Activity Level and Phonological Short-Term Memory Processes in Boys with ADHD

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Introduction

Phonological-storage/rehearsal deficits are documented consistently in children with ADHD (cf. Kaspr et al., 2012) and are associated with impaired language acquisition, reading comprehension, understanding classroom instructions, and social problems (cf. Bolden et al., 2012). The association between phonological storage/rehearsal deficits and ADHD behavioral symptoms, however, is less well understood.

Recent research suggests that the impact of phonological storage/rehearsal deficits on activity level is complex and may vary depending on the type of task and the demands placed on the individual. For example, some studies have found that children with ADHD move more than controls during tasks that require sustained attention, while others have found no significant differences between groups. The present study aimed to examine the relationship between phonological storage/rehearsal deficits and activity level in children with ADHD, controlling for various potential confounds.

Method

Participants

Eighteen children with ADHD (9 with ADHD, 9 with ADHD) and 17 TD children aged 6 to 12 years participated in the study following a comprehensive clinical evaluation (i.e., K-ADS clinical interview, standardized parent/teacher rating scales). The children were recruited by or referred to the Children’s Learning Clinic (CLC-IV) through community resources (i.e., pediatricians, community mental health clinics, school system personnel, self-referral). The CLC-IV is a research-practice training clinic located in the surrounding community for conducting developmental, clinical research and providing pre and post comprehensive diagnostic and therapeutic services. In our base, children with ADHD demonstrated learning, behavioral or emotional problems, as well as TD children (those without a suspected psychological disorder) whose parents agree to have them participate in developmental clinical research studies.

Procedure

Phonological memory tasks. Word lists of increasing length (2, 4, and 8 words) were presented to and recalled by children following a brief (1 s) interval to assess the short-term memory capacity while restricting the need to actively rehearse the information. The brief 3 s delay condition was utilized to minimize the influence on episodic memory (the brief memory register for holding acoustic information). Performance scores (% of trials correct) were examined to determine each child’s vocal span—defined as the maximum set size at which a child recalls correctly all stimuli in the correct serial order at least 95% of trials—related to increased delay (i.e., 12-s, 21-s) were used to assess their ability to actively maintain information in the STM. The two extended delay conditions were selected to equate the delay interval between adjacent conditions (i.e., 9 s intervals between 1 and 12 s, and between 12 and 21 s) and allow sufficient time to challenge the articulatory (syractical) rehearsal mechanism based on earlier findings demonstrating that children are able to maintain words by means of covert rehearsal up to 30 s (Starr 1977). All phonological memory measures were counterbalanced to control for order effects.

Control (C) conditions. Children’s activity level was assessed while they used the MicroFit® Paint program for free consecutive movements across two conditions (C) by following the children’s activity level during the following conditions: (a) 4-second delay and (b) 8-second delay. Free consecutive movements allow small deviations in the children’s hands while the program monitors a variety of interactive tools, and serves as pre and post conditions to assess and control for demand characteristics (e.g., interacting with the same computer in the same room in the same chair), and potential within-day fluctuations in attentional behavior (e.g., fatigue effects).

Activity level: MicroFit® MotionLogger (Ambulatory Monitoring Inc., 2004) actigraphy were used to measure children’s activity level (see Figure 1). The accelerometry-sensitive devices resemble a wristwatch and were set to be in Proportional Integrating Measure (PIM) mode, which measured the intensity of movement (i.e., quantifies gross activity level). Movement was sampled 16 times per second (16 Hz) and collapsed into 1-min epochs. Data were downloaded via a hardware interface and analyzed using the ActionW2 software program (Ambulatory Monitoring Inc., 2004) to calculate mean activity frequencies for each child during the control and WM tasks. Children were told that the actigraphy were “special watches” that let them play the computer W2 games. The Observer (Noldus Information Technology, 2005) live observation software was used to count start and stop times for each task, which were matched to the time-stamps of each dictation from the actigraphy. Actigraphy were placed immediately before the actigraphy above the children’s left and right ankles using Velcro® bands. Ablation placement was used in cases of poor placement due to the presence of frequent movement. The children were asked to avoid wearing items that may affect the readings (e.g., metal objects).

Results

Impact of phonological storage on activity level.

The (2) ADHD, TD (C5, I PH, 4, 6-word conditions, C2) Mixed-model ANOVA revealed significant main effects for set size, probe, and the interaction (Figure 1). Children with ADHD moved significantly more than TD children during the 4-word condition (ES=1.24), but not the 2- and 6-word conditions (p<0.06). Activity level increased in children with ADHD between the 2-word and 4-word conditions (ES=0.58), and remained stable across the 4-word and 6-word conditions (p<0.15). TD children were more active during the 4-word condition relative to the 4-word (ES=0.54) and 2-word conditions (ES=0.55).

Impact of rehearsal duration on activity level.

The impact of rehearsal demands on children’s activity level was examined by comparing each child at their individual phonological span, defined as maximum set size at which a child recalls at least 90% of the stimuli correctly as recommended by Cowan et al. (2005), and examining changes in performance associated with increased delay (i.e., 12- and 21-delay conditions relative to the 3-delay). The (2) ADHD, TD, 12- and 21-delay conditions, C2 (Mixed-model ANOVA revealed significant main effects for delay, probe, and the interaction (Figure 2). Children with ADHD moved significantly more than TD children during the 12- and 21-second delay conditions (ES=0.94) but not the 3-second delay condition (p<0.07). Rehearsal delay did not significantly impact activity level for children with ADHD (p>0.06), whereas TD children exhibited decreased motor activity during the 12- and 21-second delay conditions (ES=-0.56) and 21- and 30-delay intervals relative to the 3-delay interval.

Discussion

Children with ADHD and typically developing children both evinced similar magnitude increases in activity level as a function of increasing storage demands; however, this increase occurred at lower cognitive loads for children with ADHD relative to TD children. These findings are consistent with the smaller capacity phonological storage available in children with ADHD, and suggest that previous failures to find a relationship between phonological memory and activity level may have been attributable to task limitations (Bolden et al., 2012).

After controlling for phonological storage capacity, motor activity in children with ADHD was unaffected by increasing rehearsal demands, whereas TD children became moderately less active during the longer delay conditions. Given that these rehearsal conditions did not affect the task quality, these findings suggest that high levels of activity may impede rehearsal of phonological information across an extended delay.

Table 1. Sample and Demographic Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADHD (N=18)</th>
<th>TD (N=17)</th>
<th>p-value</th>
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<tr>
<td>Age (yrs)</td>
<td>9.6 ± 1.2</td>
<td>9.7 ± 1.1</td>
<td>0.76</td>
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<tr>
<td>Gender (M/F)</td>
<td>12/6</td>
<td>12/5</td>
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<tr>
<td>Diagnosis</td>
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<td>TD</td>
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Table 2. Results of the Mixed-model ANOVA

<table>
<thead>
<tr>
<th>Condition</th>
<th>ES</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-word</td>
<td>1.24</td>
<td>0.01</td>
</tr>
<tr>
<td>4-word</td>
<td>0.94</td>
<td>0.07</td>
</tr>
<tr>
<td>6-word</td>
<td>0.58</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Figure 1. Impact of Rehearsal Duration on Activity Level

Figure 2. Impact of Phonological Storage on Activity Level

Graphs depicting activity level in children with ADHD (ADHD) and typically developing children (TD) during the 12- and 21-second delay conditions, C2 (Mixed-model ANOVA revealed significant main effects for delay, probe, and the interaction (Figure 2). Children with ADHD moved significantly more than TD children during the 12- and 21-second delay conditions (ES=0.94) but not the 3-second delay condition (p<0.07). Rehearsal delay did not significantly impact activity level for children with ADHD (p>0.06), whereas TD children exhibited decreased motor activity during the 12- and 21-second delay conditions (ES=-0.56) and 21- and 30-delay intervals relative to the 3-delay interval.