longitudinal research indicates that childhood RD is associated with weaker reading skills at adult-age, yet still, wide variance in adult reading skills have been reported (e.g., Bruck, 1993; Maughan et al., 2009; Undheim, 2009). The proportion of adults with the history of RD that have been found to have improved in their reading and spelling skills varies from 7 to 60 percent (e.g., Maughan et al., 2009; Parrila, Georgiou, & Corkett, 2007; Schulte-Körne, Deimel, Jungemann, & Remschmidt, 2003; Undheim, 2009), depending on the definition, cut-off, sample used, and orthography. Most of the studies continuing beyond adolescence and young adulthood have been conducted in English-speaking countries (e.g., Maughan et al., 2009). To our knowledge, only a few exceptions exist in German (Schulte-Körne, Deimel, Jungemann, & Remschmidt, 2003; Strehlow et al., 1992), in Norwegian (Undheim, 2009), and in Finnish (Korhonen, 1995). However, as orthographies vary in the

consistency of letter-sound correspondences (Seymour, Aro, & Erskine, 2003), which has implications on how different domains of reading skills (fluency and accuracy) develop (e.g., Landerl & Wimmer, 2008), more longitudinal research of the persistence of RD is needed in different language environments.

There is limited knowledge on the mechanisms related to cognitive skills that are associated with persistence of RD and on childhood RD's associations with adult-age cognitive skills. Among the cognitive predictors of reading, phonological skills and rapid automatized naming (RAN) have been the most extensively studied. Phonological skills are known to predict reading acquisition at early stages (see Papadopoulos, Spanoudis, & Georgiou, 2016) and early deficits in phonological awareness to predict later RD at school-years (e.g., Carroll, Solity, & Shapiro, 2016; Puolakanaho et al., 2007; Torppa et al., 2015). Phonological deficits also tend to be persistent (e.g., Svensson & Jacobson, 2006; Wilson & Lesaux, 2001), and associated especially with reading accuracy (Kairaluoma, Torppa, Westerholm, Ahonen, & Aro, 2013). RAN has been found to be closely related to reading fluency in childhood (e.g., Georgiou, Parrila, & Kirby, 2009; Heikkilä et al., 2015; Moll, Fussenegger, Willburger, & Landerl, 2009; Papadopoulos et al., 2016) and in adulthood (e.g., Vukovic, Wilson, & Nash, 2004). Childhood RAN skills have also been found to predict developmental dyslexia (Landerl et al., 2013). Torppa and colleagues (2015) found that early problems in RAN differentiated a group of children that had persistent dyslexia in adolescence from children with no later dyslexia. Despite these findings, knowledge of the association between the childhood RAN and adult-age reading, and of the association between adult-age RAN and persistence of RD is still insufficient.

Processing speed and working memory have also been linked to reading skills and RD. General processing speed has been found to reflect in problems of RAN, to predict reading fluency and to mediate the RAN–reading association among children (Papadopoulos

et al., 2016). Moreover, earlier studies indicate working memory problems to be related to reading difficulties and to RAN–reading relationship among children (Cowan et al., 2017; Gathercole, Alloway, Willis, & Adams, 2005; Majerus & Cowan, 2016; Papadopoulos et al., 2016). However, knowledge of how adult-age processing speed and working memory are related to adult-age reading skills or to persistence of childhood RD is insufficient. Similarly, association between general intelligence (IQ) and RD is unclear. Although IQ is considered independent from development of RD per se (e.g., Ferrer et al., 2010; Fletcher, 2009; Kortteinen, Närhi, & Ahonen, 2009), there are some long-term associations between IQ and persistence of RD: individuals with higher childhood IQ have been found to have better adult-age spelling skills relative to childhood skills than their peers with lower IQ (Strehlow, 1992). RD and verbal intelligence in particular are known to have reciprocal long-term relationship (e.g., Ingesson, 2015; Stanovich, 1986; Swanson, 2012). Reading comprehension problems, which are commonly seen as secondary deficits due to compromised reading fluency and accuracy (Lyon et al., 2003), but also as the common product of problems in decoding and language comprehension (Simple View of Reading; Gough & Tunmer, 1986), have been found to be especially related to components of verbal intelligence, vocabulary in particular (e.g., Swanson, Barnes, Fall, & Roberts, 2018).

Besides cognitive predictors, other factors during development can affect later RD outcome. At primary school age and in adolescence, various factors buffering the negative implications of reading problems have been identified, including early entry to special education (Ehrhardt, Huntington, Molino, & Barbaresi, 2013), as well as supportive and motivational interaction with peers, teachers, and parents (Al-Yagon, 2016; Sideridis, Stamovlasis, & Antoniou, 2016). Likewise later in life, support experienced from significant others has been found to be important for social and emotional well-being of individuals with RD (e.g., Carawan, Nalavany, & Jenkins, 2016; Stack-Cutler, Parrila, & Torppa, 2015).

However, the association of individual experience of received support at school-age with adult-age reading skills is less clear.

Besides affecting later reading skills, childhood RD is known to be a risk factor for lack of education beyond the school years: students with RD are more likely than their peers to leave school after compulsory education, to drop out, or to choose vocational education (see e.g., Hakkarainen, Holopainen, & Savolainen, 2015; McLaughlin, Speirs, & Shenassa, 2014). There is also evidence of higher unemployment rates among individuals with poor reading skills (Caspi, Entner Wright, Moffitt, & Silva, 1998) or with childhood RD (Undheim, 2003), and of lower qualifications or incomes compared to non-RD peers at group-level (Maughan et al., 2009; McLaughlin et al., 2014). It is of interest whether individuals, who in spite of childhood RD have good enough adult-age reading skills (i.e., *not* meeting the criteria for adult-age RD), are able to educate themselves more and be less probably unemployed than their counterparts with adult-age RD.

In sum, due to the scarcity of longitudinal research, more information is needed about the adult-age reading, cognitive skill, education and employment outcomes of individuals with childhood RD. Moreover, the predictive role of different cognitive and extrinsic factors for adult-age reading skills and for persistence of RD is still to be confirmed. To gain better understanding on these issues, we examined a group of Finnish adults who had been referred to a learning disability clinic at school age, and whose primary deficit in childhood had been RD, defined as a deficit to read with adequate speed. In childhood, they had no comorbid socio-emotional problems or difficulties in learning mathematics. To characterize the long-term outcomes of childhood RD we scrutinized the proportion of individuals not meeting the set criterion for adult-age RD. We also examined adult-age reading and cognitive skills, attained educational level, and employment, as well as childhood cognitive factors, special education attendance and the number of support providers as

possible predictors of adult-age reading skills. The following research questions were addressed:

1. Which proportion of individuals with documented childhood RD do not have RD continuing to adult-age, and how do they differ from individuals with adult-age RD and from control individuals in (a) reading skills (speed, accuracy and comprehension), (b) cognitive skills, or (c) education and employment outcome?
2. Do the two childhood RD groups (with or without adult-age RD) differ from each other in childhood (a) reading skill level, (b) cognitive skills, or (c) special education and experienced support?
3. Within the childhood RD group, are reading skills (speed, accuracy and comprehension) in adulthood predicted by childhood (a) reading skills, (b) cognitive skills, or (c) the amount of special education received and experienced support?

Method

Participants and procedure

Two groups of participants were studied: adults with RD documented in childhood (RD; n=48), and controls with no known history of RD (n=37). Participants for the childhood RD group were selected from the clinical archival data of former clients of the Clinic for Learning Disabilities (CLD) at the Niilo Mäki Institute (NMI) in Jyväskylä, Finland, and they were further divided into two groups (i.e., with and without adult-age RD) according to their adult-age reading skill. The CLD offers neuropsychological assessment and counseling for children with learning disabilities (LDs). Children with socio-emotional problems or global developmental delay were not referred to the clinic (for details see Närhi, 2002). The present participants were selected from the archives on two criteria: RD was their only childhood LD (i.e., z-score $\leq$-1.5) and they were over 20 years of age. Thus, children with comorbid mathematical difficulties (z-score $\leq$-1.5) or emotional and attention problems (z-score $\leq$-1.0

in teacher/parent ratings) were excluded to form as homogeneous group as possible. All subjects were Caucasian and spoke Finnish as their native language.

Of the 76 identified individuals 66 were contacted, as no contact information was found for 9 subjects, and one subject had died. Forty-nine individuals (74.2% of the 66 individuals that were reached) agreed to participate in the follow-up assessments. One participant with low scores on the childhood IQ measures (full scale IQ 60) was dropped from the sample. This produced the final sample size of 48 in the RD group.

A control group (n=37) was formed from a large sample provided by the Population Register Center, in which each participant from the clinical dataset was matched with 5 controls based on age, gender and home town at the age of seven, i.e., at the beginning of compulsory education. All five controls matched for each of the RD participants were contacted in random order, the aim being to provide one matched control participant for each RD participant. For 11 of the RD participants, none of the five control participants were reached, or all of them declined or cancelled their appointment, and one potential control participant with a low IQ was dropped from the sample, yielding the final control group of 37 individuals.

Within the RD group, the individuals who participated in the follow-up assessments in adulthood (n=48) and those who did not participate (n=27) did not differ significantly in age or gender distribution, although there were slightly more males among the non-participants (22/27, 81.5%) than participants (30/48; 62.5%). No significant differences were found in childhood RD level, RAN, VIQ or PIQ, emotional and attention problems, or in parental education level.

The RD group with matched controls (n = 37) and those without controls (n = 11) did not differ in terms of gender distribution, but there was a difference ($p < .05$) between the groups in age: the individuals with RD who did not have controls were younger (M = 23.5

years) than those with matched controls (M = 27.05 years). To find out whether the attrition of some of the controls creates a bias in the results, the analyses were also conducted including only the RD participants (n = 37) that had matched controls in this sample. As the results replicated in these additional analyses, the original sample size was used so that a substantial proportion of the data and power of the analyses would not be lost.

Ethical approval was given by the University Ethical Committee. Written informed consent was obtained from each participant. Parents had given informed consent to use their children's assessment data for research purposes when the participants had been assessed as children. The follow-up assessments (lasting 4.5-5 hours) were conducted by licensed psychologists. The participants were given oral feedback, and offered a written summary of the test results.

Measures in Childhood

Reading skills and definition of childhood RD. Reading speed, i.e., fluency, was used to measure reading skills both in childhood and at follow-up, because in orthographies with consistent letter-sound correspondences such as Finnish, reading accuracy is typically learned at early stage (Aro & Wimmer, 2003), and reading speed is therefore a better marker of reading difficulties than accuracy.

Since the tests used at the clinic to assess reading skills have varied along the years, childhood RD was defined by reading speed in one of the two text-reading tasks described below, depending on which one was used at the time the child visited the clinic. A z-score of reading speed was calculated in both tests based on Finnish reference group.

Misku (Niilo Mäki Institute, 1992, unpublished) is an age-normed text-reading task normed for 8- to 12-year-old children with a reference group (n = 211) collected in Central Finland. In the test, the child is asked to read aloud a one-page story as quickly and correctly as possible. The time taken to complete the text was used as the reading speed measure.

ÄRPS (Niilo Mäki Institute, 1994, unpublished) is a reading skill test battery developed for 2nd to 4th graders with a reference group of children from Central Finland. In the text reading task the child is asked to read aloud a one-page story as quickly and correctly as possible. The number of words read per time unit, one minute for 2nd graders and two minutes for 3rd and 4th graders was used as the reading speed measure.

Since the two tests used in the clinic were not corresponding, reading skill measure could not be used as continuous variable. A child was classified having RD if the performance was at least -1.5 SDs below the reference group mean in one of the two reading speed tasks. Childhood RD was further categorized into a dichotomous variable as follows: "very severe" (below -2.5 SDs) or "severe" RD (-2.5 to -1.5 SDs), and this was used in the statistical analysis as an indication of the childhood RD severity.

Intelligence quotients (IQs). IQs were evaluated using the Wechsler Intelligence Scale for Children-Revised edition (WISC-R; Wechsler, 1974). Verbal intelligence quotients (VIQ) and performance intelligence quotients (PIQ) were used in the present analyses.

Rapid automatized naming (RAN). Rapid Naming Test (Ahonen, Tuovinen, & Leppäsaari, 1999; Denckla & Rudel, 1974) was used to assess automatized naming. It is a standardised test for 6- to 12- year-old Finnish children, in which the child names an array of 50 pictures or symbols presented on six boards as fast as possible trying to avoid errors. In the present study, the mean of the norm-based z-scores for rate of naming all the items in two alphanumeric item boards, i.e., Letters and Numbers, was used as a composite score for RAN. Cronbach alpha reliability, calculated from the z-scores for rate of naming the items in each of the two item boards used was .84.

Phonological skills. Phonological skills were evaluated using either the Phoneme Blending task or the Phonological Processing test, depending on the time of assessment. The Phoneme Blending task is the Finnish version of the Illinois Test of Psycholinguistic Abilities

(ITPA, Kuusinen & Blåfield, 1972; Kirk, McCarthy, & Kirk, 1968) and consists of three subtests in which the examiner presents sounds and asks the participant to voice the words the sounds form when put together. Test performance is compared to the psycholinguistic age corresponding to the child's chronological age. The Phonological Processing subtest in the neuropsychological test battery Nepsy (Korkman, Kirk & Kemp, 1998), standardized for 9- to 12-year-old Finnish children, contains two parts. In Part 1, Word Segment Recognition, the child is presented with pictures of phonologically similar words and the sound of one phoneme or a phoneme combination composing a syllable, and asked to link the sound to the right picture. In Part 2, Phonological Segmentation, the child is presented with a word and asked to form a new word by removing a sound, a syllable, or a part of a compound word. Standard scores for test performance are formed on the basis of the test reference data. Cronbach's α for Phonological Processing in the standardization data was .97 (Korkman, 2000).

As the two phonological tests were not corresponding, we had to form a dichotomous variable for phonological deficit (1=deficit; 0=no deficit). As the cut-off, a psycholinguistic age twelve months younger than chronological age was used for children assessed with the Phoneme Blending task, and a scale score of seven for children assessed with the Phonological Processing test.

Special educational support. Special educational support received during a) primary and secondary school, and during b) upper secondary education (vocational school or high school, or other) was elicited retrospectively at adult follow-up interview. Because no objective data was available, the information were based on the participants' memory, which may have varied in specificity (i.e., some individuals had clear memories on received support while others were less sure on the exact amount of support). As the quality and quantity of special educational support in general has varied along the years depending on the school or

community, our participants, with the age range from 20 to 39 years, had also had different offsets for receiving special educational support. Thus, we formed two dichotomous variables, one for primary and secondary school and the other for upper secondary education: 0="did not receive special educational support"; 1="received special educational support".

Number of support providers. Support received for RD was elicited retrospectively at adult follow-up with questions on whether support had been received from parents, teachers, special education teachers, siblings, friends, and other people. The six dichotomous measures with the values 0="no support" and 1="some support" were summed to form a score for the number of support providers. To avoid small group sizes, the sum scores were further collapsed into a single dichotomous measure with the values "support from two or less persons" and "support from more than two persons", since only few individuals had more than 4 support providers.

Measures at Adult-age

Reading fluency, accuracy, and comprehension. Reading skills were measured using a Finnish test battery on reading and spelling skills for adolescents and adults (Nevala, Kairaluoma, Ahonen, Aro, & Holopainen, 2006) that is the only test for adult reading skills available. It is standardised with comprehensive school 9th graders (n = 208). In the Word Reading Task, the participants read aloud 30 words as quickly and accurately as possible. In the Pseudo-Word Reading Task, the participants read aloud 30 pseudo-words as quickly and accurately as possible. In the Text Reading Task, the participants read aloud a text for three minutes as quickly and accurately as possible. In all tests correctly read words and errors were counted. In the Reading Comprehension Task, a text was read silently and 11 multiple-choice questions were answered based on the text without any time constraints.

Reading fluency, i.e., reading rate was based on the test manual z-scores of time used in the Word Reading Task (reversed) and in the Pseudo-Word Reading Task (reversed),

and number of words read in three minutes in the Text Reading Task. In the present data, Cronbach's α for the z-scores of reading rate in the three reading tasks was .78. Accuracy score was based on the test manual z-score of number of correctly read words in the Pseudo-Word Reading Task. The performance in the pseudoword task was used as the only measure of accuracy because the ceiling of accuracy in reading words is typically reached already at school age in Finnish (see Torppa et al., 2015), and reading pseudowords can therefore be considered to be a more sensitive and reliable measure of accuracy. The Cronbach's α for the accuracy in Pseudoword reading task in the test manual was 0.74 (Nevala et al., 2006). Comprehension score was the test manual z-score of the correct answers in the Reading Comprehension Task. Cronbach's α for the right answers in the present sample was .59.

Self-evaluation of reading skills. Self-evaluation of reading skills was examined with a question adopted from a six-item self-rate questionnaire on the importance and utility of academic skills, based on earlier questionnaires on similar topics (Eccles & Wigfield, 1995). Participants were instructed to evaluate their reading skills in relation to peers on a Likert scale ranging from 1 = "below average" to 5 = "above average". To avoid small group sizes, the self-ratings were further collapsed into a three-category variable of 1 = "below average", 2 = "average", and 3 = "above average".

IQ. An abbreviated version of the Wechsler Adult Intelligence Scale – IV (WAIS IV, Wechsler, 2008) was used to evaluate adulthood IQ. As in the Wechsler Abbreviated Scale of Intelligence – II (WASI-II, Wechsler, 2011; see e.g., Irby & Floyd, 2013), the subtests Vocabulary and Similarities were used to produce a Verbal Comprehension Index (VCI), and Block Design and Matrix Reasoning to produce a Perceptual Reasoning Index (PRI). These indexes were computed using partition according to the WAIS IV test manual (Wechsler, 2008). Test-retest reliability above .90 for the VCI and a range from .86 to .87 for the PRI in the WASI-II is commonly reported (Irby & Floyd, 2013).

The Processing Speed Index (PSI) was produced from Symbol Search and Coding. In the Finnish standardization sample, the mean reliability for the PSI is .90 (Wechsler, 2008).

Digit Span. We also examined the group differences in the Digit Span subtest (i.e., forward and backward spans) of the Working Memory Index (WMI) in the WAIS IV, which can be considered as a combination measure of short-term memory and working memory. Total raw score of the Digit Span was used in the analyses.

Phonological skills. Adult-age phonological skills were measured with the Syllable Blending task, which is an unpublished test standardized with a sample of comprehensive school 9th graders (n = 208). In the Syllable Blending task, lengthening strings of syllables (three items with same number of syllables) were presented, and the participant was asked to voice the pseudowords formed by the syllables when put together. Correctly presented pseudowords were counted. In the present study, raw scores of the task were used as a measure.

RAN. Naming speed was examined with the Letters board of the Rapid Naming Test, also used in childhood and standardized with the same sample of comprehensive school 9th graders as the reading and phonological tasks. The raw score was used in the analysis.

Educational attainment. Educational attainment was elicited by interviewing. Upper secondary education was classified into three categories of 0="has not finished vocational or high school", 1="vocational school qualification", and 2="high school qualification". Highest level of further education was classified into categories 1="vocational school qualification", 2="university of applied sciences degree/attending university of applied sciences", 3="university degree/ attending university".

Employment. Employment status was also elicited by interviewing. The current employment status was used as a measure because the information of the participants' employment history, e.g., of the length of unemployment periods during lifetime, were based

on the participants' memories and were therefore not completely comprehensive. Furthermore, because of the small sample size, a specified classification of the current employment status (i.e., whether the participant works part-time or is on maternity leave) would have made the group sizes small and weaken the power in the analyses. Thus, a dichotomous variable was formed with categories 0="employed" and 1="unemployed". We classified the participants as unemployed if they were job seekers or laid off, and not studying, not working full-time or part-time, not in the military service, not on maternity or sickness leave, nor on disability pension.

Statistical Analyses

Descriptive statistics and percentages were used to study the proportion of adult-age RD among the childhood RD group. To test group differences in adult-age reading status and the other adulthood and childhood measures, we used multivariate analyses of variance (MANOVA) for continuous measures, and the χ^2 test for categorical variables. A Fisher's exact test instead of a chi squared test was used when more than 20 percent of the cells in the cross tabulation had expected values smaller than 5. To examine childhood predictors of adulthood reading fluency, accuracy and comprehension, we first examined bivariate correlations between the variables. We then ran linear regression analyses for each reading measure, including only those childhood variables in the models that had a correlation with a *p*-value of .10 or smaller with the adult-age reading measures.

One-tailed testing was adopted in group-comparisons, as we expected the control group and the group with childhood RD but without adult-age RD to have better adult-age reading (e.g., Maughan et al., 2009; Undheim, 2009) and cognitive skills (e.g., Kairaluoma et al., 2013; Torppa et al., 2015; Vukovic et al., 2014), higher educational level (e.g., Hakkarainen et al., 2015) and less unemployment (e.g., Caspi et al., 1998) than the

group with persistent adult-age RD. However, in the analyses concerning educational and social support we used two-tailed tests because of the lack of earlier research.

Results

Proportion of individuals with and without adult-age RD

We defined adult-age RD on the basis of adult-age reading fluency, i.e., speed as follows: a speed z-score below -1.5 indicated adult-age RD and a z-score above -1.5 as no adult-age RD. Using this criterion, 29 (60.4%) participants were classified as individuals without adult-age RD (RD-), and nineteen (39.6 %) participants as having adult-age RD (RD+). The mean ages of the RD+ and RD- groups were 27.4 (*SD* = 5.4) and 25.5 (*SD* = 4.2) years, respectively, and did not differ from each other. There was no statistically significant difference between the two RD groups in the proportion of men, despite the higher percentage (72.4%) in the RD- group than in the RD+ group (47.4%).

Adult-age reading and cognitive skills, education, and employment in the two RD groups and the control group

Table 1 shows the group comparisons of the control group and the two RD groups (i.e., RD+ and RD-) in reading and cognitive skills. Results of the MANOVA for reading measures showed statistically significant differences between the three groups in reading fluency, accuracy, and comprehension. Pairwise comparisons (Table 1) indicated that both RD groups were statistically significantly weaker than the control group in all reading skills, and that the RD- group had better reading fluency scores than the RD+ group, as expected because it was used as the criterion for adult-age RD-grouping. The two RD groups did not differ from each other in reading accuracy or comprehension, although the effect size in reading accuracy was moderate in favour of the RD- group. In their self-evaluations of reading, the three groups differed statistically significantly (Table 1) so that the RD+ group was overrepresented in the

rating “below average” (adjusted standardized residuals, Adj. Res. = 4.8), and the control group in the rating “above average” (Adj. Res. = 3.4).

Results of the MANOVA for the cognitive measures showed statistically significant differences between the three groups also in verbal comprehension, working memory, processing speed, phonological skills, and rapid naming but not in perceptual reasoning. In verbal comprehension, processing speed, working memory, and phonological skills, the two groups with childhood RD did not differ from each other. The phonological skills of the controls were statistically significantly better than in the two RD groups. Moreover, in verbal comprehension, working memory, and processing speed, the effect sizes in pairwise comparisons were moderate to high in favour of the controls in each measure, although the group differences failed to reach statistical significance (see Table 1). The RAN scores were statistically significantly better in the RD- group than in the RD+ group, and the RD- group did not differ from the control group (Table 1). However, the effect sizes indicated a considerable difference both between the RD+ and the control group as well as between the two RD groups (Table 1).

Table 1 shows the group comparisons in education and employment. The two RD groups and the control group differed significantly in upper secondary education: there were more individuals with high school degree within the control group (Adj. Res. = 3.5) than within the RD groups, and the proportion of control group members with vocational school degree was smaller (Adj. Res. = -3.1) than those of the two RD groups. Higher education (university of applied sciences or university degree) was more common within the control group (Table 1) than within either of the RD groups (Adj. Res. = 3.3). The proportion of unemployed (Table 1) was higher within the RD+ group (Adj. Res. = 2.2) than within the RD-, or within the control group.

Differences in childhood measures between the two RD groups

The MANOVA indicated that the RD- group had performed significantly faster in childhood RAN than the RD+ group, effect size being moderate between the groups (Table 2). The groups did not differ in childhood VIQ, PIQ, or RD severity level (RD and severe RD), or in the proportion of individuals with phonological deficits, individuals having received special educational support, or having had more than two support providers.

Predictors of adult-age reading fluency, accuracy and comprehension among the childhood RD group

As the bivariate correlations in Table 3 show, RAN was the only childhood variable that correlated with adult-age reading fluency at a statistically significant level in the RD group. As the correlations of both the severity of childhood RD and the number of support providers with reading fluency were also close to significant ($p \leq .10$), we included them in the regression model in addition to RAN. As Table 4 shows, none of the three variables alone predicted adult-age fluency, but the model was significant, indicating that the performance in childhood RAN, the level of childhood RD and number of support providers together explained 18 percent of the variance in adult-age reading fluency. Moreover, phonological deficit correlated at a statistically significant level with adult-age accuracy, and the correlation of RAN was close to significant ($p \leq .10$) (Table 3). In the regression model with phonological deficit and RAN as predictors, phonological deficit alone predicted accuracy at a statistically significant level, and the model explained 19 percent of the variance of adult-age accuracy. Childhood VIQ and PIQ correlated significantly with adult-age reading comprehension, and in the regression model, explained 18 percent of the variance in comprehension.

Discussion

The present study examined the proportion of adult-age RD in a group of Finnish individuals with documented childhood RD. Reading and cognitive skills as well as education and

employment of the two childhood RD groups, i.e., with or without adult-age RD (RD+ or RD-), were compared to that of their matched controls without known history of childhood RD. In addition, childhood cognitive factors, special education attendance and the number of support providers were examined as possible predictors of adult-age reading fluency, accuracy, and comprehension among individuals with childhood RD. We found that majority of the participants had improved in their reading fluency to the level where criterion set for the RD at adult-age was not met anymore. The group without adult-age RD (RD-) performed at the level of the controls in adult-age RAN, and these two groups performed faster than the group with adult-age RD (RD+). However, both RD groups showed poorer skills than controls in phonological skills, processing speed, and verbal comprehension. The RD- group was significantly less likely to be unemployed than the RD+ group or control group, although both RD groups had lower educational attainment than the controls. Moreover, fluency in childhood RAN distinguished the RD- group from the RD+ group. Childhood RAN, severity of childhood RD and number of support providers in childhood together predicted almost a fifth of the variance in adult-age reading fluency, and almost 20 percent of the variance in reading accuracy was predicted by childhood phonological deficit and RAN. Childhood verbal and perceptual intelligence together explained a fifth of the variance in adult-age comprehension.

Our results indicated that individuals with childhood RD as a group performed poorer in adult-age reading tasks than the control group confirming earlier findings that reading problems continue into adulthood (e.g., Maughan et al., 2009). On the other hand, as much as 60.4 percent of the participants did not any more meet our criterion for adult-age RD ($\leq$ -1.5 SDs). The proportion of individuals without adult-age RD was higher than that reported in earlier research on orthographies with less consistent letter-sound connections (7 to 30 %; e.g., Maughan et al., 2009; Parrila et al., 2007; Undheim, 2009), and also higher than

the proportion of resolved RD (40%) in a Finnish sample of adolescents (Torppa et al., 2015). However, it is in concordance with the findings on adult-age RD in other consistent orthographies (Schulte-Körne et al., 2003). This might reflect the fact that in consistent orthographies, fluent reading is generally reached quickly (Aro & Wimmer, 2003) and the proportion of individuals who resolve their childhood RD by adulthood may thus be higher than in orthographies with less consistent letter-sound connections.

It should also be noted that our sample comprised individuals with childhood RD without comorbid LDs or socioemotional problems. In previous longitudinal studies with follow-up at adult-age, few studies have controlled for comorbidity, and those that have, have focused on comorbidity of emotional problems (Esser, Wyschkon, & Schmidt, 2002; Undheim, 2003). As comorbidity of RD with other learning (e.g., Landerl & Moll, 2010) or developmental difficulties, such as ADHD (e.g., Willcutt et al., 2010) is known to be common, the lower proportion of resolved RD in earlier studies compared to our study may be due to possible other deficits besides RD that complicate resolving. Moreover, the high proportion of individuals with resolved RD may also reflect that we used a sample of a clinical population, who had their difficulties recognized early and received support for them already during school years.

It is also noteworthy that we used mean performance of 9th graders as reference data to evaluate reading skills and to define adult-age RD, as it is the only standardized test in Finland aimed at evaluating reading skills of adults. This might overestimate the proportion of adults with "adequate" reading skills, because it is possible that reading skills still develop after 9th grade, that is, there might still be individuals who struggle with their reading in our sample compared to their same-age peers, despite having reached the level of ninth graders. The mean of the reading speed scores of the 29 participants classified as "childhood RD but without adult-age RD" was still markedly lower than those of the 37 matched controls: the

mean level was 0.83 SD lower than that of the normative sample, and only three participants (10.3 %) with childhood RD scored at or above -0.25 SD. Moreover, in our additional analyses in which we normed reading speed against the adult-age control group of the present study (using the -1.5 SD as a criterion), three individuals moved from the resolved RD group (RD-) to the adult-age RD (RD+) group, resulting in the proportion of resolved RD being slightly smaller (54.3%, 26 individual) than in the original grouping (60.4%, 29 individuals). Hence, the individuals in the RD- group, despite better performance in reading speed than individuals in the RD+ group, had not fully caught up with the controls, which is in line with earlier research (e.g., Maughan et al., 2009; Torppa et al., 2015). In addition, their reading accuracy and comprehension as well as performances in phonological skills, verbal comprehension, and processing speed, were below the level of controls and did not differ from the RD+ group. Thus, our findings suggest that childhood RD is associated with lower cognitive performance in adulthood even when reading fluency has improved.

The only major difference in cognitive skills between the RD+ and RD- groups was on RAN. The RD+ group performed significantly slower in both childhood and adult-age RAN than the RD- group. As we defined RD on the basis of reading speed, the findings particularly reflect the strong relation of RAN with reading speed established in earlier studies (e.g., Georgiou et al., 2009; Heikkilä et al., 2015; Papadopoulos et al., 2016; Vukovic et al., 2004). These findings support the stance that RAN is an important factor in reading speed, i.e., fluency, in consistent orthographies, and is applicable also in predicting the long-term persistence of RD.

Since performance in RAN is highly associated with general processing speed (e.g., Catts et al., 2002; Georgiou et al., 2009; Papadopoulos et al., 2016) and since we defined both childhood and adult-age RD on the basis of speed, our finding could be a result of faster processing of words by those with higher general processing speed. However, no major

difference was found in adult-age processing speed (PSI) between the two childhood RD groups. In additional analyses, we found no differences between the two groups in the childhood Coding subtest of the WISC R, which is commonly used as a processing speed measure (see Närhi et al., 2005). Our post hoc analyses also revealed that the partial correlation between childhood RAN and adult-age reading fluency, when controlling for adult-age PSI, was only slightly weaker (r = .27) than the bivariate correlation (r = .29). Moreover, earlier research indicates that there are several other processes, such as phonological skills, orthographic processing, working memory, and attention, which explain or mediate the relation of RAN to reading speed (e.g., Papadopoulos et al., 2016), and that RAN also exerts strong direct effects on reading speed (Papadopoulos et al., 2016). There were other findings suggesting that reading problems in the RD+ group were not merely in reading speed. First, the RD+ group evaluated their functional reading skills in general lower than other groups. Second, despite no significant group difference, reading accuracy among the RD+ group was also lower than that of the RD- group evidenced by medium effect size.

When predicting adult-age reading fluency, RAN appeared not to be the only childhood factor that had predictive power: severity of childhood RD and the number of support providers in childhood together with RAN explained variance in fluency. In addition, although reading fluency was the focus of reading skills in the present study, we also examined the childhood predictors of adult-age accuracy and comprehension, and found that, in line with earlier research (Kairaluoma et al., 2013), phonological skills had an association with reading accuracy. Our finding of verbal and perceptual IQ explaining variance in reading comprehension were also in concordance with earlier research, which has suggested association between IQ and reading, and verbal IQ and reading comprehension in particular (Ingesson, 2015; Swanson, 2012; Swanson et al., 2018). However, it should still be noted that

a rather small proportion of the variance in adult-age reading skills could be explained by the childhood variables we used.

According to our findings, childhood RD has implications for education and employment. Low educational level as a high proportion of vocational upper secondary education was found among childhood RD group, which concords with earlier research (e.g., Hakkarainen et al., 2015; McLaughlin et al., 2014). The unemployment rate was, interestingly, much higher in the RD+ group than in the RD- group or within the controls, the overall unemployment rate being 9.4 percent at the follow-up time in Finland (Statistics Finland, 2016). This clarifies earlier conflicting findings on employment among individuals with RD (Caspi et al., 1998; Undheim, 2003), and suggests that it is not childhood RD per se, but continuing problems in reading at adult-age, which is related to difficulties in employment. Obviously, this result should be interpreted with caution because of small group sizes in the present analyses. However, it could be hypothesized that there are additional factors underlying the higher unemployment within the RD+ group. The two RD groups may have chosen different fields of education with different employment opportunities, which we were unable to examine in the present study. It also remains to be examined whether adult-age RD has wider associations with problems of psychosocial wellbeing leading to difficulties in labor market.

Our sample comprised RD individuals with no additional learning or socio-emotional problems in childhood. This enabled us to minimize sample heterogeneity and the effects of comorbid disabilities on the results. Thus, our findings concerning employment should also be interpreted as reflecting outcomes of pure RD with no comorbid problems. The findings indicate that it is of relevance to employment whether a pure RD like this eases with age.

We investigated a sample drawn from clinical archives, which provided a large, systematically collected and documented dataset on childhood RD. Despite the exceptionality of this comprehensive clinical data, it should be noted that clinical samples are typically biased due to referral procedures and exclusion criteria, and the present sample is therefore likely not to be fully representative of children with RD in Finland. Additionally, as discussed above, the childhood assessment and counseling process itself may have functioned as a short-term intervention, thus inducing a positive bias compared to population samples of RD. Also, our sample was relatively small, due to which we only had sufficient power to detect medium to large effect sizes in our analyses. However, there were no group comparisons with moderate or large effect sizes that failed to reach significance. Furthermore, despite the attrition in the follow-up, the follow-up participants did not differ from the non-participants in any of the childhood measures, and thus, our sample could be considered satisfactorily representative of the full sample. As 11 of the matched control group members could not be reached, only 37 of the RD participants had a matched control to compare results with. However, the results replicated in the additional analyses using only those RD participants that had matched controls, and the attrition of some of the controls was therefore not considered to create a bias in the results.

When interpreting the results, some limitations related to the measures used should also be taken into account. First, the Digit Span subtest that we used in the present study is not comprehensive as a working memory (WM) measure, although it is widely used and considered to tap both auditory short-term memory and working memory. As working memory is a complex construct with multiple components (see e.g., Baddeley, 2017; Cowan, 2017), more comprehensive measures should be used to catch the different facets of WM more thoroughly. Second, in terms of the childhood measures, the only reading skill tests available at the time our participants visited the clinic were unpublished and unfortunately

lacked reliability and validity information. However, both reading skill tests had unpublished norms based on comprehensive data (N=211) and had been used on a routine basis at the clinic. Moreover, the individuals in the present sample had been referred to the clinical assessment because of substantial problems particularly in reading and spelling at school, detected by teachers and school psychologists. This indicates that the initial reading problems among the participants were serious and noticed not only on the basis of a single reading test. Moreover, as tests used at the clinic had varied over the years, and as the age of our participants varied from 20 to 39 years, different tests had been used to measure their reading skills in childhood. The tests were not corresponding, and therefore, we could not use continuous variables for childhood reading skill level, but instead formed dichotomized variables. The same applied to childhood phonological skill variables. We also dichotomized the variables for special educational support, support provided by others, and employment, because we would have had small group sizes in the analyses if more detailed classifications had been used. To examine special educational support, support provided by others or employment of individuals with RD more thoroughly, objective data in addition to deep interview should be used for more nuanced information. Yet another limitation concerning the measures we used, internal reliability particularly in the adult-age reading comprehension task was rather low (.59) in our sample. Therefore, it cannot be ruled out that there may have been differences between the groups in reading comprehension that we could not detect partly because of the low reliability of the task. The low reliability in the comprehension task may be due to the structure of the task: the task comprises items tapping different aspects of comprehension (e.g., fact retrieval and interpretation). In the test manual, the published reliability (Cronbach's alpha) for the comprehension task (.57) is approximately the same as in the present sample. Thus, in the future, more research should be conducted analyzing different subskills required in reading comprehension.

Based on our findings it can be concluded that a little less than two thirds of individuals with childhood RD had improved in their reading fluency to the level where RD criterion at adult-age was not met anymore. Despite attaining a lower educational level than controls and despite having lower group level performance in cognitive tests (verbal comprehension, working memory, and processing speed), individuals without adult-age reading fluency problems had been able to find employment, suggesting that better reading fluency may have significance for adult-age employment. On the other hand, attention should be paid especially to problems in rapid naming as well as to how severe the childhood RD is as they may be predictive of persistent deficits in reading fluency. Together with these cognitive factors, our findings suggest that support provided by others during childhood and adolescence, regardless of whether it is professional or not, may be valuable. This should be emphasized when planning interventions for children with RD. Moreover, it should be noted that RD affects each individual differently, and the mechanisms behind why some resolve RD and others do not can be multifold. Besides cognitive factors affecting how the difficulties in RD manifest themselves, earlier research has identified personal characteristics that contribute to successful life with RD, such as emotional stability, strong self-esteem, proactivity, perseverance, and appropriate goal-setting (e.g., Goldberg et al., 2003; McNulty, 2003; Raskind, Goldberg, Higgins, & Herman, 1999). Further discussion on how persistence of childhood RD or coping with it should be considered in relation to other factors in adult life is needed. The questions to be considered in studies on adult-age RD include, for example, how relevant it is to examine reading skills per se, or should more focus be on the complexity of underlying cognitive and social-emotional skills contributing to functional reading skill, or rather, on how successfully one copes in adult life, e.g., attains education and employment or a satisfying level of psychosocial wellbeing.

References

Ahonen, T., Tuovinen, S., & Leppäsaari, T. (1999). *Nopean Sarjallisen Nimeämisen Testi* [The Test of Rapid Serial Naming]. Jyväskylä, Finland: Niilo Mäki Instituutti & Haukkarannan koulu.

Al-Yagon, M. (2016). Perceived close relationships with parents, teachers, and peers: predictors of social, emotional, and behavioral features in adolescents with LD or comorbid LD and ADHD. *Journal of Learning Disabilities, 49*, 597-615. DOI: 10.1177/0022219415620569

Aro, M. & Wimmer, H. (2003). Learning to read: English in comparison to six more regular orthographies. *Applied Psycholinguistics, 24,* 621–635. DOI: 10.1017/S0142716403000316

Asplund, R., & Vanhala, P. (2016). Korkeasti koulutettujen työmarkkinapolut – Työllisyys, työttömyys ja syrjäytymisriski. [Labour market paths of the higher educated – Employment, unemployment, and the risk of social exclusion]. Retrieved from http://urn.fi/URN:ISBN:978-952-327-114-2.

Baddeley, A. D. (2017). Modularity, working memory and language acquisition. *Second Language Research, 33*, 299-311. DOI: 10.1177/0267658317709852Bekebrede, J. van der Leij, A., Plakas, A., Share, D., & Morfidi, E. (2010). Dutch dyslexia in adulthood: Core features and variety. *Scientific Studies of Reading, 14*, 183-210. DOI: 10.1080/10888430903117500

Bruck, M. (1993). Component spellings of college students with childhood diagnoses of dyslexia. *Learning Disability Quarterly, 16*, 171-184.

Carawan, L. W., Nalavany, B. A., & Jenkins, C. (2016). Emotional experience with dyslexia and self-esteem: the protective role of perceived family support in late adulthood. *Aging & Mental Health, 20,* 284–294. DOI: 10.1080/13607863.2015.1008984

Carroll, J., Solity, J., & Shapiro, L. R. (2016). Predicting dyslexia using prereading skills: the role of sensorimotor and cognitive abilities. *Journal of Child Psychology and Psychiatry, 57*, 750–758. DOI:10.1111/jcpp.12488

Caspi, A., Entner Wright, B. R., Moffitt, T. E. & Silva, P. A. (1998). Early failure in the labor market: Childhood and adolescent predictors of unemployment in the transition to adulthood. *American Sociological Review, 63,* 424-451.

de Jong, P. F., & van der Leij, A. (2003). Developmental changes in the manifestation of a phonological deficit in dyslexic children learning to read a regular orthography. *Journal of Educational Psychology, 95,* 22-40. DOI: 10.1037/0022-0663.95.1.22.

Cowan, N. (2017). The many faces of working memory and short-term storage. *Psychonomic Bulletin & Review*, *24*, 1158-1170. DOI 10.3758/s13423-016-1191-6

Cowan, N., Hogan, T. P., Alt, M., Green, S., Cabbage, K. L., Brinkley, S., Gray, S. (2017). Short-term memory in childhood dyslexia: deficient serial order in multiple modalities. *Dyslexia, 23,* 209-233. DOI: 10.1002/dys.1557

Denckla, M. B., & Rudel, R. G. (1974). Rapid "automatized" naming of pictured objects, colors, letters and numbers by normal children. *Cortex*, *10*, 471-479.

Eccles, J. S., & Wigfield, A. (1995). In the mind of the actor: The structure of adolescents' achievement task value and expectancy-related beliefs. *Personality and Social Psychology Bulletin*, *21*, 215–225. DOI: 10.1177/0146167295213003

Ehrhardt, J., Huntington, N., Molino, J., & Barbaresi, W., (2013). Special education and later academic achievement. *Journal of Developmental and Behavioral Pediatrics, 34,* 111-119. DOI: 10.1097/DBP.0b013e31827df53f

Eklund, K., Torppa, M., Aro, M., Leppänen, P. H. T., & Lyytinen, H. (2015). Literacy skill development of children with familial risk for dyslexia through grades 2, 3, and 8. *Journal of Educational Psychology, 107*, 126-140. DOI: 10.1037/a0037121

Esser, G., Wyschkon, A., & Schmidt, M. H. (2002). Was wird aus Achtjährigen mit einer Lese- und Rechtschreibstörung: Ergebnisse im Alter von 25 Jahren [Long-term outcome in 8-year-old children with specific reading retardation: Results at age 25 years]. *Zeitschrift fuer Klinische Psychologie und Psychotherapie, 31,* 235-242.

Ferrer, E., Shaywitz, B. A., Holahan, J. M., Marchione, K., & Shaywitz, S. E. (2010). Uncoupling of reading and IQ over time: Empirical evidence for a definition of dyslexia. *Psychological Science, 21,* 93–101. DOI: 10.1177/0956797609354084

Francis, D. J., Fletcher, J. M., Stuebing, K. K., Lyon, G. R., Shaywitz, B. A., & Shaywitz, S. E. (2005). Psychometric approaches to the identification of LD: IQ and achievement scores are not sufficient. *Journal of Learning Disabilities, 38*, 98-108.

Georgiou, G. K., Parrila, R., Manolitsis, G., Kirby, J. R. (2011). Examining the importance of assessing rapid automatized naming (RAN) for the identification of children with reading difficulties. *Learning Disabilities: A Contemporary Journal, 9*, 5-26.

Georgiou, G. K., Parrila, R., & Kirby, J. (2006). Rapid Naming Speed Components and Early Reading Acquisition. *Scientific Studies of Reading, 10,* 199-220. DOI: 10.1207/s1532799xssr1002 4

Georgiou, G. K., Parrila, R., & Kirby, J. R. (2009). RAN components and reading development from grade 3 to grade 5: what underlies their relationship? *Scientific Studies of Reading, 13*, 508-534. DOI: 10.1080/10888430903034796

Gerber, P.J. (2012). The impact of learning disabilities on adulthood: a review of the evidence-based literature for research and practice in adult education. *Journal of Learning Disabilities, 45,* 31-46. DOI: 10.1177/0022219411426858

Goldberg, R. J., Higgins, E. L., Raskind, M. H., & Herman, K. L. (2003). Predictors of success in individuals with learning disabilities: a qualitative analysis of a 20-year

longitudinal study. *Learning Disabilities Research & Practice, 18*, 222–236. DOI: 10.1111/1540-5826.0007

Gough, P. B. & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *RASE: Remedial & Special Education, 7*, 6–10.

Hakkarainen, A., Holopainen, L., Savolainen, H. (2015). A five-year follow-up on the role of educational support in preventing dropout from upper secondary education in Finland. *Journal of Learning Disabilities, 48*, 408-421. DOI: 10.1177/0022219413507603

Heikkilä, R., Torppa, M., Aro, M., Närhi, V., & Ahonen, T. (2015). Double-deficit hypothesis in a clinical sample: extension beyond reading. *Journal of Learning Disabilities, 49,* 546-560. DOI: 10.1177/0022219415572895.

Ingesson, S. G. (2005). Stability of IQ measures in teenagers and young adults with developmental dyslexia. *Dyslexia, 12,* 81-95. DOI: 10.1002/dys.306

Irby, S. M., & Floyd, R. G. (2013). Test review. Wechsler Abbreviated Scale of intelligence, Second Edition. *Canadian Journal of School Psychology, 28*, 295-299. DOI: 10.1177/0829573513493982

Kairaluoma, L., Torppa, M., Westerholm, J., Ahonen, T. & Aro, M. (2013). The nature of and factors related to reading difficulties among adolescents in a transparent orthography. *Scientific Studies of Reading, 17,* 315-332. DOI: 10.1080/10888438.2012.701257

Kirk, S. A., McCarthy, J. J., & Kirk, W. D. (1968). *Illinois Test of Psycholinguistic Abilities. Examiner's manual.* Urbana, IL: University of Illinois Press.

Korhonen, T. T. (1995). The persistence of rapid naming problems in children with reading disabilities: a nine-year follow-up. *Journal of Learning Disabilities, 28*, 232-239.

Korkman, M., Kirk, U., & Kemp, S. (1998). *NEPSY. A Developmental Neuropsychological Assessment. Manual.* San Antonio, TX: The Psychological Corporation.

Korkman, M. (2000). *NEPSY. Lasten neuropsykologinen tutkimus. Käsikirja II. Testin tausta ja soveltaminen.* Helsinki: Psykologien Kustannus Oy.

Kuusinen, J., & Blåfield, L. (1972). *ITPA:n teoria, ominaisuudet ja käyttö.* Kasvatustieteiden tutkimuslaitoksen julkaisuja 156. Jyväskylä, Finland: Kasvatustieteiden tutkimuslaitos.

Kämppi, K., Välimaa, R., Ojala, K., Tynjälä, J., Haapasalo, I. & Kannas, L. (2012). Koulukokemusten kansainvälistä vertailua 2010 sekä muutokset Suomessa ja Pohjoismaissa 1994-2010: WHO-Koululaistutkimus (HBSC-Study). Opetushallitus, Terveyden edistämisen tutkimuskeskus, Jyväskylän yliopisto. Koulutuksen seurantaraportit; 2012, 8.

Landerl, K., & Moll, K. (2010). Comorbidity of learning disorders: Prevalence and familial transmission. *Journal of Child Psychology and Psychiatry, 51*, 287–294

Landerl, K., Ramus, F., Moll, K., Lyytinen, H., Leppänen, P. H. T., Lohvansuu, K., & Schulte-Körne, G. (2013). Predictors of developmental dyslexia in European orthographies with varying complexity. *Journal of Child Psychology and Psychiatry, 54*, 686-694. DOI: 10.1111/jcpp.12029

Landerl, K. & Wimmer, H. (2008). Development of word reading fluency and spelling in a consistent orthography: An 8-year follow-up. *Journal of Educational Psychology, 100,* 150-161. DOI: 10.1037/0022-0663.100.1.150

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of Dyslexia, 53,* 1–14.

Maughan, B., Messer, J., Collishaw, S., Pickles, A., Snowling, M., Yule, W., and Rutter, M. (2009). Persistence of literacy problems: spelling in adolescence and at mid-life. *Journal of Child Psychology and Psychiatry, 50*, 893-901. DOI: 10.1111/j.1469-7610.2009.02079.x

Majerus, S., & Cowan, N. (2016). The nature of verbal short-term impairment in dyslexia: the importance of serial order. *Frontiers in Psychology, 7,* 1-8. DOI: 10.3389/fpsyg.2016.01522

McLaughlin, M., Speirs, K. E. & Shenassa, E. D. (2014). Reading disability and adult attained education and income: evidence from a 30-year longitudinal study of a population-based sample. *Journal of Learning Disabilities, 47*, 374-386. DOI: 10.1177/0022219412458323

McNulty, M. A. (2003). Dyslexia and the life course. *Journal of Learning Disabilities*, *36*, 363-381.

Mol, S. E., & Bus, A. G. (2011). To read or not to read: a meta-analysis of print exposure from infancy to early adulthood. *Psychological Bulletin, 137*, 267-296. DOI: 10.1037/a0021890

Moll, K., Fussenegger, B., Willburger, E. & Landerl, K. (2009). RAN is not a measure of orthographic processing. Evidence from the asymmetric German orthography. *Scientific Studies of Reading, 13*, 1-25. DOI: 10.1080/10888430802631684

Nevala, J., Kairaluoma, L., Ahonen, T., Aro, M., & Holopainen, L. (2006). *Lukemis- ja kirjoittamistaitojen yksilötestistö nuorille ja aikuisille.* Jyväskylä: Niilo Mäki Institute.

Niilo Mäki Institute. (1992). *Neuropsychological and achievement tests: Local normative data for Niilo Mäki Institute-Test Battery*. Jyväskylä, Finland: Author.

Niilo Mäki Institute. (1994). *Neuropsychological and achievement tests: Local normative data for Niilo Mäki Institute-Test Battery-Revised.* Jyväskylä, Finland: Author.

Närhi, V. (2002). *The Use of Clinical Neuropsychological Data in Learning Disability Research.* University of Jyväskylä. Jyväskylä Studies in Education, Psychology and Social Research, 193.

Närhi, V., Ahonen, T., Aro, M., Leppäsaari, T., Korhonen, T. T., Tolvanen, A. Lyytinen, H. (2005). Rapid serial naming: Relations between different stimuli and neuropsychological factors. *Brain and Language, 92*, 45-57. DOI: 10.1016/j.bandl.2004.05.004

Paananen, R. & Gissler, M. (2012). Cohort profile: the 1987 Finnish birth cohort. *International Journal of Epidemiology*, *41,* 941-945. DOI: 10.1093/ije/dyr035

Papadopoulos, T. C., Spanoudis, G. C., & Georgiou, G. K. (2016). How is RAN related to reading fluency? A comprehensive examination of the prominent theoretical accounts. *Frontiers in Psychology, 7,* 1-15. DOI: 10.3389/fpsyg.2016.01217

Parrila, R., Georgiou, G., & Corkett, J. (2007). University students with a significant history of reading difficulties: what is and is not compensated? *Exceptionality Education International, 17*, 195-220. Retrieved from http://ir.lib.uwo.ca/eei/vol17/iss2/4

Pennington, B. F. (2006). From single to multiple deficit models of developmental disorders. *Cognition, 101,* 385-413. DOI: 10.1016/j.cognition.2006.04.008

Puolakanaho, A., Ahonen, T., Aro, M., Eklund, K., Leppänen, P. H. T., & Poikkeus, A.-M. (2007). Very early phonological and language skills: Estimating individual risk of reading disability. *Journal of Child Psychology and Psychiatry*, *48*, 923–931. DOI: 10.1111/j.1469-7610.2007.01763.x

Ransby, M. J., & Swanson, H. L. (2003). Reading comprehension skills of young adults with childhood diagnoses of dyslexia. *Journal of Learning Disabilities, 36*, 538-555. DOI: 10.1177/00222194030360060501

Savolainen, H., Ahonen, T., Aro, M., Tolvanen, A., & Holopainen, L. (2008). Reading comprehension, word reading and spelling as predictors of school achievement and choice of secondary education. *Learning and Instruction, 18,* 201-210. DOI: 10.1016/j.learninstruc.2007.09.017

Savolainen, J., Paananen, R., Merikukka, M., Aaltonen, M., & Gissler, M. (2013). Material deprivation or minimal education? Social class and crime in an egalitarian welfare state. *Advances in Life Course Research, 18,* 175-184. DOI: 10.1016/j.alcr.2013.04.001

Schulte-Körne, G., Deimel, W., Jungermann, M., & Remschmidt, H. (2003). Nachuntersuchung einer Stichprobe von leserechtschreibgestörten Kindern im Erwachsenenalter. [Long-term Outcome for Dyslexic Children]. *Zeitschrift für Kinder- und Jugendpsychiatrie und Psychotherapie, 31*, 267-276. DOI: 10.1024//1422-4917.31.4.267

Seymour, P.H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94,* 143-174.

Sideridis, G. D., Stamovlasis, D., Antoniou, F. (2016). Reading achievement, mastery, and performance goal structures among students with learning disabilities: a nonlinear perspective. *Journal of Learning Disabilities, 49*, 631-643. DOI: 10.1177/0022219415576524

Stack-Cutler, H. L., Parrila, R. K., & Torppa, M. (2015). Using a multidimensional measure of resilience to explain life satisfaction and academic achievement of adults with reading difficulties. *Journal of Learning Disabilities, 48*, 646-657. DOI: 10.1177/0022219414522705

Stanovich, K. (1986). Matthew effects in reading: some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21*, 360-407.

Statistics Finland. (2016, January 27). Labour force survey. Retrieved from http://www.stat.fi/til/tyti/2015/12/tyti_2015_12_2016-01-27_tie_001_fi.html

Strehlow, U., Kluge, R., Möller, H., & Haffner, J. (1992). Der langfristige Verlauf der Legasthenie über die Schulzeit hinaus: Katamnesen aus einer Kinderpsychiatrischen Ambulanz. [Long-term course of developmental dyslexia beyond school age: a follow-up study]. *Zeitschrift für Kinder- und Jugendpsychiatrie, 20*, 254- 265.

Svensson, I., and Jacobson, C. (2005). How persistent are phonological difficulties? A longitudinal study of reading retarded children. *Dyslexia, 12,* 3-20. DOI: 10.1002/dys.296

Swanson, H. L. (2012). Adults with reading disabilities: converting a meta-analysis to practice. *Journal of Learning Disabilities, 45*, 17-30. DOI: 10.1177/0022219411426856

Swanson, E., Barnes, M., Fall, A-M., Roberts, G. (2018). Predictors of reading comprehension among struggling readers who exhibit differing levels of inattention and hyperactivity. *Reading and Writing Quarterly, 34,* 132-146. DOI: 10.1080/10573569.2017.1359712

Torppa, M., Eklund, K., van Bergen, E., & Lyytinen, H. (2015). Late-emerging and resolving dyslexia: A follow-up study from age 3 to 14. *Journal of Abnormal Child Psychology, 43*, 1389-1401. DOI: 10.1007/s10802-015-0003-1

Undheim, AM. (2003). Dyslexia and psychosocial factors. A follow-up study of young Norwegian adults with a history of dyslexia in childhood. *Nordic Journal of Psychiatry, 57*, 221-226. DOI: 10.1080/08039480310001391

Undheim, AM. (2009). A thirteen-year follow-up study of young Norwegian adults with dyslexia in childhood: reading development and educational levels. *Dyslexia, 15*, 291-303. DOI: 10.1002/dys.384

Vukovic, R. K., Wilson, A. M., & Nash, K. K. (2004). Naming speed deficits in adults with reading disabilities: a test of the double-deficit hypothesis. *Journal of Learning Disabilities, 37*, 440-450.

Wechsler, D. (1974). Manual for the Wechsler Intelligence Scale for Children (revised). New York: Psychological Corp.

Wechsler, D. (2008). Wechsler Adult Intelligence Scale–Fourth Edition. San Antonio, TX: Pearson.

Wechsler, D. (2011). Wechsler Abbreviated Scale of Intelligence, Second Edition. San Antonio, TX: Pearson.

Wechsler, D. (2013). *Wechsler Adult Intelligence Scale-Fourth Edition. Finnish Translation.* Psykologien Kustannus Oy. Helsinki: Helsingin Painotuote Oy.

Werner, E. (1993). Risk and resilience in individuals with learning disabilities: Lessons learned from the Kauai Longitudinal Study. *Learning Disabilities Research & Practice, 8*, 28-34.

Willcutt, E.G., Betjemann, R. S., McGrath, L.M., Chabildas, N. A., Olson, R., K., DeFries, J. C., Pennington, B. F. (2010). Etiology and neuropsychology of comorbidity between RD and ADHD: the case for multiple-deficit models. *Cortex, 46 (10),* 1345-1361.

Wilson, A. M., & Lesaux, N. K. (2001). Persistence of phonological processing deficits in college students with dyslexia who have age-appropriate reading skills. *Journal of Learning Disabilities, 34*, 394-400.

Zeffiro, T. & Eden, G. (2000). The neural basis of developmental dyslexia. *Annals of Dyslexia*, *50*, 3–30. DOI: 10.1007/s11881-000-0015

Table 1. Group Comparisons of Adult-age Reading, Cognitive Skills, Education, and Employment between Control Group and the two RD Groups.

	Control (n = 37)[a]		RD- (n = 29)		RD+ (n = 19)			*Cohen's d*		
	Mean	SD	Mean	SD	Mean	SD	*F(2, 81)*[b]	C vs RD-	C vs RD+	RD- vs RD+
Reading							31.48***			
Fluency	0.31[x]	0.87	-0.83[y]	0.46	-2.63[z]	0.60	106.22***	1.58	3.72	3.47
Accuracy	0.38[x]	0.57	-0.85[y]	1.22	-1.19[y]	1.18	20.90***	1.35	1.90	0.28
Comprehension	0.81[x]	0.59	-0.04[y]	0.87	0.03[y]	0.98	11.47***	1.17	1.05	0.08
Cognitive skills							4.20***			
VCI	95.37[x]	11.95	83.66[y]	14.69	84.26[x, y]	19.15	6.10**	0.89	0.75	0.04
PRI	98.63	15.57	99.83	13.59	97.58	22.07	0.11	0.08	0.06	0.12
Digit Span	24.91[x]	3.64	22.66[x, y]	5.06	21.16[y]	4.38	5.04***	0.52	0.96	0.31
PSI	101.06[x]	17.60	91.90[x, y]	12.83	90.32[y]	13.39	4.28*	0.58	0.66	0.19
Phonological skills	8.74[x]	1.80	6.00[y]	2.42	5.32[y]	2.31	20.41***	1.30	1.72	0.29
RAN	21.24[x]	6.05	22.07 [x]	4.37	27.43[y]	5.87	8.43***	0.15	1.03	1.07
							χ^2 (4)			
Self-evaluation of reading							31.49***			
Below average	1 (2.7%)		6 (21.4 %)		12 (63.2%)					
Average	19 (51.4%)		16 (57.1 %)		12 (36.8%)					
Above average	17 (45.9%)		6 (21.4 %)		0 (0%)					
Education										
High school degree	18 (56.3%)		6 (20.7%)		3 (15.8 %)		12.02**[c]			
Vocational school degree	21 (40.6%)		21 (72.4%)		15 (78.9 %)					
No upper secondary degrees	2 (3.1 %)		2 (6.9 %)		1 (5.3 %)					
University of applied sciences or University degree	17 (58.6%)		6 (23.1 %)		3 (16.7 %)		11.29**			
Unemployed	3 (8.1%)		4 (13.8 %)		6 (31.6 %)		4.92*[c]			

Note. VCI = Verbal Comprehension Index (WAIS IV). PRI = Perceptual Reasoning Index (WAIS IV). Digit Span = Raw score of the Digit Span subtest (WAIS-IV). PSI = Processing Speed Index (PSI). RD- = Childhood RD group without adult-age RD. RD+ = Childhood RD group with adult-age RD. Groups with different

superscript letter (x, y or z) differed significantly from each other in the post hoc pair wise comparisons of ANOVA F tests ($p < .05$). Bonferroni or Dunnett's T3 corrections were used depending on equality or inequality of the variances.
[a] n = 35 in group comparisons of cognitive measures due to two missing scores in RAN
[b]Degrees of freedom 2, 80 in cognitive skills.
[c] n = 18 in group comparisons of reading and cognitive measures due to a missing score in reading comprehension.
[d] Degrees of freedom 2, 71 in Age.
[e] Fisher's exact test.
*p <.05, **p < .01, ***p < .001.

Table 2. Group Comparisons of Childhood Measures between RD- and RD+ Groups.

	RD- (n = 29)[a]		RD+ (n = 19)[b]			
	Mean	SD	Mean	SD	*F(1, 4)*	*Cohen's d*
VIQ	91.52	7.86	91.89	12.09	0.02	0.04
PIQ	98.93	12.66	100.06	9.77	0.10	0.10
RAN	-1.49	1.67	-2.62	1.68	4.90*	0.68
					χ^2 (1)	
Severe childhood RD	12 (42.9 %)		12 (63.2 %)		1.87	
Phonological deficit	14 (48.3 %)		11 (64.7 %)		1.17	
Special education	23 (92 %)		17 (94.4 %)		0.10	
Experienced support > 2 support providers	19 (67.9 %)		10 (52.6 %)		1.11	

Note. [a] n = 27 in VIQ, PIQ, and RAN due to missing cases in RAN. [b]n = 18 in VIQ, PIQ, and RAN. Severe childhood RD = reading fluency z-score at or below -2.5 compared to the mean of the norm data.
*p <.05

Table 3. Pearson Correlations of Adult-age Reading Fluency, Accuracy, and Comprehension, Childhood Cognitive Measures (IQ, RAN, Phonological Deficit), Severity of Childhood RD, Special Education, and Number of Supportive Adults in Childhood within the RD Group.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Adult-age fluency	-	.22	-.07	-.08	-.05	**.29***	-.24	.28	-.08	.26
2. Adult-age accuracy		-	.14	-.02	.06	.26	**-.41****	.15	-.10	.20
3. Adult-age comprehension			-	**.33***	**.35***	.01	-.01	-.03	-.00	-.02
4. VIQ				-	.11	-.21	-.09	.01	.08	-.18
5. PIQ					-	**.36***	.12	-.26	-.01	-.04
6. RAN						-	-.27	.08	-.36*	.10
7. Phonological deficit							-	.11	.12	-.05
8. RD severity								-	-.13	.23
9. Special education									-	-.01
10. Support										-

Note. Group sizes in the correlations vary from 41 to 48 due to missing values in some items. VIQ = Verbal Intelligence Quotient (WISC-R). PIQ = Performance Intelligence Quotient (WISC-R). Phonological deficit = Phonological deficit in childhood, a dichotomous variable based on the performance in the ITPA Phoneme Blending task or the NEPSY Phonological Processing test: 1 – phonological deficit, 0 – no phonological deficit. RD severity = RD level in childhood, a dichotomous variable for RD level based on reading fluency z-score: 1 - "very severe RD" (z-score at or below -2.5), 0 - "severe RD" (z-score -2.5 to -1.5). Special education = Special education received at comprehensive school, 0 = did not receive SE, 1 = received SE. Support = Number of support providers in childhood, 1= more than 2 support providers, 0 = 2 or less support providers.

*$p < .05$.

Table 4. Regression Coefficients for Childhood Predictors of Adult-age Fluency, Accuracy and Comprehension.

	Fluency		Accuracy		Comprehension	
Predictors	*β*	*SE*	*β*	*SE*	*β*	*SE*
VIQ					.30*	.01
PIQ					.32*	.01
RAN	.26	.09	.16	.11		
Phonological deficit			-.37*	-.89		
RD severity	.22	.30				
Special education						
Support	.18	.31				
R^2	.18		.19		.21	
F	3.15*		5.09*		5.56**	

*$p < .05$.

** p <.01.