RAPID AUTOMATIZED NAMING AND LEARNING DISABILITIES: DOES RAN HAVE A SPECIFIC CONNECTION TO READING OR NOT? A REPLICATION

Riikka Heikkilä

Master's thesis in Psychology
Supervisors: Timo Ahonen, Vesa Närhi
Department of Psychology
University of Jyväskylä
Spring 2006

RAPID AUTOMATIZED NAMING AND LEARNING DISABILITIES: DOES RAN HAVE A SPECIFIC CONNECTION TO READING OR NOT? A REPLICATION

Author: Riikka Heikkilä
Supervisors: Timo Ahonen, Vesa Närhi
Master's thesis in Psychology
Department of Psychology
University of Jyväskylä

Spring 2006
33 pages

ABSTRACT

The aim of this study was to replicate the study of Waber, Wolff, Forbes, and Weiler (2000), in which the specificity of naming speed deficits (NSD) to reading disability (RD) was examined. 193 children (ages 8 to 11) referred to a child neuropsychological clinic for evaluation of learning disabilities were studied. Receiver operating characteristic (ROC) was used to determine how well rapid automatized naming (RAN) discriminated different diagnostic groups (learning impaired (LI) with and without RD) from control and from each other. The conclusion of Waber's et al. study was that RAN was an excellent tool for detecting risk for learning disabilities in general but was not especially effective in discriminating LI children with and without RD from each other. The results of the present study were contradictory in that they referred to a more specific connection between RAN and RD than in Waber's et al. study. The results of the present study also suggested that the connection between RAN and RD was stronger when RD was defined by reading speed rather than reading accuracy. The differences between studies are discussed in the light of language differences between English and Finnish, the languages varying greatly in the transparency of their orthographies.

Keywords: rapid automatized naming, reading disabilities, learning disabilities, language differences, transparency of orthography, comorbidity

RAPID AUTOMATIZED NAMING AND LEARNING DISABILITIES: DOES RAN HAVE A SPECIFIC CONNECTION TO READING OR NOT? A REPLICATION
Riikka Heikkilä
Ohjaajat: Timo Ahonen, Vesa Närhi
Psykologian Pro Gradu -tutkielma
Psykologian laitos
Jyväskylän yliopisto
Kevät 2006
33 sivua

TIIVISTELMÄ

Tutkimuksen tarkoituksena oli toistaa Waberin, Wolffin, Forbesin ja Weilerin (2000) tutkimus, jossa tarkasteltiin nopean sarjallisen nimeämisen (RAN) spesifisyyttä lukemisvaikeuksiin. Tutkimusaineistona oli 193 oppimisvaikeuksien vuoksi tutkimuksiin tullutta 8-11-vuotiasta lasta. Toimintaominaiskäyrän (ROC-analyysi) avulla määriteltiin, kuinka hyvin RAN erotteli erilaisia diagnostisia ryhmiä (oppimisvaikeuslapset, joilla joko oli tai ei ollut lukemisvaikeutta) kontrollista ja toisistaan. Waberin ym. tutkimuksessa päädyttiin johtopäätökseen, jonka mukaan RAN ennusti tehokkaasti oppimisvaikeuksia yleensä, mutta ei ollut erityisen hyvä erottelemaan lukihäiriöisiä lapsia niistä oppimisvaikeuslapsista, joilla ei ollut lukihäiriötä. Tämän tutkimuksen tulokset erosivat edellä kuvatuista tuloksista siten, että RAN:illa näytti olevan vahvempi yhteys lukemiseen kuin Waberin ym. tutkimuksessa. Lisäksi näytti siltä, että RANin yhteys lukemisvaikeuksiin oli vahvempi silloin, kun lukemisvaikeus määriteltiin lukemisen nopeuden eikä tarkkuuden mukaan. Tutkimustulosten eroavaisuuksia pohditaan kielierojen valossa, sillä suomi ja englanti eroavat toisistaan ortografiansa läpinäkyvyyden suhteen.

Avainsanat: Nopea sarjallinen nimeäminen, lukemisvaikeudet, oppimisvaikeudet, kielierot, ortografian läpinäkyvyys, komorbiditeetti

CONTENTS

1. INTRODUCTION

Growing research evidence supports the view that one of the background skills affecting reading is rapid automatized naming (RAN), an ability to recall the names of familiar objects. Naming speed deficits (NSD) are addressed when recalling familiar objects is slow and laborious. The characteristic of NSD is found to be particularly difficulties in naming rapid serial stimuli, not the difficulties in naming discrete stimuli (Snyder & Downey, 1995; Wolf, Bowers, & Biddle, 2000).

Naming speed deficits are found to be connected to laborious word decoding, which in turn hinders reading comprehension (Bowers & Wolf, 1993). In addition to developmental factors, NSD seems to be connected to the development of reading skills also via genetic (Byrne et al., 2005; Davis et al., 2001a; Nopola-Hemmi et al., 2002; Samuelson et al., 2005) and neurological factors (Breznitz, 2005; Eckert et al., 2003; Misra, Katzir, Wolf, & Poldrack, 2004).

The interest on RAN has ensued since 1976 when Denckla and Rudel found that rapid repetitive naming of numbers, letters, colors, and objects differentiated dyslexic children not only from normal controls but also from non-dyslexic learning impaired sample. The conclusion of the study was that a deficit in automatization of verbal responses to visual stimuli correlated specifically with dyslexia and was not due to low IQ or generalized slowing of reaction time. Ever since, much of the work within rapid naming has taken place in a framework of dyslexia and reading research. Indeed, in various studies the rapid naming has been connected to reading accuracy (Neuhaus, Foorman, Francis & Carlson, 2001; Spring & Davis, 1988), reading comprehension (Badian, 1993; Neuhaus et al., 2001; Sprugevica & Høien, 2004), and reading speed (Bowers, 1993, 1995; Bowers & Swanson, 1991; Wimmer, 1993; Young & Bowers, 1995).

In addition to its strong association to reading, the other connections of rapid naming are also been studied. Linkages between RAN and phonological skills are widely discussed, as well as RAN’s connections to orthographic awareness, verbal memory, attention, and general processing speed (for review, see Heikkilä, 2005). The results of these studies vary a lot, and many of the conclusions are contradictory. Despite its speculated connections to several cognitive abilities, it seems, however, that naming speed is not connected to IQ (Bowers, Steffy, & Tate, 1988; Denckla & Rudel, 1976) or other basic cognitive processes (Wimmer, 1993). In addition to many hypotheses concerning individual skills linked to RAN, there are studies that support an eclectic view that considers RAN as a multicomponential skill that has connections to many background skills (Denckla & Cutting, 1999; Närhi et al., 2005; Wolf et al., 2000). Even though RAN is clearly connected to reading and reading disabilities, there are also studies that refer to connection between RAN and learning disabilities in general. For example, in the original study of Denckla and Rudel (1976), in which the specific connection between RAN and dyslexia was found, it was also noticed that learning impaired children without dyslexia were slower namers than control children.

Waber, Wolff, Forbes, and Weiler (2000) studied the specificity of naming speed deficits (NSD) to reading disability (RD) with 188 children (ages 7 to 11) referred for evaluation of learning disabilities. In their study, RAN differentiated children with RD from the control children very effectively. However, RAN was not as effective in discriminating children with RD from learning impaired (LI) children without RD. In addition, RAN discriminated also LI children without RD from control, though not as effectively as children with RD from control. It also seemed that in their sample of LI children, the prevalence of NSD increased with the comorbidity of different learning disabilities (RD, attention problems, and mathematic disability), but was not dependent on the type of diagnosis. According to these results, authors concluded that RAN was an excellent tool for detecting learning impairment in general, but was less effective at distinguishing LI children with and without RD from each other. Waber et al. also studied the optimal cut-off score for RAN performance. The best cut-off score was determined by selecting the cut-off that produced the greatest percent of correct classifications. Determined this way, -1.0 SD from the mean of control population seemed to be the best cut-off score.

The study of Waber et al. described above was conducted in an English-speaking country (United States). However, it is likely that the differences between languages affect to the results reached from studies concerning rapid naming. Compared to English, Finnish as a language is orthographically more regular, which means that the grapheme-to-phoneme correspondence is more straightforward than in English (for more information on differences between languages, see Aro, 2004). This difference between languages with deep versus shallow orthographies has in many studies shown to contribute to the phenotype of reading difficulties (De Jong & Van der Leij, 2003; Nopola-Hemmi et al., 2002; Wimmer, 1993) and to the connection between RAN and reading disabilities (Korhonen, 1995a; Van den Bos, 1998; Wimmer, 1993; Wimmer, Mayringer, & Landerl, 1998; Wolf, Pfeil, Lotz & Biddle, 1994).

Heinz Wimmer (1993) studied the characteristics of developmental dyslexia in a regular writing system (German). He found that the main problem with dyslexic children was a pervasive speed deficit for all kinds of reading tasks while reading accuracy showed to be generally high. The finding was at variance with earlier studies conducted in English speaking countries in which the error rate was markedly high and the reading accuracy was an essential problem among dyslexic children. The difference between these studies in reading accuracy was explained by the differences between the levels of grapheme-phoneme consistency of German and English. In a very regular language like German, the possible problems with phonemically mediated word decoding were overcome rather quickly because the correspondences between graphemes and phonemes were easy to learn. Then the only persistent problem in the background of reading deficits was naming speed. Indeed, of the different kinds of phonological and naming measures, the speed of naming numbers (letter naming was not included in the study) was the most important predictor for speed of content word reading and pseudo-word reading. Later on, many studies have verified the results of Wimmer's study and have stated that in regular writing systems, the basic problem for dyslexics is the slow speed of reading rather than reading accuracy (Landerl & Wimmer, 2000; Wimmer, 1996; Wimmer & Mayringer, 2002; Wimmer, Mayringer, & Landerl, 1998; 2000; Yap & Van der Leij, 1993) and that the persisting background skill behind reading disabilities is rapid automatized naming (De Jong & van der Leij, 1999; 2003; Landerl & Wimmer, 2000; Wimmer & Mayringer, 2002; Wolf, Pfeil, Lotz & Biddle, 1994).

The aim of this study was to replicate Waber's et al. (2000) study and to see if the results persisted also in the language with highly regular writing system (Finnish), in which the connection between RAN and reading was expected to be stronger than in languages with deeper orthography. In other words, the aim of this study was to see if rapid naming had as effective role in discriminating different kinds of learning disabled groups from each other and from control group as it did in Waber's et al. study. A need for replication came also from the fact that researches conducted with clinical samples are often biased and can usually not be generalized without strong research evidence.

The research frame of this study was highly comparable to Waber's et al. study. Both studies consisted of children referred for evaluation of learning problems, and the age group was comparable. In both studies, children with neurological impairment were excluded. There were minor differences between the IQ of the referred children and the inclusion of children with attention problems, but the main difference between studies was expected to be the mother tongue of the children.

Because this specific linkage described earlier between RAN and reading deficits in languages with orthographically regular writing system, two main hypotheses were set. First, it was hypothesized that the connection of RAN with reading was stronger in this study than found in Waber's et al. study. Second, RAN's connection to reading speed was presumed to be stronger than RAN's connection to reading accuracy.

If the hypotheses set proved to be true, it would give more support for the idea that RAN should be considered differently in different languages, and that the results reached from the languages with deep orthography like English could not be straightforwardly generalized to other languages. However, if the results attained from Waber's et al. study were repeated, it would give an opportunity to consider RAN as a tool for detecting and diagnosing learning disabilities in general, not just within the framework of reading disabilities.

2. METHODS

2.1 Participants

The sample consisted of 193 children referred to a child neuropsychological clinic for evaluation of learning disabilities. Sample was the same used in Närhi's et al. (2005) study. Selection was made by the following criteria: Finnish as the mother tongue, age 8-11 years, either verbal or performance WISC-R IQ greater or equal to 80, no acquired central nervous system damage, and no physical illness that had resulted in excessive absence from school. All measures used in this study were presented to the children as part of the assessment. To cope with missing observations in the data, a real value imputation was developed and conducted for the sample, using information received from a donor in imputation. Donor was selected on the basis of subject's age, RD status and WISC-R subtest scores (for details on imputation method, see Närhi, Laaksonen, Hietala, Ahonen, & Lyytinen, 2001).

All children in the clinical group were affected by some form of learning or other school-related problems. The most common diagnoses were Reading Deficit (RD; 72% of the sample), Attention Deficit Hyperactivity Disorder (ADHD, 60% of the sample), and Mathematics Disability (MD, 45% of the sample). Only 5% of the learning impaired (LI) sample didn't have any of these diagnoses.

All the children of clinical sample were from middle-class families from Central Finland area. The mean age of the sample was 9.6 years (standard deviation 1.0) and 76.6 percent of the sample was boys. The information of cognitive ability and naming time scores of the clinical sample is presented in the Table 1. As one can see in the Table 1, there were significant differences between the cognitive ability of the present sample compared to Waber's et al. sample, the present sample being more impaired.

TABLE 1. Mean Cognitive Ability of Referred Children in the Present and Waber's et al. Study, and Rapid Automatized Naming in Learning Impaired and Control Groups.

	Present Study		Waber et al.		Difference betw. studies
	M	SD	M	SD	t-score(df) and p-value
WISC*					
Verbal IQ	89.0	9.8	103.9	13.7	-8.73(336); p<.001
Performance IQ	93.2	12.3	101.2	12.6	-4.43(378); p<.001
Full Scale IQ	90.0	8.6	102.7	11.8	-8.57(340); p<.001
RAN-score (LI sample)					
Letters	38.0	14.5	35.5	12.5	-1.81(374); p=.1
Numbers	41.1	23.3	37.9	12.5	-1.66(232); p=.1
Colors	59.2	15.4	53.5	15.6	-3.61(246); p<.001
Objects	62.4	15.7	56.9	14.7	-3.54(626); p<.001
RAN-score (normative sample)					
Letters	28.3	7.8	23.8	4.7	-7.32(150); p<.001
Numbers	30.1	8.0	24.0	5.6	-8.80(131); p<.001
Colors	44.7	10.3	37.3	8.6	-7.13(116); p<.001
Objects	49.6	10.4	39.3	7.1	-11.54(133); p<.001

N=193 for the present study, and N=188 for Waber's et al. study in LI groups, N=119 and N=115 for the control groups in the present and in Waber's et al. study respectively. LI = Learning impaired.

* Wisc-III used in Waber's et al. study, WISC-R used in the present study.

2.2 Measures

2.2.1 Rapid Automatized Naming (RAN)

Rapid automatized (or serial) naming was assessed using four stimulus cards each containing one type of stimulus. Stimulus types were colors, numbers, letters and objects, all representing concepts familiar to children. Each stimulus card consisted of five different stimuli; each replicated 10 times, and was arranged in 5 rows by 10 column tables. Stimuli were presented in random order, with an exception that no individual stimulus was followed by itself. Children were instructed to name the stimulus as quickly and correctly as possible, and the time taken to read each card was used as an outcome score. (For details on stimulus used, see Ahonen, Tuovinen, & Leppäsaari, 2003). The mean score of letter and number naming were used for the replication part of the study.

Normative data on rapid naming included 605 children, age between 8-11 years (Ahonen, Tuovinen, & Leppäsaari, 2003). It was collected from four different schools from two cities including children who had received special education services. For reaching the ratio between the size of the clinical group and control group comparable to Waber's et al. study, 119 children were selected as a random sample from the normative group. The distribution of age in a normative group used in this study (N=119) followed the age distribution of the clinical sample. The rest of the normative group that was not used in this study (N=486), served as a norm for the definition of naming speed deficit (NSD). Then the criterion for NSD was not dependent on any group used in the study. Following Waber et al., children whose mean score on the Letters and Numbers subtests was one standard deviation slower than the mean of normative group (the part of normative group not used in this study), were classified as having naming speed deficit (NSD).

2.2.2 Reading

Reading disability (RD) was diagnosed on the basis of two text reading tests (Niilo Mäki Institute, 2004) for which the criteria for RD was a score of 1.5 SDs below the expected age or grade mean. This diagnose came from the combined rate and accuracy measures of text reading. In addition to the presented diagnose, there were also separate rate and accuracy measures available. The criteria for RD according to rate or accuracy in text reading were respectively 1.5 SDs below the age or grade mean.

2.2.3 Attention

The presence of attention problems was evaluated using a Child Behavior Checklist filled by the child's parents (Achenbach, 1991a), or a Child Behavior Checklist – Teacher's Report Form filled by the child's primary teacher (Achenbach, 1991b). The criteria for Attention Deficit diagnose involved a T-score greater than 60 on the Attention scale in either parental or teacher evaluation.

2.2.4 Mathematics

Mathematics disability (MD) was diagnosed using two tests. A primary test used was RMAT (Räsänen, 2004), the cut-off 1,5 SDs below the normative group average serving as the criteria for MD, or , if RMAT was not yet available, Arithmetic subtest of Kaufman ABC (Kaufman, 1983) was used with local normative data (Niilo Mäki Institute, 2004). Similarly, the cut-off of 1,5 SDs below normative group mean was used as a criteria for MD.

2.3 Data Analysis

Statistical analysis was carried out with the SPSS version 11.5 (SPSS Inc., 1989-2002). Receiver operating characteristic (ROC) analysis was applied to determine how accurately RAN performance predicted group membership. The area under the curve (AUC) received from ROC analysis was provided to tell how accurately the test discriminates between groups. AUC it can vary between 0.5 and 1.0, the former meaning that the test is approximately as effective as a chance and the latter meaning perfect discrimination. According to Tape (2006), AUC statistic 0.5-0.6 means a failure to discriminate between groups, 0.6-0.7 marks for poor, 0.7-0.8 fair, 0.8-0.9 good, and 0.9-1.0 excellent discriminator.

In the ROC analysis, the mean z-score of number and letter naming was used as a dependent variable and a group membership as a dichotomous state variable. As in Waber's et al. study, group comparisons included LI children vs. controls, LI children with RD vs. controls, LI children without RD vs. controls and LI children with RD vs. LI children without RD.

Logistic regression analysis was used for estimating optimal cut-off scores for RAN differentiating the groups. Prevalence and distributions of different diagnoses were conducted with cross-tabulations.

2.4 Data Modifications

The distributions of all the rapid naming measures were skewed, and they were normalized using natural logarithmic transformations. The effect of age on the results of rapid naming was taken into account by using z-scores that were obtained by counting norms for each age group (8, 9, 10, and 11 years) separately.

3. RESULTS

3.1 Prevalence of Naming Speed Deficits and Reading Disability

The prevalence of RD in LI and NSD group is presented in Table 2 and the prevalence of NSD in different diagnostic groups in Table 3. The prevalence of RD defined by speed was significantly greater than the prevalence of RD defined by accuracy both in the LI group ($\chi^2(1)=19.03$, $p<.001$) and in the NSD group ($\chi^2(1)=8.58$, $p=.003$). Prevalence of RD in the NSD group was significantly greater than prevalence of RD in the whole LI group ($\chi^2(1)=20.8$, $p<.001$).

The prevalence of NSD was clearly greater in the RD groups than in the Non-RD groups ($\chi^2(1)=28.64$, $p=.000$ when defined by speed, and $\chi^2(1)=11.49$, $p=.001$ when defined by accuracy). However, the amount of children having NSD in non-RD group was relatively big compared to the control group, in which the prevalence of NSD was 16% ($\chi^2(1)=4.04$, $p=.045$ when defined by speed, and $\chi^2(1)=22.03$, $p=.000$ when defined by accuracy).

Compared to Waber's et al. study, the prevalence of NSD in the present study was significantly smaller in all diagnostic groups (see Table 3). The prevalence of RD, instead, was significantly greater in the present study than in Waber's et al. study in LI group and NSD group with both RD definitions (see Table 2). Despite that the prevalence of NSD was greater in the LI sample without RD than in the control group in this study, the trend that NSD was relatively common also in the LI sample without RD was stronger in Waber's et al. study than in the present study ($\chi^2(1)=9.50$, $p<.01$ and $\chi^2(1)=9.64$, $p<.01$, when RD is defined by speed and accuracy respectively).

TABLE 2. The Prevalence of RD in Learning Impaired and Naming Speed Deficit Groups in the Present and In Waber's et al Study, and Differences between Studies on Prevalence.

Group	% RD (speed) Present study	Waber et al.	Difference between studies	% RD (accuracy) Present study	Waber et al.	Difference between studies
LI (N=193 present/ 188Waber)	69.4 (N=134)	58.0 (N=109)	$\chi^2(1)=5.47$ ($p<.05$)	50.8 (N=98)	32.0 (N=60)	$\chi^2(1)=14.02$ ($p<.001$)
NSD (N=111 present/ 128 Waber)	84.7 (N=94)	67.9 (N=87)	$\chi^2(1)=10.20$ ($p<.01$)	61.3 (N=68)	40.6 (N=52)	$\chi^2(1)=11.28$ ($p<.001$)

RD = Reading disability; LI = Learning impaired children; NSD = Learning impaired children with naming speed deficits. Rd was diagnosed separately using either reading speed or reading accuracy as a criterion.

Table 3. The Prevalence of NSD in LI, RD, non-RD, and Control Groups in the Present and in Waber's et al. Study, and Differences Between Studies on Prevalence.

	Present study		Waber et al.		
Group	%	N	%	N	Difference between Studies
LI (N=193/188)	57.5	111	68	128	$\chi^2(1)=4.62$, $p<.05$
RD (speed) (N=134/109)	70.1	94	80	87	$\chi^2(1)=5.50$, $p<.05$
RD (accuracy) (N=98/61)	69.4	68	85	51	$\chi^2(1)=13.74$, $p<.001$
Non-RD (speed) (N=17/79)	28.8	17	51	41	$\chi^2(1)=9.50$, $p<.01$
Non-RD (accuracy) (N=95/127)	45.3	43	60	76	$\chi^2(1)=9.64$, $p<.01$

NSD = Naming speed deficits; LI = Learning impaired children; RD = Children with reading disabilities (defined by reading speed/accuracy); Non-RD = Learning impaired children without RD.

3.2 ROC Analyses

ROC analyses were conducted to determine how well RAN time discriminated between different groups. The area under the curve (AUC) was computed to determine the extent to which RAN time differentiated groups. The mean of RAN numbers and letters z-score of naming times was entered as a continuous variable and a dichotomous group variable as a state variable.

Table 4 displays the AUC statistics and 95% confidence intervals on every comparison obtained from ROC analysis. The analysis showed that in all comparisons, RAN time discriminated groups significantly better than chance; none of the 95% confidence intervals included 0.5. RAN was clearly at its best on discriminating RD groups from control, area under the curve covering 86-87% of the whole area. To measure the statistical significance of RAN's superiority in discriminating RD vs. Control groups compared to other comparisons, a critical value Z for different comparisons was calculated. Formula used was $Z=(A_1-A_2)/\sqrt{(Se_1^2+Se_2^2)}$, in which A_1 and A_2 marked for AUC statistics compared, and Se_1 and Se_2 for standard error for corresponding AUC statistics. A critical value Z followed the standardized normal distribution, and p-value was obtained from the table, in which the cumulative distribution functions were presented (Nissinen, 2000). The test showed that

RAN discriminated RD vs. Control groups significantly better than it discriminated other groups (comparisons 1, 4, 5, and 6 in Table 4), Z-value ranging from 1.90 to 4.97, and p-value from .029 to .000 respectively. The only exception was the difference between comparisons 2 and 7 (see table 4), which approached significance p=.055 (Z=1.60).

Despite the clear superiority of RAN discriminating RD groups from control, RAN discriminated reliably also between the whole LI group and control children (comparison 1 in Table 4), and between children with RD and LI children without RD (Non-RD LI) when RD was determined by reading speed (comparison 7 in Table 4). Based on AUC statistics and the classification of Tape (2006), RAN was poorer on discriminating between Non-RD LI and control children (comparisons 4 and 5 in Table 4), and between RD and Non-RD LI children when RD was defined by reading accuracy (comparison 6 in Table 4). The difference between these comparisons and the other comparisons were significant with only one exception (the difference between comparisons 4 and 7 in Table 4 approached significance p=.058, z-score being 1.57), z-score ranging from 1.80 (p<.036) to 5.30 (p<.001).

AUC statistics were systematically lower in the present study than in Waber’s et al. study. Both RD versus control comparisons and Non-RD LI versus control comparisons reached AUC statistic significantly lower than in Waber’s et al. study (See table 4).

3.3 Cut-off Scores

Logistic regression was used to estimate which cut-off score best discriminated the groups. This was done by making a dichotomous cut-off variable for each cut-off score used in analysis. Then a separate logistic regression was computed for each cut-off, group variable being dependent variable and cut-off variable being categorical predictor (or covariate) variable. From the analysis it was possible to say how many cases were correctly classified. From the same analysis, the rate of false positives and false negatives was obtained. Results of the analyses are reported in the Table 5.

As was done in Waber's et al. study, the best cut-off score was determined by selecting the cut-off that produced the greatest percent of correct classifications. For most of the comparisons, -0.5 SD showed to be the best cut-off with only small difference to -1.0 SD, while for accuracy based RD vs. control and accuracy based RD vs. LI children without RD, the best cut-off score seemed to be -1.0 SD from the mean. The percent of correct classifications was at its best .75 on RD (speed) vs. Non-RD comparison, with false positives .44 and false negatives .17. When considering the other comparisons, in the point where the percent of correct classifications was on its highest, the amount of false positives ranged from .16 to .45 and the amount of false negatives from .17 to .31.

TABLE 4. Area Under the Curve (AUC) and 95% Confidence Intervals (CI) for the Present and in Waber's et al. Study Group Comparisons, and the Difference Between Studies.

	AUC (95% CI)		Comparison between studies
Group Comparison	Present Study	Waber et al.	z-scores and p-values
1. LI vs. Control	.79 (.74 -.84)	.84 (.79 -.89)	1.36; p=.087
2. RD(accur) vs. Control	.86 (.81 -.91)	.95 (.91 -.99)	2.81; p=.003
3. RD(speed) vs. Control	.87 (.83 -.91)	.92 (.88 -.96)	1.68; p=.005
4. Non-RD(accur) vs. Control	.71 (.64 -.78)	.79 (.73 -.85)	1.68; p=.005
5. Non-RD(speed) vs. Control	.60 (.51 -.69)	.72 (.64 -.80)	1.95; p=.026
6. RD(accur) vs. Non-RD	.67 (.59 -.74)	.76 (.68 -.84)	1.59; p=.056
7. RD(speed) vs. Non-RD	.79 (.71 -.86)	.74 (.67 -.81)	-0.98; p=.164

Note: LI=Learning impaired children; RD = Reading disabilities; RD(accur)= Learning impaired children with reading disabilities, RD defined by reading accuracy; RD(speed) = Learning impaired children with reading disabilities, RD defined by reading speed; Non-RD = Learning disabled children without RD.

TABLE 5. The Percent of Correct Classifications (false positives/false negatives on the best cut-off points) on Different RAN Cut-Off Scores in the Present and in Waber's et al. Study

	-0.5 SD		-1.0 SD		-1.5 SD		-2.0 SD		-2.5 SD	
Group Comparison	Present	Waber	Present	Waber	Present	Waber	Present	Waber	Present	Waber
LI vs. Control	**.71** (.28/.29)	.75	.68 (.16/.43)	.78 (.13/.31)	.63	.74	.57	.70	.50	.66
RD (accur.) vs. Control	.53 (.28/.19)	.84	**.54** (.16/.31)	.88 (.13/.10)	.53	.87	.50	.82	.47	.79
RD (speed) vs. Control	**.63** (.28/.17)	.81	.62 (.16/.30)	.84 (.13/.19)	.60	.82	.55	.77	.49	.71
RD (accur) vs. Non-RD	.60 (.60/.19)	.63	**.62** (.45/.31)	.65 (.60/.10)	.61	.68	.58	.68 (.31/.33)	.60	.67
RD (speed) vs. Non-RD	**.75** (.44/.17)	.65	.70 (.29/.30)	.65 (.51/.19)	.64	.68	.56	.67 (.23/.43)	.47	.61

Note: LI=Learning impaired children; RD = Reading disabilities; RD(accur)= Learning impaired children with reading disabilities, RD defined by reading accuracy; RD(speed) = Learning impaired children with reading disabilities, RD defined by reading speed; Non-RD = Learning disabled children without RD.

3.4 Comorbidity of Diagnoses and the Prevalence of NSD in Different Clinical Groups

As was done in Waber's et al. study, a description of clinical profiles of LI children in the clinical data was provided. Distribution of RD, ADHD, MD, and all kinds of combinations of these are displayed in Table 6, with information on prevalence of NSD in each group. Groups defined after diagnoses were all mutually exclusive. Clinical data had some missing information on diagnoses of MD and ADHD. Because all the definitions of diagnoses required information of the classification in all three diagnoses, missing information presented a problem for classification, and even the information available could not be used. Contentual interpretation for missing values were that children referred for evaluation of learning problems didn't exhibit any signs of deficit in question, and therefore were not examined for them. Then a missing value would in high probability mean no problems at skills not examined. Based on this assumption, missing values were coded as zero, meaning that a child didn't have a diagnosis for deficit in question. After doing this, all information available could be taken into account. Prevalence of NSD in the different diagnosis groups didn't change markedly as a consequence of replacement of missing values (see Table 6), which was taken as a confirmation of preceding assumption.

The prevalence of NSD in the clinical groups was somewhat different in the present sample compared to Waber's et al. sample, as can be seen in Table 6. The prevalence of NSD in the present sample was over 30% in all groups but didn't increase with the amount of comorbid diagnoses, as was the case in Waber's et al. study. The prevalence of NSD showed to be 60-70% in those groups involving RD, even over 90% in RD+MD group, while in the groups without diagnosis of RD, the prevalence was approximately 30%. Because of the small frequencies of children in different groups, the difference between the present and Waber's et al. study was explored with the Fisher's exact test, which describes the probability to obtain the distribution in question by random. The results of the test are presented in Table 6. In all the differences found, the prevalence of NSD was greater in Waber's et al. study.

Another difference between Waber's et al. and the present study was the composition of the groups. The comorbidity of different diagnoses was fairly high in the present clinical sample: 61% of the sample had more than one diagnosis and only 5% of the sample did not have a diagnosis at all. In Waber's et al. LI sample, comorbidity of different diagnosis was far more uncommon: only 23% of the sample had more than one diagnosis and 38% of the sample didn't have any diagnosis. The difference between studies on the prevalence of comorbidity was significant ($\chi^2(1)=55.77$, $p<.001$).

TABLE 6. The Percent of Naming Speed Deficits (NSD) in Groups with Different Combinations of Reading, Mathematics, or Attention Deficits. Difference Between Studies on the Prevalence of NSD.

	Present Study		Waber's et al Study		Difference between studies
Deficits	% with NSD	N	% with NSD	N	Fisher's exact test
Reading, Math, Attention	67 (67)	39 (39)	100	3	p=.318
Reading, Attention	59 (52)	39 (23)	100	2	p=.366
Math, Attention	31 (31)	13 (13)	100	5	p=.015
Reading, Math	92 (91)	26 (22)	94	33	p=.377
Reading	60 (57)	35 (23)	82	23	p=.046
Math	25 (29)	8 (7)	82	39	p=.003
Attention	33 (27)	24 (15)	64	14	p=.051
None	33 (0)	9 (5)	43	69	p=.244

Note: Reading Deficit is defined by speed and accuracy of text reading. Missing values are coded as zero. Information before replacement of missing values is presented in parentheses.

4. DISCUSSION

The aim of this study was to replicate Waber's et al. (2000) study of rapid naming and to test RAN's efficacy on discriminating between different kinds of clinical and control groups also in a language that is orthographically more regular than English. Over and above the minor differences between studies, the present study seemed to differ from the Waber's et al. study in two major ways. First, RAN's connection to learning disabilities appeared to be more specified to RD in this study than in Waber's et al. study. Second, RAN seemed to differentiate better the RD groups from their comparison when RD was defined by speed rather than accuracy.

4.1 RAN's Specificity to Reading Disabilities

Beginning with the topic of specificity of naming speed deficits to reading disability, there were three aspects that support the conclusion that in Finnish language, the connection between RAN and learning disabilities was more specified to RD than in Waber's et al. study, in which the conclusion was that NSD was a good indicator of learning impairment in general, and was not necessarily specific to reading deficits.

First, the results of Waber's et al. study suggested that the likelihood of NSD increased with the number of diagnoses, but was not dependent on the type of diagnosis. Children with more than one diagnosis had a nearly 100% likelihood of having NSD, which was taken as a sign that prolonged naming speed was an indicator of learning problems as general, not depending on any specific diagnosis. In the present study, the prevalence of NSD didn't increase with the amount of diagnosed learning disabilities. Instead, the high prevalence of NSD was connected with the diagnosis of RD, comorbid diagnoses not increasing it markedly.

Second, ROC analyses revealed that RAN discriminated significantly better RD groups from control group than any other groups. According to Tate's (2006) classification for AUC statistics, RAN was a good discriminator only for RD vs. Control comparisons, showing fair or poor discriminating power in all the other comparisons. RAN was not especially good in discriminating between non-RD LI children from control children, RAN's discriminating power being at best .71, which means barely fair in Tate's classification. These results differed significantly from Waber's et al. study, in which RAN discriminated better between non-RD and Control groups. In addition, RAN differentiated reliably RD group from Non-RD LI group when RD was defined by reading speed. Third, although the prevalence of NSD was greater in the Non-RD LI group than in the control group, the trend was significantly stronger in Waber's et al. study than in the present study.

The results are in line with the hypothesis set and with the findings of previous studies. According to former research evidence, RAN is one of the strongest and most persistent variables connected to reading disabilities in languages with highly regular orthographies (De Jong & van der Leij, 1999; 2003; Korhonen, 1995; Landerl & Wimmer, 2000; Wimmer, 1993; Wimmer & Mayringer, 2002; Wolf, Pfeil, Lotz & Biddle, 1994). According to Wolf and Bowers (1999), there are two reasons for RAN's strong connections to reading. First, RAN requires the same kinds of lower level perceptual and linguistic processes that are necessary for reading, and second, the processing speed requirements of RAN and reading are very comparable. In short, Wolf and Bowers claim that processes involved in reading and RAN are highly comparable. Bringing this to a level of language differences, it might be argued that the similarity of RAN and reading processes may be even greater in the languages with highly regular orthography. According to Aro (2004), in transparent orthographies like Finnish, rather simple processes of phonemic assembly and the knowledge of grapheme-phoneme correspondences are sufficient tools for reading, while in English, in which the correct recoding of words is hampered by complex grapheme-phoneme correspondences, more complex processes (including separate logographic processing skills and word-specific knowledge) are needed. Even though the processes needed in RAN are not fully known, it is obvious that these additional processing skills needed when reading English are not required in rapid naming, and then the processes of RAN and reading are more comparable in languages with transparent orthographies than in English. Then it might be reasoned that while the background skills behind reading English or other deep orthographies are more abundant than needed when reading more transparent orthographies like Finnish, the proportional weight of RAN is greater in languages with transparent orthographies.

However, the reason why RAN didn't have as strong connection also to other learning disabilities as it did to reading needs further research. All told, the number of the research on rapid naming connected to learning disabilities in general is until now been very low, and more studies on the background skills of rapid naming are needed before far-going conclusion can be drawn.

The second discrepancy found between the studies that deserves attention relates to RAN's ability to discriminate groups when using different kinds of definitions for RD. In the present study, there seemed to be a trend that RAN was more effective on discriminating groups when RD criterion was based on speed rather than accuracy. RAN was significantly better on discriminating between RD and non-RD LI groups when RD was defined by speed rather than when defined by accuracy. In Waber's et al. study RAN seemed to be better on discriminating groups when RD was defined by accuracy than when defined by speed. However, the differences between RD by accuracy and RD by speed didn't seem to be as clear as they were in the present study.

The results of the present study are in line with the results of Wimmer and his colleaques. According to their results, in the languages with highly regular orthographies, RAN was strongly connected to the reading speed, while reading accuracy had a very minor part in reading deficits and was not in the focus on the research on RAN and RD (Landerl & Wimmer, 2000; Wimmer, 1996; Wimmer & Mayringer, 2002; Wimmer, Mayringer, & Landerl, 1998; 2000; Yap & Van der Leij, 1993). In English, instead, the accuracy of reading seems to be a more integral part of reading and reading disabilities, and difficulties in accuracy of reading persist longer than in languages with more regular orthographies (e.g. Aro & Wimmer, 2003).

4.2 Methodological and Statistical Considerations

The differences between the present and the study of Waber et al. described above were not likely to be due to socioeconomic status, age or selection criteria of the subjects because they were highly comparable between studies. However, there were some differences between the studies that were mostly due to the statistical and sample differences. They are discussed briefly.

First, the prevalence of NSD was significantly greater in Waber's et al. study than in the present study. However, as was shown in Table 1, there were no differences in naming times of alphanumeric stimuli between LI samples. One explanation for the clear difference between studies on the prevalence of NSD may be due to the differences between control groups used. As shown in Table 1, the children in the Waber's control group were significantly faster namers in all subtasks than the children in the control group used in the present study. Then the difference between naming time in the control group and the LI group is greater in Waber's et al. study and more children are classified as having NSD.

What made American control children faster namers than Finnish children is not easy to say. One possible reason is the length of the stimulus words. In Finnish version of rapid naming tasks, object naming consists of two syllable-words and number and color naming of two or three syllable-words. Letters are monosyllabic in both Finnish and English. Then the length of the words in Finnish might explain some of the differences between naming times but not all. Furthermore, if the difference between control groups was explained by the length of the words, one should expect the same difference also in the LI group. However, there were no differences between the naming times on letters and numbers between the LI samples.

Second difference between studies can partly be explained by the same reasons described above. In the present study, the AUC statistics were lower than in Waber's et al. study and there were statistically significant difference between the studies on RD vs. control and Non-RD LI vs. control comparisons. However, because the naming times in the normative group used in Waber's et al. study were significantly faster than in the present study, the difference between control group and referred group was naturally greater in Waber's et al. study, and the effect was greater compared to the present study. If this effect was taken account, the difference between the studies on AUC statistics might not be as significant as it now was.

The third difference between studies concerns the composition of clinical groups with different kind of combinations of learning disabilities. The comorbidity of different diagnoses was far more common in the present study than in Waber's et al. study. The reason for this is probably due to the difference in the selection of the clinical sample. In Waber's et al. study, children with Attention Deficit Hyperactivity Disorder-Hyperactive or Combined type had been excluded, and included only inattentive type of Attention Deficit. In the present sample, all kinds of Attention Deficits were included, increasing the prevalence of that kind of diagnoses and increasing comorbidity. The prevalence of children having no diagnoses was also significantly greater in Waber's et al. sample, having relatively great prevalence of NSD (43% of those LI children having no diagnoses), while in the present sample amount of the LI children having no diagnoses was very small. One third of these children had NSD, but because of small size of the group, far-going conclusions could not be considered. Another reason for greater comorbidity in the present sample might be for some part due to the IQ. As seen in Table 1, cognitive ability of the present sample was lower in all measures than the IQ of Waber's et al. sample, which may contribute to the larger amount of learning disabilities.

What influence might the lower IQ have on results? As noticed, the present sample was more impaired than Waber's et al. study. There was a minor difference between the studies on the selection criteria on the LI samples. In Waber's et al. study, the Full Scale IQ of the selected children was 80. In the present study, either Verbal or Performance IQ was greater than 80, which meant that some of the children had Full Scale IQ below 80. As noticed, the lower IQ might have effects on the comorbidity of learning disabilities. For example, the lower IQ could partly explain the greater prevalence of RDs in the present sample compared to Waber's et al. sample. However, IQ is not found to be connected to NSDs (Bowers et al, 1988; Denckla & Rudel, 1976), which could, over and above the explanations described earlier, explain the finding that despite the greater prevalence of RDs in the present study compared to Waber's et al. study, the prevalence of NSDs was relatively low albeit he strong connection between RAN and reading in this study. Besides the prevalence of learning disabilities, the lower IQ might have effects on the level of LIs, which should be taken account if this group was explored more deeply. Note that when children with Full Scale IQ below 80 were excluded from the present sample, the results didn't change: the difference between studies on IQs and naming times remained almost the same.

Finally, in the search of the best cut-off score for RAN there is some aspects to consider. Using percent of correct classifications as a criterion, the best cut-off score were selected for the naming time. However, selecting the best cut-off score according to a percent of correct classifications might not be the best way of doing the selection. Based on only sensitivity (percent of true positives) and specificity (percent of true negatives), the method does not take the prevalence into account. Then it is possible that the size of the groups in comparison may have effect on the result. For example, a big control group with typically small amount of false positives in small cut-off scores, may effect to the direction of optimal cut-off scores showing to be smaller (e.g. further from the mean), while smaller control group would effect in the opposite direction supporting a selection of a bigger cut-off score (e.g. closer to the mean). In addition, the percent of correct classifications was at best only .75 in this study (see Table 5), which means that the possibility of false classification was at least .25. Because of the great amount of false diagnoses, it can be questioned if the search of the best cut-off score has any practical clinical meaning.

One could also question if RAN really is a proper tool for diagnosing reading disabilities or any other learning disabilities. According to this study, RAN was at its best when discriminating between RD and control groups. However, for defining reading disability, there are abundantly instruments far better than RAN measures to reach the diagnosis (Hammill, 2004). What comes to RAN as a tool for diagnosing learning disabilities in general, the result is even more coincidental. Then, the more proper practical use for RAN measures would be to specify RD diagnosis and to search for the underlying causes of RD, not necessarily diagnosing RD or other learning disabilities.

4.3 Conclusion

To conclude, the results of the present study indicated that in clinical sample in orthographically transparent language like Finnish, RAN seemed to be more connected to RD than to other learning disabilities. The result diverged from the results of Waber et al. (2000), whose conclusion was that RAN was an excellent tool for detecting learning disabilities in general but not specifically for reading disabilities. Explanations for the difference found between studies were searched from the characteristics of languages that differ on the transparency of the orthography. The results indicate that RAN may differ on its connections to learning disabilities in different languages and then the results attained from a language with deep orthography may not be generalized to languages with more transparent orthographies. However, further research is needed on the issue, especially on the background skills of RAN in different languages and in general. As Waber et al. mentioned in Waber's et al. study, diverse diagnostic groups may demonstrate naming speed deficits for various reasons, and there is a need to study if the underlying cause for slow naming is linguistic skills, non-linguistic processing skills, or something else. In addition, the need for more studies on this area is obvious to confirm the results because clinical samples vary a lot and may be biased in several ways.

REFERENCES

Achenbach, T. M. (1991a). *Manual for the child behavior checlist/4–18 and 1991 profile.* Burlington, VT: Department of Psychiatry, University of Vermont.

Achenbach, T. M. (1991b). *Manual for the teacher's report form and 1991 profile.* Burlington, VT: Department of Psychiatry, University of Vermont.

Ahonen, T., Tuovinen, S., & Leppäsaari, T. (2003) *Nopean sarjallisen nimeämisen testi.* Jyväskylä: Niilo Mäki Institute.

Aro, M. (2004). *Learning to read. The effect of orthography.* University of Jyväskylä. Jyväskylä studies in Education, Psychology and Social Research 237.

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

Badian, N. A. (1993). Phonemic awareness, naming, visual symbol processing, and reading. Reading and Writing: An Interdisciplinary Journal, 5, 87-100.

Bowers, P.G. (1993). Text reading and rereading: Predictors of fluency beyond word recognition. Journal of reading behavior, 25, 133-153.

Bowers, P.G. (1995). Tracing symbol naming speed's unique contributions to reading disabilities over time. *Reading and Writing: An Interdisciplinary Journal, 7*, 189-216.

Bowers, P. G., Steffy, R., & Tate, E. (1988). Comparison of the effects of IQ control methods on memory and naming speed predictors of reading disability. *Reading Research Quarterly, 23*, 304-309.

Bowers P. G., & Swanson, L. B. (1991). Naming speed deficits in reading disability: Multiple measures of singular processes. Journal of Experimental Child Psychology, 51, 195-219.

Bowers, P. G. & Wolf, M. (1993). Theoretical links between naming speed, precise timing mechanisms and orthographic skills in dyslexia. *Reading and Writing: An Interdisciplinary Journal, 5*, 69-85.

Breznitz, Z. (2005). Brain Activity During Performance of Naming Tasks: Comparison

Between Dyslexic and Regular Readers. *Scientific Studies of Reading, 9*(1), 17-42.

Byrne, B., Wadsworth, S., Corley, R., Samuelsson, S., Quain, P., DeFries, J. C., Willcutt, E., & Olson, R. K. (2005). Longitudinal twin study of early literacy development: Preschool and kindergarten phases. *Scientific Studies of Reading, 9*(3), 219-235.

Davis C. J., Gayan J., Knopik V. S., Smith S. D., Cardon L. R., Pennington B. F., Olson R. K., & DeFries J. C. (2001a). Etiology of Reading Difficulties and Rapid Naming: The Colorado Twin Study of Reading Disability. *Behavior Genetics, 31* (6), 625-635.

De Jong, P. F., & Van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology, 91* (3), 450–476.

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* (1), 22-40.

De Jong, P. F. & Vrielink, L. O. (2004). Rapid automatic naming: Easy to measure, hard to improve (quickly). *Annals of Dyslexia, 54* (1), 65-88.

Denckla, M. B., & Cutting, L. E. (1999). History and significance of rapid automatized naming. *Annals of Dyslexia, 49*, 29–42.

Denckla, M.B. & Rudel, R.G. (1976). Rapid automatised naming (R.A.N.): Dyslexia differentiated from other learning disabilities. *Neuropsychologia, 14*, 471–479.

Eckert, M. A., Leonard, C. M., Richards, T. L., Aylward, E. H., Thomson, J., & Berninger, V. W. (2003). Anatomical correlates of dyslexia: frontal and cerebellar findings. *Brain), 126*, 482-494.

Hammill, D. D. (2004). What we know about correlates of reading. *Exceptional Children, 70* (4), 453-468.

Heikkilä, R. (2005). Nopea sarjallinen nimeäminen ja sen yhteydet kielellisiin ja ei-kielellisiin taitoihin – kirjallisuuskatsaus. *NMI Bulletin, 15*(2), 15-35.

Kaufman, A. S. (1983). *Kaufman Assessment Battery for Children*. Circle Pines, MN: American Guidance Service.

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

Landerl, K., & Wimmer, H. (2000). Deficits in phoneme segmentation are not the core problem of dyslexia: Evidence from German and English children. *Applied Psycholinguistics, 21* (2), 243-262.

Misra, M., Katzir, T., Wolf, M., & Poldrack, R. A. (2004). Neural Systems for Rapid Automatized Naming in Skilled Readers: Unravelling the RAN-Reading Relationship. *Scientific Studies of Reading, 8* (3), 241-256.

Neuhaus, G., Foorman, B., Francis, D. & Carlson, C. (2001). Measures of information processing in rapid automatised naming (RAN) and their relationship to reading. *Journal of Experimental Child Psychology, 78*, 359–373.

Niilo Mäki Institute (2004). *Neurospychological and achievement tests: Local normative data for Niilo Mäki Institute–test battery.* Jyväskylä, Finland: Author.

Nissinen, K. (2000). *Tilastomenetelmien peruskurssi.* Jyväskylän yliopisto, tilastotieteen laitos.

Nopola-Hemmi, J., Myllyluoma, B., Voutilainen, A., Leinonen, S., Kere, J., & Ahonen, T. (2002). Familial dyslexia: Neurocognitive and genetic correlation in a large Finnish family. *Developmental Medicine & Child Neurology, 44* (9), 580-586.

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

Närhi, V., Laaksonen, S., Hietala, R., Ahonen, T., & Lyytinen, H. (2001). Computerizing the clinician. Treating missing data in a clinical neuropsychological dataset – data imputation. *The Clinical Neuropsychologist, 15*(3), 380-392.

Räsänen, P. (2004). *RMAT – Laskutaidon testi 9-12 -vuotiaille.* Jyväskylä: Niilo Mäki Institute.

Samuelsson, S., Byrne, B., Quain, P., Wadsworth, S., Corley, R., DeFries, J. C., Willcutt, E., & Olson, R. K. (2005). Environmental and genetic influences on pre.reading skills in Australia, Scandinavia, and the United States. *Journal of Educational psychology, 97*(4), 705-722.

Snyder, L. S., and Downey, D. M. (1995). Serial rapid naming skills in children with reading disabilities. *Annals of Dyslexia. 45*, 31– 49.

Spring, C., & Davis, J. (1988). Relations of digit naming speed with three components of reading. *Applied Psycholinguistics, 9*, 315-334.

Sprugevica, I. & Høien, T. (2004). Relations between enabling skills and reading comprehension: A follow-up study of Latvian students from first to second grade. *Scandinavian Journal of Psychology, 45*, 115–122.

Tape, T. G. (2006). *Interpreting diagnostic tests.* Retrieved May 8, 2006 from http://gim.unmc.edu/dxtests/roc3.htm.

Van den Bos, K. P. (1998). IQ, phonological awareness and continuous-naming speed related to Dutch poor decoding children's performance on two word identification tests. *Dyslexia, 4* (2), 73-89.

Waber, D. P., Wolff, P. H., Forbes, P. W., & Weiler, M. D. (2000). Rapid automatized naming in children referred for evaluation of heterogeneous learning problems: How specific are naming speed deficits to reading disability? *Child Neuropsychology, 6* (4), 251-261.

Wimmer, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics, 14* (1), 1-33.

Wimmer, H. (1996). The nonword reading deficit in developmental dyslexia: Evidence from children learning to read German. *Journal of Experimental Child Psychology, 61*, 80-90.

Wimmer, H. & Mayringer, H. (2002). Dysfluent Reading in the Absence of Spelling Difficulties: A Specific Disability in Regular Orthographies. *Journal of Educational Psychology Copyright, 94*(2), 272–277.

Wimmer, H., Mayringer, H., & Landerl, K. (1998). Poor reading: A deficit in skill-automatization or a phonological deficit? *Scientific Studies of Reading, 2*, 321–340.

Wimmer, H., Mayringer, H., & Landerl, K. (2000). The double-deficit hypothesis and difficulties in learning to read a regular ortography. *Journal of Educational Psychology, 92* (4), 668-680.

Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology, 91*, 415–438.

Wolf, M., Bowers, P. G., & Biddle, K. (2000). Naming-speed processes, timing, and reading: A conceptual review. *Journal of Learning Disabilities, 33* (4), 387-407.

Wolf, M., Pfeil, C., Lotz, R., & Biddle, K. (1994). Towards a more universal understanding of the developmental dyslexias: The contribution of orthographic factors. In

Berninger, Virginia Wise (Ed). The varieties of orthographic knowledge, 1: Theoretical and developmental issues. Neuropsychology and cognition, Vol. 8 (pp. 137-171). New York, NY, US: Kluwer Academic/Plenum Publishers. xvi, 380 pp.

Yap, R., & Van der Leij, A. (1993). Word processing in dyslexics. An automatic decoding deficit? *Reading and Writing: An Interdisciplinary Journal, 5*, 261-279.

Young, A., & Bowers, P. G. (1995). Individual difference and text difficulty determinants of reading fluency and expressiveness. *Journal of Experimental Child Psychology, 60*, 428-454.