Assessment of Working Memory in Children With Attention-Deficit/Hyperactivity Disorder

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Objective: This research investigated the cognitive abilities and the working memory in children and youngsters with three different types of attention-deficit/hyperactivity disorder (ADHD): (a) mainly with attention-deficit, (b) hyperactive and impulsive, and (c) combined. Method: A computerized test called Infant Cognitive Abilities Test, which measures five cognitive abilities based on the Cattell-Horn-Carroll model, was used. Thirty-two children from both sexes, aged 7 to 15 years, from the Hospital das Clínicas, suffering from ADHD and a control group with 30 children from a state elementary school (first through eighth grades) were submitted to the test. Results: The results showed that there were significant differences with regard to the reaction time of the working memory of the different types of ADHD. Conclusion: Children suffering from ADHD had high test scores for the visual memory items of the test, when compared with the results in the auditory memory items. 

Keywords: attention-deficit; inductive reasoning; working memory; short-term memory

Introduction

The concept of hyperactivity is a subjective medical construct and has appeared as a nosological entity, as a neurological disease, and during the observation of learning disabilities. At first, learning disabilities and attention-deficit/hyperactivity disorder (ADHD) had the same dimension in the scientific world, hampering the differential diagnosis between them.

The etiology of ADHD may be multifactorial including genetic, biological, and neuropsychological factors. The genetic vulnerability is higher than 50% in ADHD (Barbosa, Barbosa, & Nascimento, 1999a, 1999b). Exposition to a variety of chemical substances during pregnancy and complications such as long duration of delivery may be related to ADHD (Van der Meere, 1996; Watson & Ramey, 1978; Yarrow, 1978). The biological deficit is supported by brain neuroimaging studies in which ADHD is basically a genetically inherited dysfunction of the prefrontal cortex, partially due to a deficiency in the dopamine neurotransmitter. Neuropsychological studies also suggest that ADHD is associated with alterations in the prefrontal cortex and its projections to subcortical structures, thus characterizing this disorder by frequent levels of inattention, hyperactivity, impulsivity, disorganization, and social inability, involving deficits in the inhibitory system or executive functions of the working memory (Baddeley, 1996; Baddeley, Lewis, Eldridge, & Thomson, 1984; Baddeley, Logie, Bressi, Della Salla, & Spinnler, 1986; Fallgatter & Hermann, 2001). Several studies report that the main characteristics of ADHD are related to a difficulty to inhibit or restrain impulses. Based on these findings, we may say that this difficulty to inhibit impulses enables the efficient operation of some psychological processes, such as the executive functions.

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The executive functions are mental complex activities needed for planning, organizing, guiding, revising, and monitoring the necessary behavior to achieve goals. These functions start to develop in the first year of the child’s life and continue to develop until adolescence. Through executive functions, we can focalize the attention on an activity without the interference of distracting stimuli. The executive functions allow us to guide our actions by received instructions rather than by external influences (i.e., they allow the self-regulation of behavior or the inhibition of impulses to enable us to do what we intend to do).

The behavioral and cognitive dysfunctions in ADHD may directly interfere in the academic lives of these children, with dramatic consequences in their global development (Meili, 1955; Pennington & Ozonoff, 1996; Posner & Cohen, 1984; Swanson & Posner, 1991; Watson & Ramey, 1978). In many cases, the etiology of ADHD remains obscure, and further research is needed to help in the prevention and cure of this disorder.

In a review of the literature from 2002 to 2004, we have found 1,774 articles on ADHD (sources: MEDLINE and PsycINFO), and we have verified that there are currently several studies on ADHD, although we have only found one Brazilian article that correlates ADHD with working memory. Our study aimed to show the interaction of ADHD with working memory. We present in this study five subtests to assess the working memory according to the C-H-C model. This model has contributed to the consistency and credibility of one of the most currently accepted theories of human intelligence. This integration is an evolution in the ideas contained in the factorial model of the structures of human cognition abilities (Pasquali, 2001; Primi, 2002).

### Material and Method

In this study, we used the Infant Cognitive Abilities Test (TIHC), which was developed to assess the working memory in Brazilian children (adapted by Primi, 2002). The battery contains five activities that measure five cognitive abilities: inductive reasoning (IR), auditory short-term memory (AM), visual short-term memory (VM), auditory working memory (AWM), and visual working memory (VWM). The computerized TIHC test was also compared to the independent external evaluation obtained by the school teachers of the same children.

The participants of the study were 32 children with a diagnosis of ADHD from both genders, aged between 7 and 15 years, recruited in the Hospital das Clínicas, Child and Adolescence ADHD outpatient unit (SEPIA), University of São Paulo- Brazil, and a control group with 30 children from a state elementary school (1st through 8th graders). Each child took 30 minutes to finish the whole test.

The reasoning and memory measures given by the TIHC were compared between the ADHD groups (see Table 1). This initial analysis was performed to compare the memory in the ADHD children subgroups (i.e., those predominantly inattentive, hyperactive/impulsive, and combined type). One-way Wilcoxon W test with a significance of 0.05 was used. The SPSS was the software used for the analyses.

<table>
<thead>
<tr>
<th>Items of the Cognitive Abilities Child Test for ADHD Groups</th>
<th>Mean</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive reasoning</td>
<td>20.43</td>
<td>0.96</td>
<td>0.39</td>
</tr>
<tr>
<td>Reaction time–inductive reasoning</td>
<td>3.45</td>
<td>0.81</td>
<td>0.45</td>
</tr>
<tr>
<td>Auditive storage memory</td>
<td>6.40</td>
<td>0.71</td>
<td>0.49</td>
</tr>
<tr>
<td>Visual storage memory</td>
<td>10.5</td>
<td>0.80</td>
<td>0.45</td>
</tr>
<tr>
<td>Extension time–visual storage memory</td>
<td>4.0</td>
<td>2.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Reaction time–visual storage memory</td>
<td>1.46</td>
<td>1.90</td>
<td>0.16</td>
</tr>
<tr>
<td>Auditive working memory</td>
<td>25.62</td>
<td>0.67</td>
<td>0.51</td>
</tr>
<tr>
<td>Visual working memory</td>
<td>5.28</td>
<td>0.49</td>
<td>0.61</td>
</tr>
<tr>
<td>Reaction time–visual working memory</td>
<td>3.60</td>
<td>0.75</td>
<td>0.48</td>
</tr>
<tr>
<td>Reaction time for the whole TIHC</td>
<td>2.04</td>
<td>1.26</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Scores in the memory subscales of the TIHC have not evidenced significant differences between the ADHD subtypes. It may be said that in terms of different types of memory, reaction time, and IR, the three subtypes of ADHD children pertain to the same population and are not independent groups according to these variables. Therefore, for the comparison of these scores, we separated the groups according to the presence/absence of ADHD and used ANOVA with a significance level of 0.05.

Results

The scores in the memory subtests were not significantly different in the three different ADHD subtypes. This suggests that in our sample, these subtests did not find independent subgroups of ADHD participants. Comparing the ADHD group and controls, we verified that in the AM subtest, there was a significant difference between the ADHD and the control groups. The reaction time for the inductive reasoning (RT-IR), visual short-term memory (RT-VM), visual working memory (RT-VWM), and reaction time for the whole test were also statistically significant between ADHD-C group compared with the control group (see Table 2).

On the other hand, in the RT-IR, the score for ADHD groups has shown to be significantly faster when compared with controls \( (F = 93.89, p = .00) \), and the interaction between the two groups was higher, with 61% (see Table 3). The reaction time of the ADHD-C group was significantly higher when compared with the control group, and the correlation between these two groups was also high, 61% (i.e., even though the ADHD-C group has shown a significantly lower time than the control group, it also had good performance in this cognitive ability, which means that its ability in this capability is higher than that of the control group).

According to these results, the inattention subgroup was faster and committed more errors than both the hyperactive and the combined groups. They also had better scores that were almost similar to those of the control group (see Figure 1).

Another significant finding between ADHD and controls was the AM being the mean score of the control group, 6.40 \( (F = 23.95, p = .00) \), and the standard deviation, 1.54. The correlation of both groups was 28.5%.

Table 4 shows that the AM extension was significantly higher in the control group (recall of 11 words) than in the ADHD group (recall of 8 words). The correlation between groups was 24.4%. The ADHD-I subtype scored 8 and the ADHD-HI subtype scored 6 \( (F = 23.95, p = .00) \).

Table 5 shows data from the VM, with the hyperactive subtype performing better in this ability (score = 22 items) than did the control group (score = 20 items), but the results were not statistically significant \( (F = 0.49, p = .61) \).

At the same time, the VM and reaction time (RT1) means for this task did not show significant differences between groups, even though the scores and performance of the control group were higher than those of the ADHD...
group. Figure 2 shows that the ADHD group achieved 22 items in this task and the control group reached 20 items. As the total number of items of this task is 27 items, it may be suggested that ADHD children had good performance in these memory tasks and that the reaction time for the ADHD group was very low compared with the control group.

Moreover, there was a significant difference between the ADHD group and controls with regard to the reaction time for extension in the VM. The control group had the maximum time of 35.91 s, mean of 17.4511, and standard deviation of 7.9280; the ADHD group had a maximum time of 14.50 s, mean of 4.2000, and standard deviation of 3.1200. The interaction between them was 14.6% (see Table 6).

The reaction time in the VWM task was significantly different between groups ($F = 29.55$, $p = .00$). The ADHD group showed shorter time to respond (9.10 s) when compared with the control group (15.87 s). The reaction time means for the control group were higher than for the ADHD group. The effect of the interaction of this variable was 33%. However, the performance of both groups was not significantly different ($F = 2.44$, $p = .12$; see Figure 3).

Table 7 displays data from the VWM. The control group had lower scores in this cognitive capability compared with the ADHD group, and there was higher variety in this task, without significant differences between them ($F = 2.05$, $p = .15$).

In Table 8, there are the scores (number of correctly answered items) and the extensions (extension item) for the AWM task. The inattention subtype had better, although not significant, capacity in this ability than the other subtypes. Scores ranged from 15 to 46 items remembered, and the complete extension ranged from 6 to 7 items recalled.

Table 9 shows data from the RT for the whole test and the mean is higher than the statistical significance between groups with a correlation of 50% in this task. The control group had a mean of 4.7346 ($F = 57.20$, $p = 0.00$) and standard deviation of 1.7146; the whole RT was 9.53 seconds. The hyperactive subtype had a longer time compared with the other subtypes with a mean of 2.4234 and standard deviation of 0.9933; RT was 3.90 seconds.

**Conclusion**

The results of this study suggest that the behavior of children with ADHD has a different neuropsychological
pattern with regard to IR and WM. The children presented different performances in the five tasks of the test, indicating that there are differences in many aspects of the memory test. Moreover, there was significant difference between the reaction time between the groups with and without ADHD.

Based on these data, we consider that the ADHD-I subtype had a better performance in reaction time compared with the ADHD-C group. However, the performance was much better in the ADHD-HI subtype.

In the IR task, the ADHD group had a better time than the control group, but the score was better for the group without ADHD. The scores of the VWM task were also better for the ADHD group, and the RT of the whole test was significantly faster for the ADHD group compared with the control group.

According to the literature, the results for the nonhyperactive group should be better when compared with the group with hyperactive patterns (Kuntsi, Oosterlaan, & Stevenson, 2001; Perchet & Garcia-Larrea, 2000). Some studies show that nonhyperactive participants present less visual-motor impairment, lower processing speed, and higher ability to remember verbal material, compared with the hyperactive group (Cohen et al., 2000; Logan & Cowan, 1984).

On the other hand, other studies showed more difficulty in remembering visual materials than verbal ones when
comparing the inattentive and the hyperactive subtypes. We found in this study that the ADHD group, inattention subtype, showed more difficulties than the other group. The performance of the hyperactive subtype group was the closest to the control group compared with the ADHD group as a whole. The results of this task agree with the literature. Denckla (1989, 1991), Sonuga-Barke, Taylor, and Sembi (1992), Strauss and Alphal (1992), and Rohde (1997) suggested that there are no differences between the performance of mainly hyperactive and normal or control participants.

Our study showed that ADHD and control groups had different performances on the whole test. There were no differences in the performance of ADHD subtypes, not being statistically significant between this group; however, there were significant differences between some ADHD subtypes and the control or normal group. Moreover, the ADHD group had shorter time in the whole test compared with the control group. Even though the ADHD group was faster, there were few mistakes; thus, the performance in some tasks of the test for the ADHD group was good but not higher than for the control group. Therefore, there were actually no statistically significant differences.

The correlation of the VWM and the reaction time between the whole ADHD and control groups was 50% in the five test tasks (thus, in the whole test, i.e., it had a great significance in the study).

In conclusion, we found that although the ADHD group had lower reaction time in the working memory for some tasks, they also had good performance compared with the control group. This fact is interesting because predominantly hyperactive and impulsive children with ADHD are fast, commit less errors, and have higher performance than the control/normal group.
Table 8
Data From the Auditory Working Memory (AWM) of the Infant Cognitive Abilities Test (TIHC) Between the Attention-Deficit/Hyperactivity Disorder (ADHD) and Control Groups (N = 62)

<table>
<thead>
<tr>
<th>Item</th>
<th>Group</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score AWM</td>
<td>control</td>
<td>30</td>
<td>16.00</td>
<td>55.00</td>
<td>30.0333</td>
<td>10.7301</td>
</tr>
<tr>
<td></td>
<td>inattention</td>
<td>10</td>
<td>15.00</td>
<td>46.00</td>
<td>29.2000</td>
<td>9.7956</td>
</tr>
<tr>
<td></td>
<td>hyperactive</td>
<td>11</td>
<td>11.00</td>
<td>45.00</td>
<td>24.3636</td>
<td>11.3514</td>
</tr>
<tr>
<td></td>
<td>combined</td>
<td>11</td>
<td>11.00</td>
<td>33.00</td>
<td>23.6364</td>
<td>7.2563</td>
</tr>
<tr>
<td>Extension AWM</td>
<td>control</td>
<td>30</td>
<td>1.00</td>
<td>7.00</td>
<td>3.5667</td>
<td>2.0457</td>
</tr>
<tr>
<td></td>
<td>inattention</td>
<td>10</td>
<td>0.00</td>
<td>6.00</td>
<td>3.2727</td>
<td>1.7939</td>
</tr>
<tr>
<td></td>
<td>hyperactive</td>
<td>11</td>
<td>0.00</td>
<td>5.00</td>
<td>2.9230</td>
<td>1.4187</td>
</tr>
<tr>
<td></td>
<td>combined</td>
<td>11</td>
<td>0.00</td>
<td>4.00</td>
<td>1.9230</td>
<td>0.9467</td>
</tr>
</tbody>
</table>

Table 9
Data From Reaction Time of the Infant Cognitive Abilities Test (TIHC) Between the Attention-Deficit/Hyperactivity Disorder (ADHD) and Control Groups (N = 62)

<table>
<thead>
<tr>
<th>Item</th>
<th>Group</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time</td>
<td>control</td>
<td>30</td>
<td>1.68</td>
<td>9.53</td>
<td>4.7346</td>
<td>1.7146</td>
</tr>
<tr>
<td></td>
<td>inattention</td>
<td>10</td>
<td>1.20</td>
<td>3.61</td>
<td>1.8693</td>
<td>0.7611</td>
</tr>
<tr>
<td></td>
<td>hyperactive</td>
<td>9</td>
<td>1.04</td>
<td>3.90</td>
<td>2.4234</td>
<td>0.9933</td>
</tr>
<tr>
<td></td>
<td>combined</td>
<td>10</td>
<td>1.02</td>
<td>3.61</td>
<td>1.8823</td>
<td>0.8165</td>
</tr>
</tbody>
</table>

References


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