The Effects of Emotional Dysregulation on Executive Function in Adolescents Diagnosed with Attention Deficit Hyperactivity Disorder in Childhood.

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Abstract

Deficits in executive function and emotional dysregulation are known to distinctly impact individuals with a diagnosis of attention deficit hyperactivity disorder (ADHD). There is a scarcity of literature investigating how these factors are dynamically linked and influence functionality in adolescents. The aim of this study was to examine the relationship between emotional dysregulation and executive function in adolescents with ADHD through the use of anger and cognitive performance measures. Eighty-nine ADHD participants between the age of 7-11 years old and eighty-five age-matched controls participated in the research. All participants were required to complete a series of anger tasks including the Buss-Perry Aggression Question and State-Trait Anger Inventory-2, alongside cognition protocols such as the Stroop Colour-Word Tasks and the Weschler Adult intelligence Scale. In addition to these, ADHD symptom severity was assessed through the use of teacher- and parent-rating scales. A one-way analysis of variance's (ANOVA) revealed a series of significant interactions between groups ($P<.05$), indicating a diagnosis of ADHD greatly impacted cognitive performance and produced anger scores greater than controls. These patterns were consistent across Working Memory and Stroop tasks, though not in processing speed which produced no significant interaction between controls and ADHD groups ($P>.05$). A moderation analysis further analysed the relationship between remitting and persisting ADHD participants and revealed a significant relationship between anger scores and both symptom severity and cognitive performance ($t(78) = 2.32$, $p = .02$, CI: .95-12.50). Results indicated that when increased levels of trait anger were coupled with a remitting diagnosis, cognitive performance on Stroop Word-Colour tasks were significantly impacted relative to persisters ($t(78) = -2.90$, $p < .01$). These findings suggest that emotional dysregulation impacts cognitive performance in both persisting and remitting adolescent ADHD groups. Secondly, a remitting diagnosis revealed that the relationship between anger and cognitive

performance experienced greater impairment. Evidence in the present study supports the notion that emotional dysregulation and executive functioning are linked in individuals with a diagnosis of ADHD and may impact achievement in social, schooling or workplace environments. Future research efforts should consider identifying differences in anger presentation between remitting and persisting adolescent groups, and also the impact this association has on lifestyle factors.

Introduction

Attention Deficit Hyperactivity Disorder

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder with clinically significant developmental impairments. The diagnosis is distinguished by difficulties in inattention, hyperactivity, and impulsivity (Thapar & Cooper, 2015). Amongst school aged-children, ADHD is one the few psychiatric disorders to frequently affect approximately 3-7% of adolescence (American Psychiatric Association [APA], 2015). Historically, ADHD is more frequently diagnosed in males than in females (Thapar & Cooper, 2015), and in addition to the complexities of inattention, hyperactivity, and impulsivity, research has identified impairments in executive functions such as working memory, processing speed, planning, problem-solving, and inhibition (Molitor et al., 2019; Weigard & Huang-Pollock, 2017; Willcutt et al., 2005). These executive functions are known to greatly influence performance-based tasks when compared to age matched controls (Baddeley, 2012; Molitor et al., 2019; Weigard & Huang-Pollock, 2017).

The complexity of this heterogenous neurodevelopmental disorder is well represented in past literature, with substantial research examining etiological risk factors, neurocognitive impairments, diversity in symptomatic expressions, long-term developmental trajectories, and comorbid disorders (Castellanos et al., 2006; Luo et al., 2019). Individuals with ADHD are also more susceptible to a wide range of co-occurring behavioural and psychiatric conditions, further increasing the difficulty of diagnosis and impacting the route of treatments needed to enable functionality in day-to-day living (Luo et al., 2019; Reale et al., 2017).

Symptomatic Display

There are 18 symptoms that may be exhibited by an individual with ADHD which are outlined in the Diagnostic and Statistical Manual of Mental Disorders (APA, 2015). For a

diagnosis of ADHD to be met, children under the age of 17 years require a combination of at least six of these behaviours and adolescent/adults above the age of 17 years require at least five (APA, 2015). These behaviours must be observed for a minimum period of six months in at least two or more environmental settings and be considered as irregular for the average age bracket of the individual (APA, 2015).

A diagnosis of ADHD falls into one of three presentations: (1) predominantly inattentive, (2) predominantly hyperactive and impulsive, or the more common, (3) combined inattentive, hyperactive, and impulsive behaviours (APA, 2015; APA, 2000; Luo et al., 2019). Typically, impairments become more apparent when individuals are placed in mentally taxing situations that warrant the restraining of impulses, limiting the ability to fidget, and managing behavioural outbursts (Barkley, 2014). Definitions of the ADHD disorder have evolved and changed considerably over the years, though the consistent presence of hyperactivity, impulsivity and inattention have remained when parental- and teacher-ratings are utilised during the period of diagnosis (Barkley, 2014).

The average age of an ADHD diagnosis is approximately 10 years old (Caye et al., 2016). The persistence of ADHD represents a relatively new topic in literature and there is a call to better understand the variables which influence symptom persistence into adulthood. Current research shows a reduction in adolescent symptoms such that 50-80% no longer meet the criteria of an ADHD diagnosis in adulthood (Barkley et al., 1990; Biederman et al., 2000; Halperin et al., 2008; Hill & Schoener, 1996); however, adolescents with a severe childhood diagnosis and poor neuropsychological functioning have been shown to be at an increased risk of maintaining symptoms (Agnew-Blais et al., 2016). Additionally, certain comorbidities such as conduct disorder, opposition defiance disorder, and mood disorders have been associated with an increased persistence and greater severity of ADHD symptoms (Jensen et al., 1997).

Hyperactivity-Impulsivity

Hyperactive behaviours are characterised by constant fidgeting or moving, an inability to sit still, or excessive talking (American Psychiatric Association [APA], 2013). Conversely, impulsivity is distinguished by behavioural displays such as difficulties in waiting turns, interrupting others, or intruding on others games/space/conversations (APA, 2013). It has been suggested that hyperactivity and impulsivity result from a breakdown in emotional-related impulsivity, which differs from inattention as this is associated with a breakdown in emotional regulation (Martel, 2009). A breakdown in the regulatory control of emotion is more commonly known as emotional dysregulation (APA, 2013; Barkley, 2014; Martel, 2009).

Research utilising symptom rating scales has identified poor inhibition and associated hyperactivity are prominent impairments known to coexist in both adolescent and adult suffers of ADHD (Willcutt, 2012; Barkley, 2014). Individuals with ADHD are often known to respond impulsively regardless of the situation or consequences associated with their actions (Barkley, 2014). The lack of judgement and scanning of one's environment can place these individuals in dangerous situations which may result in destructive behaviours that affect relationships, themselves, or property in the process (Barkley, 2014). Additional lifestyle related presentations of hyperactivity-impulsivity also include the inability to wait their turn, pursuing immediate gratification for a smaller reward, taking short cuts to finish a task faster, and un-sportsman like conduct such as sharing, cooperation, and restraint (Barkley, 2014).

A recent meta-analysis identified the differences between adult and adolescent hyperactive and impulsive behaviours, these were measured in both continuous performance and stop-go tasks (Barkley, 2014; Hervey et al., 2004; Lijffijt et al., 2005). Researchers concluded that regardless of age, all individuals displayed relatively similar inhibitory

deficits, which were characterised by poor regulation in impulsivity and excessive hyperactive behaviours (Barkley, 2014; Hervey et al., 2004; Lijffijt et al., 2005).

These enduring individual deficits may alter in display over time, with symptoms often changing in frequency and intensity if an individual continues to meet a clinical diagnosis of adulthood ADHD (Halperin & Schulz, 2006). It appears that in maintaining a diagnosis, hyperactivity and impulsivity begin to form their own separate categorical dimensions as impulsivity (particularly verbal aspects) tends to display more in adults than hyperactive tendencies (Barkley, 2011; Murphy & Barkley, 1996).

Inattention

Attention is classified as the cognitive structures that support the ability to process information (Barkley, 2014; Chun et al., 2011; Peterson & Posner, 2012). When one or more of these cognitive structures fails, the corresponding processes can be impaired causing inattention (Barkley, 2014). Inattention is characterised as an inability to remain focussed for prolonged periods of time, constantly shifting from one task to another, leaving tasks incomplete, requiring constant supervision to remain on task, and/or when an individual seems to be in a state of daydreaming (Barkley, 1990; Barkley, 2014; Boonstra et al., 2005; Hoza et al., 2001).

In contrast to hyperactivity-impulsivity, which may see a symptomatic decline over time, inattention has previously been documented to persist through to late adolescence and early adulthood (Biederman et al., 2000; Currie & Stabile, 2006; Mayes & Calhoun, 2007; Rogers et al., 2011). The effects of prolonged inattentive impairments can have enduring repercussions to functionality, particularly in areas such as social life, health, education, employment, and economic status (Barkley, 2006; Biederman et al., 2006; Currie & Stabile, 2006; Pelham et al., 2007; Rogers et al., 2011).

There is a paucity of literature surrounding the long-term effects of inattention for adult suffers (Barkley, 2014). A collaborative approach with parental and spouse reporting techniques indicate that adults with ADHD tend to display similar complications related to inattention to those seen in childhood (Barkley et al., 2008; Barkley, 2014; Murphy & Barkley, 1996). This is supported by research utilising neuropsychological measures to test executive function in manual response tasks which indicate that adults exhibit similar impairments to childhood inattention, particularly when activities require high-attentional demands or when individuals present with high-distractibility across different environments (Barkley, 2014; Lijffijt et al., 2005; Reimer et al., 2010; Roberts et al., 2011).

Neuroanatomy

The neuroanatomical structures in ADHD affected brain regions are understood to be underdeveloped in comparison to typical developing adolescence (Luo et al., 2019; Mackie et al., 2007; Nigg & Casey, 2005). Research suggests that neuronal deficits impact the prefrontal cortex and result in a developmental weakness to the frontostriatal and frontocerebellar neural loops (Brennan & Arnsten, 2008; Nigg & Casey, 2005). These brain regions are required in high-level cognitive functions, often mediating particular impairments such as goal-direct behaviours within executive function (Barkley, 2014; Hart et al., 2013).

A series of magnetic resonance imaging (MRI) studies assessed the degree of brain function in ADHD individuals compared to age matched controls. A significant deficit was recognised across a multitude of neuronal networks, impacting right and left hemispheric activity to fronto-striato-thalamic and fronto-parieto-cerebellar systems (Barkley, 2014; Cortese et al., 2012; Hart et al., 2013). Impairments to these regions were particularly apparent as ADHD individuals produced cognitive-domain dissociated deficits in areas such as inhibitory control, attention, working memory, and timing functions (Barkley, 2014; Cortese et al., 2012; Hart et al., 2013).

Existing research discusses brain maturation and the considerable impact this has on the presentation of this disorder (Castellanos et al., 2002; Giedd et al., 2002; Shaw et al., 2007; Vaidya, 2012). A review of this literature reflected a series of longitudinal designs, large sample sizes, and ages ranging between 5 and 18 years (Vaidya, 2012). Relative to controls, ADHD participants demonstrated a 3–4 year delay in maximum cortical thickness, as well as a reduction in lobe volume with 4% less white and gray matter (Castellanos et al., 2002; Shaw et al., 2007; Vaidya, 2012). These results highlighted a substantial delay in brain maturation within those with the disorder, when compared to typically developed adolescent (Castellanos et al., 2002; Shaw et al., 2007; Vaidya, 2012).

Previous MRI research has depicted a significant difference between those who remitted or persisted with a diagnosis of ADHD. Adolescent persisters produced brain scans with a considerably thinner cortical mantle within the prefrontal cortex in comparison to remitters (Vaidya, 2012). This group of persisters then went on to produce a thinning of the cortical mantle within the parietal cortex through adolescence, an area responsible for sensory input, bodily awareness, and spatial coordination of the world (Giedd et al., 2002; Vaidya, 2012). This combination of results demonstrates a series of independent brain maturation trajectories not only between controls and ADHD groups, but also between individuals who persist with a disorder and the remitters who no longer meet criteria for a diagnosis.

With these developmental differences in neuroanatomy and brain maturation, there is a corresponding effect on emotion regulation and executive functioning (Barkley, 2014; Garon et al., 2008; Miyake et al., 2000). Although these effects are dependent on multiple factors including environmental and genetic influences (Vaidya, 2012), these findings present important implications for future research.

Executive Function Theory

It has been proposed that the constellation of symptoms associated with a diagnosis of ADHD may be best understood as a disorder of executive function and self-regulation (Barkley, 2014). Barkley's executive function theory is known to be a prominent neuropsychological theory amongst past and present literature (Brocki et al., 2008). The term executive function is generally used to determine the efficiency of 'top-down' cognitive processes, such as information processing, emotional regulation, and goal-directed behaviours (Castellanos et al., 2006). It is suggested that inhibitory control is one of the key components to the neuropsychological deficits experienced in ADHD individuals, which include prepotent inhibition, response interruption, and interference control (Barkley, 1997; Brocki et al., 2008). These elements of inhibitory control are closely linked to areas of executive function and effectively impacts 'top-down' capabilities that are essential to the regulation of different behaviours, emotions, and cognitive capabilities (working memory, processing speed, and interference control) (Barkley, 1997; Brocki et al., 2008).

Robust evidence identifies an integrative model of these executive functional deficits in cognitive processing as an interplay of genetics and neuroanatomy (Biederman, 2006). An overview of imaging studies has evaluated the effects of cognitive impairment through the display of brain regions and the structural differences to fronto-subcortical pathways and neurochemical imbalances between dopaminergic and noradrenergic systems (Biederman, 2006; Castellanos et al., 2006).

Deficits to executive function can often be influenced by situational factors which intensify symptom severity (Porrino et al., 1983). The effects of environmental demand are particularly distinguishable when ADHD individuals are required to suppress their behaviours during high demand activities, affecting the level of deviancy displayed in comparison to low demand activities (Barkley, 2014). Research suggests the more complex

and taxing a task becomes, the more likely individuals are to produce poor results, due to a greater demand on the regulation of emotion, behaviour, and cognitive capabilities (Barkley, 2014; Marzocchi et al., 2002). This represents a disorder that is extremely disabling when demands are high and exceed the individual's capabilities (Barkley, 2014).

Intellectual capabilities and executive function research are implicit of school related difficulties, though many adolescents demonstrate varying degrees of impairment with reading, writing, inhibition, and memory, the degree of difficulty experienced by ADHD youth is markedly higher (Barkley, 1997). Barkley explains deficit differences occur depending on diagnosis; those with a single diagnosis of either hyperactivity/impulsivity or inattention present with greater difficulty in focussing, are sluggish, have inaccurate information processing, and have problematic memory retrieval (1997). Comparably, a combined type diagnosis of inattention and hyperactivity/impulsivity present with these factors alongside a deficit in persistence, working memory, and inhibition (Barkley, 1997). Similar results were detected in a meta-analysis consisting of 83 studies and 6700 subjects (Martinussen et al., 2005). The analysis examined impairment and executive function among individuals diagnosed with ADHD, revealing difficulties in areas of planning, vigilance, set shifting, verbal memory, and spatial working memory (Martinussen et al., 2005).

The understanding that IQ results may be linked to the severity of ADHD is well represented within literature. Mahone et al. demonstrated a distinct difference between ADHD adolescence and age matched controls, evaluating the interactions between executive function deficits and IQ scores (2002). Planning, inhibitory control, response preparation, and memory search acted as the executive function construct being assessed. A significant interaction between ADHD and Full-Scale IQ was found, as well as group differences between executive function deficits at differing IQ levels (Mahone et al., 2002). However, ADHD participants exhibiting IQ scores within high- to superior- levels did not depict a

deterioration in executive function scores and remained within a similar range to that of controls (Mahone et al., 2002).

While there is robust evidence indicating that a diagnosis of ADHD is associated with stable and persisting difficulties in higher order executive processes, the nature of these deficits have been difficult to quantify (Halperin et al., 2008). There is a substantial amount of explanatory power in support of Barkley's executive function theory, though it is important to consider context and emotion as these often increase the susceptibility for executive function problems (Barkley, 1997; Brocki et al., 2008; Willcutt et al., 2005).

Emotional Dysregulation

Emotional dysregulation is defined as difficulty in the ability to regulate and modify an emotion state to engage in goal-orientated behaviours (Shaw et al., 2014; Thompson, 1994).

Among individuals diagnosed with ADHD, difficulties in emotional dysregulation can be identified by reduced patience, high frustration, anger, hostility, irritability, and excitability (Barkley & Fischer, 2010). These emotions are often difficult to down regulate, particularly when individuals remain in the situation causing the emotional event. A recent meta-analysis of 77 studies reported medium to large effects for the association between ADHD and domains of emotion processing (recognition, regulation, and callous/unemotional traits), with a diagnosis of ADHD most strongly associated with emotional reactivity (d = .95) (Graziano & Garcia, 2016). Deficits in emotion function among individuals diagnosed with ADHD are not without consequence and have been associated with persistence of ADHD symptoms (Biederman et al., 2012), current and later mood symptoms (Eyre et al., 2017; Eyre et al., 2019), the development of co-occurring conditions such as Oppositional

Defiant disorder (ODD) (Steinberg & Drabick, 2015), and impairments in a domain of social functioning (Bunford et al., 2018).

A noticeable consequence of emotional dysregulation is emotional impulsivity, which refers to the speed at which one reacts with a primary emotion that is predominantly negative (Barkley, 2014). These emotionally intense reactions are relatively normal for individuals to experience (Barkley, 2014), and individuals without an ADHD diagnosis are likely to regulate the primary emotion and respond in a manner that is socially appropriate, or in some cases, counteract the initial response by generating a secondary emotion (Barkley, 2014). The difference in ADHD individuals is the executive self-regulation of these unmoderated emotional states is lacking, reflecting the impaired 'top-down' functions of self-control and self-regulation (Barkley, 2014; Castellanos et al., 2006).

The relationship between executive function and emotional regulation are understood to have two important influences; motivational elements, and arousal states (Barkley, 2014; Ekman & Davidson, 1994; Lang, 1995). The combination of an emotion-motivation led approach leads to the understanding that if an individual is as impulsive and unregulated with their emotional responses as they are with their physical behaviour, then these are more likely to have a similar effect with motivational and arousal responses (Barkley, 2014; Fuster, 1997; Mischel et al., 1989). Barkley believes this is due to emotion being the foundation for motivation and arousal, which are core components of self-regulation and goal-directed behaviours (2014).

A prominent area of research in ADHD is the range of individuals experiencing difficulties with emotional dysregulation. Several studies have estimated that 34-70% of adolescents and adults diagnosed with ADHD experience difficulty in emotional dysregulation (Faraone et al., 2019; Posner et al., 2014; Qian et al., 2016; Rüfenacht et al., 2019). Although it is not a formal component of the diagnosis, recent studies suggest

emotional dysregulation is a core component alongside inattention, hyperactivity, and impulsivity (Karalunas et al., 2019). Heritability of the difficulties seen in emotion regulation among individuals diagnosed with ADHD suggests that emotional dysregulation may serve as a critical component in understanding the variability of ADHD trajectories and presentation (Rüfenacht et al., 2019).

The Influences of Emotion on Cognition

Emotional dysregulation has been shown to negatively affect cognitive ability in humans, impacting areas such as problem solving, reasoning, prolonged attention, perception, and the capacity to learn and memorize new material (Angie et al., 2011; Isen, 2001; Tying et al., 2017).

There is substantial research within the general population focussing on the effects of discrete emotions, which tend to be more intense, short-lived emotions, and evolve from a stimulus event that is either current or likely to occur (Angie et al., 2011). Discrete emotions such as anger and fear, require the effective use of top-down functions to regulate these strong emotions (Angie et al., 2011). The effective utilisation of such high-level cognitive functions, is an area of impairment to many individuals with an ADHD diagnosis (Castellanos et al., 2006). Impairment in these abilities is associated with an increased likelihood of an individual engaging in risky behaviours or responding impulsively and inappropriately to negative events (Angie et al., 2011; Lerner & Keltner, 2001). Several studies focusing on the impacts of fear and anger portrayed distinct results in typically developing adults (Angie et al., 2011; Bodenhausen et al., 1994a; Bodenhausen et al., 1994b; DeSteno et al., 2004; Lerner & Keltner, 2001). Individuals eliciting a response to fear were more likely to engage in risky events and employ a ‘sure thing’ attitude (Angie et al., 2011; Lerner & Keltner, 2001). Comparatively, individuals who experienced anger were more likely to engage in heuristic judgements, employ discriminatory behaviour, and be quick to

stereotype others (Angie et al., 2011; Bodenhausen et al., 1994a; Bodenhausen et al., 1994b; DeSteno et al., 2004; Lerner & Keltner, 2001).

Research within the general population outlines the importance of emotion and motivation as a key component to cognitive processes such as learning new information, retaining this information, and recalling it (Angie et al., 2011; Tying et al., 2017). That is, the more positive emotions elicited and regulated, the more likely an individual is to academically succeed. Research on the relationship between cognitive and affective function in individuals diagnosed with ADHD still has much to explore. Examining the relationship between emotion and cognitive capabilities may result in an increased understanding of heterogeneity in the population of adolescent ADHD individuals.

Rationale

Recent research has demonstrated that a childhood diagnosis of ADHD is associated with difficulties in emotional functioning (APA, 2015), specifically emotion regulation. Emotional dysregulation has been associated with an increase in ADHD associated deficits in executive functioning and inhibitory control (Karalunas et al., 2020). Currently, there is limited research examining the extent to which cognitive capabilities are associated with emotional dysregulation in these individuals. As the disorder presents with a heterogeneous range of challenges, it is important to examine the relationship between these two factors. By gaining a deeper understanding this association there is potential to influence the functionality of individuals with ADHD and improve performance in a number of settings. Therefore, the objective of this study is to examine the relationship between emotional dysregulation and executive functioning in adolescents diagnosed with and without ADHD.

Hypotheses

This relationship is investigated through three specific hypotheses, as follows:

Hypothesis one: Relative to the control group, individuals diagnosed with ADHD will perform worse on adolescent measures of executive function and processing speed. Among individuals with ADHD, those classified as symptom persisters (having a diagnosis of ADHD in adolescence), will be associated with higher rates of cognitive difficulties than remitters (those individuals diagnosed with ADHD in childhood who do not meet criteria for ADHD in adolescence).

Hypothesis two: As a group, individuals diagnosed with ADHD will display higher rates of emotionality compared to controls. Among individuals diagnosed with ADHD, symptom persistence will be associated with higher rates of negative emotionality.

Hypothesis three: Among individuals diagnosed with ADHD, negative emotionality will moderate the relationship between symptom severity and executive function.

Method

Participants

Eighty-nine adolescents between the ages of 7-11 years old (M=9.05 years, *SD*=1.28), were evaluated during an initial assessment in childhood and participated in a follow-up evaluation on average 9.30 (*SD*=1.65) years later. They were selected from a group of 169 adolescent individuals who were recruited between 1990 and 1997 for an ADHD study assessing cognition and emotional dysregulation. Of the initial 169 participants, 18 refused to participate in the follow-up assessments, two were deceased prior to finishing the research, seven were incarcerated, and 53 were unable to be located at follow-up. In an attempt to locate missing participants, known family members were contacted and information about the research was made publicly available via the internet; however, many of these individuals were unable to be located. Those who were and were not assessed at the ten-year follow-up did not differ significantly in age at initial assessment, childhood comorbidity, full scale intelligence quotient (IQ), socio-economic status (SES), or ADHD behaviour ratings at baseline (all $p>.10$).

In addition, 85 adolescents (M=18.63 years old, *SD*=1.64) who had no ADHD diagnosis were recruited using advertisements to match the same neighbourhood zip codes as the ADHD sample. Comparable to the requirements of the ADHD sample, an exclusionary process took place for controls if they presented with a chronic medical condition, neurological condition, psychosis, or were non-English speaking.

As previously reported (Halperin et al., 2008), controls did resemble the ADHD sample as closely as possible on most demographic variables, including age, gender, ethnicity, SES, and IQ ($p>.05$). The study presented with racially/ethnically diverse

participants (26.0% African-American, 23.8% Caucasian, 35.4% Hispanic, and 14.4% mixed or other ancestry).

Ethics

Institutional Review Boards provided approval of all procedures for participating institutions. Written informed consent was obtained from all adolescents above the age of 18 years and for those under 18 years of age, consent was provided by both parents and adolescents prior to commencement of the study.

Procedure

Childhood Assessment

At initial assessment in childhood, all participants underwent an evaluation using parental reporting on the Diagnostic Interview Schedule for Children (DISC), version 2.1 or 2.3, dependent on when they were recruited. Teachers of each child completed a set of scales on inattention/overactivity from the IOWA Conners (Pelham et al., 1989) to ensure cross-sectionality of ADHD symptoms, results greater than 1.5 SD above the mean age for age and gender were required to participate.

Follow-up Assessment Measures

As part of the analysis at follow-up, all participants were required to complete the Buss-Perry Aggression Questionnaire (AQ) and the State-Trait Anger Expression Inventory-2 (STAXI-2). Difficulties with anger served as the measures of emotion dysregulation. The AQ is a 29-item, four factor self-report questionnaire that measures levels of aggression: Physical Aggression, Verbal Aggression, Anger, and Hostility (Buss & Perry, 1992). For each of the 29-items, participants scored themselves using a 5-point Likert scale, ranging from one being extremely unlikely/characteristic and through to five being extremely likely/characteristic for the individual (Buss & Perry, 1992). Higher total scores of all factors equated to greater

endorsement of aggression (Gallagher & Ashford, 2016). Buss and Perry define anger as a psychological form of arousal and formulation to aggress (Buss & Perry, 1992).

The STAXI-2 was utilised to measure trait experience of anger (Spielberger, 1999). The STAXI-2 is a 57-item questionnaire with 9 subscales measuring state and trait anger and expressions of angry emotions. The state anger scale is comprised of three subscales: Feeling Angry, Feel Like Expressing Anger Verbally, and Feel Like Expressing Anger Physically. The second scale of trait anger is divided into two subscales: Angry Temperament and Angry Reaction. For this study, analyses were conducted on the composite trait anger measure. The use of STAXI-2 has extensive supporting research in determining its qualities as a valid and reliable tool in measuring state and trait anger (Spielberger, 1999).

The kiddie-SADS Present and Lifetime Version (Kaufman et al., 1997) was completed by each participant and the parents of- at follow-up to assess for the presence ADHD symptoms. Evaluation of these clinical measures were conducted by PHD-level psychologists or trained graduate students, all blind to the participants involved. Based on the results of this interview ADHD participants were subdivided into two groups, those who continued to meet the ADHD diagnostic criteria ("Persisters" *n*=38) and those who no longer met the criteria for an ADHD diagnosis ("Remitters" *n*=51). In order to meet the criteria for Persistence, participants were required to meet the DSM-IV ADHD criteria with at least six symptoms of inattention and/or Hyperactivity-Impulsivity present, impairment across multiple settings is also required in an accordance with these requirements (APA, 2000; APA, 2013; APA, 2015). To effectively separate the remitters from persisters, remitters were required to present with five or fewer symptoms of Inattention and Hyperactivity-Impulsivity. In childhood, a large proportion of participants met criteria for ADHD-C, though there was a distribution of subtypes identified amongst Persisters at follow-up: 31.8% ADHD-C, 47.7% ADHD-Inattentive Type, and 20.5% ADHD-Hyperactive-Impulsive (Halperin et al., 2008).

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The Wechsler Adult Intelligence Scale, Third Edition (WAIS-III), is an internationally recognised intelligence scale assessing the strengths and weaknesses of individuals intellectual abilities (Silva, 2008; Wechsler, 1997). Results generated two sets of index scores; Working Memory (WMI) and Processing Speed (PSI). In determining the specificity of dysfunction, each of these index scores acted as dependent variables.

The Stroop Colour and Word task is a neurological assessment that evaluates an individual's ability to maintain cognitive control when faced with conflicting stimuli (Scarpina & Tagini, 2017; Golden & Freshwater, 1978). The cognitive dimensions of the task aim to assess cognitive interference and cognitive speed across three outcome measures; these are Word-Reading, Colour-Naming, and Colour-Word (Golden & Freshwater, 1978; Halperin et al., 2008).

Statistical Analysis

IBM SPSS Statistics version 25.0 was used to analyse the collection of data. Significance was assessed by estimating bias-corrected 95% confidence intervals, with the implementation of bootstrapping procedures. One-way analysis of variance (ANOVA) and Tukey HSD Post Hoc tests were conducted to examine the relationship between emotional dysregulation and neuropsychological functioning. Childhood status (control, remitter, and persister) functioned as the independent variable, and the two cognition tasks (Stroop and WAIS-III) and anger measurements (STAXI-2 State and Trait anger and AQ Anger) acted as dependent variables in these analyses.

A moderation analysis was conducted in ADHD groups to analyse the relationship between symptom change (persister/remitter) and adolescent emotion dysregulation on neuropsychological functioning. ADHD group status, measures of emotion dysregulation,

and the group x emotion interaction term were included in a hierarchical linear regression to examine the relationship of these variables on the three stroop tasks (word, colour, and word-colour) and the two WAIS-III subscales (working memory and processing speed), all of which acted as dependent variables.

Results

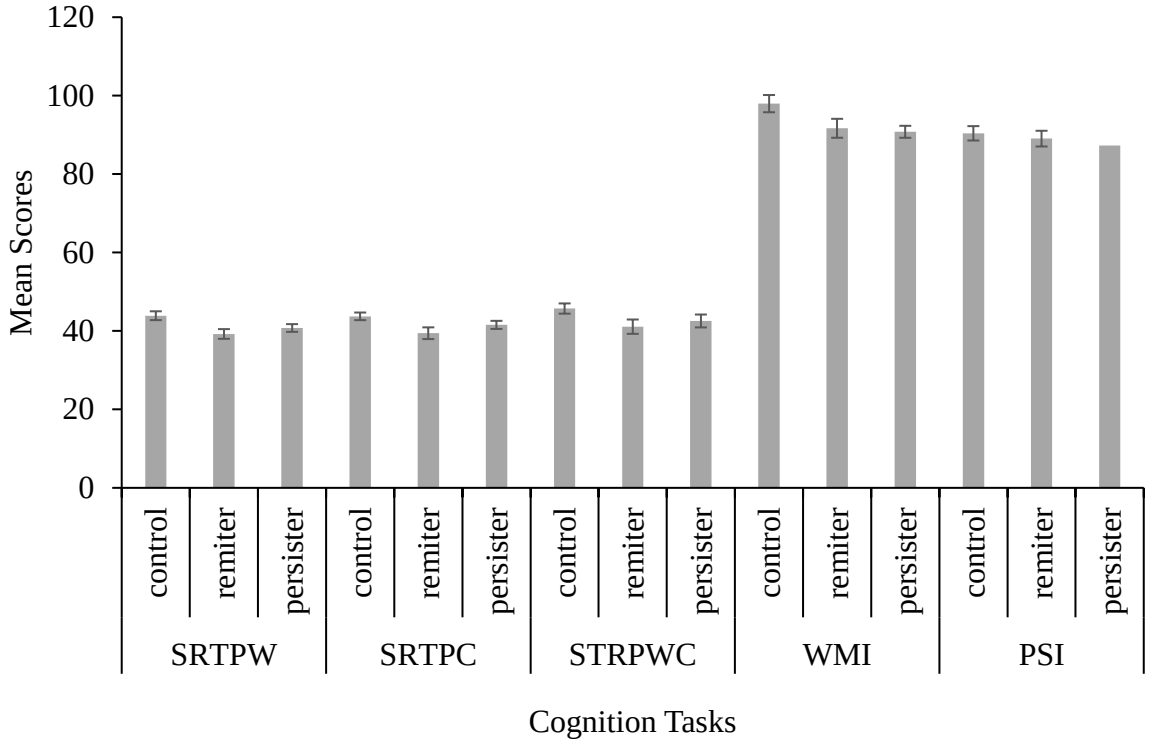
Cognition Tasks

One-way ANOVA analyses examining the relationship between group status (control and ADHD) and adolescent cognitive function as assessed by the Stroop showed a statistically significant difference between groups on Stroop Word Scores, $F(2, 171)=5.62$, $p=.004$; Stroop Colour Scores, $F(2, 171)=4.11$, $p=018$; and Stroop Word-Colour Scores, $F(2,171)=3.81$, $p=.024$. Post hoc comparisons using the Tukey HSD test indicated that the mean Stroop scores for controls significantly differed from remitters in the Word (MD=4.66, SE=1.45), Colour (MD=4.30, SE=1.51), and Word-Colour (MD=4.62, SE=1.75) tasks. However, there did not appear to be a significant difference between the persister and remitter groups, as well as the persister and controls groups across all three Stroop tasks ($p>.05$).

As indicated in Figure 1, a statistically significant difference was found between groups on the WAIS-III Working Memory subscale, $F(2,169)=4.20$, $p=.017$). While there was an observable trend in Working Memory performance, post hoc analyses revealed that only the relationship between persisters and controls was found to be significantly different (MD=7.18, SE=2.99). Performance on the Processing Speed subscale did not significantly differ between groups, $F(2,169)=.738$, $p=.480$.

Figure 1.

Mean scores of Stroop and WAIS-III Cognition Tasks



Note. This figure demonstrates mean scores of each cognition task at follow-up are shown for adolescents in control, remitter, and persister groups (error bars portray standard errors). The three Stroop task T scores are represented as Word (STRPW), Colour (STRPC), and Word-Colour combined (STRPWC). The two WAIS-III generated standard scores assessing Working Memory (WMI) and Processing Speed (PSI).

Anger Tasks

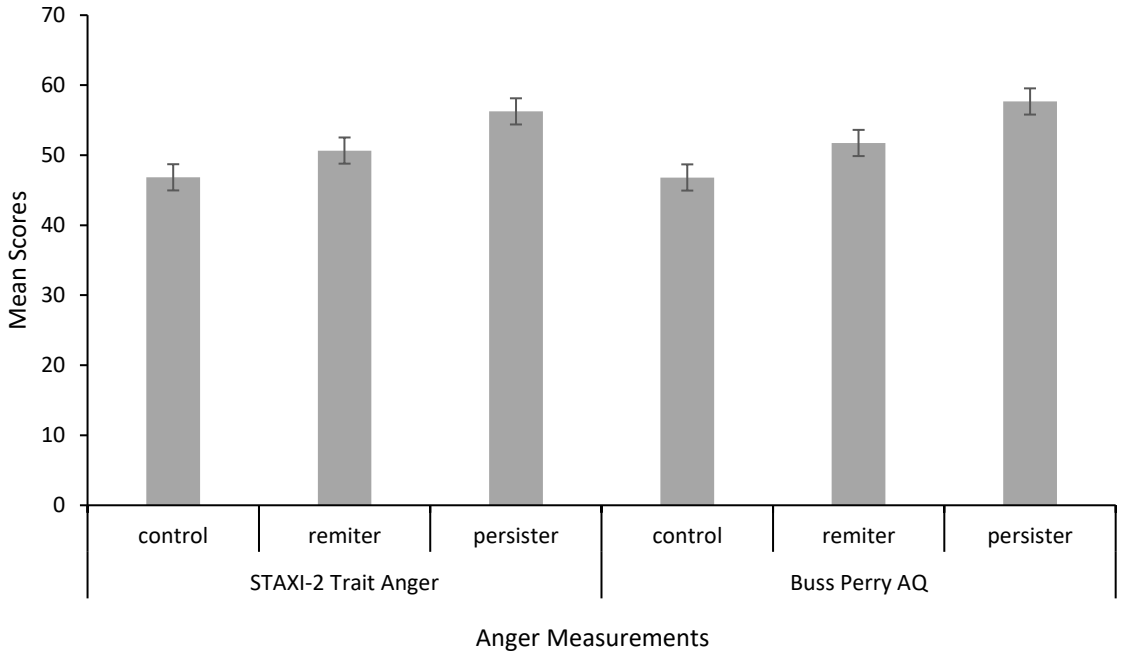
As can be seen in Figure 2, Oneway ANOVAs resulted in significant between groups difference in both STAXI-2 Trait Anger, $F(2, 166)=12.83$, $p=.000$; and Total Anger Expression , $F(2, 165)=15.36$, $p=.000$.

Post hoc analyses revealed that on Total Anger Expression, persisters had higher levels anger relative to remitters (MD = 5.93, SE = 2.19) and Controls (MD=10.86, SE=1.99)

and remitters reported higher levels of anger relative to controls (MD = 4.93), SE = 1.80). Post hoc comparisons also identified a significant difference in Trait Anger scores between persisters and remitters (MD=5.60, SE=2.04) and persisters and controls (MD = 9.42, SE = 1.88).

Figure 2.

Mean STAXI-2 Trait Anger and Buss Perry Anger scores of control and ADHD groups.



Moderation Analysis

A series of hierarchical linear regressions were conducted to examine the effect of persisting/remitting ADHD, adolescent anger, and the anger by ADHD interaction on adolescent cognition.

As can be seen in Tables 1 (STAXI-2 Trait Anger) and 2 (AQ Anger), adolescent cognitive performance was regressed on ADHD group status in Step 1, adolescent anger in Step 2, and the anger by group interaction term in Step 3. For all analyses, reported significant differences follow from significant F-tests.

In Step 1, a main effect was not seen across all measures of adolescent cognitive performance. As can be seen in Table 1, Step 2 analyses revealed that STAXI-2 Trait Anger was significantly negatively associated with PSI , $t(78) = -2.38$, $p = .02$,, and Stroop Word-Colour Reading, $t(78) = -2.02$, $p = .05$. While Trait Anger was no longer significantly associated with PSI after the inclusion of the interaction term in step 3, the main effect of Trait Anger on Word-Colour Reading remained, $t(78) = -2.91$, $p = .005$. Additionally, the group by anger interaction term was significant, $t(78) = 2.06$, $p = .04$. Post hoc analyses conducted using the PROCESS macro for SPSS revealed that the relationship between ADHD Remitter/Persister status and Stroop Word-Colour reading was significant when STAXI-2 Trait Anger was high (84th percentile), $t(78) = 2.32$, $p = .02$, CI: .95-12.50, but not at lower (16th and 50th) levels of the moderator. As can be seen in Figure 3, results were graphed in excel with group status as the moderating variable, to get a better understanding of the directionality of the significant moderation effects in relation to persisting and remitting ADHD. Analysis of simple slopes revealed significant differences in Stroop Colour-Word reading for remitters as a function of Anger, $t(78) = -2.90$, $p < .01$, but not for Persisters $t(78) = 0.15$, $p = .88$.

A somewhat similar pattern of results was seen when examining AQ anger. As can be seen in Table 2, AQ anger, was negatively associated with WMI $t(78) = -1.99$, $p = .05$. PSI, $t(78) = -3.15$, $p < .01$, Stroop Colour Reading, $t(78) = -2.30$, $p = .02$, and Stroop Word-Colour reading, $t(78) = -3.06$, $p < .01$ at Step 2. After including the interaction term, only the main effect of AQ Anger on Stroop Word Colour reading remained, $t(78) = -2.97$, $p = .004$.

Table 1.

A liner regression predicting ADHD adolescent cognitive performance as a function of diagnostic status and STAXI-2 Trait Anger.

	WMI	PSI	Word	Colour	Word-Colour
Step1					
Group status	-.02	-.10	.12	.15	.08
Step 2					
Group status	.003	-.02	.12	.19	.15
Trait Anger	-.10	**-.27***	.01	-.13	**-.23***
Step 3					
Group status	.01	-.02	.12	.18	.13
Trait Anger	-.01	-.23	-.02	**-.30***	**-.44****
Trait X Group	-.16	-.06	.05	.26	**.31***

Note. * p<.05 **p<.001. Significant negative standardized beta coefficients are shown in bold. Cognitive performance is measured across Working Memory (WMI), Processing Speed (PSI), and the three Stroop subscales Word, Colour, and Word-Colour. Anger is measured through Total Anger Expression (AQ Anger). Group status includes both ADHD groups of remitters and persisters.

Table 2.

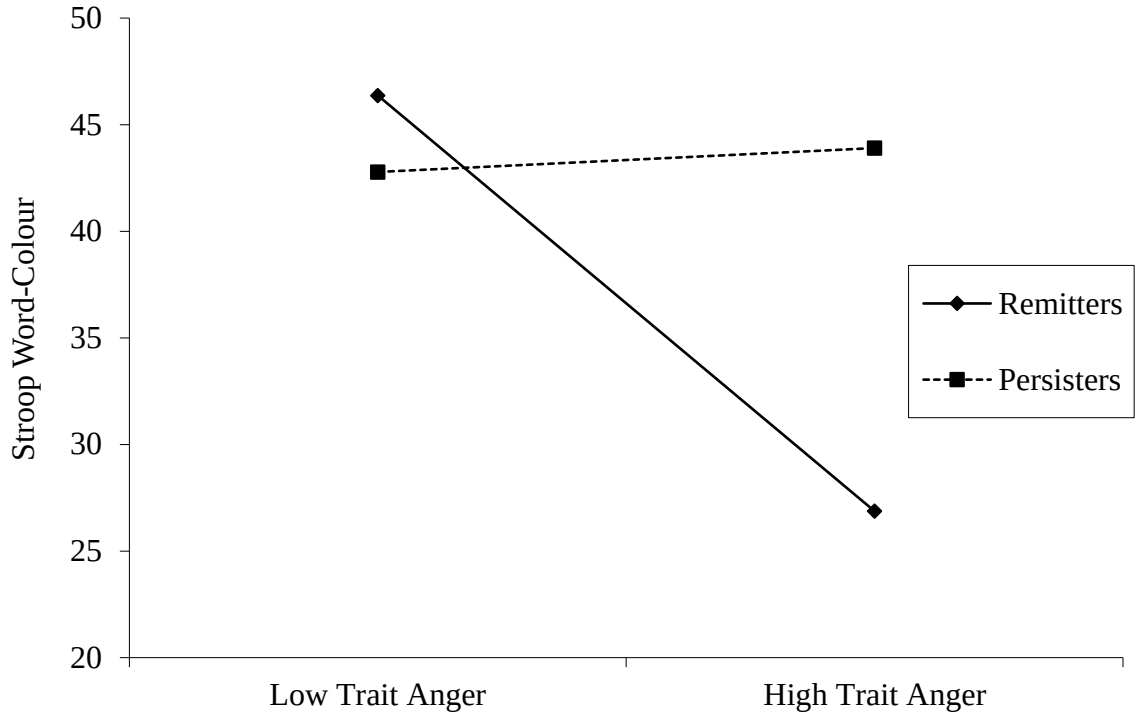
A liner regression predicting ADHD adolescent cognitive performance against as a function of diagnostic status and AQ Anger.

	WMI	PSI	Word	Colour	Word-Colour
Step1					
Group status	-.01	-.09	.14	.15	.10
Step 2					
Group status	.04	.01	.16	.22	.19
AQ Anger	**-.23***	**-.35****	-.06	**-.26***	**-.34****
Step 3					
Group status	.04	.01	.17	.22	.19
AQ Anger	-.07	-.28	.05	-.30	**-.47****
AQ X Group	-.23	-.10	-.15	.06	.18

Note. * $p<.05$ **$p<.001$. Significant negative standardized beta coefficients are shown in bold. Cognitive performance is measured across Working Memory (WMI), Processing Speed (PSI), and the three Stroop subscales Word, Colour, and Word-Colour. Anger is measured through Total Anger Expression (AQ Anger). Group status includes both ADHD groups of remitters and persisters.

Figure 3.

Moderation effects between Stroop Word-Colour and Trait Anger scores for ADHD adolescent.



Note. This figure demonstrates the relationship between Stroop Word-Colour scores and levels of Trait Anger (low and high).

Discussion

The purpose of this study was to examine the relationship between emotional dysregulation and executive function in adolescents with ADHD through the use of anger and cognitive performance measures. Results identified a significant relationship between levels of anger and the outcomes assessed regarding cognitive performance in individuals with ADHD. This relationship is consistent with previous literature (Angie et al., 2011; Isen, 2001; Tying et al., 2017) and further analysis provided depth to the discussion regarding the proposed hypotheses. Hypothesis one was partially supported by the results of this study as individuals diagnosed with ADHD performed worse on executive function tasks than controls. Counterintuitively, persisters did not show higher rates of cognitive difficulty than remitters, conflicting with our initial hypothesis. Hypothesis two was supported by the results of this study as ADHD individuals demonstrated higher rates of anger than controls. Similarly, persisters also produced rates of anger that were higher than those observed in remitters. The third hypothesis determined that negative emotionality would moderate the relationship between symptom severity and executive function. The moderating relationship was not supported by the results of this study as remitters exhibited higher rates of anger and lower scores on executive function scales than individuals with persisting symptoms.

Executive Function

WAIS-III

WAIS-III produced scores for the two executive function subscale categories; working memory and processing speed. Both subscales were utilised to examine differences between each of the control and ADHD groups. Although not uniform, differences are often seen in working memory and processing speed among ADHD individuals (Barkley, 1997;

Barkley, 2014). Results of this study indicated there were significant group differences in working memory scores between remitters, persisters, and controls.

These results suggest that regardless of whether or not individuals remit or persist with a diagnosis of ADHD, relative to controls, working memory performance remained marginally lower (Figure 1). These findings are consistent with previous research, indicating that the disorder is known to feature an impairment to the executive function system, particularly the top-down functions required for working memory (Barkley, 1997; Barkley, 2014; Brocki et al., 2008; Martinussen et al., 2005; Mahone et al., 2002; Marzocchi et al., 2002). Working memory is known to produce attentional problems in the disorder and considered to be linked to academic failure (Rogers et al., 2011). These working memory deficits are likely linked to ADHD related irregularities in neurological function within the caudate nucleus (Proal et al., 2011; Roman-Urrestarazu et al., 2016); as the caudate nucleus is responsible for storing and processing information (Grahn et al., 2008). Research shows that young persisting adults have demonstrated considerable structural deficits to caudate gray matter relative to remitters, consequentially performing poorer on working memory (Proal et al., 2011; Roman-Urrestarazu et al., 2016). This further supports the findings of the current study, where an observable group difference was found between working memory mean scores of persisters (90.78) and controls (97.96, p=.05), when compared to remitters (91.68, p=.96).

Unlike working memory, processing speed scores did not produce a significant difference (p>.05) within or between groups of persisters, remitters, and controls. This finding does not support the proposed hypothesis, nor is the finding consistent with previous literature. Currently, literature has documented a clear impairment to processing speeds, increased systematic errors, and a reduction in accuracy in ADHD groups in comparison to controls (Becker et al., 2020; Chhabildas et al. 2001; Goth-Owens et al., 2010; Jacobson et

al., 2018; Jacobson et al. 2011; Rucklidge & Tannock 2002; Walg et al., 2017; Willcutt et al. 2005). Processing speed is known to have a substantial impact on executive demand, presenting greater difficulties across response selection, response accuracy, and reading fluency (Jacobson et al., 2011). However, as demonstrated in Table 1 and 2, neither of the WAIS-III processing speed or working memory measures were correlated with group status and Trait/AQ anger (p>.05). This may be due to the multifactorial construct of processing speed and its limitations as an objective measurement. Alternatively, WAIS-III measures were comprised of two paper and pencil tasks, symbol search and coding, requiring participants to be proficient with the use of motor speed when completing the assessment. However, the WAIS-IV introduced appropriate developmental standards that were less taxing on motor demands (Lichtenberger & Kaufman, 2009).

Stroop Task

Classified as the 'Gold Standard' in attentional measures (MacLeod, 1992), the Stroop task was employed to measure cognitive control across three subcategories; Stroop-Colour, Stroop-Word, and Stroop-Word/Colour. Results indicated a significant difference between ADHD and control groups on all three subcategories of the Stroop task (p<.05). Further group analysis revealed significant mean differences in Stroop scores between remitters and controls only, and not between persisters and remitters, or persisters and controls (Figure 1). These results became more evident when breaking down the Stroop tasks individually, as the Stroop Colour and Stroop Word/Colour tasks highlighted significant differences between the remitter and control groups only.

These results are somewhat consistent with previous literature, as individuals with ADHD are known to present with greater impairment to inhibitory systems in comparison to age matched controls (Lansbergen et al., 2007). However, the lack of differences identified between remitters and persisters, and remitters and controls was an unexpected finding. Past

research states that improvement of inhibitory control in the disorder is considered to be associated with a remitting diagnosis of ADHD (Bedard et al., 2010). Suggesting that remitters should have produced greater performance rates of inhibitory control than persisters, as adolescent symptoms had reduced in remitters. However, there are reports of variability in the measurement of inhibitory control, suggesting that reaction time tasks are more likely to discriminate between ADHD groups as this is a more prominent impairment to the disorder (Halperin et al., 2008).

A review of Stroop studies has analysed ADHD inhibitory impairment against controls, with substantial differences shown in interference control between adolescent and adult participants (Lansbergen et al., 2007). The Stroop Word-Colour task requires an individual to supress a conflicting response, interference control, and response inhibition, all of which are necessities for mental flexibility (Wecker et al., 2000). When these areas of cognitive control are not adequately utilized, it often produces adverse performance outcomes (Lansbergen et al., 2007). This may be a depiction of the results obtained in the current study where ADHD groups have performed poorly on Stroop tasks relative to controls, as implications of cognitive impairment were assessed in Stroop Word (p=.00), Stroop Colour (p=.02) and Stroop Word-Colour (p=.02).

Research has identified the errors performed in Stroop tasks are significantly correlated to response times of ADHD individuals (Sorensen et al., 2014). It was stated that increased response times produced significant rates of uncorrected errors in Stroop performance, identified as an impairment to processing speed and interference control (Norman & Shallice, 1986; Sorensen et al., 2014).Comparatively, control groups produced considerably lower error rates with increased response times. These findings support the results obtained in this study, where controls performed sufficiently higher on Stroop tasks than of ADHD groups (Sorensen et al., 2014). Errors such as these have been represented as

‘slips of the mind’, known as a classical cognitive theory, these are representative of the disorders inability to inhibit conflicting responses and decreases cognitive control (Norman & Shallice, 1986; Sorensen et al., 2014).

In understanding these factors, it becomes apparent that the disorder may have a learning disability component that impacts the systems within executive function (Golden & Golden, 2002; Homack & Riccio, 2004). This provides emphasis to the results obtained, supporting the understanding that ADHD symptomatology negatively affected cognitive performance on Stroop tasks, relative to controls.

Emotional Dysregulation

STAXI-2 Task and Buss Perry

This study considered anger as a proxy measure of emotional dysregulation, with the utilisation of both STAXI-2 and Buss Perry scales allowing for a consideration of general experienced anger (AQ) and stable and enduring anger (STAXI-2 Trait Anger). Results revealed that individuals with a diagnosis of ADHD experienced significantly higher levels of anger than controls.

Oneway ANOVA outcomes resulted in a significant group difference in all adolescent groups (p=.00), as shown in Figure 2. A directional relationship occurred between controls, persisters, and remitters, with controls producing measurements of anger well below those of both ADHD groups. These findings are consistent with past research which discusses the inability to control and regulate emotions in those with ADHD, and who will typically produce higher rates of negative emotionality than controls (Hirsch et al., 2018; Matthies & Philipsen, 2014; Surman et al., 2011). Further to these studies, researchers identified a link between the prolonged effects of emotionality, a persisting diagnosis of ADHD, and impairments in areas such as work-ethic, academic achievement, social capabilities, and

relationships (Hirsch et al., 2018; Surman et al., 2011; Matthies & Philipsen, 2014; Wehmeier et al., 2010).

When comparing outcomes between ADHD groups, persisters produced higher rates of anger in both STAXI-2 and Buss Perry tasks relative to remitters. This emphasises that with increased symptom perseverance and severity comes an increase in levels of emotional dysregulation (Shaw et al., 2014). There is evidence to suggest that the effects of emotional dysregulation over time produce a prolonged impact on adolescents and adults who maintain a diagnosis of ADHD (Biederman et al., 2012; Hirsch et al., 2018; Sobanski et al., 2010; Stringaris et al., 2010; Stringaris & Goodman, 2009; Surman et al., 2011). Those who persist with a diagnosis beyond childhood present with 34-70% more difficulty in regulating emotions, comparatively, a childhood diagnosis only resembles 25-45% difficulty in downregulating their emotions (Shaw et al., 2014). The relationship between negative emotionality and ADHD is considered to produce a poor clinical outcome, which is believed to be the reason why symptoms of negative emotionality can often increase when a diagnosis of ADHD persists beyond childhood (Shaw et al., 2014).

Moderation Analysis

Past research has identified the effects of ADHD symptom severity on the level of emotional dysregulation experienced and the impacts of the disorder on executive functioning (Golden & Golden, 2002; Hirsch et al., 2018; Homack & Riccio, 2004; Petrovic & Castellanos, 2016). Evidence suggests that emotions influence cognitive performance (Healey et al., 2009), though there is limited understanding into the extent at which negative emotionality moderates the relationship between symptom severity and executive function.

The moderation analysis examines the relationship between symptom persistence, emotionality (i.e. STAXI-2 Trait Anger), and executive function (i.e. WAIS-III and Stroop),

as seen in Table 1 & 2. Results reflected a significant interaction in Stroop Word-Colour performance, with cognition becoming negatively affected by high rates of anger (p=.00). As presented in Figure 3, decreased rates of trait anger were linked to a positive relationship with the Stroop Word-Colour task performance for both persister and remitter groups. Conversely, remitters exhibiting higher rates of trait anger observed greater difficulty on Stroop Word-Colour, although this trend was not consistent in persisters, which is in contrast to previous literature.

Prior research explains that increased rates of negative emotionality and decreased rates of effortful control are characteristic of adolescent psychopathology (Muris & Ollendick, 2005). This key dimensional trait is frequently discussed in research, with an understanding that increased rates of emotional dysregulation often depict the level of impairment experienced in the disorder (Karalunas et al., 2020). As emotional dysregulation and cognitive control reportedly affect individuals with a diagnosis of ADHD (Karalunas et al., 2020), it was believed this current study would also present similar findings. These conflicting results may be due to the lack of alternate measures utilised when assessing impairments of remitters, suggesting these individuals may have underlying symptoms impacting scores. Karalunas et al. discusses the underlying patterns of irritability to greatly impact emotionality, particularly anger, suggesting this needs to be taken into consideration when determining the effects of cognition in the disorder (2019).

Research discusses the relationship identified between emotional regulation, cognition, and a childhood diagnosis of ADHD, with greater experiences of emotional dysregulation greatly impacting cognitive functioning when attempting to manage multiple tasks (Ciuluvica et al., 2013). This is not in support of the proposed hypothesis where it was suggested negative emotionality would moderate the effects of symptom severity and cognition scores. As expressed in past research, the heterogeneity in the disorder is diverse

and is believed to contribute to inconsistent findings in neurocognitive and clinical studies (Karalunas et al., 2014; Luo et al., 2019; Mackie et al., 2007; Nigg & Casey, 2005). Alongside this, a strict criterion was outlined in this study for remitters and persisters. Individuals were only placed into a persisting category if symptoms met a full diagnosis of ADHD, however, a remitting diagnosis may still present with many difficulties and merits further consideration. It is recommended that future research would capture these adversities experienced in remitters and break this group down into two groups, a partial remitter and a full remitter category.

Limitations

The research presents several limitations that are important to take consider when interpreting findings. The way each ADHD group was subdivided into remitter and persister categories may need further consideration. A persisting diagnosis was categorised as an individual who met the full criteria for an ADHD diagnosis, whereas remitters were individuals who did not meet the criteria for a diagnosis. In doing so, the study did not consider the relationship between persisting and remitting symptomatology. Opting for an additional category of partial persisters may have helped reveal further information when assessing the moderating effects within ADHD groups. This could have been a category where individuals still displayed 3-5 symptoms of ADHD and did not meet the full criteria of a diagnosis.

Further to the moderation analysis, interpretation of diagnosis types should have been considered as an influential factor. As identified in previous research, ADHD Hyperactivity/Impulsivity symptoms presented a significant relationship in both negative emotions and emotional impulsivity in comparison to ADHD Inattentive symptoms (Oliver et al., 2015). Clarification of diagnostic types may provide further understanding into the moderating relationships between symptom severity and cognition against emotional

dysregulation. This was not initially considered as an influential factor, due to symptom severity having more value to the relationship of emotional dysregulation and cognition.

Although common in longitudinal studies, attrition took place in both remitter and persister groups at the ten-year follow-up. Consequently, the loss of participants yielded a smaller sample size, reducing the power of the study and increasing the potential of error. The ten-year follow-up is also a focal point to consider, as ADHD groups were the only participants to complete the first phase of the experiment assessing parent- and teacher-rating scales. Ideally age matched controls would have been recruited at an earlier stage to determine the effects that may have also been identified within this sample.

A final consideration are the measurements utilised for emotional dysregulation, as the study only considered anger as the moderating effect on cognition. This approach may have been too narrow to understand the extent to which emotional dysregulation impacts cognition in adolescents.

Future Research

Research highlights how reading comprehension impacts areas of mental coherency and working memory within ADHD individuals (Miller at al., 2013). This suggests there are a series of comprehension deficits to word decoding, distinguishing written words, and verbally recalling what they have read (Flake et al., 2007; Lorch et al., 2004; Miller et al., 2013; Purvis & Tannock, 1997). Future research may look to expand on the cognitive impairments understood to impact the disorder, examining the relationship emotional dysregulation may have on reading comprehension proficiencies across groups of remitters and persisters.

Due to the limitations presented in this study between ADHD groups, research may also look to identify the presentations of anger between remitting and persisting adolescence.

Emotional dysregulation is frequently discussed in literature as a prominent impairment to the disorder (Angie et al., 2011; Isen, 2001; Karalunas et al., 2020; Tying et al., 2017), however, this study did not analyse differing forms of negative emotionality. Karalunas et al., highlights the need for irritability to be taken into consideration when understanding its impacts on measurements of anger (2020).

Conclusion

The purpose of this study was to examine the relationship between emotional dysregulation and executive function in adolescents with ADHD through the use of anger and cognitive performance measures. Results suggest that anger negatively affected cognitive functioning in ADHD participants, with elevated rates of trait anger significantly impacting adolescents ability to perform on Stroop Word-Colour reading tasks. Further to this, adolescents who remitted with a diagnosis of ADHD appeared to experience greater levels of trait anger and cognitive impairment than those who persisted with a diagnosis of ADHD. These findings imply that adolescents with either a remitting or persisting diagnosis of ADHD experience considerable impairment to cognitive performance when increased rates of anger are present. Interestingly, remitters appeared to experience the most significant impact on Stroop Word (p=.00), Stroop Colour (p=.01), and Stroop Word-Colour (p=.02), relative to controls. In addition to this, the effects of anger against symptomology and cognitive performance indicated remitters were again more likely to be impacted by these moderating effects than those who persisted with a diagnosis of ADHD.

In reality these results are important to consider, as they present substantial impairment to those who have remitted or persist with a diagnosis of ADHD. Impairments to emotional dysregulation present consequences that may impact on areas in life such as academic achievement, workplace settings, and career opportunities. Without an appropriate understanding into these effects and prospective treatment plans, individuals with a remitting

or persisting diagnosis of ADHD are likely to continue to display impairments to cognition and emotionality.

Although results reflected a significant difference between the moderating effects of anger and cognitive performance, the study still raises many questions around the relationship between anger and the disorder when determining the effects of cognition. As heterogeneity may have been a contributing factor to these results, exploring symptomatologic differences in emotionality may influence how the disorder is understood over a long term trajectory. Further research is required in this area, identifying where anger might act differentially between adolescent remitters and persister groups. These findings may be useful to develop an approach for ADHD adolescent, giving greater opportunity to achieve in workplace and academic settings without experiencing the constraints of emotional dysregulation.

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