Rapid Naming and Phonemic Awareness in Children With or Without Reading Disabilities and/or ADHD

Barry J. A. De Groot, PhD¹, Kees P. Van den Bos, PhD¹, Bieuwe F. Van der Meulen, PhD¹, and Alexander E. M. G. Minnaert, PhD¹

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 ADHD children 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, Rijsdijk, 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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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, 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_digits, RAN_letters, RAN_colors, and RAN_pictures. 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 Bosch et al., 2002). Second, numerous factor-analytic studies offer evidence for the distinction (Van den Bosch 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 Bosch et al., 2002; Van den Bosch & 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. 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.<sub>an</sub> (Prediction 5).

Summarizing, the present study specifically investigates how PA and RAN<sub>an</sub> 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<sub>an</sub>, 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).
<table>
<thead>
<tr>
<th>Group</th>
<th>Age (months)</th>
<th>IQ(^z) (N(100, 15))</th>
<th>(z) Score</th>
<th>WR</th>
<th>PA(_{\text{ allergy}})</th>
<th>PA(_{\text{ substitution}})</th>
<th>PA(_{\text{ com}})</th>
<th>RAN(_{\text{ digits}})</th>
<th>RAN(_{\text{ letters}})</th>
<th>RAN(_{\text{ com}})</th>
<th>RAN(_{\text{ FAC}})</th>
<th>PA(_{\text{ FAC}})</th>
<th>RANPA</th>
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<td>1.5</td>
<td>1.3</td>
<td>1.2</td>
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<td>1.3</td>
<td>1.6</td>
<td>1.3</td>
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<td>1.3</td>
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<td>95-97</td>
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<td>1.4</td>
<td>1.2</td>
<td>1.3</td>
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<td>1.4</td>
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<td>81</td>
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<td>RD+ADHD (n = 16, 7 F, 9 M)</td>
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<td>94.8</td>
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<td>Mdn</td>
<td>126.5</td>
<td>95.0</td>
<td>90-94</td>
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<td>114</td>
<td>98-100</td>
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<tr>
<td>Control (n = 1,108, 575 F, 533 M)</td>
<td></td>
<td>M</td>
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<td>99.6</td>
<td>—</td>
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<td>SD</td>
<td>16.6</td>
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<tr>
<td>Total (N = 1,262, 643 F, 619 M)</td>
<td></td>
<td>M</td>
<td>126.7</td>
<td>98.5</td>
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<td>SD</td>
<td>16.8</td>
<td>10.0</td>
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<td>60-69</td>
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</tbody>
</table>

Note. ADHD = attention-deficit/hyperactivity disorder; AQ = attentional problem behavior; PA = phonemic awareness; PA\(_{\text{ FAC}}\) = PA factor (orthogonal); RAN = rapid automatized naming; RAN\(_{\text{ FAC}}\) = RAN factor (orthogonal); RANPA = unweighted average of alphanumeric RAN (RAN\(_{\text{ an}}\)) and PA (PA\(_{\text{ com}}\)); RD = reading disability; WR = word reading.

*Subsample scores (RD: n = 18, ADHD: n = 11, RD+ADHD: n = 9, Control: n = 18, Total: n = 52).
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_{corr}). 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$_{an}$ were found to be moderately correlated, $r_{(RANan,PAan)} = .38$. 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, $r_{(RANletters-RANDigits)} = .76$, and the two PA subtasks, $r_{(PAsubstitution-PAdeletion)} = .67$. 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$_{an}$, 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.

<table>
<thead>
<tr>
<th>Variable</th>
<th>RANFAC</th>
<th>PAFAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAN digits</td>
<td>.93</td>
<td>.14</td>
</tr>
<tr>
<td>RAN letters</td>
<td>.90</td>
<td>.24</td>
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<td>PA substitution</td>
<td>.26</td>
<td>.86</td>
</tr>
<tr>
<td>PA elision</td>
<td>.12</td>
<td>.91</td>
</tr>
</tbody>
</table>

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 ($\eta^2$), 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.

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$_{sub}$ (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 $4 \times 2$
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

**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 (RANan) and PA (PAcom); 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 (RANan) and PA (PAcom); RD = reading disability.
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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 PAsubstitution 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 ($\eta^2$), 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 × 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 ($\eta^2$) 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, RANan 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 RANan (Predictions 4 and 5) impairments. Therefore, considering the presumed reciprocal relationships among WR, RAN, 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.

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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 Vooorde 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 RANan 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 RANan. One possible explanation for the subnormal RANan 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 $M - 1.5 \sigma$. 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 RANan and PA, and the combination.

Continuing the discussion on the concept of additivity, it appears that the effect sizes of RANan 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 RANan, PA, and the combination (see Table 3 and Figure 3). Despite a medium effect size, ADHD did not affect RANan 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**


