The relationship between core symptoms of ADHD and the Cognitive Reflection Test in a non-clinical sample

Rebecca N. Elisa and Benjamin A. Parris

Department of Psychology, Faculty of Science and Technology Bournemouth University.

Correspondence concerning this article should be addressed to Dr. Benjamin Parris, Department of Psychology, Faculty of Science and Technology, Bournemouth University, Fern Barrow, Poole, BH12 5BB, United Kingdom.

Telephone: +44 (0) 1202 965485

Fax: +44 (0) 1202 965314

Email:bparris@bournemouth.ac.uk

Abstract

Introduction: Attention Deficit and Hyperactivity Disorder (ADHD) symptoms are frequently linked to executive function deficits. There is reason to believe that these deficits may give rise to problems with complex reasoning and problem solving.

Methods: 86 men (N = 45) and women (N = 41) completed a self-report measure to assess ADHD symptoms, along with a complex reasoning task; the Cognitive Reflection Test (CRT). IQ was also tested due to its covariance with reasoning ability.

Results: Analysis suggested that all three symptoms of ADHD (inattention, hyperactivity, and impulsivity) are negatively related to performance on the CRT, however only inattention significantly contributed to a model that predicted CRT performance.

Conclusions: Of the three core symptoms of ADHD, inattention is most important for reasoning ability. Results are discussed in reference to an executive function model of ADHD, with particular emphasis on the role of working memory in inattention.

Keywords: ADHD, inattention, reasoning, executive function

The relationship between core symptoms of ADHD and reasoning in a non-clinical sample

Attention Deficit Hyperactivity Disorder (ADHD) is a childhood-onset neurodevelopmental disorder with core symptoms of inattention, hyperactivity, and impulsivity. These primary symptoms vary in degree between sufferers of the disorder, which has led to division of ADHD into three subgroups: the combined type (ADHD-C), the predominantly inattentive type (ADHD-I), and the predominantly hyperactive-impulsive type (ADHD-HI).

It is estimated that symptoms of ADHD persist into adulthood in around 60% of cases (Kessler et al., 2006), and that up to 6% of adults may have ADHD (Murphy & Barkley, 1996; Wender, Wolf, & Wasserstein, 2001). The most prominent symptom of adult ADHD appears to be inattention, with the majority of adults having either the predominantly inattentive or combined subtype (Millstein, Wilens, Biederman, & Spencer, 1997). Interest in adult ADHD and its correlates has been growing over the last decade. However little is known about it relative to its childhood manifestation.

Recently, research has supported a shift in approach, from a categorical to a dimensional view of ADHD. Symptoms can therefore be described as existing along a continuum, where, for example, people with clinically diagnosed inattentive subtype (ADHD-I) are at the extreme end (Levy, Hay, McStephen, Wood, & Waldman, 1997; Lubke, Hudziak, Derks, van Bijsterveldt, & Boomsma, 2009). This means the use of a non-clinical sample will be beneficial for analysis of the full range of symptom severity, and for understanding the nature of symptoms within the general population. Furthermore, the benefits of using a non-clinical sample include a break-away from medicated, paediatric populations which allows investigation of symptoms of ADHD independent of developmental delays, general cognitive dysfunction, or history of medication use (Cocchi et al., 2012).

ADHD has been linked to all three core executive functions (EFs); Working Memory (WM), Inhibitory Control, and Cognitive Flexibility (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Barkley's (1997) theory of ADHD cited inhibitory control as the core deficit for the disorder; however this was stated to be specific only to the ADHD-C and predominantly hyperactive-impulsive (ADHD-HI) subtypes. Recent arguments have put forward working memory as the core deficit in ADHD-I (Diamond, 2005). Evidence suggests that both ADHD-C and ADHD-I have problems with inhibitory control (although there are differences in types of errors) but only ADHD-I has specific problems with WM (Carr, Henderson, & Nigg, 2010; Huang-Pollock, Mikami, Pfiffner, & McBurnett, 2007; Johnstone & Clarke, 2009; Wåhlstedt & Bohlin, 2010).

ADHD is regularly cited as being linked to difficulties with complex reasoning and problem solving, however, we are aware of very few studies that have investigated these higher-level abilities in ADHD directly (Harrier & DeOrnellas, 2005; Tamm & Juranek, 2012). Diamond (2013) lists the three core EFs, along with self-regulatory processes, as part of a system that facilitates complex reasoning and problem solving. Based on Diamond's model, impairments in all or just one of the core EFs would lead to poorer performance on reasoning tasks. Indeed, Tamm & Juranek reported poorer performance on a reasoning task in the ADHD group. A question remains, however, as to *which* core symptom of ADHD is more likely to lead to poorer reasoning. Harrier and DeOrnellas found that only ADHD-I and ADHD-C groups had difficulty on a planning and reasoning task, while ADHD-HI children showed no difficulty compared to controls suggesting that inattention drives the relationship between ADHD and reasoning.

The aim of the present study was to identify which of the symptoms of ADHD is related to performance on a recently established reasoning task; the Cognitive Reflection Test (CRT; originally discussed by Kahneman and Frederick, 2002, and later developed by Frederick, 2005). The test has its heritage in tasks from the heuristics and biases literature of Tversky and Kahneman (1974) who identified a number of heuristics (roughly described as general rules of thumb), reliance upon which causes predictable biases or systematic errors in reasoning and judgment. Although consisting only of three-items, the CRT was found to strongly predict performance on these earlier tasks (Hoppe & Kusterer, 2011; Toplak, West, & Stanovich, 2011), and other assessments of reasoning ability (Hoppe & Kusterer, 2011; Oechssler, Roider, & Schmitz, 2009) making it a reliable and easy to administer test. In the CRT, participants must coordinate the demands of both comprehension and the manipulation of information, meaning they are constrained by the limited resources of working memory. However, the task is also designed to elicit an immediate and incorrect first response that must be inhibited in order to be successful. Whilst originally thought to be a measure of cognitive effort (Frederick, 2005), recent work suggests that working memory capacity is the strongest predictor of performance on the CRT (Stupple , Gale, & Richmond, 2013). Importantly, the CRT is purported to measure a dimension that is separable from that which is assessed in general IQ tests. Of the limited literature that has looked into ADHD and reasoning abilities, the majority of tasks used are subsets from IQ tests.

It is possible that all three symptoms of ADHD will be related to CRT performance. Impulsivity would seem the most likely candidate, firstly because of the impulsive heuristic response the CRT elicits. Secondly, the inhibition hypothesis of ADHD has already been linked to effort in the context of the cognitive-energetic model (Sergeant, 2000). However, the link between working memory capacity and CRT performance (Stupple , Gale, & Richmond, 2013), and working memory and inattention predicts that inattention is likely to be a major factor influencing performance on the CRT.

The current study investigated the relationship between core ADHD symptoms in a non-clinical population and performance on the CRT. We expected that one or more symptoms of ADHD would be related to, and predict poor performance on the CRT. However, based on the relationship that both inattention and CRT performance have to working memory, it was predicted that the core symptom of inattention would have the greatest predictive power. Such a finding would suggest that inattention is the most important factor in potential reasoning deficits in ADHD and that inattention might play a role in reasoning deficits, beyond IQ, in the general population.

Method

Participants

Ninety participants were recruited for this research. Four participants who disclosed a diagnosis of ADHD were excluded as the sample was intended to represent the general population. This left a sample of 86 men (N = 45) and women (N = 41) aged 18-74 years (*M* = 23.97, *SD* = 10.22), who were recruited largely through opportunity sampling. All participants gave written informed consent to participate in the research, which was approved by Bournemouth University Ethics Committee.

Materials

Cognitive Reflection Test (CRT). From Frederick (2005). The test is composed of three items as follows:

(a) A bat and ball cost £1.10 in total. The bat costs £1.00 more than the ball. How much does the ball cost?

(b) If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?

(c) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half the lake?

In order to answer correctly it is necessary to suppress and/or evaluate the quick intuitive answer that immediately comes to mind (Frederick, 2005). The solution to the bat and ball problem is 5 pence, to the widget problem is 5 minutes, and to the lily pad problem is 47 days.

Weschler's Test of Adult Reading (WTAR). To assess cognitive ability, an intelligence quotient was obtained from the WTAR, which shares normative data sets with the Weschler Adult Intelligence Scale (WAIS) and the Weschler Memory Scale (WMS).

Connors Adult ADHD Rating Scale–Self-Report: Short Version (CAARS-S:S). The CAARS-S:S (Connors, Erhardt & Sparrow, 1999) is a 26 item self-report measure designed to assess current ADHD symptoms in adults. Items are rated on a 4-point Likert-type scale, where 0 = *not at all* and 3 = *very much.* The measure contains 5 factor-derived subscales; A: inattention/memory problems, B: hyperactivity/restlessness, C: impulsivity/emotional lability, D: problems with self-concept and E: an ADHD index comprised of items from the other subscales.

Procedure

Each participant was individually administered each test item (test administration order was counterbalanced to control for order effects).

Results

On the CAARS questionnaire 32.6% of participants scored above the established average on the composite subscale for ADHD. For individual symptoms; 58.1% of participants scored above average for inattention, 27.9% scored above average for hyperactivity, and 20.9% scored above average for impulsivity.

Correlations showed WTAR IQ did not have a significant relationship with CRT scores (see Table 1). Of the CAARS questionnaire, only one subset showed a significant relationship with WTAR IQ, this was Impulsivity (see Table 1.) Reflecting the difficulty of the CRT, over half of participants (58.1%) failed to get a single correct answer, and only 12.8% got all three questions correct. CAARS subsets for inattention, hyperactivity, and impulsivity were significantly and negatively correlated with CRT scores (see Table 1).

(Table 1 about here)

To assess the relative input of each ADHD symptom on CRT score, hierarchical regression was carried out with WTAR IQ included as a covariate. Incidentally, IQ did not explain a significant amount of variance ([$F(1,84) = 2.313$, $p = .174$]. Inattention was the only of the three symptoms to make a significant contribution to the model (see Table 2.) Neither hyperactivity nor impulsivity explained a significant amount of variance once inattention had been accounted for, therefore the best model did not include them [$F(2,83) = 8.217$, $p = .001$]. No further investigation was carried out on CAARS subset E, as this composite measure was accounted for by the other subsets.

(Table 2 about here)

Discussion

The aim of this study was to relate the core ADHD symptoms to performance on a measure of reasoning ability. The results suggest that all three symptoms were related to performance on the cognitive reflection test. However, only inattention made a significant contribution to a model that predicted CRT performance. Participants with higher scores on the subset for inattention were less likely to be successful on the task. This suggests that even non-clinical symptoms of inattention can affect the tendency to engage in effortful cognition.

There are several explanations for the relationship between inattention and CRT performance. Stupple, Gale, and Richmond (2013) found working memory (WM) to be a strong predictor of CRT performance and describe it as being essential to success on the task. This executive function has also recently been put forward as the core deficit in ADHD-I (Diamond, 2005). The limited literature on the relationship between inattention and WM in children tends to support Diamond's view (Klingberg et al. 2005; Lui & Tannock, 2007; Martinussen & Tannock, 2006), and a study looking at groups with pure hyperacivity-impulsivity and pure inattention in adults, found only those with inattention had a deficit in WM compared to controls (Gansler et al. 1998). We suggest it is likely that working memory deficits associated with even non-clinical inattention, affect the ability to solve the complex reasoning problems of the CRT, however this is an area for further work.

Secondly, the CRT was originally created for the assessment of cognitive effort, and to identify those with a 'miserly' approach to cognition. While it would be inappropriate to describe people with inattentive symptoms as 'miserly', they may be less able to apply the necessary effort for the task, due to self-regulatory and motivational problems. Deficient self-regulation is associated with ADHD and is thought to be a result of EF problems (Barkley, 2001; 2004). Working memory in particular is thought to be essential for successful self-regulation (Hofmann, Friese, Schmeichel, & Baddeley, 2011), and it is suggested self-regulation is strongly linked with attentional control (Fonagy & Target, 2002; Rueda, Posner, & Rothbart, 2011). In light of this it is understandable that those with inattentive symptoms would be most likely to have difficulty with the CRT.

The successful use of a non-clinical sample in this research supports the dimensional view of ADHD symptoms, in that members of the general population report having symptoms (often low levels) of ADHD. Over a third of participants scored above average on the composite measure for ADHD (a T-score of above 56 on the CAARS), not necessarily indicating a need for clinical intervention, but suggesting reasonable prevalence of symptoms in the general population. Interestingly the most prominent symptom in the general population appears to be inattention, with over half of participants scoring above average (but not necessarily at a clinical level) T-scores on the CAARS for this subset.

Symptoms of inattention appear to predict success on the Cognitive Reflection Test, which suggests people with these symptoms may have difficulty with reasoning and problem solving. This is likely explained by the close relationship between attentional control, working memory, and self-regulation. However, further research is required to better understand the nature of this relationship in adults.

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Table 1.

Correlations between WTAR IQ, CAARS subsets, and Cognitive Reflection Test

			Pearson Correlations						
	Mean	SD	1	2	3	4	5	6	7
1.IQ	110.77	12.83	-						
2.Inattention	56.74	11.43	-0.017	-					
3.Hyperactivity	50.61	9.91	-0.153	.548**	-				
4. Impulsivity	49.36	10.09	-0.214	.461**	.612**	-			
5. Self-Concept	53.75	11.05	0.107	.514**	.353**	.414**	-		
6. Composite	53.61	11.01	-0.90	.731**	.731**	.747**	.688**	-	
7. CRT	0.84	1.12	0.148	-.368**	-.279**	-.246**	-0.146	-.337**	-

*$p < .05$, **$p < .001$

Table 2.

Summary of regression for IQ, hyperactivity, impulsivity and inattention on CRT scores.

	Variable	*b*	SE*b*	β	*t*	R^2	*F* for change in R^2
Step 1						0.022	1.879
	WTAR IQ	0.013	0.009	0.148	1.371		
Step 2						0.155	13.128**
	WTAR IQ	0.012	0.009	0.142	1.404		
	Inattention	-0.036	0.010	-0.366	-3.623**		
Step 3						0.160	0.459
	WTAR IQ	0.011	0.009	0.130	1.263		
	Inattention	-0.031	0.012	-0.320	-2.637**		
	Hyperactivity	-0.009	0.014	-0.083	-0.678		
Step 4						0.161	0.062
	WTAR IQ	0.011	0.009	0.125	1.193		
	Inattention	-0.031	0.012	-0.314	-2.515**		
	Hyperactivity	-0.008	0.016	-0.067	-0.481		
	Impulsivity	-0.004	0.015	-0.033	-0.250		

**$p < .01$