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Abstract

Employing a large sample of children from Dutch regular elementary schools, this study assessed the contributing and discriminating values of reading disability (RD) and attention-deficit/hyperactivity disorder (ADHD) to two types of phonological processing skills, phonemic awareness (PA) and rapid automatized naming (RAN). A second objective was to investigate whether comorbidity of RD and ADHD should be considered as an additive phenomenon as to RAN and PA. A total of 1,262 children, aged 8 to 13 years, were classified as RD ($n = 121$), ADHD ($n = 17$), comorbid (RD+ADHD; $n = 16$), or control ($n = 1,108$). Phonological processing was assessed by standardized tests of PA and RAN. Disability groups were compared to each other and contrasted to the control group. Although results indicate substantial effects for all three disability groups on both types of phonological processing, and the RAN/PA compound measure in particular, effect sizes were considerably larger for the RD groups, as compared to the ADHD-only group. Theoretical and practical implications are discussed.

Keywords

reading disabilities, ADHD, comorbidity, phonological processing, phonemic awareness, RAN, word reading

The past decades have shown great advances in the understanding of reading disabilities (RDs) (Vellutino, Fletcher, Snowling, & Scanlon, 2004). However, there still remain theoretical and practical issues to be clarified. This article focuses on the relationship of RD with attention-deficit/hyperactivity disorder (ADHD). ADHD is characterized by attention dysfunction, impulsiveness, and hyperactivity (American Psychiatric Association, 2000; Tannock, 2013). It is a developmental disorder that affects approximately 5% of the general population. Although for the majority of children with ADHD no RDs are reported, estimates of the *overlap* between RD and ADHD range from 25% to 40% (e.g., August & Garfinkel, 1990; Boada, Willcutt, & Pennington, 2012; Willcutt & Pennington, 2000). These estimates are substantial and warrant further investigation into the behavioral and biological nature of this comorbidity. Various recent studies have provided a biogenetic answer to the overlap (Ebejer et al., 2010; Paloyelis, Rijdsdijk, Wood, Asherson, & Kuntsi, 2010; Stevenson et al., 2005; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). As the genetic link is beyond the scope of our study, the present research is restricted to the cognitive-behavioral level.

The cognitive-behavioral level is investigated with two well-established reading-related cognitive measures, phonemic awareness (PA) and rapid automatized naming (RAN), in children with ADHD and/or RD. These skills have been the object of study in many comparative research articles of control and RD groups of children. Possibly because of the assumption that the majority of ADHD children are normal readers, a focus on ADHD children's reading-related processes has not been very common. However, this argument evidently loses power if, as in the present study, comorbidity is an explicit research objective. Second, even if a strict definition or diagnosis of the condition of ADHD does not presume an RD, it is not unlikely that at least some randomly sampled children with the diagnostic label ADHD-only still show negative effects of their attention problems in reading

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and reading-related tasks (e.g., Boada et al., 2012). In the remainder of this introduction the available evidence regarding the specific relationships of PA, RAN, and reading in RD and ADHD groups is discussed.

Phonemic Awareness in RD and ADHD

PA can be defined as the ability to recognize and manipulate the sound constituents of oral language and to apply this insight to alphabetic knowledge and knowledge of written sublexical units of words (Ehri, 2005). It is widely recognized that PA plays an important role in the prediction of word reading proficiency, at least in the early grades of elementary school education (De Jong & Van der Leij, 1999, 2003; Van den Bos & De Groot, 2012) and of poor reading in particular, from young to adult age levels (De Groot, Van den Bos, Minnaert, & Van der Meulen, 2015; Gregg et al., 2008). Moreover, poor PA task performance is regarded by many researchers as a core deficit of dyslexia (De Groot et al., 2015; Kirby, Desrochers, Roth, & Lai, 2008; Rack, 1994; Ramus, White, & Frith, 2006; Snowling, 2001; Van den Bos, 2008; Wagner et al., 1997; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wimmer, Mayringer, & Landerl, 1998, 2000; Wimmer, Mayringer, & Raberger, 1999; Wolf & Bowers, 1999). A first prediction, therefore, is that RD groups show poor PA performance (Prediction 1).

Although deficient PA is typically associated not with ADHD but rather with RD (Boada et al., 2012; Kroese, Hynd, Knight, Hiemenz, & Hall, 2000; McGrath et al., 2011; Purvis & Tannock, 2000; Willcutt et al., 2005; Willcutt, Pennington, Olson, & Defries, 2007), there are occasional reports of poor PA performance of ADHD groups (e.g., Kroese et al., 2000), especially if the PA task employed is relatively time-consuming or imposes a relatively high level of working memory (WM) load. One example of relatively difficult PA tasks, compared to simple elision as employed by Kroese et al. (2000), are so-called reversal tasks (for example, "Say *eeb*. Now say *eeb* backward."). Examples of even more demanding PA tasks are so-called pig Latin tasks or phoneme substitution tasks, in which initial phonemes of two names must be substituted (for example, *Kees Bos* becomes *Bees Kos*). For these tasks, difficulties with attention and WM—which are characteristics of children with ADHD—may lead to attenuated performances (Bental & Tirosh, 2007; Bolden, Rapport, Raiker, Sarver, & Kofler, 2012; Tiffin-Richards, Hasselhorn, Woerner, Rothenberger, & Banaschewski, 2008; Van De Voorde, Roeyers, Verté, & Wiersema, 2011). This study uses the two types of elision and substitution as PA measures. Presumably, the elision task is has a lesser memory load than the substitution task. Assuming that phonological processing is unimpaired in the ADHD-only group, the hypothesized attenuated PA performance in children with

ADHD would therefore particularly hold for the substitution task (Prediction 2).

With regard to the group of comorbid children, the previous reasoning concerning phonological and WM components in PA tasks leads to the following hypotheses and predictions. As already implied in Prediction 1, a presumed phonological deficit that leads to a reading problem will negatively affect the PA performance of the comorbid group at least equally strongly as in the RD-only group. However, in this group there may exist additional PA difficulties tied to ADHD, attributable to WM or executive functioning (Bental & Tirosh, 2007; Bolden et al., 2012; Tiffin-Richards et al., 2008; Van De Voorde et al., 2011). Prediction 3, therefore, is that the comorbid group will show a stronger negative effect for PA compared to the RD-only group, especially when the more difficult task variant, that is, phoneme substitution, is concerned.

Rapid Automatized Naming in RD and ADHD

As predicted by the seminal double deficit hypothesis (Wolf & Bowers, 1999), a large number of studies have made clear that, in addition to PA difficulties, individuals with RD typically demonstrate impaired RAN skills (Bowers, 1995; Denckla & Rudel, 1974, 1976; Kirby et al., 2008; Logan, Schatschneider, & Wagner, 2011; Torgesen et al., 1999; Torppa, Georgiou, Salmi, Eklund, & Lyytinen, 2012; Van den Bos, 2008; Van den Bos, Zijlstra, & Lutje Spelberg, 2002; Wagner & Torgesen, 1987; Wimmer, 1993). However, the general link between RAN and word reading speed should be refined by the following note on RAN subtasks. Batteries of RAN tasks (Denckla & Rudel, 1974) originally consisted of RAN_{colors}, RAN_{pictures}, RAN_{digits}, and RAN_{letters}. For three reasons it seems important, however, to distinguish between alphanumeric (digits and letters) and nonalphanumeric (colors and pictures) subsets. First, alphanumeric naming stimuli can be considered as more automatized than nonalphanumeric stimuli (Cattell, 1886; Van den Bos et al., 2002). Second, numerous factor-analytic studies offer evidence for the distinction (Van den Bos et al., 2002). Third, the distinction is relevant because it has consistently been demonstrated that alphanumeric stimuli are significantly stronger related to word reading (WR) than their nonalphanumeric counterparts (Stringer, Toplak, & Stanovich, 2004; Van den Bos et al., 2002; Van den Bos & Lutje Spelberg, 2010; Wagner, Torgesen, & Rashotte, 1999), and this applies to broad age ranges of typically developing children as well as those with RD. Because of their more substantial relationship to reading, in the present study RAN is restricted to alphanumeric stimuli and referred to as RAN_{an}. In line with the abovementioned literature, children with RD are expected to show a serious deficiency on alphanumeric naming tasks (Prediction 4).

With regard to children with ADHD-only the literature does not provide evidence for serious problems, that is, at a deficit level, with alphanumeric RAN. Considering the abovementioned, this is not to be expected either, as, by definition, the ADHD-only group is free from RD. In contrast, RAN deficits are commonly reported for children with the combination of RD and ADHD, that is, comorbid groups (Bental & Tirosh, 2007). Shanahan et al. (2006), and more recently McGrath et al. (2011), offer the explanation of comorbidity being at least *partly* attributable to a common generic cognitive processing speed (PS) deficit, which, according to these authors, is strongly linked to RAN. Since these children also have developed WR problems, and thus typically have not fully automatized alphanumeric symbol-name associations, it can be safely assumed that the comorbid children perform *at least* as poorly as children with RD-only on RAN_{an} (Prediction 5).

Summarizing, the present study specifically investigates how PA and RAN_{an} are related to word reading fluency in children with RD and/or ADHD. Regarding PA, the groups of RD-only and RD+ADHD are expected to show severely deficient PA performances (Prediction 1). Although not as severely affected as in the RD groups, subnormal PA performances are expected in the ADHD-only group as well. This would especially apply to the phoneme substitution task which, theoretically, involves a larger WM load than the elision task (Prediction 2). The comorbid group is expected to show the poorest PA performances due to the additive or interactive negative effects of RD and ADHD (Prediction 3). Thus, comparatively, the PA performance patterns of the groups are predicted to be control > ADHD-only > RD-only > comorbid. With regard to RAN_{an}, it is hypothesized that the RD groups, that is, RD-only and RD+ADHD, are severely impaired (Predictions 4 and 5, respectively). Thus, a comparative pattern partly similar to the one described previously for PA is expected: control = ADHD-only > RD-only ≥ comorbid.

Method

Participants and Procedure

This study involves a total of 1,262 Dutch children aged 8 to 13 years, mostly from the northern Netherlands. The sample contains a group of RD-only children, an ADHD-only group, a comorbid group (RD+ADHD), and a large control group of typically developing children without RD and/or ADHD.

WR performance was assessed by the first author and undergraduate graduate students who participated in one of the learning projects of our department. Participants were classified as reading disabled (RD) when WR performance (see the Instruments section) was more than 1.5 standard deviations below the population mean. Assignment to either

category with ADHD, that is, ADHD-only or RD+ADHD, was based on external psychiatric evaluation (i.e., a clinical ADHD diagnosis), according to criteria in the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2000), as prescribed by the Health Council of the Netherlands (2000). In addition, as a measure of external validity, a Dutch questionnaire was used as an index of ADHD-related problem behavior, referred to as AQ (Scholte & Van der Ploeg, 1998/2004).

Participants were excluded if they had an IQ of more than 1.5 *SD* below average, as measured with a shortened Dutch version of the *Wechsler Intelligence Scale for Children—Third Edition* (Legerstee, van der Reijden-Lakeman, Lechner-van der Noort, & Ferdinand, 2004; Wechsler, 2005). Additional exclusion criteria were uncorrected hearing or visual disability, a diagnosis of neurological disorder, or known specific language impairments.

It should be noted that, due to missing data, the presented IQ and AQ values are based on a subsample of children (RD: $n = 18$, ADHD: $n = 11$, RD+ADHD: $n = 9$, Control: $n = 18$, Total: $n = 52$). However, based on parent/teacher inquiries and available information from school records, it was deemed unlikely that the remaining children would have yielded a different pattern.

All participants attended the upper levels of regular schools for primary education. A number of participants with ADHD and/or RD were referrals of specialized care centers or were recruited by means of advertisement via newspapers, websites, and doctors' offices or otherwise. Data collection was performed by the first author and undergraduate students either at a university research facility or at the school or care institute of the participant. For participants younger than 12 years, an informed consent was required from their parents. Older participants were required to give consent on their own behalf as well. Participants with an ADHD diagnosis were requested to refrain from using psychostimulant medication, that is, methylphenidate, 24 hr before testing sessions.

Application of the abovementioned criteria yielded the group frequencies as specified in Table 1. This table also provides descriptive statistics for age, IQ, attentional problem behavior (AQ), and WR.

The groups did not differ significantly on age, $F(3, 1261) = 0.50, p = .69$, or IQ, $F(3, 51) = 0.64, p = .59$. With regard to WR and AQ, ANOVA indicated significant main effects, $F(3, 1261) = 318.3, p < .001$, and $F(3, 51) = 13.1, p < .001$, respectively. With regard to WR, the RD groups' performances are close to two standard deviations below the population mean. Of course, this is hardly unexpected since the applied criterion included only participants who scored more than 1.5 *SD* below the population mean. However, although not as deficient as the scores of the RD groups, WR performance of the ADHD-only group can be considered as subnormal as well (z score = $-.68$). Post hoc analysis

Table 1. Group Frequencies and Descriptive Statistics (Standardized Mean, Standard Deviation [SD], Median, Minimum, and Maximum).

Group	Age (months)	IQ ^a , N(100, 15)	AQ ^a , (percentile range)	z Score											
				WR	PA _{elision}	PA _{substitution}	PA _{com}	RAN _{digits}	RAN _{letters}	RAN _{com}	RANFAC	PAFAC	RANPA		
RD (n = 121, 54 F, 67 M)	M	127.4	100.1	—	-2.0	-1.4	-1.4	-1.6	-1.2	-1.4	-1.0	-1.2	-1.5		
	SD	18.3	10.4	—	0.4	1.5	1.3	1.2	0.9	0.9	0.8	1.1	0.9		
	Mdn	127.0	97.5	50-59	-1.9	-1.4	-1.3	-1.6	-1.3	-1.3	-1.1	-1.3	-1.4		
	Min	95	83	10-19	-3.0	-3.0	-4.0	-3.2	-3.0	-3.0	-2.6	-3.3	-3.2		
	Max	164	118	95-97	1.5	1.4	0.8	1.2	1.3	0.7	1.0	1.4	0.7		
ADHD (n = 17, 7 F, 10 M)	M	122.5	97.6	—	-0.7	-0.8	-0.9	-1.0	-0.7	-0.8	-0.5	-0.7	-0.8		
	SD	15.3	10.8	—	0.7	1.3	1.2	1.3	1.2	1.0	0.9	1.1	1.1		
	Mdn	127.0	101.3	98-100	-0.9	-0.4	-0.4	-0.7	-1.0	-1.0	-0.5	-0.5	-0.8		
	Min	95	81	60-69	-1.4	-3.0	-3.0	-3.0	-2.3	-2.3	-1.8	-2.8	-2.8		
	Max	146	114	98-100	1.3	0.9	0.6	0.8	1.3	1.0	1.1	0.6	1.0		
RD+ADHD (n = 16, 7 F, 9 M)	M	124.8	94.8	—	-2.2	-1.0	-1.7	-1.7	-1.4	-1.6	-1.5	-1.3	-1.7		
	SD	19.1	9.2	—	0.5	1.1	0.9	0.9	1.0	1.0	0.9	0.8	0.9		
	Mdn	126.5	95.0	90-94	-2.1	-1.3	-1.3	-1.7	-1.7	-1.5	-1.4	-1.2	-1.6		
	Min	94	80	60-69	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-2.4	-2.8	-3.4		
	Max	165	113	98-100	1.6	0.4	-0.4	-0.5	0.7	0	0.6	0	-0.1		
Control (n = 1,108, 575 F, 533 M)	M	126.8	99.6	—	.06	0.1	0	0	0	0	0	0.1	0.1		
	SD	16.6	9.9	—	0.7	0.9	1.0	0.9	1.0	0.9	0.9	0.9	0.8		
	Mdn	127.0	101.3	50-59	0.1	0.1	0.2	0.2	0	0	0	0.2	0.2		
	Min	95	85	10-19	-1.5	-3.0	-3.0	-3.0	-3.0	-3.0	-2.7	-3.4	-2.4		
	Max	165	114	95-97	1.5	2.5	1.8	2.1	2.7	2.3	2.7	2.0	2.3		
Total (N = 1,262, 643 F, 619 M)	M	126.7	98.5	—	-0.1	-2	-0.2	-0.1	-0.2	-0.2	-0.1	-0.1	-0.1		
	SD	16.8	10.0	—	1.0	1.1	1.1	1.1	1.0	1.0	1.0	0.9	1.0		
	Mdn	127.0	97.5	60-69	0	0.1	0	0	-0.3	-0.2	-0.1	0	0		
	Min	94	80	10-19	-3.0	-4.0	-3.2	-3.0	-3.0	-3.0	-2.9	-3.4	-3.0		
	Max	165	118	98-100	2.5	1.8	2.1	2.7	2.3	2.7	2.0	2.3	2.5		

Note. ADHD = attention-deficit/hyperactivity disorder; AQ = attentional problem behavior; PA = phonemic awareness; PAFAC = PA factor (orthogonal); RAN = rapid automatized naming; RANFAC = RAN factor (orthogonal); RANPA = unweighted average of alphanumeric RAN (RAN_{an}) and PA (PA_{com}); RD = reading disability; WR = word reading.
^aSubsample scores (RD: n = 18, ADHD: n = 11, RD+ADHD: n = 9, Control: n = 18, Total: n = 52).

(Tukey's honestly significant difference) indicated large significant differences between the RD groups and the control group, $p_{(RD-only-control)} < .001$, and $p_{(RD+ADHD-control)} < .001$, as well as for the contrasts with the ADHD-only group, $p_{(RD-only-ADHD-only)} < .001$, and $p_{(RD+ADHD-ADHD-only)} < .001$. Although to a much lesser degree, the latter group also performed significantly poorer than controls, $p_{(ADHD-only-control)} = .001$. Finally, regarding AQ, both ADHD groups showed median scores above the 90th percentile of attentional problem behavior, whereas the other groups showed normal levels of rated behavior, and they did not differ significantly from each other.

Instruments

WR fluency was operationalized by the mean performance on three standardized Dutch WR tests, two of them measuring the recognition of real words, and a test for reading pseudowords. The first test uses as its raw test score the total time needed to read 50 monosyllabic words (Monosyl subtest; Van den Bos & Lutje Spelberg, 2010). The second test contains real words of varying lengths and uses as its raw test score the total number of words read correctly (out of 116) in 1 min (Brus & Voeten, 1979). The third test contains pseudowords of varying lengths and uses the total number of items read aloud correctly (out of 116) in 2 min as its raw test score (Van den Bos, Lutje Spelberg, Scheepstra, & De Vries, 1994). The raw test scores of the three tests were converted to Wechsler scaled norm scores with a mean of 10 and a standard deviation of 3. In the present study, the average of the three scaled scores form the composite WR score, which is also approximately normally distributed with a mean of 10 and a standard deviation of 3. All three WR tests are used very frequently in the Netherlands, and the reported reliabilities for the individual tests are equal to or greater than .90.

RAN was assessed by the subtests Letters and Digits of a Dutch standard test of continuous naming (Van den Bos & Lutje Spelberg, 2010), measuring alphanumeric rapid serial naming. The nonalphanumeric Colors and Pictures subtests of this testing battery also have been administered, but these results will be reported elsewhere. Participants were required to sequentially name, as quickly and accurate as possible, the alphabetic names of 50 letters (10 times d, o, a, s, p), and the names of 50 digits (10 times 2, 4, 5, 8, 9), presented column-wise on two A4-sized stimulus cards. The reported reliabilities for these subtests are .84, and .86, respectively. The time to complete each card was converted into Wechsler scaled norm scores with a mean of 10 and a standard deviation of 3. Next, the Letter and Digit scores were averaged and taken as an index of alphanumeric RAN (RAN_{an}), which is also approximately normally distributed with a mean of 10 and a standard deviation of 3.

PA was assessed by a Dutch test (PHAT-R; De Groot, Van den Bos, & Van der Meulen, 2014). The test consists of two speeded PA subtests that are presented auditorily on a computer. The subtests are Phoneme Elision and Phoneme Substitution, which consist of three practice trials and twelve experimental trials each. Instruction examples for Phoneme Elision and Phoneme Substitution are "say [streek] without the [r]" and "[Kees Bos] must be stated as [Bees Kos]," respectively. After the experimenter's actions of stopping the timer at the participant's response, and indicating the accuracy of the response, the response time and accuracy of each item are stored by the software. Next, the item response time and accuracy are combined by means of a novel standardized scoring rule, which imposes an age-dependent time penalty in case of an erroneous response. This implies, that in case of a correct answer, the response time is taken as the item score. In case of an incorrect answer, the response time is replaced by the age-appropriate time penalty—that corresponds to a poor response time—which is used as the item score instead. The values of the time penalty were estimated with an optimization procedure that is based on the item intercorrelations of the test. Finally, this computer-assisted PA test computes summed item scores and converts them into standardized scores for each subtest (i.e., $PA_{elision}$ and $PA_{substitution}$) and as a composite PA index score (PA_{com}). The reported reliabilities of these measurements are .82, .91, and .92, respectively. All three measurements are approximately normally distributed with a mean of 50 and a standard deviation of 10.

Statistical Analyses

Data preparation. While there is good reason to combine RAN and PA subtests, RAN_{an} and PA are assumed to tap quite different (latent) processes. Nevertheless, RAN_{an} and PA_{com} were found to be moderately correlated, $r_{(RAN_{an}-PA_{com})} = .38$. Therefore, to avoid confounding of the results, principal component analysis with varimax rotation and Kaiser normalization was performed on normed data of the two alphanumeric RAN subtasks, $r_{(RAN_{letters}-RAN_{digits})} = .76$, and the two PA subtasks, $r_{(PA_{substitution}-PA_{deletion})} = .67$. This procedure did result in the extraction of two orthogonal factors, which clearly bear on RAN and PA (see Table 2 for the rotated factor loadings), and are referred to as RANFAC and PAFAC. The eigenvalues of these components were 2.4 and 1.0, respectively, and 85% of total variation could be explained by their respective communalities (59.7% and 25.6%).

Next, to match the scaling of RANFAC and PAFAC, all other performance measures (norm scores) were also linearly transformed to z scores. However, as these orthogonal components, by definition, do not address the previously mentioned commonality of RAN_{an} and PA_{com} , a new composite variable, RANPA, was created by averaging the latter two measurements. Thus, three variables have been analyzed, PAFAC, RANFAC, and RANPA.

Table 2. Rotated Factor Loadings on RAN (RANFAC) and PA (PAFAC) Components.

Variable	Component	
	RANFAC	PAFAC
RAN _{digits}	.93	.14
RAN _{letters}	.90	.24
PA _{elision}	.26	.86
PA _{substitution}	.12	.91

Note. PA = phonemic awareness; PAFAC = PA factor (orthogonal); RAN = rapid automatized naming; RANFAC = RAN factor (orthogonal).

Analysis of variance. As far as the main statistical procedures are concerned, three series of univariate ANOVA were performed to examine (a) PA subtask comparisons, (b) a factorial design, and (c) group comparisons. Each model was corrected for any residual age effects by including age in months as a covariate. Dependent on the results of the PA subtask analysis, if necessary, differentiated analyses were conducted. As the groups were not matched on reading performance, and in connection to Prediction 2, the latter two series of ANOVAs were repeated including WR as a covariate.

To accommodate for unequal sample sizes, stratified random (re)sampling with replacement was performed with 1,000 iterations and the experimental group as the stratification variable. Each instance was subjected to a separate analysis, and all relevant parameters were averaged afterward to obtain unbiased estimators. The sampling procedure was designed to match the sample sizes of the RD-only and control group of each iteration to that of the ADHD-only group ($n = 17$), and it was ensured that each subsample matched the gender ratio of the ADHD-only group. Also, the sampling pool for the control group was RD-counterbalanced beforehand by trimming the opposite side of the WR distribution with the equivalent size of that of the RD-criterion, that is, more than 1.5 SD above the population mean.

Effect sizes. Effect sizes of the differences of the means are presented as Cohen's d , with values of .2, .5 and .8 being considered as small, medium, and large effect sizes, respectively (Cohen, 1988). Effect sizes in terms of explained variance are indicated by eta-squared (η^2), with values of .01, .06, and .14 being considered as small, medium, and large effect sizes, respectively (Cohen, 1973).

Results

Descriptive Statistics

Figure 1 (also see Table 1 for additional descriptive statistics) shows that the standardized means of the control group

are very close to zero, indicating that the selected reference group is quite representative of the general population of typically developing children for this age range.

Regarding the experimental groups, Figure 1 shows notable differences between the control group and the experimental groups. Within these groups there are clear differences between the ADHD-only group and the RD groups (RD-only and the comorbid group). Both RD groups perform markedly poorer than the ADHD-only group and controls on all measurements (Prediction 1). Figure 1 shows that both RAN and PA are severely impaired in the RD-only group (Predictions 1 and 4), with a small negative tilt toward PA. The comorbid group seems to perform poorest overall (Predictions 1, 3, 4, and 5). The ADHD-only group also shows subnormal performance on PA and RAN_{an}. As to PA, this was an anticipated result (Prediction 2). As far as RAN_{an} is concerned, this was an unexpected finding. As indicated in the method section we wanted to evaluate whether controlling for WR would yield different results. With regard to RAN_{an}, this procedure indicated that the RD-only, ADHD-only, and comorbid groups' predicted means ($z = -0.08$, -0.32 , and -0.19 , respectively) now approached the control group's value ($z = -0.08$). However, with regard to PA, there still remained a significantly lower z score for the RD-only group ($z = -0.32$, $p = .016$). Although the means of the ADHD-only and comorbid groups are even more negative than those of the RD-only group ($z = -0.52$ and -0.50 , respectively), these lacked the statistical power for reaching significance.

Effect Sizes of Mean Differences

Figure 2 depicts the clustered standardized effect sizes (Cohen's d ; see Note 1) on the RAN and PA factors and the linear combination of RAN_{an} and PA_{com} (RANPA) for the clinical groups, as compared to controls. Considering the confidence intervals, for the RD-only group, the effect for the composite measure of RANPA seems larger than on the separate measures. No such discrepancy is apparent for the ADHD-only and the comorbid groups, for which the effects are in similar ranges.

Second, Figure 2 indicates that the effect sizes of group membership on phonological processing clearly are largest for the RD groups (Predictions 1, 4, and 5), compared to the ADHD-only group. Notwithstanding the apparent close association with reading, it should be noted that most effect sizes, including those for ADHD-only, can be considered as large, except for the ADHD-only group's RANFAC effect, of which the value of 0.63 can be called moderate.

Analysis of Variance

PA subtask differences. First, to evaluate possible PA subtask differences in the context of Prediction 2, a 4×2

Figure 1. Plotted means (z scores) and standard error bars of WR, RAN, PA, RANFAC, PAFAC, and RANPA measures for RD-only, ADHD-only, RD+ADHD, and controls.

Note. ADHD = attention-deficit/hyperactivity disorder; PA = phonemic awareness; PAFAC = PA factor (orthogonal); RAN = rapid automatized naming; RANFAC = RAN factor (orthogonal); RANPA = unweighted average of alphanumeric RAN (RAN_{an}) and PA (PA_{com}); RD = reading disability; WR = word reading.

Figure 2. Standardized mean difference effect sizes (Cohen's d) of RANFAC, PAFAC, and RANPA per clinical group, compared to controls.

Note. ADHD = attention-deficit/hyperactivity disorder; PAFAC = PA factor (orthogonal); RANFAC = RAN factor (orthogonal); RANPA = unweighted average of alphanumeric RAN (RAN_{an}) and PA (PA_{com}); RD = reading disability.

repeated measures ANOVA was performed with experimental group as a between subjects factor, and PA subtask as a within subjects factor. The model was corrected for any

residual age effects by including age in months as a covariate. The results were a significant main effect for group, $F(3, 1258) = 128.1, p < .001$, and nonsignificant effects for

Table 3. Individual and Interactive Effects of RD and ADHD on RANFAC, PAFAC, and RANPA.

Factor	Measurement	<i>F</i>	<i>p</i>	η^2
RD versus non-RD	RANFAC	14.80	.003	.22
	PAFAC	13.94	.004	.18
	RANPA	26.51	<.001	.32
ADHD versus non-ADHD	RANFAC	3.34	.159	.05
	PAFAC	5.42	.071	.06
	RANPA	7.79	.023	.11
RD $\times$ ADHD interaction	RANFAC	1.17	.433	.01
	PAFAC	1.85	.313	.02
	RANPA	2.32	.225	.03

Note. ADHD = attention-deficit/hyperactivity disorder; PA = phonemic awareness; PAFAC = PA factor (orthogonal); RAN = rapid automatized naming; RANFAC = RAN factor (orthogonal); RANPA = unweighted average of alphanumeric RAN (RAN_{an}) and PA (PA_{com}); RD = reading disability.

subtask and the interaction, $F(1, 1258) < 1$. We will return to the specific composition of the group main effect later in this section. Regardless of the outcome, this analysis makes clear that the prediction of a poor PA performance of the ADHD-only group *cannot* be supported by referring to a particularly poor PA_{substitution} performance (Prediction 2), which evidently is not the case (also see Figure 1). On the basis of this analysis, the remaining analyses were conducted with the composite PA variable.

Next, to investigate the individual and interactive effects of RD and ADHD, and the group contrasts for RANFAC, PAFAC, and RANPA in terms of explained variance (η^2), two separate series of analyses were conducted.

Factorial design. First, three ANOVAs were performed according to a 2×2 between subjects factorial design with RD versus non-RD and ADHD versus non-ADHD as independent variables, and RANFAC, PAFAC, and RANPA as dependent variables. In Table 3 the main and interaction effects of RD and ADHD are presented.

As shown in Table 3, and in line with Predictions 1, 4, and 5, the first series of analyses revealed strong main effects of RD, with the largest effects for RANPA and a slightly larger proportion of explained variance for RANFAC, as compared to PAFAC. As to ADHD, there were no significant main effects for the individual measurements, except for a trend for PAFAC ($p = .07$), with moderate effect sizes. The variable of RANPA, however, did show a significant main effect and a fairly large proportion of explained variance. Finally, for none of the three measures, the RD $\times$ ADHD interaction effect was significant.

Group comparisons. Finally, to examine the group contrasts for RANFAC, PAFAC, and RANPA, three separate ANOVAs were performed with experimental group—consisting of the three clinical groups and the control group—as the independent variable. The main results are presented in Figure 3, depicting the effect sizes (η^2) of each of the three

measurements for the experimental groups (clustered on the horizontal axis), as compared to the control group.

From Figure 3 it becomes evident that phonological processing is particularly affected in the RD groups (Predictions 1, 4, and 5), as indicated by strong effect sizes in both the RD-only and the comorbid group. In accordance with the results of the first series of analyses, the effects in the ADHD-only group for the separate measurements seem modest (Prediction 2). Nevertheless, RANPA seems significantly affected in this group as well. In line with the absence of significant interactions that were previously reported, the proportions of explained variance for the comorbid group are almost the exact *additive* combination of the effects for RD-only, and ADHD-only (Prediction 3). Finally, the contrast of the ADHD-only and the comorbid group testing for RANPA was significant ($p = .04$). The remaining contrasts were not significant.

Discussion

This study investigates WR fluency, and two types of reading-related phonological processing—that is, RAN_{an} and PA—in children with RD and/or ADHD, who attend the upper-level grades of Dutch primary education. Previous international studies (Kroese et al., 2000; McGrath et al., 2011; Purvis & Tannock, 2000; Shanahan et al., 2006; Willcutt et al., 2005) have concluded that PA and RAN are generally more closely associated with RD than ADHD.

As predicted, and in line with many international studies (e.g., Landerl et al., 2013; Wolf & Bowers, 1999), the RD-only and comorbid groups showed highly significant PA (Prediction 1) and RAN_{an} (Predictions 4 and 5) impairments. Therefore, considering the presumed reciprocal relationships among WR, RAN, and PA (Van den Bos et al., 2002; Van den Broeck, 1997), RAN_{an} and PA were controlled for WR contributions in a secondary series of analyses, which further emphasized the reading-relatedness of these variables. With regard to RAN_{an}, the covariate analysis made clear that, although the performances of all three

Figure 3. Explained variances (η^2) of RANFAC, PAFAC, and RANPA per group.

Note. ADHD = attention-deficit/hyperactivity disorder; PAFAC = PA factor (orthogonal); RANFAC = RAN factor (orthogonal); RANPA = unweighted average of alphanumeric RAN (RAN_{an}) and PA (PA_{com}); RD = reading disability.

experimental groups now approached those of the control group, this procedure did most positively affect the two RD groups. As to PA, outcomes were somewhat different in the sense that the RD-only group still showed significantly depressed PA performances. These results suggest that non-reading-related processes pose an independent negative influence to PA performance. In this context it should be noted that, although these differences lacked the statistical power to become significant, the ADHD-only and comorbid groups showed even larger negative PA performances. If one were to speculate about the nature of the remaining deficit, WM may be considered as a plausible candidate (Bental & Tirosh, 2007; Bolden et al., 2012; De Groot et al., 2014; Landerl & Wimmer, 2000; Tiffin-Richards et al., 2008; Van De Voorde et al., 2011). The prediction that this should show as PA subtask differences in the ADHD-only group (Prediction 2) was, however, not supported by our subtask analysis. This result does not preclude the possibility, however, of both subtasks involving a substantial WM component. Further study with other, more sensitive subtask contrasts is needed to provide a satisfactory answer.

A further note on the results of the ADHD-only group should be made. For this group we assumed normal WR performance, and nondeficient RAN_{an} performance. Due to presumed WM impairments a subnormal PA performance was predicted (Prediction 2). However, the data indicated that this group *also* performs poorer than the control group on WR and RAN_{an} . One possible explanation for the

subnormal RAN_{an} and PA performances is that this partly may have been the result of relatively poor WR performance, which in turn may have been a selection artifact. That is, next to psycho-diagnostic signs of ADHD, the ADHD-only group was selected on the basis of WR performance above the cutoff criterion of $M - 1.5 SD$. The resulting relatively small ADHD-only group size may have created a vulnerability for chance findings. Anyway, returning to the issue of additivity, the subnormal WR performances of the ADHD-only group may have created a bias, which may have resulted in an over-estimation of the additive effects of ADHD. That is, if the ADHD-only sample also encompasses subnormal readers, the effects for these reading-related components are inflated. Indeed, similar to the abovementioned group comparisons, controlling for WR eliminated all significant effects of ADHD on RAN_{an} and PA, and the combination.

Continuing the discussion on the concept of additivity, it appears that the effect sizes of RAN_{an} and PA for the RD-only and ADHD-only groups do not add up in terms of *magnitude* for the comorbid group (see *d* values in Figure 2). Furthermore, analysis of variance yielded mixed evidence as to the effects on RAN_{an} , PA, and the combination (see Table 3 and Figure 3). Despite a medium effect size, ADHD did *not* affect RAN_{an} *significantly*, resulting in underadditivity for the comorbid group. This result is in line with Shanahan et al. (2006), who also found underadditivity for the comorbid group with regard to a (general) PS factor,

which can be considered as closely related to RAN (McGrath et al., 2011). With regard to PA, our data suggest that all three experimental groups are prone to difficulties with tasks involving a relatively high WM load, the comorbid group in particular (Prediction 3). However, to correctly interpret the comorbid group's poor PA performance, and to differentiate between the presumed WM based and the mainly phonologically linguistically based deficient PA performance of RD children, it would be mandatory for future research to consider independent measurements of WM capacity and executive functioning as well.

Finally, these results carry some implications for current (differential) diagnostic practices concerning children with RD and/or ADHD. In the Netherlands, a dyslexia protocol (Dutch Health Care Insurance Board; Blomert, 2006) is used which favors cases of relatively "pure" dyslexia as eligible for insured further diagnostic assessment and specialized reading treatment, and *comorbid* cases of ADHD+RD run the risk of being excluded from these assignments. However, based on the present findings of the RD-only and the comorbid groups being equally seriously impaired on reading performance, as well as having qualitatively similar underlying profiles of PA and RAN, a sharp *diagnostic* differentiation seems unwarranted.

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Note

1. Effect sizes were also calculated according to Hedges's *g* (Hedges, 1981) because in the comparisons with the RD-only group the assumption of equal variances was violated. However, the outcomes yielded a highly similar pattern. Hence, they are not reported.

References

- American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text revision). Washington, DC: Author.
- August, G. J., & Garfinkel, B. D. (1990). Comorbidity of ADHD and reading disability among clinic-referred children. *Journal of Abnormal Child Psychology*, 18, 29–45.
- Bental, B., & Tirosh, E. (2007). The relationship between attention, executive functions and reading domain abilities in attention deficit hyperactivity disorder and reading disorder: A comparative study. *Journal of Child Psychology and Psychiatry*, 48, 455–463.
- Blomert, L. (2006). *Protocol Dyslexie Diagnostiek & Behandeling* [Dyslexia protocol for diagnosis and intervention]. Diemen/Maastricht, Netherlands: Dutch Health Care Insurance Board/University of Maastricht.
- Boada, R., Willcutt, E. G., & Pennington, B. F. (2012). Understanding the comorbidity between dyslexia and attention-deficit/hyperactivity disorder. *Topics in Language Disorders*, 32, 264–284.
- Bolden, J., Rapport, M. D., Raiker, J. S., Sarver, D. E., & Kofler, M. J. (2012). Understanding phonological memory deficits in boys with attention-deficit/hyperactivity disorder (ADHD): Dissociation of short-term storage and articulatory rehearsal processes. *Journal of Abnormal Child Psychology*, 40, 999–1011.
- Bowers, P. G. (1995). Tracing symbol naming speed's unique contributions to reading disabilities over time. *Reading and Writing*, 7, 189–216. doi:10.1007/BF01027185
- Brus, B. T., & Voeten, M. J. M. (1979). *Een minuut test: vorm A en B: verantwoording en handleiding : schoolvorderingstest voor de technische leesvaardigheid, bestemd voor het tweede tot en met het zesde leerjaar van het basisonderwijs* [One minute test: A and B version: Justification and manual: School advancement test for word reading proficiency, intended for grades two through six of primary education]. Nijmegen, Netherlands: Berkhout.
- Cattell, J. M. (1886). The time it takes to see and name objects. *Mind*, 11, 63–65. doi:10.2307/2247157
- Cohen, J. (1973). Eta-squared and partial eta-squared in communication science. *Human Communication Research*, 28, 473–490.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.
- De Groot, B. J. A., Van den Bos, K. P., Minnaert, A. E. M. G., & Van der Meulen, B. F. (2015). Phonological processing and word reading in typically developing and reading disabled children: Severity matters. *Scientific Studies of Reading*, 19, 166–181. doi:10.1080/10888438.2014.973028
- De Groot, B. J. A., Van den Bos, K. P., & Van der Meulen, B. F. (2014). *Phonemic Analysis Test Revised (PHAT-R)*. Amsterdam, Netherlands: Pearson.
- 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, 450–476. doi:10.1037/0022-0663.91.3.450
- De Jong, P. F., & Van der Leij, A. (2003). Developmental changes in the manifestation of a phonological deficit in dyslexic children learning to read a regular orthography. *Journal of Educational Psychology*, 95, 22–40. doi:10.1037/0022-0663.95.1.22
- Denckla, M. B., & Rudel, R. (1974). Rapid "automatized" naming of pictured objects, colors, letters and numbers by normal children. *Cortex*, 10, 186–202. doi:10.1016/S0010-9452(74)80009-2
- Denckla, M. B., & Rudel, R. G. (1976). Rapid "automatized" naming (R.A.N.): Dyslexia differentiated from other learning disabilities. *Neuropsychologia*, 14, 471–479. doi:10.1016/0028-3932(76)90075-0
- Ebejer, J. L., Coventry, W. L., Byrne, B., Willcutt, E. G., Olson, R. K., Corley, R., & Samuelsson, S. (2010). Genetic and environmental influences on inattention, hyperactivity-impulsivity, and reading: Kindergarten to grade 2. *Scientific Studies of Reading*, 14, 293–316. doi:10.1080/10888430903150642

- Ehri, L. C. (2005). Learning to read words: Theory, findings, and issues. *Scientific Studies of Reading*, 9, 167–188. doi:10.1207/s1532799xssr0902_4
- Gregg, N., Bandalos, D. L., Coleman, C., Davis, J. M., Robinson, K., & Blake, J. (2008). The validity of a battery of phonemic and orthographic awareness tasks for adults with and without dyslexia and attention deficit/hyperactivity disorder. *Remedial and Special Education*, 29, 175–190. doi:10.1177/0741932508315951
- Health Council of the Netherlands. (2000). *Diagnosis and treatment of ADHD*. The Hague: Author.
- Hedges, L. V. (1981). Distribution theory for Glass's estimator of effect size and related estimators. *Journal of Educational and Behavioral Statistics*, 6, 107–128. doi:10.3102/10769986006002107
- Kirby, J. R., Desrochers, A., Roth, L., & Lai, S. S. V. (2008). Longitudinal predictors of word reading development. *Literacy Development in Canada*, 49, 103–110.
- Kroese, J. M., Hynd, G. W., Knight, D. F., Hiemenz, J. R., & Hall, J. (2000). Clinical appraisal of spelling ability and its relationship to phonemic awareness (blending, segmenting, elision, and reversal), phonological memory, and reading in reading disabled, ADHD, and normal children. *Reading and Writing*, 13, 105–131. doi:10.1023/A:1008042109851
- Landerl, K., Ramus, F., Moll, K., Lyytinen, H., Leppänen, P. H. T., Lohvansuu, K., & Schulte-Körne, G. (2013). Predictors of developmental dyslexia in European orthographies with varying complexity. *Journal of Child Psychology and Psychiatry*, 54, 686–694. doi:10.1111/jcpp.12029
- Landerl, K., & Wimmer, H. (2000). Deficits in phoneme segmentation are not the core problem of dyslexia: Evidence from German and English children. *Applied Psycholinguistics*, 21, 243–262.
- Legerstee, J. S., van der Reijden-Lakeman, I. A., Lechner-van der Noort, M. G., & Ferdinand, R. F. (2004). Bruikbaarheid verkorte versie wisc-rn in de kinderpsychiatrie [Applicability of a shortened version of the WISC-RN in child psychiatry]. *Kind en adolescent*, 25, 178–182. doi:10.1007/BF03060926
- Logan, J. A. R., Schatschneider, C., & Wagner, R. K. (2011). Rapid serial naming and reading ability: The role of lexical access. *Reading and Writing*, 24, 1–25.
- McGrath, L. M., Pennington, B. F., Shanahan, M. A., Santerre-Lemmon, L. E., Barnard, H. D., Willcutt, E. G., & Olson, R. K. (2011). A multiple deficit model of reading disability and attention-deficit/hyperactivity disorder: Searching for shared cognitive deficits. *Journal of Child Psychology and Psychiatry*, 52, 547–557.
- Paloyelis, Y., Rijdsdijk, F., Wood, A., Asherson, P., & Kuntsi, J. (2010). The genetic association between ADHD symptoms and reading difficulties: The role of inattentiveness and IQ. *Journal of Abnormal Child Psychology*, 38, 1083–1095. doi:10.1007/s10802-010-9429-7
- Purvis, K. L., & Tannock, R. (2000). Phonological processing, not inhibitory control, differentiates ADHD and reading disability. *Journal of the American Academy of Child and Adolescent Psychiatry*, 39, 485–494. doi:10.1097/00004583-200004000-00018
- Rack, J. P. (1994). Dyslexia: The phonological deficit hypothesis. In R. N. E. A. Fawcett (Ed.), *Dyslexia in children: Multidisciplinary perspectives* (pp. 5–37). London, UK: Harvester Wheatsheaf.
- Ramus, F., White, S., & Frith, U. (2006). Weighing the evidence between competing theories of dyslexia. *Developmental Science*, 9, 265–269.
- Scholte, E. M., & Van der Ploeg, J. D. (2004). *ADHD Vragenlijst (AVL)* [ADHD questionnaire (AQ)]. Houten, Netherlands: Bohn Stafleu van Loghum. (Original work published 1998)
- Shanahan, M. A., Pennington, B. F., Yerys, B. E., Scott, A., Boada, R., Willcutt, E. G., & DeFries, J. C. (2006). Processing speed deficits in attention deficit/hyperactivity disorder and reading disability. *Journal of Abnormal Child Psychology*, 34, 585–602.
- Snowling, M. J. (2001). From language to reading and dyslexia. *Dyslexia*, 7, 37–46. doi:10.1002/dys.185
- Stevenson, J., Langley, K. P. H., Payton, A., Worthington, J., Ollier, W., & Thapar, A. (2005). Attention deficit hyperactivity disorder with reading disabilities: Preliminary genetic findings on the involvement of the ADRA2A gene. *Journal of Child Psychology and Psychiatry*, 46, 1081–1088. doi:10.1111/j.1469-7610.2005.01533.x
- Stringer, R. W., Toplak, M. E., & Stanovich, K. E. (2004). Differential relationships between RAN performance, behaviour ratings, and executive function measures: Searching for a double dissociation. *Reading and Writing*, 17, 891–914. doi:10.1007/s11145-004-2770-x
- Tannock, R. (2013). Rethinking ADHD and LD in DSM-5: Proposed changes in diagnostic criteria. *Journal of Learning Disabilities*, 46, 5–25. doi:10.1177/0022219412464341
- Tiffin-Richards, M. C., Hasselhorn, M., Woerner, W., Rothenberger, A., & Banaschewski, T. (2008). Phonological short-term memory and central executive processing in attention-deficit-hyperactivity disorder with/without dyslexia—Evidence of cognitive overlap. *Journal of Neural Transmission*, 115, 227–234.
- Torgesen, J. K., Wagner, R. K., Rashotte, C. A., Rose, E., Lindamood, P., Conway, T., & Garvan, C. (1999). Preventing reading failure in young children with phonological processing disabilities: Group and individual responses to instruction. *Journal of Educational Psychology*, 91, 579–593. doi:10.1037/0022-0663.91.4.579
- Torppa, M., Georgiou, G., Salmi, P., Eklund, K., & Lyytinen, H. (2012). Examining the double-deficit hypothesis in an orthographically consistent language. *Scientific Studies of Reading*, 16, 287–315. doi:10.1080/10888438.2011.554470
- Van den Bos, K. P. (2008). Word-reading development, the double-deficit hypothesis, and the diagnosis of dyslexia. *Educational and Child Psychology*, 25, 51–69.
- Van den Bos, K. P., & De Groot, B. J. A. (2012, July). *Development of word-reading speed differentially linked to the development of phonemic analysis skills and alphanumeric naming speed*. Paper presented at the annual meeting of the Society for the Scientific Study of Reading, Montreal, Canada.
- Van den Bos, K. P., & Lutje Spelberg, H. C. (2010). *Continu Benoemen en Woorden Lezen (CB&WL)* [Test for continuous naming and word reading]. Amsterdam, Netherlands: Boom.
- Van den Bos, K. P., Lutje Spelberg, H. C., Scheepstra, A. J. M., & De Vries, J. R. (1994). *De Klepel* [The Klepel, a test for pseudoword reading]. Amsterdam, Netherlands: Pearson.

- Van den Bos, K. P., Zijlstra, B. J. H., & Lutje Spelberg, H. C. (2002). Life-span data on continuous-naming speeds of numbers, letters, colors, and pictured objects, and word-reading speed. *Scientific Studies of Reading*, 6, 25–49. doi:10.1207/S1532799XSSR0601_02
- Van den Broeck, W. J. M. (1997). *De rol van fonologische verwerking bij het automatiseren van de leesvaardigheid* [The role of phonological processing in automatizing reading proficiency]. Unpublished doctoral thesis, Rijksuniversiteit Leiden, Leiden, Netherlands.
- Van De Voorde, S., Roeyers, H., Verté, S., & Wiersema, J. R. (2011). The influence of working memory load on response inhibition in children with attention-deficit/hyperactivity disorder or reading disorder. *Journal of Clinical and Experimental Neuropsychology*, 33, 753–764.
- Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, 45, 2–40.
- Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, 101, 192–212. doi:10.1037/0033-2909.101.2.192
- Wagner, R. K., Torgesen, J. K., Laughon, P., Simmons, K., & Rashotte, C. A. (1993). Development of young readers' phonological processing abilities. *Journal of Educational Psychology*, 85, 83–103. doi:10.1037/0022-0663.85.1.83
- Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1999). *CTOPP: Comprehensive Test of Phonological Processing*. Austin, TX: PRO-ED.
- Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., Burgess, S. R., & Garon, T. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: A 5-year longitudinal study. *Developmental Psychology*, 33, 468–479. doi:10.1037/0012-1649.33.3.468
- Wechsler, D. (2005). *Wechsler Intelligence Scale for Children—Third Edition—Dutch Adaptation (WISC-III-NL)* (W. Kort, M. Schittekatte, M. Bosmans, E. L. Compaan, P. H. Dekker, G. Vermeir, & P. Verhaeghe, Trans.). Amsterdam, Netherlands: Pearson.
- Willcutt, E. G., & Pennington, B. F. (2000). Comorbidity of reading disability and attention-deficit/hyperactivity disorder: Differences by gender and subtype. *Journal of Learning Disabilities*, 33, 179–191. doi:10.1177/002221940003300206
- Willcutt, E. G., Pennington, B. F., Olson, R. K., Chhabildas, N., & Hulslander, J. (2005). Neuropsychological analyses of comorbidity between reading disability and attention deficit hyperactivity disorder: In search of the common deficit. *Developmental Neuropsychology*, 27, 35–78.
- Willcutt, E. G., Pennington, B. F., Olson, R. K., & Defries, J. C. (2007). Understanding comorbidity: A twin study of reading disability and attention-deficit/hyperactivity disorder. *American Journal of Medical Genetics B*, 144, 709–714.
- Wimmer, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics*, 14, 1–33. doi:10.1017/S0142716400010122
- 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 orthography. *Journal of Educational Psychology*, 92, 668–680.
- Wimmer, H., Mayringer, H., & Raberger, T. (1999). Reading and dual-task balancing: Evidence against the automatization deficit explanation of developmental dyslexia. *Journal of Learning Disabilities*, 32, 473–478.
- Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology*, 91, 415–438.