The Effects of ADHD (Beyond Decoding Accuracy) on Reading Fluency and Comprehension

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ADHD, Reading, and the Fourth Grade Shift

It has long been observed that learning disorders, especially reading difficulties, occur in combination with Attention-deficit/Hyperactivity Disorder (ADHD). Given the greater than expected co-occurrence of difficulty with reading and ADHD, the overlap between the two disorders has been a focus of study (McGrath et al., 2010). Despite the contribution of these studies, relatively little work has been done to examine the specific influence of ADHD on reading fluency and comprehension. It is clear that if an individual with ADHD has a disorder involving basic word reading, then he/she will most likely also have difficulty with reading comprehension; however, studies of children with ADHD without reading basic word reading deficits have shown that individuals with ADHD often have difficulties in reading comprehension even though they have intact word reading accuracy (Ghelani et al., 2004), perhaps as a result of their ADHD-related executive function deficits (Sesma et al., 2009).

A major shift occurs around third or fourth grade from “learning to read” to “reading to learn” (Bernstein & Waber, 1991). From this point forward, curricula emphasize fluency and comprehension rather than more basic word recognition skills. Not surprisingly, it is around fourth grade that many children with ADHD start to have academic problems, even when they had
done well in earlier grades. Beyond third grade, students are also expected to be able to incorporate cause/effect sequences, goals/plans for characters, and conclusions that relate to final events to those at the beginning of the story (Westby & Watson, 2004). Working memory deficits may impede students with ADHD from monitoring what they read (McInnes et al., 2003), as they are more susceptible to being distracted by detail when reading longer text—failing to “remember” main ideas.

**ADHD and Processing Speed**

Reading ability, including fluency, is linked to *processing speed*, or the ability to rapidly and efficiently respond to basic stimuli (Rucklidge & Tannock, 2002). Processing speed is typically defined as speed of completion of a task *with reasonable accuracy*. Processing speed tasks include tasks such as quickly associating numbers with symbols (including components of IQ tests), searching for and responding to specific targets, as well as rapid naming of visual stimuli (Willcutt et al., 2005). Thus, processing speed may be a more fundamental cognitive process that underlies the efficiency with which one can read and write. Slowed processing speed has been described as a sensitive but not specific characteristic of a broad range of disorders common to childhood (Willcutt, Sonuga-Barke, Nigg, & Sergeant, 2008).

Children with ADHD have been shown to demonstrate slowed processing speed relative to typically developing peers, across a wide variety of such tasks including: graphomotor speed (Shanahan et al., 2006); rapid “automatized” naming speed (Willcutt et al., 2010) and, reaction time on computerized tasks (Wodka et al., 2007). Thus, processing speed may represent a neuropsychological deficit in ADHD that can contribute uniquely to reading difficulties, particularly as it may influence efficiency of reading fluency among those who can read single words accurately. Further, the effects of processing speed on reading fluency can subsequently affect further development of more complex academic skills such as reading comprehension (Wolf & Katzir-Cohen, 2001), highlighting the interdependence of automaticity and comprehension. In other words, as reading becomes more automatized, less mental effort and attentional resources are required for ongoing decoding and accurate word reading; thus,
these resources can be allocated to the task of translating text into meaning.

School-aged children with ADHD are found to be slower than their same-age peers without ADHD on nearly every type of timed task, including basic skelemotor (Cole, Mostofsky, Larson, Denckla, & Mahone, 2008) and oculomotor speed (Mahone, Mostofsky, Lasker, Zee, & Denckla, 2009), as well as those involving higher order (controlled) responses (Jacobson et al., 2011; Wodka et al., 2007). Importantly, these processing deficits associated with ADHD have been described as occurring not at the level of orienting to or perceiving a stimulus, which is related to posterior brain systems, but rather between sensation/perception and action, and involve a state of preparedness to respond, including selection of an appropriate response, thought to be related to premotor and prefrontal circuits, as well as frontal-posterior connections involving these areas (Mostofsky & Simmonds, 2008). These behavioral findings implicating “executive” aspects of processing are consistent with recent anatomic MRI evidence of anomalous brain development in ADHD. For example, on the average, children with ADHD have reduced brain volume (by 3-8%) compared with children without ADHD of the same age (Bush, 2008). These effects are widespread throughout the brain, and are associated with executive dysfunction and learning problems, especially during elementary school years. Recent longitudinal studies of cerebral cortex have shown that children with ADHD reach maturation 2-5 years later in premotor brain areas (Shaw et al., 2007), thought to be critical to response control and selection, and thus may contribute to reduced efficiency of response speed.

**ADHD, Motor Skill, and Speed**

Many teachers report that children with ADHD, particularly boys, can be clumsy or have poor handwriting. While these could be by-products of hyperactivity, closer examination shows that many of these children have trouble coordinating motor skills of all types (Cole et al., 2008; Larson et al., 2007). As children with ADHD progress through school, increasing demands that include more and more writing can contribute to fatigue, difficulty with sustained performance, less than optimal classroom alertness and frustration. All these issues can contribute to impressions of increased “distractibility,” and
to marked difficulties under the demands for simultaneous writing and listening. As such, it can be important for teachers to adjust their demands for written work from children with ADHD, especially with respect to timed “pressure write” composition tasks.

The brain also controls eye movements in much the same way as it controls arms and legs (Leigh & Zee, 2006). Not surprisingly, the areas of the brain responsible for voluntary motor control of eye movements are located “next door” to the areas responsible for movement of other parts of the body, and nearly all of these are found in or connected to the frontal lobes (known to develop atypically with ADHD). Just as children with ADHD have difficulty with arm, finger and leg movements, they are also slower and less precise when making eye movements. For example, in a recently published study from our lab, when asked to keep looking right at a dot on a video screen that simply moves back and forth, children with ADHD are markedly slower in moving their eyes toward a target than children without ADHD (Mahone et al., 2009). These findings add to the evidence that children with ADHD need more time to complete tasks. Perhaps more importantly, the results suggest that students with ADHD are likely working much harder than their peers whenever they manage to keep pace with the rest of the class. Thus, they are far more likely to experience fatigue (cognitive, physical) that could adversely affect their availability for learning.

**Processing Speed and Reading Fluency**

Reading fluency, or the ability to read words quickly either in isolation or text, is especially critical for older children who are required to learn from what they are reading. The lack of fluency increases demands on other processes, such as working memory, and results in difficulty with comprehension because higher level processes have to compete with word decoding for the same time-limited resources (Shankweiler et al., 1999), creating a bottleneck. Therefore, especially for older children, it is critical that they are not only accurate at word reading, but also efficient, automatic and fluent readers. It is well established that rapid automatized naming deficits are present in individuals with dyslexia; however, automaticity deficits are also observed in children referred for learning problems, whether or not they
have dyslexia specifically (Waber et al., 2000). Experimentally, rapid naming of colors appears to be a unique deficit in ADHD (Wodka et al., 2008) and likely involves a different neural substrate than rapid letter naming (Moore & Price, 1999). Indeed, Tannock et al. (2000) found that children with ADHD were slower than controls on color naming, and that treatment with stimulant medication improved color naming (but not letter naming) in the ADHD group. It has been hypothesized that, due to decreased overt practice of color naming during the elementary school years, children with ADHD “lose” their automaticity with the task that was present in preschool years in association with more routine practice.

In a recent study from our lab, Li et al. (2008) directly examined the relationship between performance on rapid automatized naming (RAN) and reading fluency and comprehension in children with and without ADHD. Total naming time for fifty RAN stimuli was segmented into articulation time, pause time, and intra-individual variability articulation and pause times. Pause time was consistently correlated with reading fluency, suggesting that longer pause times between items were related to less efficient reading fluency. Additionally, pause variability (a marker for the response preparation aspect of executive control) was a significant predictor of reading comprehension, adding to the growing literature emphasizing the importance of executive control (beyond basic word reading) in reading fluency and comprehension.

**Multitasking and ADHD**

The relationship between ADHD and multitasking has received increased attention in recent years, given the ubiquity of electronic entertainment and communication devices, along with a perceived cultural shift toward immediate and brief responses to inputs (Richtel, 2010). Anecdotal evidence suggests that any potential difficulties with simultaneous demands may place children with ADHD at an amplified disadvantage in classrooms that are increasingly demanding with regard to multitasking (Hembrooke & Gay, 2003). The term “multitasking” includes a number of constructs, including strategic, “top-down” control of the allocation of attention and task switching. This aspect of multitasking is also related to executive function, for which
ADHD-related deficits have been well characterized (Mahone & Slomine, 2007; O'Brien, Dowell, Mostofsky, Denckla, & Mahone, 2010).

In a study from our research group presented at the 2009 meeting of the Cognitive Neuroscience Society, Ewen et al. (2009) directly examined multitasking in children with and without ADHD by assessing simultaneous processing of two computerized stimulus-response tasks using the "psychological refractory period" (PRP) paradigm. The PRP effect is present when greater interference (and thus longer response time) is observed with greater overlap between two sequentially-presented stimuli (Pashler & Johnston, 1985). In this experiment, children with ADHD showed greater interference when two processing streams overlapped, increasing their response time at a rate greater than that observed in children without ADHD. This observation suggests an increased cognitive bottleneck among children with ADHD during the simultaneous processing of two tasks; thus, multitasking required for routine daily tasks (including silent reading) may be more difficult and time consuming for individuals with ADHD than for those without. The reason for this increased interference in ADHD remains unclear. There are at least three possibilities. The first is that the central capacity is directly related to executive function, and many aspects of executive function are known to be impaired in individuals with ADHD. A second possibility is that children with ADHD may exhibit greater multi-task interference because they are less able to perform tasks automatically and therefore have to use less efficient top-down (effortful) mental processing strategies to accomplish the same results. A third possibility is that there is a true capacity limitation in ADHD that contributes to “rapid forgetting”, a phenomenon observed in our earlier studies of new learning among children with ADHD (Cutting, Koth, Mahone, & Denckla, 2003).

In summary, there is a strong suggestion that reduced processing speed associated with ADHD (even that observed in the absence of reading and language difficulties) may influence reading fluency via a variety of neurobiological and neuropsychological processes, including automaticity, sustained effort, and consistency of response preparation and retrieval fluency. There is considerable evidence that these cognitive processes are disrupted in ADHD, both at a behavioral and neurobiological level. Because children with ADHD have much more difficulty achieving a proficient level of
automaticity (Jacobson et al., 2011), they are required to think their way through some tasks their classmates find effortless. This is especially true when assignments need to be written, and children with ADHD can have particular difficulty listening to the teacher while simultaneously taking notes. In such cases, children with ADHD can benefit from separating writing and listening activities, avoiding the multi-tasking demand (e.g., allowing them to record lessons or by providing an outline of lecture materials).

**ADHD, Executive Function, and Reading Comprehension**

In many cases, even children who read fluently may not understand what they read because of deficits related to another fundamental component of executive function—*working memory*. Working memory involves temporary retention of information that was just experienced but no longer exists (Sheridan et al., 2007). Information in working memory can be stored for only short periods of time, and is dependent on *manipulation* or rehearsal. Working memory, thus, includes the memory that is needed for coping with continuous material, encompassing both storage and control functions. Deficits in working memory can undermine reading at several places (Shankweiler et al., 1999). Efficient working memory capacity is central to multitasking, as it allows for the “pause” that is necessary, between perception and action, to guide controlled behavior. Increased working memory load has been shown to negatively affect performance in typically developing children—increasing errors to levels observed among those with ADHD, with detrimental effects also seen in children with ADHD (Wodka et al., 2007).

Children with ADHD may be particularly vulnerable to difficulties in reading comprehension, even in the absence of basic word reading difficulties. Working memory has been observed to be disrupted in children with ADHD (Martinussen et al, 2005), but possibly for different reasons than in children with word decoding difficulties. Karateken and colleagues (Karataken et al., 2004) found that children with ADHD could hold (“maintain”) verbal information in the same manner as typically developing children; however their impairment occurred in the central executive (“manipulate”) component of working memory, affecting their ability to divide attention
between two tasks (i.e., multitask). These executive deficits may underlie the reports of reading comprehension difficulties observed in children with ADHD (Locascio et al., 2010; Sesma et al., 2009). Reading longer text passages requires more effortful cognitive processing, and thus greater demands on multitasking.

Conclusions and Future Directions

The neurobiological anomalies associated with childhood ADHD lead to vulnerabilities in executive control (including processing speed and working memory) that can have detrimental effects on reading fluency and comprehension, even in the absence of basic word reading difficulties. The research findings suggest that those working with children with ADHD should consider the impact of factors contributing to increased cognitive load in class settings, including demands for multitasking, speeded performance, and simultaneous writing and listening—reducing these demands when possible. These research findings also raise new questions for implementing classroom interventions. For example, if inhibition requirement imposes a working memory load for children with ADHD, how can teachers minimize “sit still” demands in order to free up brain resources to facilitate better executive control? Along the same lines, can the use of organized movement among children with ADHD positively affect cognitive control, and lead to better availability for classroom learning?

References


