Neurocognitive profiling of children with specific or comorbid reading disabilities

de Groot, Barry

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Document Version
Publisher's PDF, also known as Version of record

Publication date:
2015

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

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Rapid Naming and Phonemic Awareness in Children with or without Reading Disabilities and/or ADHD

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. A second objective was to investigate whether comorbidity, i.e., the condition in which children show RD as well as ADHD, should be considered as an additive phenomenon. A total of 1,262 children, aged 8-13 years old, 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 phonemic awareness (PA) and alphanumeric rapid automatized naming (RAN). Clinical groups were compared to each other and contrasted to the control group. Although results indicate substantial effects for all three clinical groups on both types of 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. Secondly, although not fully additive in terms of magnitude, there is clear and consistent evidence for uniquely added value by either component in the comorbid group. Further theoretical and practical implications are discussed.

This chapter is based on:
3.1 Introduction

Although the past decades have shown great advances in the understanding of Reading Disabilities (RD) (Vellutino et al., 2004), there still remain theoretical and practical issues to be clarified. This article will focus 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 percent of the general population. Although for the majority of children with ADHD no reading disabilities are reported, estimates of the overlap between RD and ADHD range from 25 to 40 percent (e.g., August & Garfinkel, 1990; Boada, Willcutt, & Pennington, 2012; Willcutt & Pennington, 2000). These estimates are substantial and certainly warrant investigation into their genetic and cognitive nature. Various recent studies have provided a biogenetic answer to the overlap between dyslexia and ADHD (Ebejer et al., 2010; Paloyelis, Rijsdijk, Wood, Asherson, & Kuntsi, 2010; Stevenson et al., 2005; Willcutt et al., 2005). Although the evidence for a genetic link is accumulating, it remains unclear how these common genes are expressed at the cognitive-behavioral level. The present study addresses this issue by investigating two established reading-related cognitive processes, i.e., phonemic awareness (PA) and rapid automatized naming (RAN), in children with ADHD and/or RD. In the remainder of this introduction the evidence regarding the specific relationships of PA and RAN with RD and ADHD will be discussed, followed by a summary of the hypotheses of the present study.

3.1.1 Phonemic Awareness

RD

Phonemic awareness (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 sub-lexical 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 et al., 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 et al., 2008; Rack, 1994; Ramus et al., 2006; Snowling,
ADHD

Although deficient PA is typically not associated 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 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.”). Other examples of relatively demanding PA-tasks are so-called pig latin tasks, and 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 working memory, or impulsive response tendencies – which are characteristics of children with ADHD after all – 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, & Wiersma, 2011). Indeed, since this study employed such quite demanding PA-tasks, the latter prediction may well apply to the ADHD groups of the present study.

Comorbidity

Applying these insights to the issue of comorbidity, we come to the following hypotheses and predictions. As far as the reading-related component of PA is concerned, at least an equally strong contribution of PA as in the RD-only may be expected for the comorbid group. However, in this group there may exist additional PA-difficulties tied to ADHD, attributable to working memory or executive functioning (Bental & Tirosh, 2007; Bolden et al., 2012; Tiffin-Richards et al., 2008; Van De Voorde et al., 2011). Therefore, we predict that the comorbid group will show a stronger negative effect for PA compared to the RD group, especially when the more difficult task variant, i.e., phoneme substitution, is concerned.

3.1.2 Rapid Automatized Naming

RD

As predicted by the seminal Double Deficit Hypothesis (DDH) (Wolf & Bowers, 1999), a large number of studies have made clear that, in addition to PA...
difficulties, individuals with RD typically demonstrate impaired *rapid automatized naming* (RAN) skills (Bowers, 1995; Denckla & Rudel, 1974; 1976; Kirby et al., 2008; Logan et al., 2011; Torgesen et al., 1999; Torppa et al., 2012; Van den Bos, 2008; Van den Bos et al., 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 RANcolors, RANpictures, RAN digits, and RAN letters. For three reasons it seems important, however, to distinguish between alphanumeric (digits and letters) and non-alphanumeric (colors and pictures) subsets. First, alphanumeric naming-stimuli can be considered as more automatized than non-alphanumeric 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 than their non-alphanumeric counterparts (Stringer et al., 2004; Van den Bos & Lutje Spelberg, 2010; Van den Bos et al., 2002; Wagner et al., 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 will be restricted to alphanumeric stimuli.

**ADHD**

In contrast to findings of significantly poorer non-alphanumeric RAN performance (i.e., color and picture naming) in ADHD groups (Cutting, David, Wilkins, Sparrow, & Denckla, 2002; Semrud-Clikeman, Guy, Griffin, & Hynd, 2000; Stringer et al., 2004; Tannock, Martinussen, & Frijters, 2000), the evidence on suppressed alphanumeric RAN performance, i.e., letter and digit naming, in ADHD groups is virtually absent. On the one hand, this can be expected because the ADHD-only group is by definition free from RD, but more susceptible to inhibitory aspects involved in the processing of non-automatized (non-alphanumeric) naming stimuli. On the other hand, there might be a snake in the grass, because earlier studies have collapsed over stimulus types, or because alphanumeric naming has been under-investigated.

**Comorbidity**

With regard to comorbidity of RD and ADHD, RAN deficits are common in individuals with the combination of RD and ADHD (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. However, as RAN was found to be strongly related to PS, and as there was confounding of RAN non-alphanumeric and alphanumeric stimuli (McGrath et al., 2011), the specific role
of alphanumeric RAN remains rather illusive (Boada et al., 2012). Therefore, the question that still seems to apply to the comorbid group is whether the earlier mentioned inhibitory difficulties with non-alphanumeric naming stimuli generalize to alphanumeric RAN stimuli. Since these children also have developed word reading problems, and thus typically have not fully automatized alphanumeric symbol-name associations, these stimuli might be vulnerable to interference as well (Stringer et al., 2004). If this is true, one might expect the comorbid group to show even more severe alphanumeric RAN difficulties than the RD-only group. Bental and Tirosh (2007) did report evidence for this expectation.

Summarizing, the present study will specifically investigate how alphanumeric RAN and PA 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. However, subnormal PA performances are expected in the ADHD-only group as well, especially for the more difficult phoneme substitution task. Comparatively, the PA-performance patterns of the groups is predicted to be: Control > ADHD-only > RD-only > Comorbid. With regard to alphanumeric RAN, it is hypothesized that the RD groups, i.e., RD-only and RD+ADHD, will be severely impaired. However, the children with ADHD-only are also expected to score significantly lower than controls, but not as poor as the RD groups. Therefore, a similar comparative pattern to the one described previously for PA is expected: Control > ADHD-only > RD-only > Comorbid.

3.2 Method

3.2.1 Participants and procedure

This study involves a total of 1,262 Dutch children aged 8-13 years of age, mostly from the Northern region of the 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.

Word reading 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 word reading performance (see Table 3.1 below) was more than 1.5 standard deviations (SD) below the population mean. Assignment to either category with ADHD, i.e., ADHD-only or RD+ADHD, was based upon external psychiatric evaluation (i.e., a clinical ADHD diagnosis), according to DSM-IV-

Participants were excluded if they had: an IQ of more than 1.5 SD below average, an uncorrected hearing or visual disability, or if they had been diagnosed with a neurological disorder or a specific language impairment. 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, website, and doctors’ offices or otherwise.

Application of the above criteria yielded the group frequencies as specified in Table 3.1. This table also includes the age characteristics for each group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Frequencies</th>
<th>Age (in months)</th>
<th>n</th>
<th>♀</th>
<th>♂</th>
<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD</td>
<td>121</td>
<td></td>
<td></td>
<td>54</td>
<td>67</td>
<td>127.4</td>
<td>18.3</td>
<td>127</td>
<td>95</td>
<td>164</td>
</tr>
<tr>
<td>ADHD</td>
<td>17</td>
<td></td>
<td></td>
<td>7</td>
<td>10</td>
<td>122.5</td>
<td>15.3</td>
<td>127</td>
<td>95</td>
<td>146</td>
</tr>
<tr>
<td>RD+ADHD</td>
<td>16</td>
<td></td>
<td></td>
<td>7</td>
<td>9</td>
<td>124.8</td>
<td>19.1</td>
<td>127</td>
<td>94</td>
<td>165</td>
</tr>
<tr>
<td>Control</td>
<td>1,108</td>
<td></td>
<td></td>
<td>575</td>
<td>533</td>
<td>126.8</td>
<td>16.6</td>
<td>127</td>
<td>95</td>
<td>165</td>
</tr>
<tr>
<td>Total</td>
<td>1,262</td>
<td></td>
<td>643</td>
<td>619</td>
<td></td>
<td>126.8</td>
<td>16.8</td>
<td>127</td>
<td>95</td>
<td>165</td>
</tr>
</tbody>
</table>

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. Of participants younger than twelve years of age, 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 psycho-stimulant medication, i.e., methylphenidate, twenty-four hours before testing sessions.

### 3.2.2 Materials

**Word reading (WR).** This standardized index of word reading fluency is based on assessments of real word- and pseudoword reading ability (Van den Bos & Lutje Spelberg, 2010; Van den Bos et al., 1994). For the present sample it is approximately normally distributed, with a mean of 10, and a standard deviation of 3 (Wechsler scores). Please refer to §1.6.1 for a detailed description.

**Rapid Automatized Naming (RAN).** Alphanumeric RAN was assessed with RANletters and RANdigits (Van den Bos & Lutje Spelberg, 2010). Separate
standardized scores were computed for the subtests, as well as a standardized index of alphanumeric RAN (RANan). For the present sample, all three measurements are approximately normally distributed, with a mean of 10, and a standard deviation of 3 (Wechsler scores). Please refer to §1.6.2 for a detailed description.

**Phonemic Awareness (PA).** PA was assessed with the subtests PAelision, and PAsubstitution (De Groot et al., 2014). Separate standardized scores were computed for the subtests, as well as a standardized composite index of PA (PAcom). For the present sample, all three measurements are approximately normally distributed, with a mean of 50, and a standard deviation of 10 (T scores). Please refer to §1.6.3 for a detailed description.

### 3.2.3 Statistical analyses

In order to avoid confounding of the results, principal component analysis (PCA) with varimax rotation and Kaiser normalization was performed on the two alphanumeric RAN tasks and the two PA tasks (also see Tables 3.2 & 3.3). This procedure has resulted in the extraction of two orthogonal factors that clearly bear on RAN and PA respectively, and will be referred to from now on as RANFAC and PAFAC. Eighty-five percent of total variation could be explained by the communalities of these two factors.

Next, all other performance measures were transformed to z scores to match the scaling of RANFAC and PAFAC.

Table 3.2 Principal Component Analysis (PCA) of RAN and PA subtasks

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Extraction SS Loadings</th>
<th>Rotation SS Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total VAR (%)</td>
<td>Cum. (%)</td>
<td>Total VAR (%)</td>
</tr>
<tr>
<td>1</td>
<td>2.39</td>
<td>59.78</td>
<td>2.39</td>
</tr>
<tr>
<td>2</td>
<td>1.02</td>
<td>25.56</td>
<td>1.02</td>
</tr>
<tr>
<td>3</td>
<td>.35</td>
<td>8.72</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>.24</td>
<td>6.04</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3.3 Rotated factor loadings of RAN (RANFAC) and PA (PAFAC) components

<table>
<thead>
<tr>
<th>Component</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>
</tr>
<tr>
<td>PAelision</td>
<td>.26</td>
<td>.86</td>
</tr>
<tr>
<td>PAsubstitution</td>
<td>.12</td>
<td>.91</td>
</tr>
</tbody>
</table>
3.2.4 Factorial design

In order to estimate the individual and interactive effects of RD and ADHD, univariate analysis of variance (ANOVA) was performed according to a 2 x 2 between subjects factorial design with RANFAC and PAFAC as dependent variables, and RD vs. Non-RD and ADHD vs. Non-ADHD as independent variables. Moreover, the model was corrected for any residual age effects by including age in months as a covariate.

To accommodate for unequal sample sizes, stratified random (re)sampling with replacement was performed with 1000 iterations and the experimental group as the stratification variable. Each instance was subjected to a separate analysis, and all relevant parameters were averaged afterwards 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 word reading distribution with the equivalent size of that of the RD-criterion, i.e., more than 1.5 SD above the population mean.

3.2.5 Group comparisons

A second series of ANOVA's were performed with one four-group variable – consisting of the three clinical groups and the control group – as the independent variable.

3.2.6 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 or 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 or large effects sizes, respectively (Cohen, 1973).

3.3 Results

3.3.1 Descriptive statistics

Figure 3.1 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. With regard to the clinical groups Figure 3.1 shows clear
differences between the control group and the clinical groups. Within the clinical 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 on all measurements.

Regarding word reading (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 only included participants who scored more than 1.5 SD below the population mean. However, although not as deficient as the scores of the RD groups, the WR performance of the ADHD-only group ($z = -0.68$) can be considered as subnormal as well.

With regard to phonological processing, Figure 3.1 shows that both RAN and PA are severely impaired in the RD-only group, with a small negative tilt towards PA. The comorbid group shows the poorest performances. Similar to their subnormal WR performance, the ADHD-only group, compared to controls, also shows subnormal performance on the phonological measures.

Figure 3.1  Plotted means (z scores) and standard error bars of WR, RAN, PA, RANFAC, and PAFAC measures for RD-only, ADHD-only, RD+ADHD, and controls

RAN and PA in children with and without RD and/or ADHD
3.3.2 Effect Sizes for mean differences

*Figure 3.2* depicts the clustered standardized effect sizes (Cohen’s $d$)\(^1\) 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 presented 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 seems to exist for the ADHD-only and the comorbid groups, for which the effects are in similar ranges.

![Standardized mean difference effect sizes (Cohen's d)](image)

Secondly, *Figure 3.2* indicates that the effect sizes of group membership on phonological processing clearly are largest for the RD groups, compared to the ADHD-only group. Notwithstanding this apparently 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.

\(^1\) Effect Sizes were also calculated according to Hedges’ $g$ (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.
3.3.3 Analysis of variance

In order to investigate (1) the individual and interactive effects of RD and ADHD and (2) those of group membership on phonological processing in terms of explained variance ($\eta^2$), two separate series of analyses were conducted.

**Factorial design (1)**

Table 3.4 contains the results of the first series of ANOVA’s, employing a factorial design, and listing the main effects and the interactions of RD and ADHD.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Measurement</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD</td>
<td>RANFAC</td>
<td>14.80</td>
<td>.003</td>
<td>.22</td>
</tr>
<tr>
<td>versus</td>
<td>PAFAC</td>
<td>13.94</td>
<td>.004</td>
<td>.18</td>
</tr>
<tr>
<td>Non-RD</td>
<td>RANPA</td>
<td>26.51</td>
<td>&lt;.001</td>
<td>.32</td>
</tr>
<tr>
<td>ADHD</td>
<td>RANFAC</td>
<td>3.34</td>
<td>.159</td>
<td>.05</td>
</tr>
<tr>
<td>versus</td>
<td>PAFAC</td>
<td>5.42</td>
<td>.071</td>
<td>.06</td>
</tr>
<tr>
<td>Non-ADHD</td>
<td>RANPA</td>
<td>7.79</td>
<td>.023</td>
<td>.11</td>
</tr>
<tr>
<td>RD x ADHD</td>
<td>RANFAC</td>
<td>1.17</td>
<td>.433</td>
<td>.01</td>
</tr>
<tr>
<td>Interaction</td>
<td>PAFAC</td>
<td>1.85</td>
<td>.313</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>RANPA</td>
<td>2.32</td>
<td>.225</td>
<td>.03</td>
</tr>
</tbody>
</table>

As shown in Table 3.4, the first 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 x ADHD interaction effect was significant.

**Group comparisons (2)**

The results of the second series of analyses are presented in Figure 3.3, depicting the explained variances ($\eta^2$) of each measure, clustered by clinical group on the horizontal axis. From Figure 3.3 it becomes evident that phonological processing is particularly affected in the RD groups, 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 of ADHD for the separate measurements seem modest. 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. Finally, post hoc testing indicated a significant difference for RANPA between the ADHD-only and the comorbid group (p = .04).

![Figure 3.3 Explained variances ($\eta^2$) of RANFAC, PAFAC and RANPA per group](image)

### 3.4 Discussion

This study sought to investigate two types of reading-related phonological processing – i.e., alphanumeric rapid naming (RAN$_{an}$) and phonological awareness (PA) – in children with RD and/or ADHD, who attend the upper-level grades of Dutch primary education. As such, it provides a rare set of findings from the Dutch population, as far as word reading related research on PA and RAN for these groups is concerned.

Results indicate large effect sizes for RAN$_{an}$ and PA in the two RD groups. Previous studies (Kroese et al., 2000; McGrath et al., 2011; Purvis & Tannock,
have concluded that PA and RAN are generally more closely associated with RD than to ADHD. Concordantly, as predicted, we found quite substantial PA and RAN\textsubscript{an} deficits in both RD-only and comorbid participants. However, also for the ADHD-only group significant effect sizes – albeit medium sized – were found, which means that this group performs below their typically developing peers. With regard to the ADHD-only group’s RAN\textsubscript{an} performance, the effect may be due – as hypothesized – to interference problems which also might account for their mildly but significantly lower WR performance (see Figure 3.1). Shanahan et al. (2006) also found slower naming speed in individuals with RD and ADHD. These results substantiate the idea that a processing speed deficit exists in both RD and ADHD, although subjects with RD clearly displayed greater RAN\textsubscript{an} and PA deficits than subjects with ADHD-only.

As to the ADHD-only group’s subnormal PA performance, a different mechanism, i.e., working memory problems, was hypothesized. This might account for their lower WR performance (see Figure 3.1) as well. Post hoc analysis revealed some interesting changes in the predictive patterns when controlling for word reading. As might be expected, this procedure positively affected the RD groups most. With regard to RAN\textsubscript{an}, the RD-only and comorbid groups’ predicted means now approached the Control group’s values, z values being -0.08, -0.19, and -0.08, respectively. The ADHD-only group still showed a negative z-score of -0.32. PA outcomes were somewhat different from RAN\textsubscript{an}, in the sense that, controlling for WR, there still remained a significantly lower z score for the RD-only group ($z = -0.32$, $p = .016$), whereas the ADHD-only and comorbid groups showed even larger negative predicted means ($z = -0.52$, and $z = -0.50$, respectively), but the latter differences lacked the statistical power to become significant. Therefore, we only can speak of trends. Altogether, this post hoc analysis suggests that non-reading-related processing may pose an independent negative influence to the ADHD groups’ RAN\textsubscript{an} performance, and in particular their PA performance. As to alphanumeric RAN, inhibitory problems might offer a viable explanation. With regard to PA, problems with working memory and/or executive functioning seem plausible candidates in the ADHD-only and comorbid groups (Bental & Tirosh, 2007; Bolden et al., 2012; Tiffin-Richards et al., 2008; Van De Voorde et al., 2011). Similarly, the significant subnormal PA performance for the RD-only group, that remained after controlling for word reading performance, might be explained by additional working memory problems (De Groot et al., 2014; Tiffin-Richards et al., 2008).

As a second main point, the discussion will be extended to the issue of comorbidity in relation to the concept of additivity. We have presented the results of two analyses. The first one investigated the effect sizes of the differences of the means of RANFAC, PAFAC and RANPA for each clinical group,
as compared to the control group. In line with the previous section, the ADHD-only group showed the smallest effect sizes.

Focusing on the comorbid group, it appears that the effect sizes do not add up in terms of magnitude (see $d$ values in Figure 3.2). This is similar to the results of Shanahan et al. (2006) who found that their processing speed factor, which can be considered as closely related to RAN (McGrath et al., 2011), as well as a RAN factor, were under-additive for the comorbid group. However, our second analysis, in which the main effects and their interactions were investigated, yielded consistent evidence for uniquely added value by either of the components of RANFAC and PAFAC (see Table 3.4 & Figure 3.3). Thus, the most severe impairments were found in children with the combination of RD and ADHD.

Finally, these results carry relevant practical implications for the (differential) diagnosis and treatment of groups 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 whereas comorbid cases of ADHD+RD run the risk of being excluded from these assignments. However, considering one of the main results of this study, that is, the RD-only and the comorbid groups are equally seriously impaired on word reading performance, and do not show qualitatively different underlying profiles of PA and RAN, a sharp diagnostic differentiation seems not warranted. One exception to the finding of qualitatively similar profiles, should, however, be mentioned. Children with both RD and ADHD, compared to those with RD-only, seem more prone to difficulties with tasks involving a relatively high working memory load. The presently employed PA substitution task provides an example. In order to correctly interpret the comorbid group’s poor PA performance, and to differentiate this from the assumed mainly phonologically-linguistically-based deficient PA performance of RD-only children, it would be mandatory to consider working memory capacity and executive functioning as well. The recent literature (Bolden et al., 2012; Holmes, Gathercole, & Dunning, 2009) provides ample examples of how such findings can be incorporated when designing adaptive treatment programs for comorbid groups.