The Influence of Depression and Anxiety on Working Memory in Children with ADHD

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Introduction

Neurocognitive deficits are widely known and recognized in Attention-Deficit Hyperactivity Disorder (ADHD) among children, significantly impacting a child's well-being, academic success, overall quality of life, and activities of daily living (Feldman & Reiff, 2014). In turn, difficulty with daily life activities such as remembering to complete important tasks, ability to follow multi-step instructions, social skills, and academic struggles, have been associated with increases in anxiety and depression (Feldman & Reiff, 2014). Furthermore, anxious thoughts and low mood have been found to impact neurocognitive deficits in children with ADHD (Roy et al., 2017).

Depression itself has a significant impact on a child's executive functioning skills. When depression is present, parts of the prefrontal cortex regions are hypoactive and therefore lead to impairment in executive functioning abilities (Snyder, 2013). In regard to anxiety, previous literature (Moran, 2016) has found that anxious arousal competes with processes located in the prefrontal cortex leaving limited neural resources for executive functioning skills (Moran, 2016). Since working memory plays a significant role in holding short term information, concentration, and following through with instructions, deficits in working memory often impact reading and mathematical abilities in children at school.

Research has explored the performance of working memory in children with ADHD and individual co-occurring disorders, finding that internalizing disorders such as depression and anxiety, both independently negatively impact working memory performance (Kofler et al., 2011; Saarinen et al., 2015; Skogan et al., 2013). Anxiety alone has been found to be associated with increased inhibition control, whereas ADHD is associated with reduced inhibition control, suggesting that anxiety may be a factor in reducing ADHD symptoms (Menghini et al., 2017). Past researchers have also proposed that anxious arousal competes with other processes located in the same area as working memory, the prefrontal cortex, leaving access to limited neural resources (Moran, 2016). Similarly, in those affected with depression, depression has been associated with decreased left prefrontal cortex activity (Nusslock, et al., 2016). Additionally, children with higher levels of internalizing symptoms have been found to perform better on a working memory task (spatial span component) (Ferrin & Vance, 2014). However, there is limited research on how multiple co-occurring diagnoses in children with ADHD impact working memory. The current study will evaluate the influences of depression and anxiety on working memory in children with ADHD.

Participants

Participants were from an archived data set at a university health care system in the Pacific Northwest, which included 581 individual children ages 7-15 years old and their biological parents, recruited between 2009 and 2015. Families were part of an ongoing longitudinal study.

Of the total sample 484 identified as White (83.3%) and 97 identified as non-White (16.7%), 373 identified as male (64.2%) and 208 identified as female (35.8%), 178 did not endorse ADHD (30.6%) and 402 endorsed ADHD (69.4%).

Procedure

At the initial visit, the parents and teachers of the children were invited to complete the ADHD Rating Scale (ADHD-RS, DuPaul et al. 1998), Connor's Rating Scale, 3rd edition (CRS-R; Connors, 2003), and an in person semi structured diagnostic interview (Kiddie Schedule for Affective Disorders and Schizophrenia – KSADS, Kaufman et al. 1997) while the child completed brief IQ screening based on a reliable and valid three subtest short form of the WISC-IV (Vocabulary, Block Design and Information; Wechsler 2003) and brief academic achievement testing (WIAT). In addition, the child also completed the MASC and CDI.

After the initial visit was completed, a best estimate *DSM-IV ADHD* (American Psychiatric Association [APA], 1994) diagnosis was established by a multidisciplinary diagnostic team. Together, they formed a diagnostic opinion based on all the available information. Their agreement rate was excellent (ADHD diagnosis kappa = .88). Disagreements were conferenced and consensus reached. On cases where consensus was not achieved, they were excluded from the participant pool and this became the clinical referred control group for the study.

Specific symptom counts and diagnosis criteria were followed by the *ADHD DSM-IV* (1994) cutoffs. Once a *DSM-IV ADHD* diagnosis was determined, families were invited to the second visit. At the second visit, the parents were asked to complete a brief IQ screening (Wechsler Adult Intelligence, 4th Edition) and academic achievement testing (Wide Range Achievement Test, 4th Edition) in addition to completing any online questionnaires they were unable to complete during the first visit. The children were required to complete additional table tasks and computerized testing, including the working memory measure, Spatial Span and Digit Span.

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Results

A Pearson correlation was run to compare the Depression scale measured by the CDI and the Anxiety scale measured by the MASC with verbal and visual working memory scales, Digit Span forwards and backwards, and Spatial Span forwards and backwards. The results of the Pearson correlation did not completely support the hypothesis as verbal working memory of children with ADHD was the only scale weakly negatively related, and only by depression.

Table 2: Correlation Between Working Memory Scales with Depression and Anxiety

Scale		SSpan Backward	SSpan Forward	Digit Span Total	Digit Span Backward	Digit Span Forward
Depression	*r*	-.049	-.082	-.187**	-.130*	-.163*
	p	.342	.111	.000	.011	.001
	n	378	378	377	377	378
Anxiety	*r*	-.064	.041	.030	.044	-.001
	p	.209	.424	.555	.388	.981
	n	382	382	381	381	382

An ANOVA was run to compare the working memory scales, Spatial Span and Digit Span, forwards and backwards, between two age groups, 7-10 years old (n = 281) and 10-14 years old (n = 122) with ADHD.

The results of the ANOVA partially supported the hypothesis. Children within the age group of 7-10 years old performed poorer on Spatial Span backwards when compared to children between the ages of 11-14 years old. In regard to Spatial Span forwards, a similar pattern was found. Children between the ages of 7-10 years old performed poorer than children 11-14 years old. With verbal working memory, the opposite was found.

Children between the ages of 11-14 years old performed poorer than children between 7-10 years old on Digit Span backwards. However, the ANOVA comparing children between the ages of 11-14 years old and children between the ages of 7-10 years old on Digit Span forwards was not statistically significant. Levene's test for equality of variances was not significant, therefore the assumption of homogeneity of variance was met for these samples.

Table 5: Descriptives of Children Ages 7-10 and 11-14 with ADHD and Working Memory Scales

	Ages 7-10 Years Old		Ages 11-14 Years Old	
	N	***M(SD)***	***N***	***M(SD)***
SSpan Backward	281	3.71(1.98)	122	4.64(2.37)
SSpan Forward	281	4.20(1.75)	122	5.78(2.22)
Digit Span Backward	280	9.84(2.88)	122	9.22(3.00)
Digit Span Forward	281	9.36(2.76)	122	9.28(2.93)

Discussion

The results of this study support the hypothesis that the verbal working memory in children with ADHD is negatively related to depression and anxiety comorbidity. However, the findings suggest that depression has a greater impact on working memory in children with ADHD than anxiety.

Additionally, the results suggest that children between the ages of 7 and 10 years old performed slightly better than children with ADHD between 10 and 14 years old on verbal working memory tasks, however, it was only partially significant. There was a significant difference in the performance of visual working memory tasks between children with ADHD ages 7 to 10 years old and children 10 to 14 years old.

Previous literature (Rubia et al., 2007; Sheridan et. al, 2014) discussed the development of cognitive control, such as, working memory or response conflict, as having different developmental trajectories. The development of cognitive control among children were well developed after the age of 10 and sustained throughout adulthood (Rubia et al., 2007). However, cognitive control for children between the ages of 5 and 10 years old were found to also have age-related changes in the ACC, and children ages 10 years and older were found to be similar to adults (Sheridan et al., 2014). These previous findings help explain the potential difference in cognitive development, more specifically, working memory as children grow older; however, it does not explain the differences between the visual and verbal working memory abilities.

The results suggest that visual working memory improves as the child grows older, whereas, verbal working memory abilities decrease as the child grows older. A potential explanation for this could be as these children grow older, it is harder for them to sustain their attention due to the decrease in stimuli. When children are younger, they are able to encounter more visual information, which could be interpreted as more stimulating. However, as they grow older, they begin to encounter more complex verbal information, which could be interpreted as more difficult and less stimulating for them.

Conclusion

The current study supports the need to address and treat depressive symptoms in children with ADHD prior to treating symptoms of ADHD. Furthermore, we also know that children with ADHD struggle in academic settings for various reasons, behavioral issues, impulsivity, attention difficulties, and working memory deficits (Crawford et al., 2006). This study found that the working memory abilities in children with ADHD differ between different cognitive developmental stages. This study indicated a significant difference between visual and verbal working memory in children at different stages. Younger children tend to have better verbal working memory than visual working memory; whereas, older children may need extra support for verbal working memory. "As children mature, they improve in their ability to self-regulate" and changes in their cognitive development also change, such as their working memory skills (Sheridan et al., 2014).

Due to this, it is important for teachers, caretakers, and parents to understand the impact of co-occurring diagnoses as well as how working memory abilities are affected during certain stages of development. With a holistic understanding of working memory deficits in children with ADHD, it will help caretakers and providers integrate more effective intervention plans to help mitigate significant working memory deficits.