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Computer-aided dyslexia assessment – Provia's usability in dyslexia screening

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ABSTRACT

Provia is a computerized battery designed for children with the aim of finding suitable training areas from Lexia, a commonly used remediation program for linguistic deficits in Finnish schools and rehabilitation centers. The objective was to study the suitability of the Finnish version of the Provia as a dyslexia screening tool. Provia was administered (in groups of 10–15 pupils) for 260 school-aged children in Finland, followed by individual neuropsychological tests (n=77) and analyses (n=75) regarding reading, writing, naming, and other related skills.

The results revealed decent validity and reliability of the battery to assess dyslexia in Finnish children (α= .83 – .85). Performance in Provia was compared to performance in a standardized and commonly used reading and spelling test Lukilasse. Errors in Provia in general as well as in its individual subtests were associated with reading (r = -.34 – -.57, p<.001) and writing (r = -.32 – -.51, p<.001). Especially the errors in Provia's phonological subtests were proven to predict reading and writing errors and slowness of reading in Lukilasse the most. The study offers clinically valuable information that can be used to further understand dyslexia as well as the usability and development of different dyslexia assessment and remediation methods.

Avainsanat:

Dyslexia, Computer-aided assessment and rehabilitation, Provia, Lexia, Lukilasse

INTRODUCTION

Dyslexia is a neurodevelopmental disorder (Snowling, Hulme & Nation, 2020) ranging from under five to 20 percent of population, depending on the criteria and severity in the continuum of reading and writing skills (Wagner et al., 2020), which are correlated with other skills and comorbidities (Snowling, Hulme & Nation, 2020). The bases are multifactorial involving phonological and other language related deficits, but also other complex sets of disturbances (Peterson & Pennington, 2015).

Reading-skill acquisition, word recognition and / or fluency problems in dyslexia are often based on phonological deficits (Lyon et al., 2003). Phonological processing and related problems often appear concurrently (Torppa et al., 2012), but sometimes possibly separately (eg. Wolf & Bowers, 1999; Wolf et al., 2002; Torppa et al., 2012). Varying difficulties of slowness and/or inaccuracy in phonological processing may result in varying influency and inaccuracy in decoding (Lyon ym., 2003) and spelling (Snowling, 2005). In the Finnish population, the reading disabilities are most often characterized by slowness (Aro et al., 2011).

Phonological awareness, slow serial naming, as well as phonological working memory are the key correlates and predictors of dyslexia (e.g., Puolakanaho et al., 2008; Torppa et al., 2007). The slowness of naming has been more strongly related to reading speed (Salmi, 2008; Torppa et al., 2012), writing speed (Bowers et al., 1999; Sunseth & Bowers, 2002), as well as reading fluency (Landerl et al., 2013); the inaccuracy of naming (Salmi, 2008; Torppa et al., 2012), phonological awareness and phonological working memory to inaccuracy in reading and spelling (Landerl et al., 2013).

Although dyslexia is by far a verbal deficit (Snowling & Hulme, 2011), dyslexics have also shown to differ from controls in non-verbal perceptual and attentional functions (Bosse et al., 2007). Especially speeded tasks (Poblano et al., 2000), e.g., perceiving moving objects, are difficult for dyslexics (Laasonen et al., 2012), who are known to be slow and clumsy in many areas of perception (Laasonen, 2002). Non-verbal short-term memory is also weaker in those with reading disabilities than in fluent readers (Laasonen et al., 2012). These findings point to a broad set of symptoms associated with dyslexia.

Fluency of reading, phonological awareness, and other linguistic skills (Snowling & Hulme, 2011) can be trained with various approaches (Huemer, 2009) and even purely non-linguistic audio-visual training (Kujala et al., 2001; Törmänen & Takala, 2009) have been shown to be beneficial. Yet a lot is still uncovered, especially regarding the assessment.

The use of computer in the screening or assessment of dyslexia is still quite uncommon in Finland, where the traditional paper-pencil method is most often used individually. Provia (Mårtens & Gunnilstam, 2009) is a computerized method designed for children with the aim of finding suitable training areas from a remediation program, Lexia, which is widely used in the treatment of dyslexia and other linguistic deficits in Finnish schools and rehabilitation centers. Provia includes many dyslexia-related tests, tests of phonological processing, reading, and spelling. However, because it does not include tests of naming, two individual tests were developed as part of this study.

This study aims to investigate the computer-based screening of dyslexia using the Finnish version of Provia. The main aim is to study the associations between different subtests of Provia as well as the integrity of the battery as a predictor of reading and spelling skills measured by other methods. Provia's tests will be compared with the tests of Lukilasse (Häyrinen et al., 1999), which is the most common test for assessing reading and spelling skills of school-aged children in Finland.

The research questions and hypothesis are:

1 How consistent are the results regarding reading and writing skills obtained by Provia with those obtained by Lukilasse? Performance in Provia in general is assumed to correlate with performance measured by Lukilasse.

2 Which subtests and difficulties in Provia are the most associated with reading and writing deficits measured by Lukilasse? Difficulties in phonological processing in Provia are assumed to be related to reading and/or spelling difficulties in Lukilasse. The slowness of naming in Provia is presumed to be related to slowness of reading in Lukilasse. The inaccuracy in Provia's phonological tasks, including naming, is presumed to predict the inaccuracy of reading and spelling in Lukilasse.

METHODS

Participants

Thirteen schools from Southern Finland were selected for the studies in Spring 2010. First-grade students (n = 260) were assessed first with Provia in groups of about 10-15 children. In the following fall the same students participated in individual testing, where naming skills were evaluated. In Spring 2011, based on performance in three subtests (Reading, Spelling and Arrange Letters), the weakest 15% (n=40) of the participants were chosen for neuropsychological testing. The performance in the three subtests was first transformed into an ordinal scale, from which a sum variable was formed for choosing the subjects for the experimental group. From the remaining data (n = 220), a control group was formed by picking students randomly until the groups corresponded by gender and the socio-economic status of parents.

In the end of the screening phase, the groups consisted of students from eleven schools and the neuropsychological evaluations were completed by 77 pupils. Because of the small sample size in the experimental group, there were only seven students who belonged to the weakest 20% in all three criterion variables, but none in the control group had as many difficulties in the chosen variables (Table 1). The parents confirmed and supplemented background information by filling in a questionnaire in the beginning of the study. Pupils with different language background (e.g., those with Finnish as a second language) participated in the group testing in Finnish but were later removed from the analyses. One pupil in the control group was excluded because of a diagnosed language difficulty, and another one was removed from the analyses because of a different language background (bilingual). Because of missing data and the exclusion criteria, eventually about 75 children were included in most analyses (the analysis of the missing data will be further explained in the following sections). In this correlational study, the data are combined and further analyzed as a whole.

Ethical considerations

The Ethical Committee of the Faculty of Behavioral Science at the University of Helsinki approved the research plan. All participants, their parents, schools, and education departments of the communes gave their permission for the studies. The designers of Provia, Martti Mårtens and Olle Gunnilstam from Stora Sköndal, Sweden, gave their approval for the use and revision of the methods in study purposes. The study was conducted as an entrepreneur, as a part of individual specialisation and development (Hanna-Mari Mäki-Karjalainen) at the

publisher and distributor of the Finnish version of Provia, CognAid Ltd. There were no other financial involvements or arrangements with other test publishers or distributors regarding Provia or other tests used in this study.

Table 1 Control and experimental groups and their deficits in Provia [X^2 (3) =61,977, p<0,01].

	Difficulties in Provia (belonging to the weakest 20% in 0, 1, 2 or 3 of the chosen criterion variables)				Total
	No difficulties	belonging to the weakest 20% in one of the chosen criterion vari-ables	belonging to the weakest 20% in two of the chosen criterion vari-ables	belonging to the weakest 20% in three of the chosen criterion vari-ables	
Control group	25	15	0	0	40
Experimental group	0	5	25	7	37
Total	25	20	25	7	77

Instruments

The participants completed ten original subtests from the Provia's Finnish version (PR, Mårtens & Gunnilstam, 2009) described in Table 2. The participants also completed two new subtests which were designed for this study: Quick naming (PR-0) and Serial naming (PR-11) (Mäki-Karjalainen, 2010; unpublished). Subtests 1-10 were completed in groups, subtests 0 and 11 individually.

As part of neuropsychological testing, the participants also completed two subtests from Lukilasse (LL, Häyrinen et al., 1999). The subtests were Read words (LL-RW), where the task is to read aloud as many words as possible in two minutes, and Spelled words (LL-SW), where the task is to write words from dictation.

Procedure

The results from Provia's and partly Lukilasse's subtests were transformed into error-percentages for analyses. LL-RW, PR-SPL, -RD and -ASW scales were originally skewed to the right, reflecting Finnish word-letter-correspondence regularities and hence the Finnish children's proficient reading and spelling skills. After the transformations, the values were all added one (1) and some variables were logarithm corrected. Also new variables were formed for the analyses, as described, e.g., in Lukilasse, where the task is to read for two minutes, an additional item was calculated into read words per minute (RPM).

Reading speed (words per minute, WPM) was counted from LL-RW by subtracting false responses or using the raw data of read words before they were counted (which were included originally in the correctly read words per two minutes, as in the Lukilasse form), and dividing the result by two. Different theoretically meaningful sum variables were also formed from different PR test sections, but Principal Component Analyses for the original subtests 1-10 (corresponding index numbers, titles, abbreviations and task descriptions are found in table 2)

showed without exception all items loading well on a single factor. Therefore, the best solution was to combine them all into a mean variable (MV), which was calculated from the error percentages (α = .843). Missing values were replaced by statistically nearby values, using Missing value analysis and Estimation maximization -method. In some other analyses, some of the data were left out because of the inclusion criteria or reliability reasons, if there were outliers that were proven not to be valid (for example someone with behavior problems was left out from the analysis if it was apparent that he/she did not perform adequately in the test situation by e.g., writing different words than asked on purpose).

Table 2 Provia's (PR) subtests used in the study

Analysis index numbers	**Subtest**	**Abbreviation**	**Task description**
1	Find a Picture for a Sounded Word	PR-FPSW	The task is to choose, which one of the seen photos fits the heard word from a sequence of sounds.
2	Phonological Awareness	PR-PA	The task is to manipulate parts of a word and decide at word, syllable, and phoneme level (e.g., syllables change their place) the right option of what is heard.
3	Arrange sounded words	PR-ASW	The task is to form a word by dragging the corresponding white labels into the right order.
4	Remember Picture Sequence	PR-RPIS	The task is to memorize and then remember the order of the seen and heard photos.
5	Remember Pattern Sequence	PR-RPAS	The task is to memorize and then repeat the pattern in the same order as seen.
6	Arrange Sounded Letters	PR-ASL	The task is to arrange seen letters into the correct order.
7	Arrange Letters	PR-AL	The task is to arrange heard letters in the correct order.
8	Spelling	PR-SPL	The task is to spell the heard words.
9	Reading	PR-RD	The task is to click the corresponding photo or text of what is heard.
10	Remember Number Sequence	PR-RNS	The task is to memorize and repeat the order of the heard numbers.
0	Quick Naming [1]	PR-QN	The task is to name familiar photos appearing on the screen as fast and as accurately as possible. The adult presses + or – depending on the answer, and marks observations on a form if needed.
11	Serial Naming [1]	PR-SN	This subtest consists of three parts, where the task is to name objects appearing on the screen serially as fast and accurately as possible. The computer counts the time per each part and the adult marks the errors and corrections, and other qualitative observations on a form. Especially the latter parts (two and three) consist of phonologically difficult items in Finnish, and naming their color and form.

1) Additional subtests designed for this study.

RESULTS

The experimental and control groups differed in their reading and writing skills as expected, but the differences when compared as means between the experimental and control group were small, and there were also ceiling effects (see Table 3).

Table 3 Experimental and control groups and their deficits

	CONTROL GROUP (n = 38–40)				EXPERIMENTAL GROUP (n = 34–37)				TOTAL (n = 74–76)				t	p
	Mean	Std.	Min.	Max.	Mean	Std.	Min.	Max.	Mean	Std.	Min.	Max.	df = 74	
PR 0 ep	28.7	10.79	5	53	33.21	15.61	13	85	30.84	13.4	5	85	-1.48	+
PR 1 ep	31.33	18.42	1	63	38.81	22.54	1	76	34.87	20.68	1	76	-1.59	ns
PR 2 ep	29.45	16.39	1	81	39.33	15.96	8	74	34.13	16.83	1	81	-2.66	**
PR 3 ep	4.83	7.68	1	34	15.11	14.85	1	68	9.7	12.66	1	68	-3.85	***
PR 4 ep	52.65	25.61	1	101	73.77	21.2	9	101	62.65	25.76	1	101	-3.89	***
PR 5 ep	26.28	20.07	1	73	56.71	24.42	1	101	40.69	26.86	1	101	-5.96	***
PR 6 ep	15	9.12	1	38	30.17	9.33	12	61	22.28	11.92	1	61	-7.18	***
PR 7 ep	54.15	11.91	24	93	61.78	11.6	39	93	57.76	12.3	24	93	-2.82	**
PR 8 ep	39.75	19.9	1	81	56.36	18.07	21	81	47.5	20.69	1	81	-3.72	***
PR 9 ep	56.5	15.31	28	98	69.33	15.19	37	101	62.49	16.47	28	101	-3.55	***
PR 10 ep	24.4	21.61	1	101	56.65	22.5	9	101	39.22	27.21	1	101	-6	***
PR 11 ep	7.06	3.77	2	17	8.13	3.95	1	19	7.57	3.87	1	19	-1.21	ns
PR MV (1–10) ep	33.54	9.11	13	50	49.42	10.14	20	71	40.93	12.44	13	71	-7.05	***
LL RW rs	68.53	15.32	38	90	58.56	16.78	28	90	63.68	16.71	28	90	2.67	**
LL RW ep	4.39	3.29	0	18	5.89	3.65	0	12	5.12	3.53	0	18	-1.88	*
LL RW p	58.66	26.33	10	90	41.39	27.38	10	90	50.26	28.04	10	90	2.77	**
LL WPM	36.12	7.54	20	45	31.96	7.93	17	45	34.09	7.96	17	45	2.34	**
LL SW rs	35.92	5.56	16	40	33.11	6.05	16	40	34.55	5.94	16	40	2.08	*
LLSW ep	10.41	12.21	0	45	18.24	14.12	1	46	14.22	13.67	0	46	-2.59	+
LL SW p	54.47	22.14	10	70	37.5	23.22	10	70	46.22	24.08	10	70	3.22	***

*p ≤ .05, **p ≤ .01, ***p ≤ .001, +p <.10, ns = non-significant
PR = Provia, indexes derived from the original parts: See table 2. LL = Lukilasse, RW = Read words; SP = Spelled words; WPM = Reading speed, words per minute, ep = error percentage, rs = raw score, p = percentile from the original normative data of Lukilasse.

The correlations between Provia (PR) and Lukilasse (LL) are clear and significant, varying from moderate to strong. There are strong correlations between the mean variable of Provia (PR-MV) and Lukilasse's Read words: (LL-RW-rs): r =.56, p<.001, as well as Spelled words (LL-SW-rs): r = .43. p<.001. When the inaccuracy of reading and writing and reading speed or the slowness of reading are examined separately, the strongest associations are between Provia's mean variable error percentage (PR-MV) and the slowness of reading in Lukilasse (WPM: r = .53, p<.001). There are also moderate correlations between PR-MV and spelling (LL-SW), or the percentage of spelling errors (ep) in Lukilasse (r=.43, p <.001). There are also moderate to strong correlations between different subtests of Provia and Lukilasse. The strongest correlations are between phonological awareness (PR-PA) and reading (LL-RW-rs: r= .57, p<.001), reading speed or the slowness of reading (LL-WPM: r =.52, p<.001), and

spelling (LL-SW-rs: r = -.51, p<.001), or the spelling error percentage (LL-SW-ep: r=.51, p<.001), see Table 4.

Table 4 Correlations between inaccuracy in different Provia's subtests (sections used in group testing) and mean variable with Lukilasse's Read and Spelled words (raw scores and error percentages as well as reading speed, n = 75)

		PR (ep, index numbers)										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1–10 (MV)**
LL	RW:rs	-.10 ns	-.57***	-0.14 ns	-.41***	-.43***	-.39***	-.34**	-.37***	-.37**	-.41***	-.56***
	SW:rs	-.20+	-.51***	-.06 ns	-.32**	-.33**	-.20+	-.03 ns	-.19 ns	-.12 ns	-.33**	-.43***
	RW:ep	.05 ns	.25*	.11 ns	.30**	.30**	.15 ns	.08 ns	-.02 ns	.26*	.20+	.23*
	SW:ep	.17 ns	.50***	.06 ns	.33**	.34**	.19+	.05 ns	.20+	.13 ns	.34**	.44***
	WPM	-.06 ns	-.52***	-.12 ns	-.36**	-.38***	-.38***	-.33**	-.40***	-.33**	-.38***	-.53***

*p ≤ .05, **p ≤ .01, ***p ≤ .001, +p <.10, ns = non-significant

PR = Provia, index numbers 1-10, see table 2, MV = Mean variable, LL = Lukilasse (RW = Read words; SP = Spelled words; WPM = Reading speed, words per minute), ep = error percentage, rs = raw score.

The reading speed in LL (rs and WPM) correlates significantly with almost all Provia's subtests, but especially with phonological awareness (PR-2: r = -.52, p<.001) and the mean variable (MV) of group testing (r =-.53, p<.001). Weak total performance in Provia MV predicts weak performance in Lukilasse RW, b = −.29, t (256) = 45.04, p < .001 (Figure 1).

Some of the items or first sections, e.g., PR-FPSW (index 1) were quite easy for the study subjects, and therefore non-significant alone. Also, the new tests of naming (index 0 and index 11) appeared less essential as such, but further analyses and modified variables taking also into account the time proportion, were made.

The most important correlates of reading and spelling turned out to concern phonological processing, as expected. Subtests of PR: error percentage indexes 2, 10, 11 (parts 2 and 3), 7, 0 and 6 (logarithm corrected) explain together the 49.8% of the variety of LL-RW scores, F (6, 69) = 11.41, p < .001. Similarly, the subtests PR-PA and PR-SN (parts 2 and 3) turned out to most predict spelling. Errors in phonological awareness and serial naming explained together 24.1% of variance of spelling errors, F (1, 73) = 11.56, p < .001, errors in phonological awareness explaining errors in spelling alone 18.3%, F (1, 74) = 15.85, p < .001. When LL errors vs. reading speed are analyzed separately, the percentage of mistakes in LL is mostly (25% of variance) explained by the error percentages in PR-11 (2&3) and PR-9, F (2, 74) = 12.34, p < .001. In turn, the reading speed (LL-WPM) is mostly (altogether 37.7% of variance) explained by the error percentages in PR indexes 2, 6, 0 and 10, F (4, 72) = 10.89, p < .001.

The errors in PR-SN are associated with reading errors (LL-RW-ep) as expected (r=.46, p<.001), whereas the errors in QN turned out to be significant only together with other variables, as e.g., part of a new mean variable. Contrary to the expectations, in the regression analyses the errors in PR accounted for the reading speed in LL more than e.g., naming speed. As the PR-SN tasks became more difficult in parts 2 and 3, they become statistically more relevant (Table 5). Therefore, a new variable consisting of the original PR-indexes 2-10 and the parts 2 and 3 of SN including their mean proportion of time was created (α = .84). The new

variable, including thus 11 items, (10 of inaccuracy and one of time) correlated significantly with the LL variables (Table 5). However, equally as good reliability is attained with the first mean variable, which was derived from the ten original subtests (α=.84), or if all the twelve subtests including naming speed would be included (α =.85).

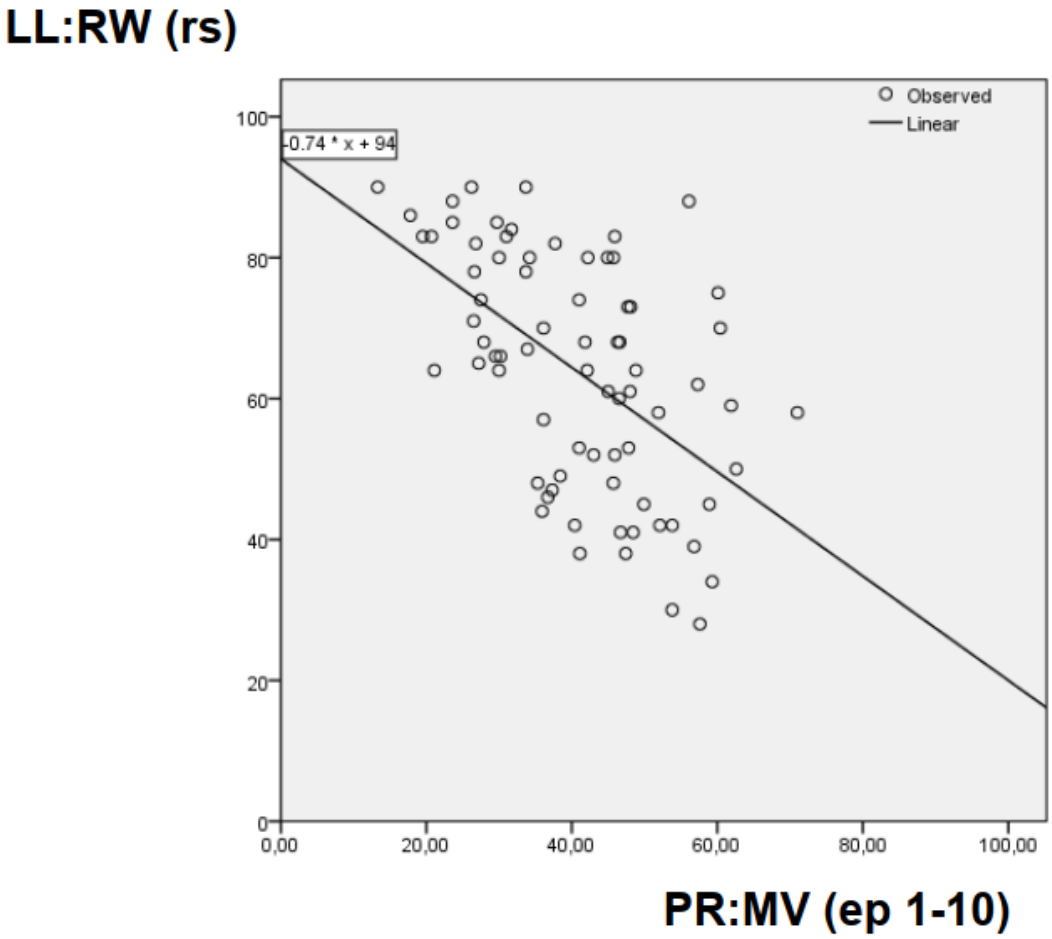

Figure 1 The association between Provia's subtests (Ind 1-10 MV) and LL:RW (rs)

Table 5. Correlations between inaccuracy and slow naming with Lukilasse's Read words and Spelled words (raw scores and error percentages as well as reading speed, n = 75)

	LL: Lukilasse				
PR: Provia	RW: rs	SW: rs	SW:ep	RW: ep	WPM
SN 2: time	-.29**	-.17 ns	-.18 ns	.20+	-,27*
SN 2: correct answers	.05 ns	.18 ns	.17 ns	-.31**	.01 ns
SN 2: errors	-.17 ns	-.32**	.31**	.26*	-.14 ns
SN 2: Provia index (0-5) (circled/25 X 5)	.05 ns	.18 ns	-.19 ns	-.32**	.02 ns
SN 3: time	-.40***	-.36**	.37***	.44***	-.33**
SN 3: correct	.33**	.25*	-.27*	-.36**	.25*
SN 3: errors	-.29*	-.22+	.23*	.33**	-.22 ns
SN 3: Provia index (0-5) (circled/50 X 5)	.33**	.25*	-.27*	-.36**	.25*
SN 3: total deficit (time & ep)	-.42***	-.37***	.38***	.45***	-.35**
SN 2 & 3: mean sum of time	-.42***	-.33**	.34**	.42***	-.36**
SN 2 & 3: ep	-.39***	-.33**	.34**	.46***	-.32**
SN 2 & 3: PR index 0-5 (circled /75 X 5)	.29*	.25*	-.27*	-.43***	.21+
SN 2 & 3: total deficit (time + ep / 2)	-.41***	-.35**	.37**	.46***	-.33**
SN: total time	-.30**	-.26*	.28*	.39***	-.25*
SN: total ep	-.28*	-.21+	.22+	.35**	-.21+
SN total deficit (ep + time)	-.33**	-.28*	.29*	.44***	-.27*
SN 3 & QN: total deficit (time + ep / 2)	-.33**	-.28*	.30*	.35**	-.29*
SN 3 and QN: ep	-.31**	-.26*	.28*	.34**	-.27*
SN & QN: mean sum of time	-.27*	-.23*	.24*	.35**	-.23*
SN 3 & QN total deficit & Ind1-10 ep)/12	-.54***	-.41***	.42***	.20+	-.50***
SN & QN & Ind 1–10 ep	-.54***	-.40***	.41***	.18 ns	-.50***
SN: total sum of time	-.30**	-.26*	.28*	.39**	-.25*
SN correct (sum of parts 1 & 2 & 3)	.30**	.27*	-.28*	-.36***	.24*
SN errors (sum of parts 1 & 2 & 3)	-.25*	-.22+	.23+	.35**	-.17 ns
SN 1-3: Provia index (0-5) (circled/91 X5)	.30*	.27*	-.28*	-.36**	.23*
SN: index 11 (circled, sum of parts 1 & 2 & 3) / 91	.36**	.31**	-.32**	-.38***	.29**
PR index 2-10 & SN 2-3 including time	-.57***	-.40***	.40***	.22+	-.53***
PR index 0-10 & SN 2-3 & QN time	-.51***	-.41***	.41***	.21+*	-.46***

*p ≤ .05, **p ≤ .01, ***p ≤ .001, +p <.10, ns = non-significant

PR = Provia, SN=Serial naming; index 11, QN=Quick Naming; index 0. Indexes 0-10 derived from the original parts: See table 2. LL = Lukilasse (RW = Read words; SP = Spelled words; WPM = reading speed, words per minute), ep = error percentage, rs = raw score.

DISCUSSION

The objective was to study the suitability of the Finnish version of the Provia as a dyslexia screening tool. The results revealed decent validity and reliability of the battery to assess the reading and writing and reading related skills of Finnish children (α= .83 – .85). Errors in Provia in general, as well as in its individual subtests, associated well with reading and writing. Weak total performance in Provia MV was found to predict weak performance in Lukilasse RW.

Especially the errors in Provia's phonological subtests were proven to predict reading and writing errors and slowness of reading in Lukilasse, as expected. However, the slowness of naming in Provia, which was presumed to be related to slowness of reading in Lukilasse, was also related to the errors in reading and writing. The inaccuracy in Provia's phonological tasks, including naming, was not only predicting the inaccuracy of reading and spelling in Lukilasse, but also the slowness of reading. Differently from expectations, in the regression analyses the errors in PR accounted for the reading speed in LL more than e.g., naming speed.

There were significant associations between different subtests of Provia and Lukilasse, measured separately as well as a mean value. However, some subtests proved to be better than others. The best predictors of reading and writing difficulties were, as expected, those regarding phonological processing. Of the original Finnish subtests of Provia (Mårtens & Gunnilstam, 2009), the best single subtest proved to be the Phonological awareness (PR-2; PR-PA). Also, other subtests which did not even have phonological content such as the RPAS, correlated with reading speed, and especially when integrated with other subtests, proved valuable. Even some sections at first seemed individually weaker, they are good to maintain as examples and introductory parts. In the factor analysis they also proved to be important parts of the mean variable (MV). Also, other mean variables were formed, and, in the future, it can be considered whether it would be sufficient to use the PR-PA as a quick first stage screening test, whether the MV of the ten original subtests should be calculated, or if the developed naming tests or one of them should be added to the battery. It is good to consider both naming errors and naming time, and the phonological content of the serial naming in the assessment, whereas the easier parts may serve as introduction to the test.

According to this study, the QN could be used only if integrated to other tests or means, whereas more studies are needed to find out more about its individual properties, since in the later analysis stages it became more relevant as part of the complex predictors of accuracy vs. time. The common reading and writing deficits including difficulties in phonological awareness, working memory and rapid (serial) naming became clear and evident through the different regression analyses between PR and LL. The results indicate not only the key correlates that are widely witnessed (e.g., Puolakanaho et al., 2008), the multifactorial bases and complex sets of disturbances in dyslexia, which have been studied and described in the literature (e.g., Peterson & Pennington, 2015).

Even the reliability of the investigated sum mean variables, Cronbach alphas ranging from .83 to .85 are strong, and the correlations range from moderate to strong as compared specially to reading speed and writing errors, it is important to consider different types of readers and their individual differences in the clinical work. It might be easy to think that most of the dyslexics suffer from phonological deficits, and that is why a quick screening could be done based on the most accurate subtest of phonological awareness (PR-PA), but in addition, it is important to continue using the traditional clinical tests to find the individual strengths and weaknesses, as well as training areas. The slowness of naming, especially slowness of serial naming (SN / PR-11), consisting of phonological content, was associated with slowness of reading, and the naming errors were in relation to reading and writing errors, but also reading speed,

which wasn't expected. Also, errors in different, almost all subtests of Provia correlated with slow reading. The strongest relations were with combined phonological errors and naming speed with all variables of Lukilasse, including reading speed and reading errors as well as writing errors, which correspond to what has been written about the double deficits of dyslexia (e.g., Wolf & Bowers, 1999). Otherwise, the Provia's original tests without the new tests of naming, would be sufficient to find not only the inaccurate readers and writers, but also slow namers and readers.

According to this study, Provia is a valid method for screening dyslexia. It is possible to use Provia in predicting reading and writing deficits cost-efficiently, even before actual diagnoses are made. By phonologically emphasized time-limitless group-testing it is possible to find not only the phonologically inaccurate readers and spellers, but also the slow namers and readers, who can be taken into further consideration and individual testing. The research helps in early identification of dyslexia that can support in the right timing of remediation and targeting rehabilitation for the correct areas based on test results. In the future, Provia might also be used as a low threshold first screening tool, before the school psychologist or special education teacher sends the results for the neuropsychologist, if needed. As Provia is primarily designed as a tool for finding suitable training areas from Lexia, it is good to keep in mind that the corresponding training areas need to be well planned, which remains the work of the professional users of Lexia.

This study focused on children in their first school years. In the future, it is important to follow how they have developed, and if the weaknesses remained or improved during maturation into adulthood. The tests which were studied should also be studied further with different age groups and populations, compared with a wider range of neuropsychological methods, considering the common comorbidities as well. As computer-assisted assessments are becoming more common, it is important to create guidelines for the users and continue developing the methods up to date.

Even though the phonological assessment and training areas have been well studied before, this study has shown the importance of the core as well as the diversity of evaluation methods that can be used. The study offers clinically valuable information that can be used to further understand dyslexia as well as the usability and development of different dyslexia assessment and remediation methods.

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