Neurocognitive Profile in Children with Attention Deficit/Hyperactivity Disorder and Dyslexia

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ABSTRACT

Objective: The current study aimed to examine the neurocognitive deficits of children with ADHD and/or Developmental Dyslexia (DD) using neurocognitive tests.

Material and Methods: The participants of the study consisted of children diagnosed with Dyslexia (N=33), ADHD (N=32), and DD+ADHD (N=37) who applied to the Department of Child and Adolescent Psychiatry, Faculty of Medicine, Ankara University. The control group consists of 30 primary school children aged 7-11 with similar sociodemographic data. K-SADS-PL is used for the DSM-5 diagnoses of the patients and the control group. Stroop Test, Trail Making Test, Verbal Cancellation Test, and Wechsler Intelligence Scale for Children-Revised (WISC-R) were used to evaluate the cognitive functions of the groups in detail.

Results: Children with ADHD and/or Dyslexia were evaluated to have significant deficits in all neurocognitive measures such as reaction inhibition, selective attention, sustained attention, shifting attention, and visuospatial short-term memory compared to the healthy control group (p<0.001). Children with ADHD-only revealed the most significant weaknesses in reaction inhibition, and visuospatial short-term memory measures (p<0.001). The comorbid group exhibited significant weakness on almost all neurocognitive measures compared with the control group, but did not perform significantly lower than the ADHD-only and Dislexia-only groups.

Conclusion: It has been shown that children with ADHD and/or Dyslexia have multiple neurocognitive deficits, and our study supports the multiple cognitive deficit hypothesis.

Keywords: Attention-deficit/ hyperactivity disorder, dyslexia, multiple cognitive deficit hypothesis; neurocognitive functioning

INTRODUCTION

Developmental Dyslexia (DD) is a neurodevelopmental disorder characterized by difficulties in correct and/or fluent word recognition, spelling (letter-sound matching) difficulties, and weakness in decoding written code (1). Dyslexia leads to undesirable consequences such as decreased participation in education, low academic achievement, and lack of self-confidence (2). The incidence of dyslexia in school-age children is reported to be 5-9% (1,3).

Since reading skill involves many visual, linguistic, cognitive and attention processes, reading difficulties in children can arise from weaknesses in many different structures and situations. When children with dyslexia are compared with the healthy control group, it has been revealed that other specific executive functions such as verbal fluency, response inhibition, processing speed and shifting attention are impaired (4,5,6). After controlling for general intellectual skills, differences were observed in a few of the executive function tasks (4,6). Considering the findings in the literature collectively, they provide evidence supporting the 'multiple cognitive deficit hypothesis'.

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common developmental disorders of childhood characterized by inattention, hyperactivity and impulsivity that are unsuitable for the individual's developmental level (7). Its prevalence is reported to vary between 3-12% worldwide (8).
ADHD is caused by dysfunction in the prefrontal-striatal circuits, leading to executive dysfunction (9). In many studies, it has been reported that children with ADHD are weaker than other individuals in processing speed, response inhibition, working memory, verbal fluency, and shifting attention (4,10,11). In a meta-analysis, especially in all functions of executive functions in groups with ADHD; they stated that there is a significant deterioration in response inhibition, vigilance, working memory and planning (12). Weakness in executive function tasks was significant in both clinical and community samples and could not be explained by symptoms of other disorders, academic achievement, or differences in intelligence between groups (12). On the other hand, some researchers argued that the effectiveness of executive functions in diagnosing ADHD is limited due to the heterogeneous nature of this disorder (13,14). In a study, it was reported that 26% of children with ADHD did not score in the range of clinically significant impairment in any of the Executive Function measures, 40% had impairment in only one area, and 34% had impairment in more than one area (15). Similarly, another study found that 18-27% of individuals with ADHD did not show any impairment in Executive Function measures, and only 4-13% had a significant impairment in five or more measures of Executive Function (16).

Several hypotheses have been proposed to understand the neurocognitive relationships in the comorbidity of dyslexia and ADHD (4,17). Willcutt et al. reported that children with ADHD were associated with inhibition defects, children with dyslexia were associated with phonological awareness and verbal working memory defects, and there were defects in all measurements in the Dyslexia+ADHD group (18). Studies have shown that most of the children with dyslexia or ADHD exhibit significant weakness in neurocognitive measures and the comorbid group exhibits as much impairment as the Pure Dyslexia and Pure ADHD groups (4,19). According to the multiple defect hypothesis, multiple genetic and environmental risk factors potentially work together to increase susceptibility to the disorder. These etiological factors produce behavioural symptoms by affecting the relevant neural systems and cognitive processes. As a result, a single etiological or cognitive factor cannot be sufficient for the emergence of a disorder. For a behavioural disorder to occur, each multiple cognitive deficits are required, one of which is due to multiple etiological factors.

This study aims to examine the neurocognitive deficits in Dyslexia and ADHD in a relatively broad framework using neuropsychological tests and to determine whether a neuropsychological profile specific to Dyslexia and ADHD can be obtained by revealing the relative importance of these defects. Our study hypotheses that children with dyslexia and/or ADHD will have significant deficits in all neurocognitive measures when compared to the healthy control group. It is expected that children with ADHD and/or Dyslexia will have deficiencies in neurocognitive functions such as reaction inhibition, selective attention, continuous attention, alternating attention, and visuospatial short-term memory when compared to the healthy control group.

**MATERIAL and METHODS**

**Participants and Procedures**

Participants who applied to the Ankara University Faculty of Medicine Child and Adolescent Psychiatry Outpatient Clinic with complaints of course failure, difficulty in reading and writing and/or lack of attention and hyperactivity and diagnosed with Dyslexia-only, ADHD-only or Dyslexia+ADHD, and a healthy control group 132 case included. The diagnosis group of the sample consisted of children aged 7-11 going to the 2nd-5th grade, who applied to the child psychiatry outpatient clinic for the first time and/or had previously been diagnosed with Dyslexia and/or ADHD. The healthy control group consisted of children between the ages of 7-11, attending primary school, without any psychiatric and/or neurological disorders and course failure problems.

Inclusion criteria were being diagnosed with Dyslexia and/or ADHD according to DSM-5 criteria, not having a comorbid psychiatric disorder, and having normal total intelligence (WISC-R<90). Exclusion criteria of the study were the presence of another psychiatric diagnosis accompanying dyslexia and ADHD, mental retardation or borderline dull-normal mental functioning (WISC-R<90), any known neurological or systemic disease, hearing and having vision problems and using drugs that affect cognitive abilities.

Subjects who gave verbal assent and whose parents presented written informed consent participated in the study following a complete description of the study. In addition to clinical evaluations based on DSM-5, the SLD clinical observation battery (SLD-COB) was utilized to confirm and exclude SLD diagnosis in the study and control groups, respectively. The WISC-R was also performed with all participants during psychometric evaluation to exclude the presence of intellectual disabilities. The application and evaluation of these tests were performed by experienced psychologists with specific training and experience in their application. Child and adolescent psychiatrists in the research team evaluated all participants for comorbid psychiatric disorders using the Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version–DSM-5 (K-SADS-PL-DSM-5). The researchers completed sociodemographic data forms with information provided by the parents of all participants. During the second session, the Stroop Test, Trail Making Test, Line Direction Determination Test, and Marking Test were administered together in one session. To control for potential confounding effects caused by clinical features, it was ensured that the patients were at their first referral and had not yet started psychostimulant medication, or if they were on medication, they had stopped taking it at least 48 hours before data collection practices. The study was approved by the Ankara University, Ankara Faculty of Medicine Clinical Research Ethics Committee (Date and Number: 10/10/2016, 15-709-16) and all procedures were in accordance with the standards in the Declaration of Helsinki.
Measures

Special Learning Disorder-Clinical Observation Battery (SLD-COB): The SLD-COB was initially developed by Korkmazlar in 1992 and then revised to involve new subscales. Nine subscales are included in the assessment, which evaluate reading, writing, and arithmetic skills, Gessell figures, the ability to draw a clock, right-left discrimination, lateralization, as well as before-after relationships and ordering. Each subscale is described as being consistent or inconsistent with SLD (20). In addition to supporting DSM-5-based SLD diagnosis, we used the data gathered from the SLD-COB to assess the presence and the severity of impairment in reading.

Wechsler Intelligence Scale for Children-Revised (WISC-R): This scale was established to determine the IQ levels of children between 6 and 16 years. Initially, the scale was developed by Wechsler as the Wechsler-Bellevue scale to assess adults. Then the WISC was arranged for children in 1949 based on this adult scale. The WISC-R is a version of the original WISC that was revised in 1974 (21). The Turkish adaptation of the WISC-R was developed by Savaşır and Şahin (22). This scale consists of verbal and performance parts, and IQ scores are identified in three parts: verbal, performance, and full-scale IQ.


K-SADS-PL is a semi-structured diagnostic instrument developed by Kaufman et al. (1997) according to DSM-IV criteria to assess the present and lifetime psychopathology in children and adolescents (23). The Turkish adaptation of the updated version of K-SADS-PL according to DSM-5 criteria was conducted by Unal et al. (24).

Stroop Color and Word Test: It was developed by Stroop, and its Turkish validity and reliability were conducted by Karakaş et al. (25). The Stroop test presumably is the most used measure to evaluate cognitive control, in a sense of selective attention and cognitive flexibility. The primary measure of Stroop tests, known as ‘the Stroop effect’, refers to the significant performance deficit in response to stimuli that contain a dominantly represented task-irrelevant dimension compared to task-relevant or neutral features. It is often described as measuring the individual’s ability to shift cognitive set, and believed to provide a measure of cognitive inhibition or the ability to inhibit an overlearned response (25).

Trail Making Test: This test was developed by Reitan, and the Turkish validity and reliability study was conducted by Gündüz et al. (26, 27). Trail Making Test (B) is a psychomotor measure to evaluate cognitive control in the sense of the ability to change the cognitive sets. To perform this task, participants are required to switch between numbers and letters. They must draw a line between the circled letters and numbers. The tester records the reaction time (RT) during the session. Perseveration and reaction time are dependent variables that provide information about the cognitive control of the participants (27).

Verbal Cancellation Test: The Verbal Cancellation Test (CT) was originally developed by Weintraub and Mesulam (28,29). CT is used in the literature to measure vigilance/sustained attention and visuo-spatial skill. The Turkish version was developed within the context of the Neuropsychological Test Battery for Cognitive Potentials.

CT (Cognitive Test) was standardized for Turkish children between the ages of 6 and 11 years. The test–retest reliability coefficients of CT scores changed between 0.45 and 0.83.27 (30).

Statistical Analysis: Statistical analyses were performed using the SPSS 21.0 statistical package program. The Kolmogorov-Smirnov Normality Test was used to assess the data’s conformity to a normal distribution. For comparing categorical variables, the Chi-square Test and/or Fisher's Exact Test were employed. One-way analysis of variance (One-way ANOVA) was used to compare the means of more than two independent samples, and post hoc analysis comparisons were conducted using the Tukey HSD method. In cases where normal distribution was not achieved, the Kruskal-Wallis one-way analysis of variance, a nonparametric analysis of variance, was used. When a Kruskal-Wallis test was rejected, Dunn's test, a non-parametric pairwise multiple comparisons procedure based on rank sums, was used as a post hoc procedure. It is a non-parametric analog to multiple pairwise t-tests following rejection of an ANOVA null hypothesis. To address the possibility of Type 2 errors when comparing groups, the effect size was calculated using eta squared (31). Values around 0.01 are considered small, around 0.06 as medium, and around 0.14 as large (32). The test results of the four groups are shown in Table 2 for comparison. Pearson and Spearman Correlation Analysis methods were used to determine the level of correlation in continuous data. Probability values (p) smaller than 0.05 were considered statistically significant.

RESULTS

There were no significant differences in terms of age, gender, school grade level, monthly family income, maternal and paternal age among the four groups. The sociodemographic and clinical characteristics of the subjects are shown in Table 1.

Kruskal-Wallis H test showed that there were significant differences in Stroop Test, Trail Making Test, Verbal Cancellation Test and WISC-R verbal IQ score between the four groups (DD-only, DD+ADHD, ADHD-only, TDC), but there were no differences between the groups’ WISC-R performance and total IQ scores. Dunn’s pairwise tests were carried out for the four groups. The post hoc tests were performed with a significance level of $p = 0.008$ [0.05/6], Bonferroni adjusted for all possible group comparisons. Post hoc comparisons among the four groups revealed the presence of significant differences between the children with ADHD (ADHD-only, DD+ADHD) and non-ADHD children (dyslexia, TDC) on most neurocognitive measures Compared to the dyslexia-only group, children with ADHD (DD-only, DD+ADHD) demonstrated poor ability in the Stroop Test, Trail Making Test, Verbal Cancellation Test. Children with dyslexia (DD-only, DD+ADHD) had lower verbal IQ scores than non-dyslexic children. However, there were no differences in neurocognitive measures between DD-only group and DD+ADHD group (Table 2).
Table 1. The sample’s sociodemographic characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>DD-only (n=33)</th>
<th>DD+ADHD (n=37)</th>
<th>ADHD-only (n=32)</th>
<th>TDC (n=30)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (months)a</td>
<td>106 (25)</td>
<td>106 (19)</td>
<td>104.5 (29)</td>
<td>107 (21)</td>
<td>0.98</td>
</tr>
<tr>
<td>Gender (n,%)b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girl</td>
<td>16 (48.5%)</td>
<td>10 (27%)</td>
<td>9 (28.1%)</td>
<td>15 (50%)</td>
<td>0.08</td>
</tr>
<tr>
<td>Boy</td>
<td>17 (51.5%)</td>
<td>27 (73%)</td>
<td>23 (71.9%)</td>
<td>15 (50%)</td>
<td></td>
</tr>
<tr>
<td>School grade level (n,%)b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd Grade</td>
<td>10 (30.3%)</td>
<td>8 (21.6%)</td>
<td>8 (25%)</td>
<td>8 (26.7%)</td>
<td>0.99</td>
</tr>
<tr>
<td>3rd Grade</td>
<td>8 (24.2%)</td>
<td>11 (29.7%)</td>
<td>9 (%28.1)</td>
<td>7 (23.3%)</td>
<td></td>
</tr>
<tr>
<td>4th Grade</td>
<td>7 (21.2%)</td>
<td>9 (24.3%)</td>
<td>6 (18.8%)</td>
<td>7 (23.3%)</td>
<td></td>
</tr>
<tr>
<td>5th Grade</td>
<td>8 (24.2%)</td>
<td>9 (24.3%)</td>
<td>9 (28.1%)</td>
<td>8 (26.7%)</td>
<td></td>
</tr>
<tr>
<td>Monthly family income (TL)a</td>
<td>3000 (1900)</td>
<td>2250 (1725)</td>
<td>2875 (2100)</td>
<td>2500 (1137)</td>
<td>0.83</td>
</tr>
<tr>
<td>Maternal age</td>
<td>36 (9)</td>
<td>35 (9)</td>
<td>38.5 (8.75)</td>
<td>36 (5.5)</td>
<td>0.72</td>
</tr>
<tr>
<td>Paternal age</td>
<td>40 (9.5)</td>
<td>40 (7.5)</td>
<td>39.5 (10.75)</td>
<td>38 (5.25)</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Note: Medians are shown with Interquartile Range in parentheses, DD: Developmental Dyslexia, TDC: Typically Developing Children, ADHD: Attention Deficit Hyperactivity Disorder, a: Kruskal-Wallis H test, b: Pearson Chi-Square test.

Table 2. Comparisons of four groups on neurocognitive measures

<table>
<thead>
<tr>
<th>Test</th>
<th>DD-only (IQR)</th>
<th>DD+ADHD (IQR)</th>
<th>ADHD-only (IQR)</th>
<th>TDC (IQR)</th>
<th>H</th>
<th>p</th>
<th>ηp2</th>
<th>Corrected for multiple comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroop Test</td>
<td>41 (11)</td>
<td>47 (11)</td>
<td>45 (16)</td>
<td>37 (7)</td>
<td>53.59</td>
<td>&lt;0.001</td>
<td>0.39</td>
<td>TDC, DD&gt; ADHD, DD+ADHD</td>
</tr>
<tr>
<td>Trail Making Test</td>
<td>151 (31)</td>
<td>165 (40)</td>
<td>159 (56)</td>
<td>122 (33)</td>
<td>43.49</td>
<td>&lt;0.001</td>
<td>0.31</td>
<td>TDC&gt; DD&gt; ADHD, DD+ADHD</td>
</tr>
<tr>
<td>Verbal Cancellation Test</td>
<td>56.3 (1.8)</td>
<td>55 (2.3)</td>
<td>55.8 (2.2)</td>
<td>58 (1.5)</td>
<td>37.18</td>
<td>&lt;0.001</td>
<td>0.26</td>
<td>TDC&gt; DD&gt; ADHD, DD+ADHD</td>
</tr>
<tr>
<td>WISC-R verbal IQ score</td>
<td>90 (14.5)</td>
<td>92 (15)</td>
<td>103 (23.5)</td>
<td>98.5 (16)</td>
<td>14.47</td>
<td>&lt;0.001</td>
<td>0.09</td>
<td>TDC, ADHD&gt;DD, DD+ADHD</td>
</tr>
<tr>
<td>WISC-R performance IQ score</td>
<td>113 (17.5)</td>
<td>111 (21)</td>
<td>107 (18.75)</td>
<td>100.5 (25.25)</td>
<td>6.63</td>
<td>0.08</td>
<td>0.02</td>
<td>n.a.</td>
</tr>
<tr>
<td>WISC-R total IQ score</td>
<td>100 (14.5)</td>
<td>103 (17)</td>
<td>104 (18.75)</td>
<td>98 (16)</td>
<td>2.19</td>
<td>0.53</td>
<td>&lt;0.01</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

DISCUSSION

Children with ADHD and dyslexia exhibited significant deficits in all neurocognitive measures when compared to the healthy control group. The most important deficits are seen in reaction inhibition. Children with ADHD-only revealed the most significant weaknesses on reaction inhibition and visuospatial short-term memory measures. Children with dyslexia-only were evaluated to have deficits only in visuospatial short-term memory measurements. The comorbid group exhibited significant weakness on almost all neurocognitive measures compared with control group, but did not perform significantly lower than the ADHD-only groups.

In our study, we identified deficits in reaction inhibition, selective attention, sustained attention, shifting attention, and visuospatial short-term memory measurements in children diagnosed with ADHD. Studies have reported that children with ADHD have poor cognitive functions such as processing speed, inhibition, working memory, verbal fluency and shifting attention compared to other individuals (5,15,18,33). In the meta-analysis of Willcutt et al., especially in all functions of executive functions in groups with ADHD; stated that there was significant impairment in response inhibition, vigilance, distraction, working memory and planning (33). The current study, children with ADHD performed poorly on measures of response inhibition, selective attention, sustained attention, altered attention, and visuospatial short-term memory. These results are consistent with the results of previous studies (34,35).

In this study, it was observed that children with dyslexia-only took significantly longer to complete the Trail Making Test and Verbal Cancellation Test compared to the control group. However it was evaluated that the scores of the children with dyslexia from the Stroop Test compared to the healthy control group were not statistically different, and according to these results, it was evaluated that the children with dyslexia did not have a defect in response inhibition. Maura et al., in all neurocognitive measurements except verbal fluency and visuospatial short-term memory measurements in children with dyslexia; reported defects in altering processing speed, verbal working memory, and attention (36). According to the results of these tests in our study, it was evaluated that children with dyslexia-only had difficulties in neurocognitive functions such as instant attention, sustained attention, distraction and visuospatial memory. These results support the multiple cognitive deficit hypothesis in children with dyslexia in line with the literature.

In the current study, it was determined that there was a statistically significant deficit in all neurocognitive measures for the comorbid group (DD+ADHD) when compared to the control group. In previous studies, it was found that ADHD-DD cases exhibited significant weaknesses in almost all neurocognitive measures when compared to healthy control groups. However, the comorbid group did not show significant differences when compared to the Dyslexia-only and ADHD-only groups (4, 34). Therefore, the findings obtained from the hypotheses proposed to understand the comorbidity between dyslexia and ADHD are clearly consistent with the multiple cognitive deficit hypothesis (4). These results support the multiple cognitive deficit hypothesis in children with comorbid group (DD+ADHD) in line with the literature.

The current study has several strengths and limitations. We tried to form a homogeneous group by excluding possible confounding factors such as comorbid neurodevelopmental disorders, major medical comorbidities and drug use. In addition to detailed psychometric evaluation, all cases underwent clinical examination by experienced child psychiatrists using a semi-structured interview form. The results of the present study should be evaluated with certain limitations in mind. The cross-sectional nature of the study restricts the ability to establish a cause-effect relationship. The relatively small sample size may be another limitation. Most neurocognitive measures were assessed with one or two tasks. Indeed, adding more tasks for each domain would enhance the validity and interpretability of the results. Although most children with ADHD did not receive stimulant therapy, it would be better for no child with ADHD to receive stimulant therapy for baseline comparison. Our study did not analyze the neurocognitive features of ADHD subtypes. It would be more descriptive to evaluate specific neurocognitive weaknesses among ADHD subtypes and compare it with children with dyslexia.

CONCLUSION

Taken together, all the results support the multiple defect hypothesis, demonstrating a significant overlap of neurocognitive deficits between both neurodevelopmental disorders. Both children with DD and ADHD exhibit weaknesses in multiple neurocognitive measures, and the comorbid group shows deficits consistent with both DD and ADHD without any additional impairments.

Acknowledgements: none

Conflict of interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author Contributions: YT, BGK: Data Collection, design of the study, YT: manuscript preparation, revisions. All the authors have read, and confirm that they meet, ICMJE criteria for authorship.

Ethical approval: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and/or with the Helsinki Declaration of 1964 and later versions.

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Medical Science and Discovery, 2023; 10(7):481-486

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