Comorbidity between attention deficit hyperactivity disorder and reading disabilities : Implications for assessment and treatment

Ana Miranda* María Jesús Presentación** Rebeca Siegenthaler** Carla Colomer* and Vicente Pinto**

*Department of Developmental and Educational Psychology

University of Valencia, Spain

**Department of Developmental, Educational and Social Psychology, and Methodology

Jaume I University, Castellón, Spain

Correspondence concerning of this article should be addressed to Ana Miranda, Department of Developmental and Educational Psychology.

University of Valencia

Avda. Blasco Ibañez, 21.

46010 Valencia (Spain)

Electronic mail may be sent to Ana.Miranda@uv.es

Abstract

Comorbidity of attention deficit hyperactivity disorder (ADHD) and reading disorder (RD) is greater than what would occur by chance. Considering the well-documented adverse impact of both ADHD and RD on development, the presence of both conditions may lead to particularly poor outcomes for affected people. This chapter, which reviews 43 research studies carried out in the last decade that have focused on the link between ADHD and RD, is divided into two broad nuclei of contents. First, studies are described that contribute information about characteristics of the comorbid phenotype. Second, studies related to procedures directed toward evaluation and intervention in this problem are analyzed. The review carried out does not make it possible to extract definitive results on the exact nature of ADHD and RD comorbidity or, even less, reach conclusions about its causes. However, the literature-based evidence shows a cognitive profile of ADHD+RD characterized by failure of various functions that can produce more severe functional deficits and worse neuropsychological, academic, and behavioral outcomes. Furthermore, the analysis of the set of results from the studies shows a limited efficacy of pharmacological and psychopedagogical treatments, and highlights the need for continued research on this topic.

From a clinical and educational standpoint, the conclusions derived from this review underline the importance of performing an exhaustive evaluation of children and adolescents with symptoms of ADHD and/or RD, in order to be able to plan interventions with greater possibilities of success in each case.

Comorbidity between attention deficit hyperactivity disorder and reading disabilities: Implications for assessment and treatment

Introduction

Attention deficit hyperactivity disorder (ADHD) and reading disabilities (RD) are two of the most frequent childhood developmental disorders. Each of them affects between 6% and 9% of school-age children, although these percentages decline to 5% when the DSM-IV-TR (2000) criteria are applied.

Subjects with RD are characterized by a reading performance, measured by individually-administered normalized accuracy or comprehension tests, that is far below what would be expected given the child's chronological age, IQ, and corresponding grade in school. Historically, experts have basically agreed in identifying a series of abilities or skills generally falling under the epigraph of phonological processing as responsible for RD in alphabetic languages. Various parameters can reflect adequate or inadequate phonological processing and, therefore, differentiate between good and poor readers: decoding skills ("phonological decoding" or "word decoding"), phonological awareness ("phoneme awareness"), and lexical access speed. In addition, although less important and less frequent, difficulties in performing naming speed ("rapid naming skills"), verbal stimuli (letters, words, digits) and, even, non-verbal (colors, drawings) tasks (Pennington, Groisser & Welsh, 1993; Purvis & Tannok, 1997) have been highlighted. For some authors, this double deficiency detected in people with dyslexia reflects the intervention of processes independent from reading, giving rise to interesting proposals like the double-deficit model by Wolf and Bowers (1999).

Furthermore, other studies suggest that in the RD groups there is an association between phonological processing dysfunctions and a marked inability to store and process verbal material in the short-term memory (Rapala & Brady, 1990; McDougall, Hulme, Ellis & Monk, 1994). The majority have specifically related reading problems to a deficit in the phonological loop which could damage, for example, temporal auditory processing. However, only a few have suggested that there could also be difficulties in the other essential component of WM storage, the visuospatial, or even in some of the central executive (CE) functions.

Generally, although not all the questions have been answered, it is possible to conclude that there is a large body of empirical evidence showing that phonological storage and processing skills would be more affected than executive functioning processes in RD, in contrast to the tendency usually found in ADHD.

On the other hand, ADHD is a persistent pattern of inattention and/or hyperactivity/impulsivity, more frequent and serious than what is usually observed in subjects at a similar developmental level. Basing their work on the similarity between ADHD symptoms and the consequences of frontal lobe damage, many authors have pointed out that in ADHD the executive functions (EF), understood as the set of cognitive functions involved in the problem-solving processes when trying to achieve a certain objective or goal, might be especially affected.

These executive functions encompass many domains: problem-solving strategies, inhibitory control at a cognitive and/or motor level, working memory, self-regulation, cognitive flexibility, interference control or planning.

In general, the neuropsychological models of ADHD recognize the important role of the EF in this disorder (Barkley, 1997; Rapport, Chun, Shore & Isaacs, 2001). However, the empirical findings in this regard are not as consistent as might be expected. The meta-analytic review by Willcutt, Doyle, Nigg, Faraone and Pennington (2005) suggests that ADHD is associated with weaknesses in several key EF domains. The strongest and most consistent effects were obtained on measures of response inhibition, vigilance,spatial working memory, and some measures of planning.

This review also point to the existence of dysfunctions with very little executive charge in ADHD, dysfunctions that affect, for example, processing speed, naming speed, and fine and gross motor skills. In sum, there is sufficient evidence to defend the existence of a primary executive dysfunction in ADHD, but when the effect size of the EF in groups with and without ADHD is analyzed, the results only show a moderate effect, suggesting, therefore, that EF weaknesses are neither necessary nor sufficient to cause all cases of ADHD.

It has been demonstrated that ADHD and RD present a higher index of co-occurrence than what would be produced by mere chance. Thus, the estimations of RD among children diagnosed with ADHD range, according to different authors, from 10% to 40% (Del'Homme, 2007). On the other hand, among the population of children diagnosed with RD, the presence of ADHD has been estimated at between 15% and 40% (Shaywitz, Fletcher & Shaywitz, 1995; Willcutt & Pennington, 2000).

By themselves, these data are sufficiently noteworthy to justify researchers' interest not only in studying the two disorders separately, but also in analyzing their high comorbidity. Considered in isolation, the basic symptomatology that defines RD and ADHD does not coincide, and the research has focused on identifying the combination of dysfunctions that could constitute the main deficit in the ADHD+RD group. These dysfunctions must, logically, affect phonological processing (PP), working memory (WM) and executive functioning (EF). In addition, the high coincidence of the two disorders (ADHD+RD) poses additional questions for investigation: What are the specific psycho-cognitive characteristics of this group? Are these characteristics similar to or different from those exhibited by the pure ADHD and RD groups? Can one of the disorders be considered more "primary" than the other? How should this group be evaluated? Should the treatments for the ADHD+RD group include phonological processing and EF, or should they focus on one specific aspect?

In an attempt to respond to these and other similar questions, different hypotheses have been proposed. The phenocopy hypothesis defends the idea that the only neuropsychological functions affected in ADHD+RD would be those characteristic of the RD group, related to phonological processing (Pennington et al., 1993). The cognitive subtype hypothesis considers the ADHD+RD group as a specific disorder (Rucklidge & Tannock, 2002), and predicts that the neuropsychological impairments follow an interactive pattern, different from those that characterize pure ADHD and RD. The hypothesis of a common genetic origin for both disorders (Willcutt et al., 2003) predicts the existence of some neuropsychological deficits common to RD, ADHD and ADHD+RD.

De Jong, Oosterland and Sergeant (2006) carried out an excellent review of the bibliography on the comorbidity of ADHD and RD, analyzing the repercussions of the results in identifying ADHD and RD endophenotypes and their comorbidity. These researchers concluded that executive functioning deficits, (particularly in inhibition and working memory) appear to be an endophenotypic candidate for the comorbidity of ADHD and RD. The present study, along the lines of de Jong et al. (2006), is designed to examine the most recent studies that contribute to the knowledge base about the cognitive profile of the comorbid group (ADHD+RD). Furthermore, completing the analysis of comorbidity, a second objective of this study consists of reviewing the studies on diagnosis and treatment focused on the specific problematic of the ADHD+RD group, rating their usefulness in order to act with the greatest efficacy in the practical realm.

Method

Systematic literature searches were conducted using PsycINFO, ERIC and Medline databases from 2000 to July 2010. The terms ADHD, attention-deficit disorder and attention deficit/hyperactivity disorder were cross-referenced separately with reading disability, reading disorder, and dyslexia. The tables of contents of journals that commonly publish articles relevant to this topic were also reviewed (*Exceptional Children, Journal of Abnormal Child Psychology*, *Journal of the American Academy of Child and Adolescent Psychiatry, Journal of Attention Disorders*, *Journal of Learning Disabilities and Learning Disability Quarterly*). The broad search strategy resulted in a total of 514 articles. In an initial filtering, articles were eliminated that were duplicated (145), had only a theoretical nature (e.g., reviews that did not include an empirical study) (139), or were not strictly scientific articles, such as dissertation abstracts (29), erratum, introductions to a special issue or summaries (28). In the second filtering, among the empirical studies, articles were eliminated that focused on the analysis of causal biological factors (e.g., genetic, neurological, perinatal risk) (49), or did not include the ADHD+RD comorbid group (81).

Results

Finally, a total of 43 publications met the conditions established in the present study. Of them, seventeen analyzed specific components of the set of cognitive processes that seem to be involved in the relationship between ADHD and RD by comparing the performance of the pure groups and the combined group. Another 13 studies, with more complex proposals, combined measures of various cognitive domains in order to test the double dissociation hypothesis and further examine the profile of the group with both problems and the nature of the comorbidity. Finally, 13 studies were designed to test the efficacy of evaluation tests and treatments in these clinical groups. The following sections review the most interesting results from the research in each of these categories.

ADHD and RD. Single dissociation studies

The majority of the set of more specific studies have focused on the comparative analysis of the groups on measures related to reading (phonological awareness and naming speed, above all) or actual reading performance (reading words and pseudowords, text reading and reading comprehension). Other investigations have concentrated on the study of cognitive processes linked to executive functioning (EF).

Finally, a few studies have examined the repercussions of ADHD and RD and/or their association in the academic and socio-emotional spheres, providing information to further understand their transcendence in functional terms (see Table 1).

Insert Table 1

Reading processing. One of the most complete studies among those that have evaluated reading in these groups was conducted by Ghelani, Sidhu, Jain and Tannock (2004). These authors applied a battery of tests of reading component processes (lexical access, text reading, reading comprehension and naming speed) to adolescents with ADHD, RD, RD+ADHD and controls. Regarding lexical access and text reading, Ghelani et al. (2004) found that, while the adolescents with RD (RD and ADHD+RD groups) showed significant difficulties on all the word, pseudoword and text reading measures, the adolescents with ADHD showed adequate reading skills, although with subtle difficulties in text speed and accuracy and word speed. Reading comprehension was evaluated by means of a read-aloud task and another silent reading task, which showed different deficits in the groups on these measures. Specifically, the adolescents with ADHD had slight difficulties in silent reading comprehension. The adolescents with RD (problems in word identification and word attack) obtained scores on reading comprehension (oral and silent) which, although low compared to the control and ADHD groups, were within normal range. As expected, the comorbid group performed similarly to the RD group on the silent reading tasks, but they had better scores on oral comprehension. One noteworthy finding is that, while both groups of adolescents with RD (alone and with ADHD) showed a generalized impairment in naming speed for all types of stimuli (words, digits, colors and figures), the group with ADHD showed a low response only on colors and figures. Ghelani et al. (2004) concluded that these results could provide evidence of the existence of a processing speed problem related to inattention.

The importance of naming speed in RD + ADHD in Chinese readers who use a non-alphabetic system (Cantonese) has also been highlighted by Chan, Hung, Liu and Lee (2008). In Cantonese-speaking children with RD+ADHD and pure ADHD, these researchers analyzed the prevalence of different impairments related to reading problems: phonological processing, naming speed and orthographic processing. They found that the RD+ADHD group had a significant impairment in naming speed (62.8% of the cases). The combined group also experienced deficits in orthographic knowledge (37.2%) and, to a lesser degree, phonological problems (11.6%). With regard to the number of concurrent reading deficiencies, 41.9% of the Chinese children with RD+ADHD had only one cognitive impairment, 39.5% had 2 impairments, and 4.7% presented 3 impairments, with the most common being the combination of naming speed and orthographic processing deficits. Furthermore, the fact that the important naming speed problems of the RD+ADHD children do not occur to the same degree in children with ADHD alone (18.4%) provides support for the hypothesis of a specific naming speed deficit in RD.

Time Perception. One of the explanatory hypotheses for identification of ADHD is the existence of a deficit in time perception. Toplack, Rucklidge, Hetherington, John and Tannock (2003) studied time perception in children and adolescents with ADHD (with and without RD), using two tasks related to the duration of tones. The first task consisted of determining which was the longer of two sounds (duration discrimination). The second consisted of reproducing the duration of tones (duration estimation). These authors also used a third control task consisting of frequency discrimination. Both groups (ADHD and ADHD+RD) presented some alterations on the duration discrimination tasks and also on the accuracy with which they reproduced the intervals on the duration estimation task, although the comorbid group was affected more severely. However, there were no alterations on the control task of frequency discrimination. Likewise, both the participants with ADHD and those with ADHD+RD showed a significant intra-individual variability on the duration estimation task. The authors concluded that deficits related to time estimation are associated with ADHD, and more consistently with ADHD+RD, and that these deficits, together with the great intra-individual variability, can have cascade effects in the time organization of the behavior in children and adolescents with these disorders. Nevertheless, the absence of an RD group in the study by Toplack et al. (2003) makes it impossible to draw solid conclusions about time perception in this clinical group and its differences with the ADHD groups.

Somewhat different results on time perception were obtained by Tiffin-Richards, Hasselhorn, Richards, Banaschewsky and Rothenberger (2004), who examined the performance of German children using a computer-mediated finger-tapping paradigm. The time perception of auditory stimuli was evaluated using discrimination tasks (which involve only time perception) and reproduction tasks (which also require motor responses). Tiffin-Richards et al. (2004) did not find differences among the groups (ADHD, RD, ADHD+RD and control) on any task, which would indicate that the capacity to maintain a certain response rate (free-tapping) or adjust the response to a certain stimulus pattern (synchronized tapping) was not affected in any of the clinical groups. Furthermore, the groups analyzed did not show differences in intra-individual variability when reproducing different intervals. However, without reaching significance, the RD and ADHD+RD groups showed special difficulties in reproducing rhythmic patterns when the complexity of these patterns was increased.

Temporal auditory processing. In order to analyze the hypothesis of the temporal auditory deficit in RD and its relationship with ADHD, different psychoacoustic tasks have been used by Breier et al.: psychoacoustic tasks of continuous voice onset time, continuous tone onset time, judging temporal order and discrimination, with verbal auditory stimuli (phonemes) and non-verbal ones (tones). In contrast to their first results (Breier et al., 2001), the latest studies of children with RD and/or ADHD have not completely confirmed the existence of a temporal auditory processing deficit in any of the cases. Instead, they provide support for the existence of a specific impairment in language perception in children with RD. It was observed that the groups with RD did not present a specific sensitivity to the intervals between stimuli (ISI), but they performed worse on tasks with verbal stimuli than children without RD, and this occurred independently of the presence of ADHD (Breier , Gray, Fletcher, Foorman & Klaas 2002). When analyzing the temporal and non-temporal auditory perception of non-verbal stimuli, a deficit was found only in the detection of tones with an asynchronous temporal onset in children with RD. However, the presence of ADHD was associated with a general reduction in performance across tasks. The pattern of results did not indicate a pervasive impairment in auditory temporal function in children with RD, but it did suggest a possible sensitivity to backward masking in this group. Results also indicated that the comorbid presence of ADHD is a significant factor in the performance of children with RD on psychoacoustic tasks. (Breier, Fletcher, Foorman, Klaas & Gray, 2003). An additional finding was that there was a significant correlation between phonological processing (phonological awareness and decoding) and auditory processing measures, although only in the groups without ADHD (controls and RD).

Motor Skills. Kooistra, Crawford, Dewey, Cantell and Kaplan (2005) analyzed different motor measures (gross, fine and integrated) in ADHD and their relationship to the presence of other disorders such as RD and ODD. The researchers compared the performance of children with ADHD, RD, ADHD+RD, ADHD+ODD, ADHD+RD+ODD and controls on the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) and the Beery Test of Visual-Motor Integration (VMI). Kooistra et al. (2005) found that all the groups, except pure ADHD, scored lower than the control group on the gross and fine motor skills test. On the VMI, all the clinical groups performed significantly worse than the control. The results suggest that the motor problems of ADHD appear to be associated with the presence of comorbidity, and that the level of RD seems to be a key factor in predicting them.

Working Memory (WM).The studies have been based on the Baddeley working memory model, which proposes the subdivision of the WM into three components: a control system with limited attentional capacity called the central executive (CE), assisted by two subsidiary slave systems, the phonological loop, responsible for temporary storage and processing of verbal information; and the visuospatial sketchpad, specialized in short-term retention of visual information.

Roodenrys, Koloski and Grainger (2001) investigated the phonological loop and CE in children with RD and both RD and ADHD, showing that the children with RD and ADHD+RD were impaired in their use of the phonological loop compared to the control group.

Likewise, both groups, RD and ADHD+RD, performed worse than normal controls on tasks involving a combination of the phonological loop and CE, with the comorbid group showing poorer functioning than the RD group. Finally, ADHD+RD performed worse than RD and control groups on tasks that only evaluated the CE. The authors concluded that the data demonstrate a deficit in phonological loop functioning associated with RD, and an independent deficit in the central executive associated with ADHD. However, children with only ADHD did not participate in their investigation, so that this study cannot directly demonstrate that CE deficits are specific to ADHD.

Martinussen and Tannock (2006) found that verbal and spatial CE and spatial storage were affected in children with ADHD, RD and ADHD+RD, while only the two groups with RD showed an additional deficit in verbal storage. Specifically, symptoms of inattention, and not those of hyperactivity/impulsivity, were associated with memory impairments. Furthermore, these authors found that reading achievement and inattention symptoms contributed unique variance to verbal CE processing, and they concluded that verbal central executive deficits (WM) may be a common neuropsychological weakness in children who exhibit inattention symptoms and/or language learning problems.

Another study by Kibby and Cohen (2008) provided information confirming the consistency of verbal memory deficits affecting RD and RD+ADHD groups. They applied the Children's memory scale (CMS: Cohen, 1997) to children with ADHD, RD, RD+ADHD and controls. The results of between-groups comparison analyses showed that spatial memory was partially affected in the ADHD group, especially in subjects who were not taking medication. However, the RD group was affected on verbal memory tasks, specifically on tasks that require a phonetic coding of the material, as their coding by meaning was correct. Finally, the RD+ADHD groups had impairments consistent with both disorders, but no additional deficits.

Laasonen, Leppämäki, Tani and Hokkanen (2009) administered the WAIS-III to a sample of adults from the Adult Dyslexia and Attention Deficit Disorder Project in Finland (Project DyAdd). The findings demonstrated that only the two groups with dyslexia, with and without ADHD, showed a poorer performance on WM, while all the clinical groups were poorer in processing speed than controls.

In addition to working memory, some studies have also evaluated an extended spectrum of executive functions. Seidman, Biederman, Monuteaux, Doyle, and Faraone (2001) evaluated children with ADHD with and without learning disabilities (LDs), both in reading and in arithmetic, comparing them with a control group on a broad battery of neuropsychological tests. In their analysis, participants with ADHD+RD performed significantly worse than ADHD and controls on the Stroop test and on a list- learning test (WRAML), although, surprisingly, they performed better on the auditory CPT (Continuous performance test). The authors found that more severe neuropsychological dysfunctions were associated with comorbid LDs in ADHD children, especially when arithmetic difficulty was present.

Academic and socio-personal adaptation. The studies on this topic agree that the academic failure of children with ADHD seems to worsen when there is an associated RD. Bonafina, Newcorn, McKay, Koda and Halperin (2000), for example, studied the academic and behavioral functioning of children with ADHD divided based on their full scale IQ (FSIQ) and reading ability. Generally, the academic performance in language and mathematics of children with ADHD and reading problems was significantly lower than that of children with

ADHD but no RD. With regard to behavioral functioning, there were no significant differences in behavioral problems (ODD and CD) among the 4 groups, although there was a tendency toward a greater problematicity in the 2 groups with more extreme reading levels (brilliant and severe RD).

The relationship of the mathematics disorders (MD) and RD in school children with ADHD has also been explored by Capano, Minden, Chen, Schachar and Ickowicz (2008). For this purpose, they evaluated a large sample of children with ADHD, ADHD+RD, ADHD+MD and ADHD+RD+MD on cognitive, language, mathematical achievement and reading tests. Capano et al. (2008) found that MD was common in school-age children with ADHD (18.1% de MD+ADHD) and frequently associated with RD (9.9% de ADHD+ RD+MD). Their results also showed that the ADHD and RD association (just as with MD) is related to lower scores on IQ, language and academic variables, than ADHD alone. However, the ADHD+RD+MD group was the most affected, which would indicate a unique biological cause.

The longitudinal study by Willcutt, Betjemann, Pennington et al. (2007) shows special interest in closely examining the academic, social and behavioral functioning of groups with RD and/or ADHD. Their sample is composed of children and adolescents identified in the Colorado Learning Disabilities Research Center Twin Study and re-evaluated after a period of 5 years, when they were adolescents or young adults. The findings confirmed that the comorbidity of RD and ADHD is frequently stable over time. Even when children with RD or ADHD do not meet the criteria for both disorders, often over time their scores for the other disorder rise. Regarding the groups analyzed, it was shown that the initial RD were associated with high scores on academic difficulties, depression and behavioral problems. The initial ADHD group was related to academic (significant, although less than the RD group) and social difficulties. This group, together with the RD+ADHD group, showed high scores on almost all the comorbid disorders (anxiety, depression, ODD, CD, alcohol and marijuana abuse) 5 years later. Moreover, the group with RD+ADHD also presented more stable deficits in reading than the RD, and were more affected than the pure RD and ADHD groups on measures of academic functioning and social difficulties. They also received more psycho-stimulant medication and special education. These results confirm that the co-occurrence of RD and ADHD increases the risk of negative results in adolescents and young adults, and they highlight the need for interventions for this group that take both disorders into account.

Finally, the longitudinal study by Pisecco, Baker, Silva and Brooke (2001) looked closely at the possible existence of initial temperamental and linguistic markers of RD and ADHD. Pisecco et al. (2001) investigated whether children who showed clear enough symptoms to receive a diagnosis of RD and/or ADHD at the age of 11 had presented differences in linguistic skills and temperamental traits ("locus of control") when they were 3 and 5 years old. In their study, the participants were children with ADHD, RD+ADHD, RD and controls, all of them taken from the Dunedin Multidisciplinary Health and Development Study (New Zealand). The authors expected that the children who had RD at the age of 11 would have shown deficits in linguistic skills (reception and expression) at the ages of 3 and 5, and that the children in the groups with ADHD would exhibit more "low control" behaviors at the ages of 3 and 5. They found that boys from the RD groups consistently exhibited deficiencies in receptive language; specifically, the children with reading disabilities and ADHD experienced the most significant receptive language impairment. In regard to expressive language, children from the RD-only group exhibited significantly more language related problems at age 3 than the children from the comparison group. For locus of control, at 3 and 5 years old, only the group that would later receive a diagnosis of RD+ADHD showed a significantly greater number of “uncontrolled” behaviors. In contrast to what was expected, locus of control was not an early indication of greater risk of having ADHD than RD.

ADHD and RD. Double Dissociation Studies

In double dissociation studies, processes are selected that are presumed to be primarily impaired in one disorder, but not in the other, so that a classic double dissociation occurs when two disorders are associated with opposite patterns of impairment in two different cognitive domains. The findings offer important information for increasing knowledge about the comorbid group and explaining the comorbidity between ADHD and RD (see Table 2).

Insert Table 2

Several studies support a partial double dissociation between ADHD and RD, without revealing common deficits between the two disorders and comorbid group showing the additive combination of the deficits associated with each single disorder. Willcutt et al. (2001) compared individuals with ADHD, RD, RD+ADHD and controls on measures of executive functioning and phonetic awareness. They found that children with ADHD had difficulties in executive functioning, specifically in inhibition, but not in working memory, set-shifting or phonological processing, when intelligence was introduced as a covariable in the analyses (FSIQ was covaried), while the children with RD exhibited phonological deficits and verbal working memory deficits. The comorbid group showed impairments on virtually all measures. Therefore, these authors found a partial double dissociation between RD and ADHD, with phonological processes and verbal working memory deficits associated with RD but not with ADHD, and inhibitory deficits associated with ADHD but not with RD.

Different naming speed tasks (colors and digits), together with balancing tests were applied to children with RD, ADHD, RD+ADHD and controls in a study by Raberger and Wimmer (2003). The most noteworthy findings show an association between poor performance on naming speed tasks and RD, and a relationship between poor balance and ADHD.

Consistent with the central prediction of a double dissociation, Weiler, Berstein, Bellinger and Waber (2002) found that children with ADHD/IA (with a predominance of inattention) differed from those without an attention disorder on the Serial Search task but not on the auditory processing task; the reverse was true for children with RD. Weiler et al. (2002) applied a task of rapid auditory processing, which consisted of identifying whether pairs of tones of different durations, separated by different intervals between ISI stimuli, were equal or unequal. There was a main effect in the groups with RD, as the good readers made significantly fewer errors than the RD on the auditory processing task. However, the groups with ADHD/IA made significantly more errors on the Serial search task. Decomposition of the visual search task into component operations demonstrated that children in the ADHD/IA group had a slow processing rate that was not attributable to inattention. In sum, the children with ADHD were not globally poor at information processing or inattentive, but they demonstrated diminished visual processing speed.

On the contrary, in a previous study Weiler, Berstein, Bellinger and Waber (2000) failed to support the anticipated doble dissociation . Weiler at al. (2000) analyzed processing speed and its relationship with oral and written language measures, visuospatial skills and motor speed, in a clinical sample of children who were candidates for learning difficulties, classified as ADHD, RD, ADHD+RD and controls. All the groups scored significantly below the norm on processing speed, although the deficit was more pronounced in the ADHD group than in the RD group. The most notable conclusion is that this deficit was shared by ADHD and RD, producing additive effects of the pure disorders in the comorbid group.

The idea that ADHD and RD are linked with two opposite patterns of impairments in different processes has also been supported by McGee, Brodeur, Symons, Andrade and Fahie (2004). These authors evaluated phonological awareness, together with time perception and attention, in a sample composed of 4 groups of children (ADHD, RD, ADHD+RD and controls). The results of the phonological task of sound blending showed that the children with RD, alone or combined with ADHD, scored significantly lower than the ADHD and control groups on this measure. Significant differences were also found between the groups on a duration estimation task. Specifically, the ADHD and ADHD+RD groups made longer and more variable time estimations than the RD and controls, which would support the hypothesis that a time perception deficit is a specific marker of ADHD but not RD. Children with both, ADHD and RD had an additive combination of the ADHD-only and RD-only groups without interaction effect.

However, other studies have reported that neuropsychological deficits of the group ADHD+RD are different from the additive combination of the deficits associated with ADHD pure and RD pure, suggesting that the whole is more than the sum of each part, as predicts the cognitive subtype hipothesis. Rucklidge and Tannock (2002a) suggest that ADHD and RD are separable cognitive profiles. Their results show that ADHD groups (regardless of RD status) demonstrated slower processing speed, were slower at naming objects, and had inhibition deficits, as well as greater variability in responses. On the other hand, the RD adolescents (regardless of ADHD status) had poorer verbal working memory and were much slower at rapid naming (RAN) of letters and words. The group of children with ADHD+RD had a more severe automatization problem than the children with only ADHD or RD. This group was also more impaired in mental arithmetic and working memory than the ADHD group, and produced additional cognitive deficits, including slower rates of naming numbers and colors and overall slower reaction times and less accuracy in responses on the StopTask (Go Reaction Time and Percent Correct). Based on these findings, Rucklidge and Tannock (2002a) suggest that automatization would be a good candidate for future endophenotypic studies of comorbid ADHD and RD.

In agreement with these results, Bental and Tirosh (2007) found unique deficits in rapid naming and a more severe impairment in working memory in the comorbid ADHD+RD group. Moreover, the comorbid group shared basic characteristic impairments in attention and executive functions with the pure ADHD group, and in reading domain functions with the pure RD group. Forward stepwise regression pointed to associations between executive functions and word reading accuracy in children with ADHD, in contrast to associations between linguistic functions and word accuracy in non-ADHD. Therefore, the combination of cognitive deficits in the subgroup of children with both ADHD and RD, and the relationship between accuracy in word decoding and executive functions, suggest a distinct clinical profile for the co-morbid condition.

Together, the two previous studies provide support for the cognitive subtype hypothesis. However, others, as discussed below, would at least partly support the common etiology hypothesis, as they have found at least one deficit common to ADHD, RD and ADHD+RD, with the profile of the comorbid group being similar to those of the other two groups separately.

Purvis and Tannock (2000), using only inhibition and phonological processing tasks, detected that the two RD groups (pure RD and RD+ADHD) were significantly impaired on the phonological processing measures, while the ADHD, RD and ADHD+RD were all found to be associated with inhibitory control. However, the inhibitory deficit of the group with ADHD was more generalized, while in the RD group it appeared to be more linked to slowness in performing the task applied (Stop task), which required choosing an answer. With regard to the comorbid group, they exhibited the deficits of both pure groups in an additive fashion.

Shanahan et al. (2006), provided support for the common etiology hipothesis. In the study a complete battery of tests (coding subtest WISC-R; Trailmaking Test; RAN; STROOP; Stop Signal Task; GDS; CPS; ETS) was applied to children and adolescents with RD, ADHD and RD+ADHD. In the first place, Shanahan et al. (2006) found that all the processing speed measures were correlated, and that the factorial analysis revealed two task-dependent factors (verbal output and motor output). They also observed that the RD and ADHD groups had similar patterns of deficits, although with different magnitudes. Both groups had a processing speed deficit that extended to all the tasks in the battery; however, in contrast to other results (Weiler et al., 2000; 2002), the relationship with RD was stronger. The comorbid group did not differ significantly from the RD group on any factor. Finally, on closer examination of the nature of the ADHD+RD combination, they found that the interaction between the RD and ADHD groups was significant, suggesting a non-additive relationship. Complementary analyses of underadditivity and correlations indicated that the processing speed deficits of the comorbid group were at least partially shared by RD and ADHD. Consequently, the conclusion was drawn that processing speed is a shared cognitive risk factor that can help to explain the nature of the comorbidity.

Willcutt, Pennington, Olson, Chhabildas and Hulslander (2005) evaluated a large sample of subjects from the Colorado Learning Disabilities Research Center (CLDRC) twin study on measures of component reading and language skills, executive functions, and processing speed. They found a dissociation between the groups with and without RD on measures of reading and language skills, but none of the neuropsychological tasks was specifically associated with ADHD. The children with ADHD, those with RD, and children with both RD and ADHD, all exhibited difficulties in processing speed (slower and more variable response), response inhibition and verbal working memory, while set-shifting deficits were not associated with either disorder when FSIQ was controlled. Since the three groups had overlapping deficits, the authors concluded that RD and ADHD could have a common genetic base, proposing processing speed as the main common deficit. The verbal working memory and response inhibition tasks were less compelling candidates for the common deficit because the relations between ADHD and working memory and RD and inhibition were relatively weak and inconsistent.

Verbal working memory (VWM) is another process identified as a deficit common to RD, ADHD and their association. Therefore, it has been proposed as a factor that could explain the high degree of overlap between the two disorders. Thus, Tiffin-Richards, Hasselhorn, Woerner, Rothenberger and Banaschewski (2008) evaluated the main deficits of RD and ADHD, finding that language processing functions were impaired in the dyslexic group, while the ADHD group was impaired on cognitive flexibility. However, all of the groups, ADHD, RD and ADHD+RD, were affected on verbal working memory, leading to the conclusion that VWM could be a cognitive deficit common to ADHD and dyslexia.

In other cases, general memory problems have been found, measured by means of N-back tasks, only in the two groups with RD. Van De Voorde, Roeyers, Verté and Wiersema (2010) used linguistic and executive functioning tasks, measured in relation to a baseline measure of functioning (that is, a low memory or inhibition load condition compared to a high load). These authors found no evidence of response inhibition problems in ADHD or RD, taking into account a baseline measure. Furthermore, although the performance of the subjects with ADHD in the memory condition (1-back) was worse than that of the RD, the deficits disappeared when comparing them with the control condition (0-back). The most interesting result for our purposes was that the children with ADHD and those with RD showed a highly inaccurate and variable response style. Above all, it should be pointed out that the percentage of errors of the children in the comorbid group was nearly equal to the sum of the means of the two single-disorder groups, suggesting that different factors underlie the high error rate in both disorders.

Finally, the only double dissociation study that found the profile of the comorbid group to be similar to that of only one of the disorders is the study by De Jong et al. (2009a). These authors used a lexical decision task to measure lexical access skills, along with measures of inhibition and visuospatial working memory. The results showed that the disorders evaluated were associated with impairments in inhibition and lexical decision, deficits that were more severe in RD than in ADHD. However, the visuospatial working memory was affected only in the group with ADHD alone and not in the comorbid group or the RD group. Nevertheless, all main effects for ADHD were lost after covarying for both age and IQ, so that in ADHD the impairments were dependent on IQ, suggesting that the overlap in lexical decision and inhibition has a different origin for ADHD and RD.

Assessment and Intervention in ADHD and RD

The few studies in this review that deal with evaluation have examined the validity of different instruments to discriminate the comorbid ADHD+RD condition (see Table 3). Thus, Rucklidge and Tannock (2002b) set out to determine the discriminant validity of the BADDS (Brown ADD Scales). The two groups with ADHD+ RD and ADHD who participated in the study obtained significantly higher scores than the RD and control groups on all the scales. The recommended cutoffs resulted in high rates of false negatives but few false positives. Therefore, these authors point out that the scale can be used for screening out ADHD, but not for its diagnosis, due to its low sensitivity. Dewey, Crawford and Kaplan (2003) analyzed the discriminant and predictive power of another test designed for parents, the PRECAA (Parent Ratings of Everyday Cognitive and Academic Abilities). The authors found that this instrument correctly classified 81% of the children with ADHD, and was sensitive to group differences between children with RD and children with ADHD+RD. Finally, Dewey Crawford, Kaplan and Fisher (2001) examined the predictive power of a memory test (WRAML) in the diagnosis of ADHD, RD or both. The WRAML only classified 58.5% of the participants correctly, while academic, intellectual and behavioral measures together correctly classified 73.1%. These results suggest that the use of a measure of memory functioning, such as the WRAML, does not significantly improve the predictive accuracy of a diagnosis of ADHD, RD or both, beyond what is provided by the more standard academic, intellectual, and behavioral diagnostic measures.

Insert Table 3

The intervention studies deal with the two most common treatment modalities for ADHD, that is, pharmacological and psychopedagogical interventions. Several studies have shown the benefits of Methylphenidate (MPH) in reading performance and other cognitive impairments frequently present in ADHD. The contribution by Tannock, Martinussen and Frijters (2000) demonstrates that naming speed deficits are improved but not normalized by stimulant medication. These authors randomly assigned children with ADHD and ADHD+RD to 4 intervention conditions lasting one week each: placebo; low dosage (10 mg); medium dosage (15 mg); and high dosage (20 mg). They found a lineal effect of dosage on color-naming speed, with the naming time declining from 55.8 seconds in the placebo condition to 51.1 seconds in the group with the highest dosage. In sum, MPH selectively improved color-naming speed but had no effect on the speed of naming letters or digits.

Grizenko, Bhat, Schwart, Ter-Stepanian and Joober (2006) carried out a prospective, double-blind, placebo controlled, randomized, 2-week crossover trial to study the response to MPH in children with ADHD and different types of learning disabilities (LD) in reading and mathematics. These authors analyzed the degree of weekly improvement in each group of children, using the Consensus Clinical Response (CCR) scale, which evaluates basic ADHD symptomatology through observations of parents, teachers and therapists. One interesting initial finding was that the children with ADHD+LDs responded significantly less to the Methylphenidate than the children with ADHD without LDs (55% versus 75%). But possibly the most surprising result was that the children with ADHD and LDs responded differentially to the MPH. Thus, while the group of children with RD presented a more positive response pattern, not unlike that of the group with ADHD alone, the group of children with MD responded very little to the medication.

Keulers et al. (2007) analyzed the effects of MPH on reading performance in a unique 0.5 mg twice-daily dosing schedule for 4 weeks. Reading performance was compared with General Linear Model repeated measures among three groups: an experimental group of children with both ADHD and dyslexia; a control group of children with ADHD; and another control group of children with dyslexia. At the pretest evaluation, the group with ADHD obtained better scores than the two groups with dyslexia. The posttest evaluation showed that the medication improved the basic symptomatology of the groups with ADHD and greatly increased the number of correctly read words of the children in the ADHD and comorbid dyslexia group, compared with the children in the two control groups.

Finally, Bental and Tirosh (2008) analyzed the immediate effect of MPH on decoding in the comorbid condition of ADHD+RD in Primary School boys with normal intelligence and linguistic skills. The boys were administered a single dose of the psychostimulant (0.3 to 0.4 mg/kg), with weekly intervals between testing sessions. Paired comparisons and first trial group comparisons of performance in the placebo condition and under methylphenidate were conducted. The basic finding was that the MPH selectively improved strategy/set shifting and facilitated improvement in both rapid naming and word/nonword accuracy. Moreover, the authors found significant differences between the MPH and placebo conditions on strategy/set shifting but not on spelling.

Two studies that fall into the general category of pharmacological interventions have studied the effects of Atomoxetine on cognitive processing and reading performance. De Jong et al. (2009b) analyzed the possible benefits of administering Atomoxetine (0.6 mg/kg for 7 days and 1.2 mg/kg for the following 21 days) for the EF (visuospatial memory, inhibition) and on lexical decision tasks in four groups of children: ADHD, ADHD+RD, RD, and control. The analyses showed that the children in the two groups with ADHD significantly improved the basic symptomatology of the disorder with the medication. Furthermore, the children in the ADHD+RD group improved inhibition with the atomoxetine treatment compared to placebo. No differential effects of atomoxetine were found for lexical decision in comparison to placebo. In addition, no effects of atomoxetine were found in the ADHD and RD groups. The authors suggest the possibility that ADHD and ADHD+RD are two different disorders at the neuropsychological and neurochemical levels.

One interesting question addressed by Sumner et al. (2009), although tangentially, consists of finding out to what extent the effects of atomoxetine on certain component skills related to reading may correlate with changes in overall reading performance. For this purpose, they analyzed the effects of an intervention with Atomoxetine, at doses ranging from 1.0-1.4 mg/kg once daily for 16 weeks, in adolescents distributed in two groups: ADHD and ADHD+Dyslexia. The atomoxetine significantly improved the basic symptomatology and reading comprehension standard scores in the two groups of adolescents with ADHD. Spelling subtest improvement was significant for the ADHD group, whereas the ADHD plus dyslexia group showed significant reading decoding improvements. The analysis of the change in neurocognitive processes helped to interpret the results. Thus, the ADHD group showed more marked improvement in the component scores related to central executive functioning, and the ADHD and comorbid dyslexia group showed more marked improvement in component scores related to the phonological loop. These data suggest that the brain systems related to the therapeutic benefit of atomoxetine in reducing ADHD symptoms may be different in individuals with ADHD with dyslexia and ADHD without dyslexia.

Other studies in this review have dealt with rating the efficacy of different types of psychoeducational interventions. The study conducted by Crabtree, Alber-Morgan & Konrad (2010) was designed to examine the effects of self-monitoring and active responding on the reading comprehension of three high school seniors with learning disabilities and ADD (attention deficit disorder). According to the special education teacher, all three participants demonstrated deficits in reading comprehension. The intervention consisted of stories, self-monitoring response sheets, immediate recall worksheets and quizzes. After the intervention was implemented, there was an immediate and substantial increase in the number of correct responses. During maintenance, all three participants continued to increase their correct responses. All three participants also demonstrated substantial and consistent increases in quiz accuracy when the intervention was introduced.

Only the study by Hecker, Burns, Elkind, Elkind and Katz (2002) was designed to determine the potential benefits of the use of modern technologies in the reading performance of post-secondary students with a diagnosis of ADHD. The majority of the participants were taking psychostimulant medication, and 25% suffered from RD. The dependent variables used were reading speed and comprehension, along with distractibility and fatigue while reading, rated by means of self-assessment, independent reading logs and results on reading tests, before and after applying a computer program. The software used provides a synchronized visual and auditory presentation of text, and incorporates study skill tools for highlighting and note taking. The comparison of the two evaluation times showed that performance clearly improved after the intervention. Specifically, the subjects improved their attentional capacity (with fewer distractions), increased time spent reading as well as reading speed, and reduced stress and fatigue. However, no differences were found on comprehension between the pre-treatment and post-treatment evaluations, although the participants with very low comprehension improved their scores somewhat.

The overall objective of Rabiner and Malone (2004) was to examine whether attention problems moderate the impact of tutoring on the development of children's early reading skills. As a group, participants in their study had greater attention problems than the general population. The program was designed for low-readiness children from disadvantaged backgrounds, and emphasized a phonics-based, mastery-oriented approach to the development of initial reading skills. Tutoring began with an individual assessment of the child's skill development, and progressed according to each child's ability to master the skills taught. Throughout first grade, tutors worked with the children individually three times a week during 30-min sessions. Two of these sessions took place during school hours, and one occurred during the parent–child groups. The authors found that the children with RD alone improved their reading performance significantly, while the children with RD and associated attention problems did not benefit from the intervention.

Finally, mention will be made of an intervention that combined psychostimulant medication (MPH) with the Reading to Read (RTR) program. With this combined treatment, Kastner, Tingstrom and Edwards (2000) investigated the relationship among the scheduling time of a repeated reading intervention, MPH, and measures of oral-reading fluency, in 6 ADHD boys who had no comorbid diagnoses except RD. There were two conditions: RTR intervention conducted 45 min – 1 h after ingestion of MPH (optimal), and RTR intervention conducted 3-4 h after ingestion of MPH (non-optimal). The RTR intervention ended for each subject either when he reached grade level in the sequence or when the school year ended. Each student met individually with the interventionist 3 to 5 days per week. The RTR materials consisted of 57 100-word passages from the beginning, middle, and ending thirds of each book in the series, with 2 alternative forms (A and B). All participants mastered passages more quickly during the optimal condition than during the non-optimal condition. In addition, more participants made fewer reading errors, had higher levels of correct words per minute, and read passages more quickly during RTR administered during the optimal MPH period.

Discussion

One objective of this study was to identify the exact nature of reading disabilities in ADHD. The purpose was to find out whether children with the comorbid type showed the typical impairments of each of the two disorders separately, ADHD and RD, or whether they experienced a combination of the characteristics of each, with the same or greater severity.

The majority of the findings show that, as occurs in the pure RD group, the ADHD+RD group presents phonological awareness impairments (McGee et al., 2004; Willcutt et al., 2001; Willcutt, Pennington, Olson et al. 2005), makes more mistakes, and is slower than controls and pure ADHD on performing all types of phonological processing tasks, such as word and pseudoword reading, phonological suppression, segmentation, phonological synthesis or spelling (McGee et al., 2004; Purvis & Tannock, 2000; Tiffin-Richards et al., 2008; Van de Voorde et al., 2010). Similar deficits seem to occur in adulthood (Laasonen, Lehtinen, Leppämäki, Tani & Hokkanen, 2010).

Naming speed problems in the RD and ADHD+RD groups have been detected in various studies, arguing that this process is a specific marker for RD (Raberger & Wimmer, 2003; Seidman et al., 2001; Van de Voorde et al., 2010), even in non-alphabetic systems (Chan et al., 2008). Even so, the conclusion cannot be drawn that there is a complete dissociation between ADHD and RD on naming speed measures, as differentiated results have been found depending on the type of stimuli presented. Thus, the ADHD group obtains worse time scores than the control group on color and object naming, but no differences are found on letter and number naming (Rucklidge & Tannock, 2002a). One possible explanation is that color and object naming are more perceptually/semantically based, while letter and number naming require more phonological resources. However, the most significant finding is that the ADHD+RD group is slower on all the rapid naming tasks and has slower reaction times.

It can be said, then, that naming speed is a basic deficit in children and adolescents with RD with all types of stimuli (verbal and non-verbal), and in ADHD with non-verbal stimuli. The comorbid group shows a combination of the impairments of the pure groups, in agreement with the double dissociation hypothesis (Raberger & Wimmer, 2003; Seidman et al., 2001; Van de Voorde et al., 2010), although there are also data indicating that the ADHD+RD group is more impaired, as proposed in the specific subtype hypothesis (Rucklidge & Tannock, 2002a).

Related to rapid naming, in spite of being a more general construct, processing speed has shown its value in explaining the relationship between ADHD and RD in many studies, and it could represent an essential deficit shared by both disorders (an endophenotype) (De Jong et al., 2009a; Ghelani et al., 2004; Laasonen et al., 2009; Willcutt, Pennington, Olson et al, 2005; Shanahan et al., 2006; Weiler et al., 2000; 2002). More exhaustively, a response style characterized by great intra-individual variability in task performance could also be a cognitive impairment shared by subjects with ADHD, RD and ADHD+RD, as proposed in the common etiology hypothesis (Van de Voorde et al., 2009; Willcutt, Pennington, Olson et al, 2005).

It still remains to be seen whether time perception is affected in individuals with ADHD and ADHD+RD. Some studies (Toplack et al., 2003) have found that time estimation deficits are associated with ADHD, and especially with ADHD+RD, and may be influencing the time organization of the behavior of people with these disorders. However, other studies have not found the same tendency (Tiffin-Richards et al., 2004)

Greater agreement exists about the idea that groups with RD and ADHD+ RD are characterized by having worse temporal auditory functioning, especially with verbal stimuli. It also seems that these groups show a backward masking effect with non-verbal stimuli of an asymmetric temporal onset (Breier et al., 2001; 2002; 2003; Weiler et al., 2002).

The possible perceptual and motor impairments in RD and ADHD, and the effects of other concurrent disorders like MD (Mathematics disorder), CD (Conduct Disorder) or DCD (Developmental Coordination Disorder), have been studied very little. For now, it is known that the RD+ADHD+MD group is different from the ADHD+MD and ADHD+RD groups, as it presents significantly greater impairments in both expressive and receptive language (Capano et al., 2008). Similarly, the RD+ADHD+MD group shows a poorer performance on different neuropsychological tasks (Seidman et al., 2001), and, more importantly, the perceptual-visual problems seem to be more related to the presence of ADHD and RD than to ADHD itself (Crawford & Dewey, 2008).

The executive functions addressed in the studies reviewed were inhibition and working memory. Although some studies find inhibition impairments only in the ADHD group and the comorbid group (Willcutt et al., 2001), others have also found RD to be related to behavioral inhibition (De Jong et al., 2009a; Purvis & Tannock, 2000; Willcutt, Pennington, Olson et al, 2005), thus questioning the role of inhibitory control as the only cognitive marker of ADHD, and suggesting a true comorbidity of the children with ADHD+RD. In contrast, surprisingly, more recent studies have not found response inhibition problems in any group, that is, ADHD, RD, or ADHD+RD (Bental &Tirosh, 2007; Van de Voorde et al., 2010).

The conclusions that can be drawn about working memory depend especially on the distinction between the different modalities. The few studies that have analyzed visuospatial working memory have obtained completely disparate results. However, all the studies that have evaluated verbal working memory have found impairments in both the ADHD+RD group and the RD group (Kibby et al., 2008; Roodenrys et al., 2001; Rucklidge et al., 2002; Van de Voorde et al., 2009; Willcutt et al., 2001). Moreover, some findings show that the impairments in the WM affect the three groups, ADHD, RD and ADHD+RD (Martinussen et al., 2006; Tiffin Richards et al., 2008; Willcutt, Pennington, Olson et al, 2005).

The review carried out confirms that the co-occurrence of ADHD and RD increases the risk of negative results in the daily functioning of the children, adolescents and young adults affected (Bonafina, et al., 2000; Capano et al., 2008; Willcutt, Betjemann, Pennington et al., 2007). Subjects in the comorbid group usually present more severe and more stable impairments than subjects with only RD and only ADHD on academic and social measures. They also show higher scores on anxiety, depression and CD, which causes them to receive more psychotherapy, psycho-stimulant medication and special education.

Regarding ADHD and RD treatments, it can be said that the studies, to a greater or lesser extent, found positive effects of the interventions, pharmacological and non-pharmacological, on subjects' reading performance. Likewise, as would be expected, the pharmacological interventions report significant improvements in the basic symptomatology of ADHD subjects. However, it is necessary to be cautious in drawing conclusions, due to the methodological limitations of the reduced number of studies analyzed, such as variability in the diagnostic criteria utilized, different reading tests applied, limited duration of the intervention, a low number of participants, or different doses prescribed in the pharmacological treatments and whether or not they were maintained while the evaluations were performed.

Future Directions

Synthesizing, although it provides interesting information, the review carried out does not make it possible to extract definitive results on the exact nature of ADHD and RD comorbidity or, even less, reach conclusions about its causes. The studies suggest that the ADHD+RD group presents a profile characterized basically by a combination of symptoms of the two pure groups. These results could be consistent with the studies indicating that one or more genes increase the risk of ADHD and RD, with a stronger influence in the comorbid group (Pennington, Willcutt & Rhee, 2005; Willcutt, Pennington, Olson & DeFries, 2007). In sum, common genetic influences contribute to ADHD and RD comorbidity, but the mechanisms of these common genes are unknown.

Both ADHD and RD can also be partly due to a cognitive impairment in the ability to process information rapidly and efficiently (an endophenotypic candidate for ADHD+RD comorbidity). However, other studies seem to support both the cognitive subtype hypothesis and the common etiology hypothesis. It is possible, as stated by De Jong et al. (2006), that some subtypes of ADHD and RD have the same genetic origins, while other subtypes and their combinations are separate disorders. More research is necessary in order to discover the cause or causes of the high comorbidity between ADHD and RD, and to be able to decide among the different causal models proposed.

A recent study by Willcutt, Betkemann, Wadsworth et al. (2007) is an example of the line of research that should be developed. Willcutt, Betkemann, Wadsworth et al. (2007) set out to examine the etiology of the association between ADHD and RD in preschool children who had not yet received reading instruction and, therefore, had not adverse experiences that could unleash the comorbidity (phenocopy hypothesis). Phenotypic analyses revealed small but significant correlations between high scores on inattention (DSM-IV) and low performance on the pre-reading measures (phonological awareness, rapid naming, verbal memory, vocabulary, grammar/morphology and print knowledge), which did not occur in any case with hyperactivity/impulsivity. The results confirm, therefore, that the RD and ADHD association is already present in the Kindergarten period.

The study by Willcutt, Betkemann, Wadsworth et al. (2007) also included multivariate twin analyses which indicated that practically all the phenotypic correlations between inattention and pre-reading are attributable to common genetic influences, which seem to be especially strong in phonological awareness, rapid naming and verbal memory. For the authors, these results suggest that the association between pre-reading difficulties and ADHD in preschool children is at least partly due to common genetic influences.

The difficulties in learning to read in students with ADHD are probably going to be more severe and more evident during adolescence and adulthood, when the working memory and other executive functions are necessary for understanding texts with some complexity and progressing toward independent learning. Thus, longitudinal studies are needed to analyze the development of this association throughout the life cycle.

Implications for the assessment and treatment

Given the high rate of ADHD and RD comorbidity, knowledge about the causes underlying their overlapping is essential, especially because the intervention procedures for these two disorders are very different. Traditionally, learning disabilities are considered linguistic impairments, and ADHD is considered a behavioral impairment. Although it is important to continue to investigate the characteristic deficits affecting the ADHD and RD association and understand them better, the knowledge already available can help to provide better interventions for the problem.

Individuals with ADHD+RD have more severe cognitive impairments and worse results in academic, social and emotional realms than the pure ADHD or RD, so that evaluations and interventions should be specifically designed for this comorbid group. Specifically, the evaluation of ADHD and RD should be psycho-educational and complex, contemplating all those aspects that have been shown to be affected to some degree. First, it is necessary for the evaluation of suspected ADHD subjects to include the analysis of reading skills and the different processes involved in them. Likewise, the evaluation of RD should include psychological tests that can detect ADHD. Second, in addition to screening and diagnosing both disorders, would be necessary that the evaluation includes a detailed history of cognitive, motor, perceptual and language development. Third, a study should also be conducted of academic performance, with special attention to mathematical skills. Finally, an evaluation of the behavioral and emotional problems and disorders that usually co-occur with ADHD+RD should be included.

These aspects should also be considered when designing individualized intervention programs directed toward all the deficiencies and needs detected. Furthermore, given the chronic nature of the comorbid syndrome, the entire life cycle should be contemplated, adapted to the different stages of development. The intervention should be, therefore, a psychological and educational one that addresses both the main deficiencies of ADHD and RD and the problems most frequently associated with their comorbidity. For some subjects, pharmacological treatment should also be included. Although the medication does not teach the student knowledge that he or she has not acquired, it can help to foster a favorable disposition toward learning.

In the school context, it is necessary for Special Education teachers, but also for the entire school team, to receive training in how to interact with children with these problems. They should know about the characteristics and causes of the two disorders, their long-term effects, and the interventions that have proven most beneficial. Children with ADHD and RD will have to receive accommodations in school that will help them to control their deficiencies: modify the instruction method to make it more dynamic, divide the tasks into parts to avoid an excessive load on the working memory, prolong the time of the activities and tests to adapt them to the slower processing style, modify the student's environment and situation to facilitate the inhibition of stimuli not relevant to the tasks, take advantage of the possibilities of the new technologies to avoid the fatigue produced by the necessary reading practice. Adolescents and adults should also receive help to face and control their growing academic and work-related responsibilities. For example, tutors can help them program and control the development and achievement of their daily objectives, break down long-term projects into components, train them in the use of facilitating materials, and teach them strategies of self-direction (self-observation and self-evaluation to monitor the performance of activities and studies). Especially interesting is the specific teaching of strategies to promote text comprehension, such as paraphrasing, summarizing, posing questions, prediction or finding the main idea.

Finally, it is important to keep in mind the feelings of helplessness and frustration that, unfortunately, are usually produced by ADHD and RD in students and their families. In these cases, it is imperative to complement educational and pharmacological interventions (if appropriate) with supportive counseling.

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- Papers included in the review

Table 1.- Single dissociation studies.

Study	Sample/ age	Groups	Measures	Results	
Bonafina et al. 2000	N=54 7-11	A, A(bright readers), A+R, A+R(low)	WRAT-R	Spelling	A+R groups < A groups
			WRAT-R	Arithmetic	A+R groups < A groups
			CBCL , ICTQ	Conductual functioning	n. d.
Breier et al. 2001	N=95 7-15	A, R, R+A, C	VOT/TOT	Auditory temporal functioning	R, R+A < C, A
			CTOPP	Phonologic processing	R, R+A < C, A
Breier et al. 2002	N=142 7-14	A, R, R+A, C	Discrimination /TOJ task (2/3 elem.)	Auditory temp. Functioning(verbal)	R, R+A < C, A
				Auditory temp. func.(no verbal)	n. d.
			CTOPP, RAN	Phonologic processing	R, R+A < C, A
Breier et al. 2003	N=150 7-14	A, R, R+A, C	Psychoacoustics tests (BMLD, GDT, TOT)	Auditory temporal functioning	R, R+A < C, A
				Auditory no temporal functioning	n. d.
				Auditory functioning temporal/no temporal	A, R+A < C, R
Capano et al. 2008	N=476 7-12	A, A+R, A+M, A+R+M	WISC-R	CI	A+M, A+R, A+R+M <A; A+R+M<A+R
			CELF-3	Language receptive	A+R+M< A+M, A+R<A
			CELF-3	Language expressive	A+R+M< A+R <A; A+R+M<A+M
			WRAT-3, WRMT	Reading achievement	A+R+M< A+R < A+M <A
			WIAT	Mathematical achievement	A+R+M < A+M < A+R <A
Chan et al. 2008	N=92 X=8.2	A, R+A	HKT-SpLD	Naming speed	R+A < A
				Phonologic processing	n. d.
				Orthographic processing	R+A < A
Ghelani et al. 2004	N=96 14-17	A, R, A+R, C	GORT-4	Reading rate and accuracy	R, A+R < A < C
			TOWRE	Rapid word reading	R, A+R < A < C
			GORT-4, GSRT	Reading comprehension	n. d.
			CTOPP	Rapid naming speed (objects, color)	A+R< A < C; R < C
			CTOPP	Rapid naming speed (letters, digits)	R, A+R < A, C
Kibby & Cohen 2008	N=113 6-15	A,R, R+A,C	CMS	Visual-spatial STM	A main effect
				Verbal STM	R main effect
				LTM and C.E.	n.d.
Kooistra et al. 2005	N=291 X=11.7	A, R, A+R, A+O, A+R+O,	BOTMP	Motor skills (gross, fine)s	R, A+O, A+R, A+R+O < A, C
			VMI	Visual-motor integration	A, R, A+O, A+R, A+R+O < C

		C			
Laasonen et al. 2009	N=119 18-55	A, R, R+A, C	WAIS-III	Verbal WM: Processing Speed	R, R+A < A, C A, R, R+A < C
Martinussen & Tannock 2006	N= 143 7-13	A,R,A+R,C	Digits Forward FW (WRALM) Digits Backward	Verbal Storage Spatial Storage and C.E. Verbal C.E.	R, A+R < A, C A, R, A+R < C A, R, A+R < C
Pisecco et al. 2001	N=383 3-5	A, R, R+A, C	RDLS RDLS Lack of control scale	Receptive language Expressive language Lack of control	R, R+A < C (3/5 years) R<C (3 years) R+A < A, R, C
Roodenrys, et al. 2001	N=48 9-10	R,A+R,C	Span tasks CHIPASAT Memory Updating Random Generation	Phonological Loop Phon. Loop and C.E. Phon Loop and C.E. Central Executive	R, A+R < C A+R < R < C A+R < R, C A+R < R, C
Seidman et al. 2001	N= 275 6-17	A,A+R, A+M, A+R+M, C	Broad battery of neuropsychological test	Stroop WRALM list learning Auditoty CPT	A+R < A, C A+R < A, C A, C < A+R
Tiffin et al. 2004	N=68 10-13	A, R, A+R, C	Finger tapping tasks	Free tapping Synchronized tapping Un-paced tapping Rhythm reproduction	n. d. n. d. n. d. R, A+R < C, A
Toplak et al. 2003	Estudio 1: N=100 6-11 Estudio 2: N=98 13-16	A, A+R, C A, A+R, C	Psycophysical task	Frecuency Duration Reproduction	n. d. Estudio 1: A, A+R < C Estudio 2: A+R < A, C Estudio 1: A+R < A, C Estudio 2: A+R < A, C
Willcutt et al. 2007	N=306 8-18	A, R, R+A, C	CBCL, YSR CBCL, YSR CBCL, YSR Anxiety/Depression	Academic outcomes Socials outcomes Externalizing comorbidity Internalizing comorbidity	R+A < A < C R+A < A < R, C A, R+A < R < C A, R+A < R < C

A: ADHD only; C: Control; M: Mathematical Disorder; R: RD only; O: ODD; n.d. (no differences)

BMLD: Binaural Masquing Level Differences; BOTMP: Bruininks-Oseretsky Test of Motor Proficieny; CBCL: The Child Behavior Checklist; C.E. (Central Executive); CELF-3: Clinical Evaluation of Language Function-3 (Semel, Wiig & Secord, 1995); CHIPASAT (Children's Paced Auditory Serial Addition Task); CMS: Children's Memory Scale; CTOPP: Comprehensive Test of Phonological

Processing; FW: Finger Windows task; GDT: Gap Detection Threshold; GORT-4: Gray Oral Reading Test -Fourth Edition; GSRT: Gray Silent Reading test; HKT-SpLD: Hong Kong test of Specific Learning Difficulties in Reading and Writing; ICTQ: IOWA Conners Teacher´s Questionnaire; LTM : Long Term Memory; PIAT-R: Peabody Individual Achievement Tests Revised; RAN: The Rapid Automatized Naming subtests; RAP: Rapid Auditory Processing; RDLS: Reynell Developmental Language Scales; STM: Short Term Memory; TOJ: Temporal Ordering judgment task; TOT: Tone onset time; TOWRE: Test of Word Reading Efficiency; VF: Visual Filtering test; VMI: Visual-Motor Integration test; VOT: Voice Onset Time; WIAT: Wechsler Individual Achievement test; WISC-R: Wechsler Intelligence Scale for Children Revised; WRALM: Wide Range Assessment of Memory and Learning; WRAT-3: Wide Range Achievement Test; WRAT-R: Wide Range Achievement Test Revised; WRMT: Woodcock Reading Mastery Test Revised; YSR: Youth Self Report.

Table 2.- Double dissociation studies.

Study	Executive Functions			Linguistic Skills		
	Measures	Results		Measures	Results	
Bental & Tirosh	MFFT	Inhibition:	n.d.	NDB	Phonological Decoding	R, A+R < A, C
2007	CRS	Attention:	A, A+R < R, C	THWQ	Spelling Accuracy	R, A+R < A, C
N=86	PMT	Planning:	n.d.	RRP-ESAC	Reading Comprehension	n.d.
	WCST	Set-shifting:	n.d.	RAN (digits)	Rapid Naming	A+R < A, C
	Span tasks	Verbal WM:	R+A < A, C	NDB	Phonemic Synthesis	n.d.
	Word Fluency	Verbal fluency:	n.d.	NDB	Phonemic deletion	A, R, A+R < C
De Jong et al.	SSP (RT)	Inhibition:	R main effect	Lexical Decision task	Lexical decision	A and R main effect
2009a	SSP (omission)	Attention:	A and R main effect	(MRT Pseudowords)	Decoding Process	R, A+R < A < C
N=120	SSP (commission)	Impulsivity:	A main effect			
	CBTT	Visuo-spatial WM:	A < R, A+R, C			
McGee et al.	CPT	Vigilance	n.d.	Sound Blending	Auditory Phonological	
2004	CPT (dur. est.)	Time perception	A main effect		Awareness	R main effect
N=113	Time production	Time perception	n.d.			
Purvis & Tannock	CPT	Inhibition:	A main effect	WAS	Word Attack	R main effect
2000	ST	Inhibition:	R main effect; A trend	TAA	Auditory Analysis	R large effect, A small effect
N=68				PST	Phoneme Segmentation	R, R+A < A < C
Raberger & Wimmer	Balancing tasks	Balancing	A main effect	Naming task	Continuous Rapid Naming	R main effect
2003						
N=40						
Rucklidge & Tannock	ST	Inhibition	A, R+A < C	RAN (numbers)	Naming Speed	A+R < A, C
2002a		Response execution	A+R < C	(colors)	Naming Speed	A+R < A, R, C
N=108	Arithmetic, span task,			(letters)	Naming Speed	A+R < A, R, C; A+R < A
	digits task	WM	A+R < A, C	(objects)	Naming Speed	A, A+R < C; A+R < R
	Symbol search/coding	Processing Speed	A, A+R < C	Stroop (color-word)	Naming Speed	A, A+R < C; A+R < A
Shanahan et al.	Motor output measures	Processing speed	A and R main effect	Verbal output measures	Processing speed	A and R main effect
2006	TT	Processing speed	R main effect	RAN (numbers)	Processing speed	R main effect
N=395						
Tiffin-Richards et al.	Digits Backward	WM	A and R main effect	MT	Phon. Short term memory	R main effect
2008	WCST	Set-shifting	A main effect	Morpho-syntactic tests	Morpho-syntactic processing	R main effect
N=79						
Van de Voorde et al.	Go/no-go	Inhibition:	A+R < A, R, C	Phonological tasks	Phonological Processing	R main effect
2010	N-back (0)	WM baseline	A main effect	RAN	Naming speed:	R main effect
N=76	N-back (1)	WM	A and R main effect			
Weiler et al.	Processing speed tasks	Processing speed	A+R < A < R	Written language tasks	Written language	R, A+R < A

2000 N=82				Oral language tasks	Oral language	n..d.
Weiler et al. 2002 N=230	VF	Visual processing speed	Main effect A	RAP	Auditory processing speed	Main effect R
Willcutt et al. 2001 N=314	CPT, ST WCST, CNT Span tasks, TT	Inhibition Set-shifting WM	A main effect n.d. R main effect	PLT, PDT, LAC	Phoneme Awareness:	R main effect
Wilcutt et al. 2005 N=437	SST,GDS WCST, TT WM tasks Processing speed tasks	Inhibition: Set shifting: verbal WM Processing speed	A, R, R+A < C n.d. R, R+A < A < C A, R, R+A < C	PLT, PDT, LAC ONR LD-O	Phoneme Awareness: Phonological Decoding: Orthographic Coding:	R, R+A < A, C R, R+A < A, C R, R+A < A < C

A: ADHD only; A+R: ADHD+RD; C: controls; R: RD only; R+A: RD+ADHD. n.d.: no differences.

CBTT: Corsi Block Tapping test; CNT: Contingency Naming Test; CPT: Continuous Performance Test; CRS: Conners' Rating Scales; LAC: Lindamood Auditory Conceptualization Test; LD-O: Lexical Decision by Orthography; MFFT: Matching Familiar Figures Test; MT: Mottier test; NDB: Nitzan Diagnostic Battery; ONR: Oral Nonword Reading task; PDT: Phoneme Deletion task; PLT: Pig Latin Test; PMT: Porteus Maze; PST: Phoneme Segmentation Task; RAN: Rapid Automatized Naming; RAP: Rapid Auditory Processing; RRP-ESAC: Report of Reading Performance of Elementary School Age Children; RT: Reaction Time; SSP: Stop Signal Paradigm; ST: Stop task; TAA: Test of Auditory Analysis; THWQ: Test of Hand Writing Quality; TT: Trailmaking test; VF: Visual Filtering test; WAS(WJMRT-R): Word Attack Subtest of the Woodcock-Johnson Reading Mastery; WCST: Wisconsin Card Sorting Test.

Table 3.- Evaluation and intervention studies.

Study	Sample/ Age	Groups	Evaluation/ Intervention	Measurements		Results
Bental & Tirosh 2008	N=25 7-11	A+R, A+R (C)	MPH	ARFRT , LNST, LSST	Word reading accuracy, nonword reading accuracy and rapid naming	Significant improvements
				WCST	Strategy/set shift	A+R>A+R (P)
Crabtree et al. 2010	N=3 17-18	L, L+A	Self Monitoring	GAS, IRW, SMRS	Immediate recall accuracy	Significant improvements
					Quiz accuracy	Significant improvements
de Jong, et. al. 2009b	N=102 8-12	A, R, A+R, P	Atomoxetine	DSM-IV	ADHD symptomatology	A y A+R>R y P
				CBTT	Visuospatial working memory	A+R>A, R y P
				SSP	Inhibition	A+R>A, R
				LDT	Lexical decision	No improvements
Dewey et al. 2003	N=159 8-16	A, R, A+R	PRECAA usefulness	PRECAA	Memory, cognition, coordination and learning	A, A+R>R
				WRAML WJ-R VMI, BOTMP	Language	A+R>A, R
					Academic	No improvements
					General memory	A, A+R>R
					Language skills	R, A+R>A
					Visual-motor skills, motor skills	

						No improvements
Dewey et al. 2001	N=291	A, R, A+R, C	WRAML predictive acuracy	CBCL, WRAML, WRAT	General memory	The WRAML did not substantially improve predictive accuracy over more standard diagnostic tools
Grizenko et al. 2006	N=95 6-12	A, A+L (R, M)	MPH	CCR, CPT, RASS	Treatment response	A, A+R>A+L, A+M
Hecker et al. 2002	N=20 19-57	A, A+R	Computer: Kurzweil 3000™	GORT-3, OSST NDT	Attention, stress, speed and fatigue Comprehension	Significant improvements No improvements
Kastner et al. 2000	N=6 9-10	A+R	Combined: RTR, MPH	CBA	Instructional level	All participants mastered more quickly during the optimal condition Most participants made fewer reading errors, had higher levels of correct words per minute, and read passages more quickly
Keulers, et al. 2007	N=43 6-12	A (C), R (C) A+R (E)	MPH	DMT, EMT BV	Reading scores Visual sustained attention	A+R>A, R A, A+R>R
Rabiner & Malone 2004	N=581 X=5.7	A, R, A+R, C	Tutoring	DRS DSM-III-R	Reading achievement Attention	R>A, A+R Attention problems predicted diminished reading achievement
Rucklidge & Tannock 2002b	N=98 13-16	A, R, A+R, C	Validity of BADDS	BADDS CRS-R, OCHSS	BADDS	A y A+R>R y C Moderated correlations between Brown, CRS-R and OCHSS
Summer et al. 2009	N=56 10-16	A, A+R	Atomoxetine	AD/HD-RS K-TEA WMTB-C	ADHD symptomatology Reading decoding standard All other measures Central Executive Phonological loop Visuo-spatial sketchpad	A=A+R A+R>A Significant improvements A>A+R A+R>A No improvements

Tannock et al. 2000	N=47 7-12	A, R, A+R	MPH	RAN	Color naming speed Letters naming speed	Significant improvements No improvements

A: ADHD only; C: Controls; E: Experimental; L: Learning Disabilities; M: Mathematical Disabilities; P: placebo; R: RD only.

Intervention. MPH: Methylphenidate; PRECAA: Parent Ratings of Everyday Cognitive and Academic Abilities; RTR: Reading to Read.
Measurements. AD/HD-RS: AD/HD Rating Scale; ARFRT: Animal Retrieval and food Retrieval Tests; BADDS: Brown ADD Scale; BOTMP: Bruininks-Oseretsky Test of Motor Proficiency; BV: Bourdon-Vos Test; CBA: Curriculum Based Assessment; CBCL: Child Behaviour Checklist; CBTT: Corsi Block Tapping Task; CCR: Consensus Clinical Response; CPT: Continuous Performance Test; CRS-R: Conners´ Rating Scales-Revised; DMT: Drie Minuten Test; DRS: Diagnostic Reading Scale; DSM-IV, DSM-III-R; Diagnostic and Statistical Manual of Mental Disorders; EMT: Een Minuut Test; GAS: Globe Anthology Series; GORT-3: Gray Oral Reading Test-3; IRW: Immediate Recall Worksheet; K-TEA: Kaufman Test of Educational Achievement; LDT: Lexical Decision Task; LNST: Listening Number Span Test; LSST: Listening Sentence Span Test; NDT: Nelson-Denny Test; OCHSS: Ontario Child Health Study Scales; OSST: One Sample Sign Test; RAN: Rapid Automatized Naming Test; RASS: Restricted Academic Situation Scale; SMRS: Self-Monitoring Response Sheets; SSP: Stop Signal Paradigm; VMI: Visual Motor Integration Developmental Test; WJ-R: Woodcock Johnson Psychoeducational Battery-Revised; WMTB-C: Working Memory Test Battery for Children; WRAML: Wide Range Assessment of Memory and Learning; WRAT: Wide Range Achievement Test; WRMT: Woodcock Reading Mastery Test; WCST: Wisconsin Card Sorting Test.