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Running Head: RAN'S SPECIFICITY TO RD

Rapid Automatized Naming and Learning Disabilities: Does RAN Have a Specific Connection to Reading or Not?

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Abstract

This work is an extension of a study by Waber, Wolff, Forbes, and Weiler (2000) in which the specificity of naming speed deficits to reading disability (RD) was examined. 193 children (ages 8 to 11) evaluated for learning disabilities were studied. It was determined how well rapid automatized naming (RAN) discriminated between different diagnostic groups (learning impaired (LI) with and without RD) from controls and from each other. Whereas Waber et al. concluded that RAN was an excellent tool for detecting risk for learning disabilities in general, the results of the present study point to a more specific connection between RAN and RD.

Keywords: rapid naming, learning disabilities, reading disabilities, comorbidity

Rapid Automatized Naming and Learning Disabilities: Does RAN Have a Specific Connection to Reading or Not?

Growing research evidence supports the view that one of the background skills affecting reading is *rapid automatized naming* (RAN), the ability to recall names of serially presented familiar objects or symbols. *Naming speed deficits* (NSD) is the term used to describe slow and laborious recall of familiar objects, especially when presented as serial stimuli (for review of rapid naming, see Bowers & Newby-Clark, 2002; Wolf, Bowers, & Biddle, 2000; Vukovic & Siegel, 2006).

Most of the research within rapid naming has taken place within the framework of dyslexia and reading research. Indeed, in various studies rapid naming has been connected to reading accuracy (e.g. Spring & Davis, 1988), reading speed (e.g. Berninger, Abbott, Thomson, & Raskind, 2001; Wimmer, 1993; Young & Bowers, 1995) and reading comprehension, either directly (Badian, 1993; Sprugevica & Høien, 2004) or via laborious word decoding (Spring & Davis, 1988).

In the context of reading and language, the connections of rapid naming to phonological skills (e.g. Wolf et al., 2000) and to orthographic knowledge (e.g. Bowers, Golden, Kennedy & Young, 1994; Manis et al. 2000) have been studied, as has RAN's connection to broader skill areas like general processing speed (Kail, Hall & Caskey, 1999). The results of these studies vary widely, and many of the conclusions are contradictory. Despite speculation on its connections to several cognitive abilities, it seems, however, that naming speed is not connected to general intelligence (Bowers, Steffy, & Tate, 1988; Denckla & Rudel, 1976; Meyer, Wood, Hart, & Felton, 1998). Alongside the many hypotheses concerning the link between individual skills and RAN are studies that support an eclectic view according to which RAN is best seen as a multicomponential skill that has connections with many background skills (Denckla & Cutting, 1999; Närhi et al., 2005; Wolf et al., 2000).

Because RAN can be measured before reading instruction begins, the strong findings on its reading-related predictive power has made RAN one of the most useful tools for predicting children at risk for reading difficulties (De Jong & Van der Leij, 2003; Puolakanaho et al., 2007). RAN has also been found to predict reading disabilities at school age (e.g. Manis, Doi & Bhadha, 2000; Korhonen, 1995; Scarborough, 1998) and to differentiate children with reading disability (RD) from controls without RD (Denckla & Rudel, 1976; O'Malley, Francis, Foorman, Fletcher, & Swank, 2002; Wolf, 1986). Differences between RD and control groups seem to occur also in adulthood (Vukovic, Wilson, & Nash, 2004).

Despite suggestions that naming speed could serve as a diagnostic measure of reading at school age (Carver, 1991; Davis & Spring, 1990), print-based diagnostic tests have been developed that are more effective than RAN in discriminating RD children from Non-RD children (Hammill, 2004), and RAN has not always fulfilled the criteria for an acceptable measure for clinical use (Hammill, Mather, Allen, & Roberts, 2002). Therefore one of the suggestions for the primary clinical use of RAN test is to use it as a predictor of reading performance before reading instruction begins (Reiter, 2001; Wolf et al. 2000) and during school age as one of the tools for exploring the background of reading disabilities more thoroughly (Hammill, 2004).

When exploring RAN in the context of learning disabilities, children with learning disabilities without RD have been faster namers than children with RD (Denckla & Rudel, 1976; Denckla, Rudel, & Broman, 1981; Ho, Chan, Leung, Lee, & Tsang, 2005). Comparisons between different kinds of learning disabilities have been rare and most of the studies of rapid naming have focused on either reading, language impairments or specific learning problem such as attention deficit/ hyperactivity disorder or arithmetic disabilities. One of the few studies that has pointed to a connection between RAN and learning disabilities in general is the original study by Denckla and Rudel (1976) in which a specific connection between RAN and dyslexia was found. They also noticed that learning-impaired children without dyslexia were slower namers than control children.

In the studies on RAN that focus on learning disabilities other than RD support has been found for the view that rapid naming is connected to arithmetic disabilities (Van der Sluis, de Jong & van der Leij, 2004), number fact disorders (Temple & Sherwood, 2002) and calculation fluency (Koponen, Mononen, Räsänen, & Ahonen, 2006; Koponen, Aunola, Ahonen, & Nurmi, 2007), while in other studies the connection between rapid naming and arithmetic skills has not been unambiguously supported (de Jong & Van der Leij, 1999).

The connection between rapid naming and attention has been studied as well, also with mixed results. In comparisons between children with attention problems and children with reading disabilities, most studies have found children with RD to be slower namers than children with attention problems (Felton, Wood, Brown, Campbell, & Harter, 1987; Närhi & Ahonen, 1995), and poor performance in rapid naming has been found to be associated with RD and not ADHD (Felton & Wood, 1989; Raberger & Wimmer, 2003). However, results may be affected by the type of attention problem. When comparing children with ADHD-inattentive type with children with ADHD-hyperactive type, the former group has been significantly slower in rapid naming than the latter (Hynd et al. 1991; Thomson et al., 2005).

With the aim of addressing the issue of rapid naming and learning disabilities in general, Waber, Wolff, Forbes, and Weiler (2000) studied the specificity of naming speed deficits (NSD) in relation to reading disability (RD) in 188 children (ages 7 to 11 years) referred for evaluation of learning disabilities (RD, ADHD-inattentive type, and mathematics disability). In their study, RAN differentiated children with RD from the control children very effectively. However, RAN was not as effective in differentiating children with RD from *learning-impaired* (LI) *children without RD* (Non-RD). In addition, RAN also differentiated learning impaired Non-RD children from controls, although not as effectively as children with RD from controls (the discriminating power was of about the same size as in the RD versus Non-RD comparison). It also seemed that in their sample of LI children, the prevalence of NSD increased with the comorbidity of different learning disabilities, but was not dependent on the type of diagnosis. The authors concluded that RAN was an excellent tool for detecting learning impairment in general, but was less effective in distinguishing RD children from other LI children. Waber et al. also studied the optimal cut-off score for RAN performance, i.e. that which would produce the greatest percentage of correct classifications. Determined in this way, -1.0 SD from the mean of the control population seemed to be the best cut-off score.

The aim of this study was to extend the study by Waber et al. (2000) to see if their results on RAN's ability to detect learning impairments in general were confirmed among subjects from a different cultural and language background. The need for further study also arises from the fact that studies conducted with clinical samples often produce biased results and usually can not be generalized without robust research evidence.

Methods

Participants

The sample consisted of 193 children referred to a child neuropsychological clinic for evaluation of learning disabilities. The sample was the same as that used in the study by Närhi et al. (2005). Selection was made according to the following criteria: Finnish as the mother tongue, age 8-11 years, either verbal or performance WISC-R IQ of 80 or above, no acquired central nervous system damage, and no physical illness that had resulted in excessive absence from school. All the measures used in this study were administered to the children as part of the assessment. To cope with missing observations in the data (5,2%), a real value imputation method was developed (for details on the method, see Närhi, Laaksonen, Hietala, Ahonen, & Lyytinen, 2001).

All the children in the clinical group were affected by some form of learning or other school-related problems. The most common learning disabilities were *Reading Disability* (RD), *Attention Deficits* (AD), and *Mathematics Disability* (MD). All the children in the clinical sample were from middle-class families resident in the Central Finland area. The mean age of the LI sample was 9.6 years (standard deviation 1.0) and 76.6 percent of the sample were boys. Information on the cognitive ability and naming time scores of the clinical sample is presented in Table 1. As can be seen, there were differences in cognitive ability between the present sample and that of Waber et al., the present sample having significantly lower IQ. One should also note that while the naming times were very comparable between the studies in LI groups, the control group of Waber et al. was significantly faster than the control group of this study. This may have effects on the prevalence of the NSD and also on the ROC analyses, as discussed later.

Table 1 about here

Design

Reading disability (RD) was diagnosed separately for speed and accuracy on the basis of one of two text reading tests (as the test used at the clinic was changed during the data collection), one normed by grade and the other by age (Niilo Mäki Institute, 2004). The reading speed criterion for RD was 1.5 SD below the mean text reading rate for age or grade, and the accuracy criterion for RD was 1.5 SD below the mean percentage of correctly read words for age or grade. The RD diagnosis was based on text reading only; the discrepancy-based criterion used in Waber's et al. study was not used in this study. For the analyses, the LI children not having RD were also grouped. Children not having RD by speed were assigned to a Non-RD-speed group and children not having RD by accuracy were assigned to a Non-RD-accuracy group. Because of the overlap between the RD groups, the Non-RD-speed group contained children with RD-accuracy and the Non-RD-accuracy group included some children with RD-speed.

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

Mathematics disability (MD) was diagnosed using two tests. The primary test used was the RMAT (Räsänen, 2004) or if the RMAT was not yet available, the Arithmetic subtest of the Kaufman ABC (Kaufman, 1983) was used with local normative data (Niilo Mäki Institute, 2004). For both measures, a cut-off of 1.5 SD below the normative group mean was used as the criterion for MD. Of the measures, the RMAT is time-limited accuracy measure and the Kaufman-ABC purely a measure of accuracy.

Measures

Rapid Automatized Naming (RAN). Rapid automatized naming was assessed using two stimulus cards, one containing letters and the other containing numbers. Each of the stimulus cards consisted of five different items, each replicated 10 times. The items were arranged in a fixed pseudo-random order, so that no individual item was repeated successively. The children were instructed to name the stimulus as quickly and correctly as possible, and the time taken to read each card was used as the outcome score. Errors made were not considered in the analyses. To compare the results with Waber et al., the mean of the letter and number naming scores was used in the analyses and in the NSD definition. A mean score one SD slower than the normative mean served as the criterion for NSD.

The normative data on rapid naming were obtained from 605 children, aged 8-11 years (Ahonen, Tuovinen, & Leppäsaari, 2003). The data were collected from four different schools in two cities, and included children who had received special education services. To obtain a ratio between the size of the clinical group and control group similar to that in Waber et al., a random sample of 119 children was selected from the normative group for analysis. The age distribution in the normative group used in this study (N=119) followed that of the clinical sample. The remainder of the normative group not used in this study, (N=486) was used for the purpose of defining naming speed deficit (NSD).

Statistical Methods

Statistical analysis was carried out with SPSS version 11.5. *Receiver operating characteristic* (ROC) analysis was applied and the *area under the curve* (AUC) obtained from the ROC analysis was taken as a measure of how accurately RAN performance predicted group membership. The AUC value ranges between 0.5 and 1.0, the former indicating a non-informative result and the latter a perfect discriminator. According to an arbitrary guideline an AUC value of 0.5-0.7 indicates *a poor* or *less-accurate*, 0.7-0.9 a *fair* or *moderately accurate*, and 0.9-1.0 an *excellent or higly accurate* discriminator (Swets, 1988; Tape, n.d.).

In the ROC analysis, the mean z-score for number and letter naming was used as a dependent variable and group membership as a dichotomous state variable. The group comparisons consisted of 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 to estimate optimal cut-off scores for RAN that would discriminate between the groups. The prevalences and distributions of the different diagnoses were conducted with cross-tabulations.

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

Results

Prevalence of Reading Disability and Naming Speed Deficit

The prevalence of RD in the LI and NSD groups is presented in Table 2 and the prevalence of NSD in the different diagnostic groups in Table 3. The prevalence of RD defined by speed (RD-speed) was significantly greater than the prevalence of RD defined by accuracy (RD-accuracy) both in the LI group ($\chi^2(1) = 19.03$, $p < .001$) and in the NSD group ($\chi^2(1) = 8.58$, $p = .003$). Of the LI children, 78% had RD of some kind. Of the RD sample 35% had RD-speed only, 11% had RD-accuracy only, and 55% had both RD diagnoses.

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

In comparison with Waber et al., the prevalence of NSD in the present study was significantly smaller in all groups (see Table 3). This may in great part be due to the difference between naming times in control groups used. As shown in Table 1, there were no differences in the naming times of the alphanumeric stimuli between the LI samples. Instead, the children in Waber's control group were significantly faster namers in both subtasks than the controls used in the present study. The faster naming times in Waber's controls thus increased the distance between the LI and the control group and increased the prevalence of NSD.

The prevalence of RD in the LI and NSD groups on both RD definitions was significantly greater in the present study than in Waber et al. (see Table 2). Despite the greater prevalence of NSD in the Non-RD groups than control group in the present study, the tendency for NSD to be more common in the LI sample without RD was stronger in Waber et al. than in the present study ($\chi^2(1)=9.50$, $p<.01$ and $\chi^2(1)=9.64$, $p<.01$, Non-RD-speed and Non-RD-accuracy, respectively).

Tables 2 and 3 about here

ROC Analyses

For the ROC analysis the mean *z*-score of the naming times in the RAN numbers and letters tests was entered as a continuous variable and a dichotomous group variable was used as a state variable. Table 4 displays the AUC statistics and 95% confidence intervals for every comparison obtained from the ROC analysis. The analysis showed that in all the comparisons, RAN time discriminated between the groups significantly better than chance.

To compare RAN's ability to discriminate different groups from each other in this study and in Waber et al., a critical value *Z* for the comparisons between AUC statistics was calculated. The formula used was $Z=(A_1–A_2)/(Se_1^2+Se_2^2)^{½}$, in which A_1 and A_2 mark the AUC statistics to be compared, and Se_1 and Se_2 the standard error for the corresponding AUC values (Hopley & van Schalkwyk, 2001). The critical value, *Z*, followed the standardized normal distribution, and a p-value was obtained from the table in which the cumulative distribution functions were presented (StatSoft, Inc.).

The test described above was also used for comparing the AUC statistics within this study. The test showed that the AUCs were significantly greater in the RD–Control comparisons than other comparisons, except one (see table 4), *Z*-values ranging from 1.90 to 4.97, and *p*-values from .029 to .000, respectively. The AUC for the RD-control comparison can be classified as *good* (Tape, n.d.). RAN also discriminated reliably between the whole LI group and control children, and between children with RD-speed and Non-RD-speed (AUC between 0.7-0.8 indicating *fair* or *moderately accurate* discrimination according to Swets, 1988 and Tape, n.d.). The AUCs for the Non-RD versus control comparison were classified as *fair* and *poor* and thus could not be considered very reliable (Tape, n.d.). The comparison between RD-accuracy and Non-RD-accuracy also showed *poor* discrimination.

The AUC values were systematically lower in the present study than in Waber et al. Both the RD vs. control comparisons and Non-RD vs. control comparisons obtained a significantly lower AUC value than Waber et al. (see table 4), while no difference between the studies in the LI–control and RD–Non-RD comparisons were found. The controls in Waber et al. were relatively fast namers as compared to controls in this study. This might explain the relatively large AUC values in LI-control comparisons of Waber et al, and the difference between studies in these comparisons.

Waber et al. found that 1) RAN discriminated LI children from controls (AUC .84), especially if they had RD (AUCs .92 and .95 for controls vs. RD-speed and RD-accuracy, respectively), and 2) also, but to a lesser extent, discriminated Non-RD children from controls (AUCs .72 and .79 when RD was defined by speed and accuracy, respectively), and RD from Non-RD children (AUCs .74 for RD-speed and .76 for RD-accuracy). The results of this study were basically the same, but whereas Waber et al. concluded that RAN had some utility in distinguishing between RD children and other LI children but showed greater reliability in discriminating between LI children and controls, the results of the present study showed that when RD was defined by speed, the discriminating power of RAN was about the same size (AUC .79) in both the LI vs. control and RD-speed vs. Non-RD-speed analyses. In this study RAN also discriminated better between RD and Non-RD (AUC .79) than between Non-RD and controls (AUC .60), when RD was defined by speed, while in Waber et al. these statistics were about the same size.

Table 4 about here

Cut-off Scores

Logistic regression was used to estimate which cut-off score best discriminated between the groups. This was done by assigning a dichotomous cut-off variable for each cut-off score used in the analysis. A separate logistic regression was then computed for each cut-off, the group variable being the dependent variable and the cut-off variable the categorical predictor variable. The analysis yielded correctly and incorrectly classified cases.

Following Waber et al., the best cut-off score was the one that produced the greatest percentage of correct classifications. For most of the comparisons, -0.5 SD was the best cut-off although the difference between -0.5SD and -1.0 SD was small. The highest percentage of correct classifications was 78% for the RD (speed) vs. Non-RD comparison, with 23% false positives and 21% false negatives. For the other comparisons, at the point where the percentage of correct classifications was at its highest, the proportion of false positives ranged from 19% to 46% and false negatives from 21% to 41%.

Table 5 about here

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

As in Waber et al., a description of the clinical profiles of the LI children was provided. The distribution of the RD, AD, and MD groups, and the different combinations of these, are displayed in Table 6, with information on the prevalence of NSD in each group. The groups identified were all mutually exclusive. There were some gaps in the clinical data with respect to the diagnoses of MD and AD. The most likely reason for a missing diagnosis was that children referred for the evaluation of learning problems did not exhibit any signs of the deficit in question, and therefore were not examined for them. In other words, a missing diagnosis would in high probability mean no problems in the skills not evaluated. On this assumption, children with missing diagnostic information were coded as not having the disorder in question. The prevalence of NSD in the different diagnostic groups did not change markedly with the replacement of missing information (see Table 6).

The prevalence of NSD in the clinical groups was somewhat different in the present sample compared to that in Waber et al., as can be seen in Table 6. The prevalence of NSD in the present sample was 26-30% in the LI groups without RD and 59%-89% in the LI groups with

RD of some kind. Thus, unlike in the sample of Waber et al. in which the prevalence of NDS increased with the comorbidity of learning impairments, in the present sample the prevalence of NSD increased with diagnosed RD.

Table 6 about here

Another difference between Waber et al. and the present study was in the composition of the groups. In the present sample the prevalence of learning disabilities was rather high (RD 78%, AD 60%, and MD 45%) compared to the sample in Waber et al. (RD 32%, AD 13%, and MD 43%). Accordingly, the comorbidity of different diagnoses was fairly high in the present clinical sample: 64% of the sample had more than one diagnosis and only 4% of the sample had none. In the LI sample in Waber et al., comorbidity was far more uncommon: only 23% of the sample had more than one diagnosis and 37% of the sample had no diagnoses. The difference between the studies in the prevalence of comorbidity was significant ($\chi^2(1)=64.72$, $p<.001$).

Discussion

The aim of this study was to extend the study by Waber et al. (2000) on rapid naming and to test the efficacy of RAN in discriminating between various clinical and control groups. The results of this study concurred with those obtained by Waber et al. and previous studies in that RAN differentiated RD from controls (e.g. Denckla & Rudel, 1976; O'Malley et al.; 2002; Wolf, 1986) and that the connection between RAN and RD was found to be stronger than the connection between RAN and learning problems in general. The results of the Non-RD vs. control and RD vs. Non-RD comparisons were parallel in that all the discriminations were statistically significant but not as robust as in the RD vs. control comparisons. Over and above the minor differences between the studies, the present study seemed to differ from Waber et al. in one major respect. While Waber et al. concluded that RAN was an excellent diagnostic indicator of learning problems that may include, but are nor limited to, reading (p. 258), the results of the present study point to a more specific connection between RD and RAN. There are three main reasons for this.

First, in the study by Waber et al. 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 interpreted to mean that prolonged naming speed was an indicator of learning problems in general, independently of any specific diagnosis. In the present study, the prevalence of NSD did not increase with the number of diagnoses. Instead, the prevalence of NSD was significantly greater in the groups with RD (59-89%) than in the LI groups without RD (26-30%). It should be noted that this comparison was made against a Non-RD-group in which there were no problems in either reading accuracy or reading speed.

Second, the ROC analyses revealed that RAN differentiated between the RD groups significantly better than any of the other groups from the control group. According to Tape's (n.d.) classification for AUC statistics, RAN was a good discriminator only for the RD vs. control comparisons, showing fair or poor discriminating power in all the other comparisons. RAN was not especially good in discriminating between the Non-RD-LI children and control children, RAN's discriminating power being at best .71, which means barely fair in Tape's classification. In addition, RAN reliably differentiated the RD-speed group from the Non-RD-speed group.

Third, although the prevalence of NSD was greater in the Non-RD groups than in the control group, the trend was significantly stronger in Waber et al. than in the present study. The present results are in line with those of previous studies. Previous research has shown that RAN is one of the strongest and most persistent variables connected to reading disabilities (e.g. De Jong & van der Leij, 2003; Korhonen, 1995; Wimmer, 1993). According to Wolf and Bowers (1999), the processes involved in reading and RAN are highly comparable, which explains the strong connection between these two tasks. In light of these studies the result that RAN was strongly connected to RD was no less than expected.

A more interesting result was that the connection between RAN and the other learning disabilities failed to be replicated. Beginning with attention problems, the results of this study are in line with those of previous studies that have not found a consistent connection between RAN and ADHD (e.g. Felton et al. 1987; Närhi & Ahonen, 1995; Semrud-Clikeman, Guy, Griffin & Hynd, 2000) and have claimed that RAN is more strongly connected to RD than ADHD (e.g. Felton & Wood, 1989; Raberger & Wimmer, 2003). However, the link between RAN and attention may be mediated by the subtype of attention problems, in which case the inattentive type of ADHD would be expected to be linked to RAN while the hyperactive type would not (Hynd et al. 1991; Thomson et al., 2005). In the study by Waber et al., only children with the inattentive type of ADHD were studied whereas the present study included children with a range of attention problems. This difference could explain the stronger connection between RAN and attention problems in Waber et al. than in the present sample; however, this hypothesis remains to be confirmed in further studies.

The connection between RAN and MD also warrants more profound investigation. In the MD groups the prevalence of NSD varied between 29% and 89% and hence the result does not reveal very much about the connection between RAN and MD. However, the fact that the highest prevalence of NSD was found in the MD+RD group might lend support to the previous suggestion that NSD, or “retrieval deficit” is one of the contributors to the comorbidity of MD and RD (Geary, 1993; Geary, Hanison, & Hoard, 2000), whereas difficulties in number naming were not evident in the children with MD alone (Geary et al., 2000). In light of the studies by Koponen (Koponen et al., 2006; Koponen et al., 2007) it is arguable that had the measure used in the identification of MD been based on calculating speed rather than accuracy, the connection between RAN and MD might have been stronger.

Taken together, the results of this study underpin the results of previous studies in which the connection between RAN and RD has been stronger than the connection between RAN and learning problems in general (Denckla & Rudel, 1976; Denckla, Rudel, & Broman, 1981). However, because of the comorbidity commonly found between different kinds of learning disabilities (Adler, Barkley, Wilens, & Gingsberg, 2006; Biederman et al., 2004; Knopik, Alarcón, & DeFries, 1997), the results of both this study and that of Waber et al.strongly indicate the need to take comorbid LIs into account when studying RAN and RD.

Methodological and Statistical Considerations

Because clinical samples often differ greatly in their composition, it is important to look more closely at he samples used when comparing studies. The differences between the present study and that of Waber et al. are unlikely to be due to subjects' socioeconomic status, age or the selection criteria used since they were highly comparable. However, some of the differences between the two studies may in part have been caused by statistical and sample-related differences. These will be discussed briefly.

First, the prevalence of NSD was significantly greater in Waber et al. than in the present study. As explicated before, this may in great part be due to the difference between naming times in control groups while the naming times in LI groups were about the same size between studies (Table 1). In addition to the prevalence of NSD this difference between studies also has implications on the AUC statistics so that the LI vs. control comparisons reach greater values in Waber et al. than in the present study. This may in part explain the difference between studies in this matter. What made the Finnish control children slower namers than the US children is not easy to say, while both of the normative groups were appropriate. However, the discrepancies between the studies on these measures may have no theoretical importance relative to the primary question, since the relationships between the groups remain the same.

The second difference between the studies concerns the composition of the clinical groups with their different combinations of learning disabilities. The comorbidity of different diagnoses was far more common in the present study than in Waber et al., which may partly be a resultof the inclusion criteria used, especially for AD. Waber et al. excluded children with hyperactivity, and no such exclusion criterion was applied in the present study. This naturally increased the prevalence of attention problems in the present sample and thus comorbidity. There was also a difference between studies in the prevalence of reading disabilities, the present sample including more children with RD. This was not likely to be due to the reading tasks used because of the high correlation between text reading and word reading fluency in the second grade both in children whose languages have transparent orthography (.89 in Greek) and also in English (.91; Georgiou, Parrila, & Papadopoulos, 2008). While the inclusion criterion for RD was stricter in the present study (1,5 SD from the normative mean) than in the study by Waber et al. (1.0 SD from the normative mean or a reading level -1,5 SD from expected according to IQ), and hence should not lead to a higher prevalence of RD, the differences between the studies are more likely to be based on differences in the referral procedures of the clinic, as explicated below.

Third, there was difference between the studies in intelligence, the present sample being lower in IQ. There was a minor difference between the studies in the selection criterion for the

LI samples, as the present sample included some children with Full Scale IQ below 80, which was an exclusion criterion in Waber et al. However, when these children were excluded, the difference between the studies remained. One reason for the lower IQ and also for the higher comorbidity of learning disabilities in our sample may be the selection of children to the clinic for the evaluation of learning disabilities. The clinic serves a relatively large area covering several municipalities and children were referred to the clinic if the local services for assessment and support had not been sufficient. This could explain why comorbid disorders, which are often considered more problematic, were more frequent in our sample. While some of the LI groups (math only and no LI groups this study and almost all of the comorbid groups in Waber et al.) were very small, the outcomes within these should be considered cautiously.

Finally, there was a problem in the definition of the RD subgroups and their Non-RD controls in Waber et al. While the RD subgroups were defined by problems of either speed or accuracy, the Non-RD-speed group might include children with reading accuracy problems and the Non-RD-accuracy group children with reading speed problems. For this reason, the comparisons between the Non-RD and RD or control groups are difficult to interpret. This problem should not affect the difference between the studies, but it might explain why the discriminatory power of RAN was at its lowest in these particular comparisons.

Conclusion

To conclude, the results of the present study indicated that in a clinical sample, RAN seemed to be more connected to RD than to other learning disabilities. This conclusion diverged from that of Waber et al. (2000), in which RAN was considered as an excellent tool for detecting learning disabilities in general but not specifically for detecting reading disabilities.

The results also indicate that RAN may have different connections with different learning disabilities; this would mean that the results obtained for a specific learning impairment may not be generalizable to all learning impairments. However, further research is needed on this issue, especially on whether problems in RAN performance are similar among different diagnostic groups and whether such groups differ in the background skills needed for the successful performance of a RAN task. As Waber et al. mentioned, different diagnostic groups may demonstrate naming speed deficits for different reasons, and thus there is a need to explore whether the cause of slow naming lies in linguistic skills, non-linguistic processing skills, or something else. In addition, there is an obvious need for more studies in this area to confirm the present results, as the criteria used to identify LIs and clinical samples vary widely and may be biased in several ways.

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Table 1.

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

	Mean		Standard deviation		Difference
Measure (N[a])	This study	Waber et al.	This study	Waber et al.	t-score(df)
WISC[b] (193/188)					
Verbal IQ	89.0	103.9	9.8	13.7	8.73(336)***
Performance IQ	93.2	101.2	12.3	12.6	4.43(378)***
Full Scale IQ	90.0	102.7	8.6	11.8	8.57(340)***
RAN score, LI sample[c] (193/188)					
Letters	38.0	35.5	14.5	12.5	1.81(374)
Numbers	41.1	37.9	23.3	12.5	1.66(232)
RAN score, normative sample[c] (119/115)					
Letters	28.3	23.8	7.8	4.7	7.32(150)***
Numbers	30.1	24.0	8.0	5.6	8.80(131)***

Note. LI = Learning impaired, Difference = Difference between studies on cognitive ability.

[a]The first N gives the sample size in the present study and the second the sample size in Waber et al. [b]WISC-R was used in the present study, Wisc-III in Waber et al. [c]The information on the RAN-score statistics needed to compare the studies was received from Peter Forbes (Personal communication 31.5.2005).

***$p < .001$.

Table 2.

The Prevalence of RD in Learning Impaired and Naming Speed Deficit Groups in the Present Study and in Waber et al.

	% RD-speed (N)			% RD-accuracy (N)		
Group (N[a])	This study	Waber	Difference	This study	Waber	Difference
LI (193/188)	69.4 (134)	58.0 (109)	5.47*	50.8 (98)	32.0 (60)	14.02***
NSD (111/128)	84.7 (94)	67.9 (87)	10.20**	61.3 (68)	40.6 (52)	11.28***
No NSD (82/60)	48.8 (40)	36.6 (22)	5.42*	36.6 (30)	15.0 (9)	11.32***

Note. RD = Reading disability; LI = Learning impaired children; NSD = Learning impaired children with naming speed deficits. No NSD = LI Children without NSD. RD was diagnosed separately using either reading speed or reading accuracy as a criterion.

[a] The first N gives the sample size in the present study and the second the sample size in Waber et al.

*p < .05. **p < .01. ***p < .001

Table 3.

The Prevalence of NSD in LI, RD, Non-RD, and Control Groups in the Present Study and in Waber et al.

	% NSD (N)		Difference
Group (N[a])	This study	Waber et al.	$\chi^2(1)$
LI (193/188)	57.5 (111)	68 (128)	4.62*
RD-speed (134/109)	70.1 (94)	80 (87)	5.50*
RD-accuracy (98/61)	69.4 (68)	85 (51)	13.74***
Non-RD-speed (59/79)	28.8 (17)	51 (41)	9.50**
Non-RD-accuracy (95/127)	45.3 (43)	60 (76)	9.64**

Note. 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 (defined by reading speed/accuracy).

[a] The first N gives the sample size in the present study and the second the sample size in Waber et al.

*p < .05. **p < .01. ***p < .001

Table 4.

Area Under the Curve (AUC) and 95% Confidence Intervals (CI) for Group Comparisons. Difference Between the Studies in AUC Statistics.

Group comparison	AUC (95% CI)		Difference
	This study	Waber et al.	z-score
LI vs. Control	.79 (.74 ,.84)	.84 (.79 ,.89)	1.36
RD vs. Control			
Speed	.87 (.83 ,.91)[ab]	.92 (.88 ,.96)	1.68*
Accuracy	.86 (.81 ,.91)[a]	.95 (.91 ,.99)	2.81**
Non-RD vs. Control			
Speed	.60 (.51 ,.69)	.72 (.64 ,.80)	1.95*
Accuracy	.71 (.64 ,.78)	.79 (.73 ,.85)	1.68*
RD vs. Non-RD			
Speed	.79 (.71 ,.86)[b]	.74 (.67 ,.81)	-0.98
Accuracy	.67 (.59 -.74)	.76 (.68 ,.84)	1.59

Note. LI = Learning impaired children; RD = Learning impaired children with reading disabilities, RD defined by reading speed and accuracy; Non-RD = Learning disabled children without RD, defined by speed and accuracy.

[a] In this study the AUC statistics for the RD vs. control comparisons were significantly greater than the AUC statistics in the other comparisons, with one exception (see b). [b]In this comparison Z = 1.60; p = 0.55.

*p < .05. **p < .01.

Table 5.

The Percentage of Correct Classifications on Different RAN Cut-Off Scores (False Positives / False Negatives on the Best Cut-off Points).

Group Comparison	0.5 SD	1.0 SD	1.5 SD	2.0 SD	2.5 SD
LI vs. Control	.71 (.19/.39)	.68 (.15/.45)	.63	.57	.50
RD vs. Control					
Speed	.78 (.23/.21)	.77 (.17/.29)	.73	.68	.60
Accuracy	.76 (.30/.18)	.77 (.22/.23)	.76	.71	.68
RD vs. Non-RD					
Speed	.75 (.19/.41)	.70 (.15/.49)	.64	.56	.47
Accuracy	.60 (.42/.34)	.51 (.39/.63)	.61	.58	.60

Note. LI=Learning impaired children; RD = Learning impaired children with reading disabilities, RD defined by reading speed and accuracy; Non-RD = Learning disabled children without RD, defined by speed and accuracy.

Table 6.

Percentage of Naming Speed Deficits (NSD) in Groups with Different Combinations of Reading, Mathematics, or Attention Deficits.

	% with NSD		N	
Deficits	This study	Waber et. al.	This study	Waber et al.
RD, MD, AD	64 (64)	100	42 (42)	3
RD, AD	59 (54)	100	44 (26)	2
MD, AD	30 (30)	100	10 (10)	5
RD, MD	89 (91)	94	27 (22)	33
RD	60 (54)	82	37 (24)	23
MD	29 (29)	82	7 (7)	39
AD	26 (17)	64	19 (12)	14
None	29 (0)	43	7 (4)	69

Note: RD = Reading disability, MD = Mathematic disability, AD = Attention deficit. RD is defined by speed and accuracy of text reading. Information before replacement of missing values is given in parentheses.