

**DO WE SEE IT THE SAME WAY? EVENT PERCEPTION IN ADHD: DESCRIPTION
AND LINKS TO SOCIAL IMPAIRMENTS**

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Abstract

Attention-Deficit/Hyperactivity Disorder (ADHD) is associated with functional impairments across the lifespan, including in the social domain. The cognitive processes underlying the disorder, as well these associated social impairments, are still being debated. This points to the need for introducing new approaches. Event perception, the process of perceiving ongoing streams of activity into whole events, provides a unique perspective on the cognitive and social deficits in ADHD and how they might be related. Event perception is a compelling approach due to its methodological advantages, theory, and originality. Therefore, the overarching goal of this dissertation is the use of event perception to elucidate cognitive underpinnings of ADHD and associated social impairments.

In the background section of this dissertation, I review the evolution of scientific conceptualizations of ADHD as a disorder and its core features, including cognitive underpinnings. In addition, I highlight the cognitive components of the disorder, revealing a need for continued exploration of possible cognitive contributors. Next, I deliver an overview of the functional impairments associated with ADHD, with a special focus on social difficulties. Current theories regarding the factors that contribute to social impairment among those with ADHD are presented along with their methodological, conceptual and practical shortcomings. To address these flaws, I propose turning to event perception as a mechanism of social cognition. This section ends with a description of the guiding Event Segmentation Theory, links between event perception and ADHD, and potential event perception related contributions to the ADHD literature.

The first study addresses event perception as a cognitive deficit among those with ADHD, while the second addresses the relationship between event perception, symptoms of

ADHD, and social functioning. Results of the two studies point to event perception differences associated with ADHD, as well as symptoms of ADHD acting as mediators in the relationship between event perception and social impairment. As a first initiative to apply event perception to ADHD and its related impairments, these results contribute to current conceptualization of ADHD, as well as support the use of event perception to further inquiries into ADHD and development of future interventions. The dissertation is concluded with a broad discussion of the meaning of the results, as well as limitations, implications and future research directions.

Chapter 1: Background

History and Diagnosis of ADHD

Attention Deficit-Hyperactivity/Impulsivity Disorder (ADHD) is defined by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V) as a neurodevelopmental disorder characterized by chronic, developmentally inappropriate and impairing levels of inattention and/or hyperactivity-impulsivity (American Psychiatric Association, 2013). Some examples of inattention symptoms include being easily distracted, making careless mistakes, and failing to give close attention to detail, while examples of symptoms of hyperactivity include talking excessively, frequent fidgeting, and difficulty waiting for his/her turn (APA, 2013). ADHD occurs in roughly 5% of children and is more frequent in males than in females in the general population, and females are more likely than males to present primarily with inattentive features (APA, 2013).

Conditions that are consistent with current descriptions of ADHD date back in the medical literature as early as the late 1790s (Lange, Reichl, Lange, Tucha, & Tucha, 2010). Since these early descriptions of ADHD-like disorders, the distinction between inattentive and hyperactivity symptoms and their role in the disorder have been discussed extensively (Lange et al., 2010). Across the years, views of the disorder have ranged from primarily a disorder of hyperactivity with features of attention deficit to primarily a disorder of inattention with or without features of hyperactivity (Lange, 2010). Indeed, the distinction between these symptoms remains an important feature of ADHD, as is reflected in the separate diagnostic presentations associated with each. In the current DSM-V, ADHD is split into three categories based on symptom presentation: Predominantly Inattentive (PI), Predominantly Hyperactive–Impulsive (HI), and Combined Type (CT). Consistent with this and the longstanding conceptual issues related to the relationship between the symptoms, there is increasing evidence that inattentive symptoms and

hyperactivity symptoms are distinct aspects of ADHD with differing profiles of executive functioning and attention deficits (e.g., Barkley, 1997; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002).

For diagnostic purposes, ADHD is conceptualized categorically. It was first in the DSM-III when specific cutoff scores were introduced in an attempt to increase diagnostic validity (Lange et al., 2010). However, psychological disorders, in particular externalizing ones such as ADHD, are increasingly conceptualized as continuous in nature (Carragher et al., 2014), suggesting that symptoms can be impairing even without meeting full criteria for the disorder. For instance, researchers have identified individuals who do not reach the threshold for a psychiatric diagnosis, but who are severely psychosocially impaired (Angold, Costello, Farmer, Burns, & Erkanli, 1999; Costello, Angold, & Keeler, 1999). In ADHD research specifically, there is increasing evidence that ADHD exists along a continuum (e.g. Asherson & Trzarskowski, 2015; Levy, Hay, McStephen, Wood & Waldman, 1997; Lubke, Hudziak, Derks, van Beijsterveldt & Boomsma, 2009; Mous et al., 2014), and that the functional impairments associated with the disorder are related to symptom levels (e.g. Holmberg & Bölte, 2014; Humphreys, Galan, Tottenham & Lee, 2016; Scholtens, Rydell, Yang-Wallentin, 2013). For instance, research that has conceptualized ADHD along a continuum has in a non-clinical pre-school sample of children found associations between ADHD symptoms and a range of later socio-emotional problems (Wåhlstedt, Thorell, & Bohlin, 2008). Similarly, ADHD symptoms in community samples of adolescence have been associated with academic difficulties (Birchwood & Daley, 2012; Diamantopoulou, Rydell, Thorell, & Bohlin, 2007), peer dislike (Diamantopoulou, Henricsson & Rydell, 2005), and low self-esteem and depression (Kita & Inoue, 2017).

In all of the early accounts of ADHD, attention and hyperactivity related symptoms were documented primarily in children, and in general attention and hyperactivity related mental disorders have been characterized as childhood disorders throughout the history of the DSM (Lange et al., 2010). While the current description in the DSM-V characterizes ADHD as a neurodevelopmental disorder, suggesting that it emerges in childhood, increasingly there is evidence that symptoms of ADHD and associated impairments continue into adulthood (Barkley, 2002). The persistence of ADHD into adulthood has been well documented by genetic, neuroimaging, and longitudinal studies (Carmona et al., 2012; Kessler et al., 2005; Rasmussen & Gillberg, 2000; Ribases et al., 2009). In fact, research indicates that ADHD continues into adulthood for up to two thirds of those diagnosed as children, and worldwide estimates place ADHD in adulthood between 1.2-7.7%, which has resulted in a push towards viewing ADHD as a lifelong disorder (Simon, Czobor, Bálint, Mészáros, & Bitter, 2009; Wender, Wolf, & Wasserstein, 2001).

Evolution of Core Cognitive Features of ADHD

Conceptualizations of the underlying cognitive and neurological features of the disorder are continuously evolving. Currently, there remains debate regarding the underlying cognitive and structural anomalies associated with ADHD. The debate around the underlying brain regions associated with ADHD is driven in part by uncertainty regarding the specific neurocognitive deficits associated with ADHD. Despite attentional deficits being a core symptom of ADHD, when researchers have attempted to uncover specific attention processes impaired among those with ADHD (e.g. divided, selective, and sustained attention), results have been mixed. Some studies have failed to observe attention deficits (Hazell et al., 1999; Pearson, Yaffee, Loveland & Norton, 1995; Taranowski, Prinz, & Nay, 1986), or have only found small

differences in attention ability (Bálint et al., 2009) between those with ADHD and controls. It is also unclear whether individuals diagnosed with different subtypes of ADHD display variances in attention abilities (Eeland, Johansen, & Ueland, 2009). That is, when using tasks designed to assess basic attentional processes, results have been inconsistent. If attentional impairments in ADHD cannot be reliably observed, what are other possible underlying cognitive deficits of the disorder?

A widely shared view is that ADHD is characterized by reduced abilities in the executive functions that regulate attention and other cognitive processes. For instance, children and adolescents with ADHD have been found to lack in executive functions such as planning, inhibition, working memory, and attention shifting (e.g. Gau & Shang, 2010; Pennington & Ozonoff, 1996; Toplak, Bucciarelli, Jain, & Tannock, R 2009). In fact, among researchers and clinicians alike, the executive function deficit model has come to be the dominant paradigm to understand the neuropsychology of ADHD, spurring a comprehensive literature focused on inhibition as the core underlying cognitive factor of ADHD (Homack & Riccio, 2004; Lijffijt, Leon, Verbaten, & van Engeland, H. 2005; Romine et al., 2004; van Mourik, Oosterlaan, & Sergeant, 2005; Willcutt, Doyle, Nigg, Faraone & Pennington., 2005).

Such executive functions are thought to be sub served by the frontal lobes (Lyon & Krasnegor, 1996). For instance, the most influential of executive functioning theories of ADHD to date has was founded on the neuropsychological functions of the prefrontal lobes (Barkley, 1997). In this theory, Barkley (1997) proposed that poor behavioral inhibition was the central deficiency in ADHD. He further suggested that behavioral inhibition was linked to other executive functions that together serve to bring behavior under the control of internally

represented information and self-directed actions, ultimately resulting in greater goal-directed action and task persistence.

Indeed, most investigations into the anatomical substrates of ADHD have focused on the role of the frontal brain. While many studies of children and adolescents with ADHD have found reductions in total brain volume compared to age- and sex- matched controls linked to symptom severity (Krain & Castellanos, 2006), other studies have identified that the frontal lobe, and the prefrontal cortex more specifically, are significantly smaller and account for disproportionate amount of the reductions (Castellanos et al., 1996; Durston et al., 2004; Mostofsky, Cooper, Kates, Denckla, & Kaufmann, 2002). However, despite the extensive evidence that ADHD is associated with executive function impairments and prefrontal lobe abnormalities, many also suggest that there are other brain regions and cognitive impairments involved.

For instance, using neuroimaging techniques, researchers have found structural abnormalities in the basal ganglia and the cerebellum among those with ADHD (e.g. Aylward et al., 1996; Berquin et al., 1998; Castellanos et al., 1996; Castellanos, Lee, & Sharp, 2002; Mostofsky, Reiss, Lockhart, & Denckla, 1998; Teicher et al., 2000). The basal ganglia are associated with various functions including control of voluntary motor movements, procedural learning, habit formation, and eye movements (Crossman & Neary, 2014; Hikosaka, Takikawa, & Kawagoe, 2000; Middleton & Strick, 1994). The cerebellum is involved with the coordination of motor movements, as well as non-motor functions such as timing and attentional shifting (Allen, Buxton, Wong & Courchesne, 1997; Rao et al., 1997). Importantly, these structures appear to have overlapping functions. One functional area common to these subcortical structures is temporal information processing (Toplak, Dockstader & Tannock, 2006), leading

some researchers to focus on timing disturbances associated with ADHD (e.g. Huang et al., 2012). Another functional area that these subcortical structures have in common is motor control, leading to recent theories that ADHD is characterized by motor abnormalities (e.g. Ben-Pazi, Gross-Tsur, Bergman, & Shalev, 2003; Lijffijt et al., 2005; Piek, Pitcher, & Hay, 1999). Indeed, some researchers have suggested that cerebellar motor control underlies the development of cognitive control, or executive functioning, tying together the predominant executive functioning theory of ADHD with the evidence implicating subcortical structures involved in motor control (Koziol & Lutz, 2013).

A review of this literature clearly indicates that there is still an extensive debate on the etiology of this disorder. While the historical line of thinking has been that this disorder has underlying attention-related deficits, new emerging evidence suggests that this might not be the whole story. The theoretical, cognitive, and anatomical underpinnings of ADHD are an evolving area of research, and this calls for continued exploration of cognitive deficits associated with ADHD using a range of methodologies and approaches.

Associated Impairments

Children, adolescents, and adults with ADHD experience significant impairments in their everyday life. The most common functional impairments in children and adolescents with ADHD are decreased school performance and social difficulties (APA, 2013; Hoza, 2007). In terms of school performance, difficulties in school are often what alert parents and teachers to the presence of ADHD in children. These children have been found to persistently have lower grades, lower reading and math skills as assessed by standardized tests, and increased grade retention (Barkley, Fischer, Edelbrock, & Smallish, 1990; Loe & Feldman, 2007). Children with ADHD are also more likely to be expelled or suspended from school (Loe & Feldman, 2007).

Furthermore, they use more ancillary services – such as tutoring or after-school programs – as well as more special education services than children without ADHD (Barkley et al., 1990; Biederman et al., 1996; Loe & Feldman, 2007). Research has identified similar academic difficulties among adolescents with ADHD (Barkley et al., 1991; Bauermeister et al., 2007; Biederman et al., 1998; Frazier et al., 2007). These academic challenges are in part related to a dearth of practical academic skills, such as failure to complete homework, poor comprehension of material, poor study skills, low test and quiz grades, and poor preparation for class (Evans, Axelrod, & Langberg, 2004; Hinshaw, 1992; Robin, 1998; Zentall, 1993).

While academic difficulties are traditionally viewed as the main area of functional impairment for children and adolescents with ADHD, the socio-emotional difficulties of children and adolescents with ADHD are also quite prominent. In fact, in a recent study, 26–85% of those with ADHD showed clinically significant impairment in social behavior, which exceeded the 15–55% of children with ADHD who showed clinically significant impairment in academic performance (McConaughy, Volpe, Antshel, Gordon, & Eiraldi, 2011). Specifically, findings suggest that children with ADHD are less socially preferred, have fewer dyadic friendships, and are more often socially rejected (Hoza et al., 2005). These children also tend to have problematic peer relationships in general (e.g., Bagwell, Molina, Pelham, & Hoza, 2001; Blachman & Hinshaw, 2002; Hoza, 2007; Normand et al., 2011). Likewise, children with ADHD have been shown to have fewer friends and an increased amount of conflict with other children as well as with adults (Barkley, 2001; Nijmeijer et al., 2008). Other aspects of social impairments reported in childhood ADHD are poor parent-child relationships (Johnston & Mash, 2001; Podolski & Nigg 2001) and impairments in sibling relationships (Mikami & Pfiffner, 2008). In addition, the majority of adolescents and young adults with ADHD have been found to

have the same type of social impairments that were present during childhood; they have fewer friends and difficulties keeping friendships (Bagwell et al., 2001; Sibley, Evans, & Serpell, 2010).

As well as social difficulties, individuals with ADHD consistently exhibit difficulties with emotion regulation (Shaw, Stringaris, Nigg, & Leibenluft, 2014). Emotion regulation difficulties have long been identified as a component of the disorder (Wender, 1995). Recently, researchers have emphasized emotion dysregulation as a core feature of ADHD and a significant contributor to the functional impairments associated with ADHD (Barkley & Fischer, 2010; Bunford, Evans, & Wymbs, 2015; Nigg, Blaskey, Stawicki, & Sachek, 2004; Shaw et al., 2014). Studies report that up to 45% of children with ADHD have difficulties with emotion regulation (Barkley & Fischer, 2010; Shaw et al., 2014; Surman et al., 2013). Within the ADHD literature, ADHD has been associated with emotional reactivity and with reduced emotional inhibition, recognition, and empathy (Cadesky, Mota, & Schachar, 2000; Maedgen & Carlson, 2000; Walcott and Landau, 2004). In a recent meta-analysis, results revealed that youth with ADHD are impaired in the ability to recognize and understand emotions and emotional reactivity (Graziano & Garcia, 201). In addition, emotion regulation difficulties may explain the high comorbidity of ADHD with mood and anxiety disorders (Chronis-Tuscano et al., 2010; Seymour et al., 2012).

Adulthood Impairments.

Like ADHD in childhood and adolescence, adulthood ADHD is also linked to significant functional impairments across many domains. Adults with ADHD show decreased occupational performance, decreased workplace functioning, increased economic problems, increased risk for substance dependence and abuse, driving risks, and impairments in marital and interpersonal

relationships (Able, Johnston, Adler, & Swindle, 2007; Biederman et al., 2006; Murphy & Barkley, 1996). Older adults with ADHD reported being less well-off financially, having lower educational achievement, and greater social isolation due to their ADHD (Brod, Schmitt, Goodwin, Hodgkins, & Niebler, 2012). Perhaps due to these difficulties, adults with ADHD have directly reported significantly lower quality of life than adults without ADHD (Brod, Johnston, Able, & Swindle, 2006; Mick, Faraone, Spencer, Zhang, & Biederman, 2008).

In terms of socio-emotional functioning, there is evidence that adults with ADHD have deficits in social–emotional competence, specifically that they may be less attuned to emotional stimuli than are adults without the disorder (Friedman et al., 2003). Adults with ADHD report increased emotional lability and emotion regulation difficulties (Skirrow & Asherson, 2012; Able et al., 2007; Barkley & Fischer, 2010; Shaw et al., 2014; Surman et al., 2013). Adults with ADHD have also been discovered to show increased impairments in marital and interpersonal relationships (Able, et al., 2007; Biederman et al., 2006; Murphy & Barkley, 1996), a three times greater odd of being divorced or never married and had less family members in their network (Michielsen et al., 2015), and increased anxiety and depression (Michielsen et al., 2013).

Occupationally, adults with ADHD demonstrate decreased occupational performance and decreased workplace functioning (Able et al., 2007; Biederman et al., 2006; Murphy & Barkley, 1996). Children with ADHD who are followed to adulthood are more likely to be unemployed, have significantly worse job performance ratings, more likely to be and more often fired, and have more chronic employment problems (De Quiros & Kinsbourne, 2001; Halmøy, Fasmer, Gillberg, & Haavik, 2009; Murphy & Barkley, 1996). In addition, one study found that adults with ADHD experience increased dysfunctional career beliefs, decision-making confusion and work related anxiety (Painter, Prevatt, & Welles, 2008). Evidently, not only do the symptoms of

ADHD often continue into adulthood, but the functional impairments associated with the disorder also remain problematic throughout the lifespan.

Social Impairments: Causes and Interventions.

Of the functional impairments associated with ADHD, social difficulties are substantive because of they are pervasive, prevalent, and have influence on other domains of functioning. For instance, social problems in childhood result in significant difficulties with peer relationships and suffering a variety of social impairment, from being rejected and neglected by peers (Flicek, 1992), to bullying or being bullied (Bagwell, Molina, Pelham, & Hoza, 2001), to engaging in less social activities (Heiman, 2005). Difficulties in peer relationships, in turn, are predictive of negative outcomes later in life, such as delinquency, substance abuse, and psychological maladjustment (Rubin, Bukowsky, & Parker, 1998; Parker & Asher, 1987). Peer functioning has also been found to predict later psychological functioning, above and beyond other common childhood influencers, such grades or IQ (Cowen, Pederson, Babigian, Isso & Trost, 1973). To compound this issue, the social problems apparent in adolescents with ADHD typically begin in childhood and often continue into adulthood (Bagwell et al, 2001; Friedman et al., 2003). Given the developmental continuity of social difficulties for children with ADHD and the long-term negative outcomes, providing effective interventions to address these social impairments is critical.

Currently, there are some evidence-based treatment options for children, adolescents, and adults with ADHD; pharmacological intervention, parent-management training, and cognitive-behavioral interventions are viewed as most effective (Daley et al., 2014; Fabiano, Schatz, Aloe, Chacko, & Chronis-Tuscano, 2015; Van der Oord, Prins, Oosterlaan, Emmelkamp, 2008; Young, Moghaddam & Tickle, 2016). However, none of these intervention options have reliable effects

on social functioning. Research has found that pharmacological interventions do not produce consistent benefits on long-term academic achievement and social skills (Langberg & Becker, 2012; Ryan, Katsiyannis, & Hughes, 2011; Whalen & Henker, 1991). In fact, lack of improvement in peer relationships is viewed as a significant disadvantage of medication treatment (Hoza et al., 2005). In one study, children with ADHD who received methylphenidate and psychosocial intervention that included social skills training did not differ in terms of measures of social functioning from a control group of children with ADHD who received methylphenidate only, suggesting no advantage of the psychosocial component either (de Boo & Prins, 2007). Since then, researchers have been actively exploring and developing new interventions targeted at the social difficulties of those with ADHD, such as parent-delivered social skills interventions, play-based interventions, and peer-based interventions (Wilkes-Gillan, Bundy, Cordier & Lincoln, 2014; Wilkes-Gillan, Bundy, & Cordier, Lincoln, & Hancock, 2015; Mikami et al., 2013; Barnes, Wilkes-Gillan, Bundy, & Cordier, 2017).

To aid this process, it is important to consider the underlying causes of ADHD. Unfortunately, this phenomenon remains poorly understood. Discussions of the causes of peer difficulties among individuals with ADHD range the core symptoms of ADHD themselves, to deficits in social skills, to cognitive processes like working memory and executive functions. In terms of the symptoms of ADHD themselves, research has highlighted excesses of negative social behaviors that are the result of the core symptoms of ADHD, such as frequent interruptions that are characteristic of hyperactivity symptoms and passivity that is characteristic of inattentive symptoms (Hoza, 2007; Landau & Moore, 1991; Wheeler & Carlson, 1994). For instance, observational studies have shown that children with ADHD make more demands, command statements, and negative responses during peer interactions, consistent with symptoms

of hyperactivity (Cunningham & Siegel, 1987). In one study, children with ADHD were able to demonstrate appropriate social conduct when on medication (de Boo & Prins, 2007), indicating that amelioration of the symptoms led to improved social behavior. Empirical support for the relationship between core behavioral symptoms of ADHD and social problems is derived from studies demonstrating significant correlations between social problems and ratings of inattention ($r = 0.61$; Humphrey, Storch, & Geffken, 2007) and hyperactivity ($r = 0.53$ to 0.61 ; Andrade, Brodeur, Waschbusch, Stewart, & McGee, 2009).

Some have argued that the symptoms of ADHD are negatively associated with social functioning because they interfere with social skills. For instance, it was suggested that inattention would limit opportunities to learn social skills (Cunningham, Siegel & Offord, 1985), and to attend to the social cues necessary to apply social skills (Landau & Milich, 1988), while hyperactivity and impulsivity would contribute to negative behaviors that would limit utilization of social skills (Whalen & Henker, 1992). Because of this, and as an alternative to medication, professionals began focusing on social skills training as a core component of intervention efforts for ADHD (Mrug, Hoza, & Gerdes, 2001; Nixon, 2001). Unfortunately, although social skills training has been effective for improving the social functioning of aggressive and antisocial children (Webster Stratton, Reid, & Hammond, 2001), the results have been mixed for children with ADHD (Forness & Kavale, 1996). Often, there is a lack of generalizability of social skills to actual social contexts, leading to doubt in the field about the utility of social skills training for children with ADHD (Forness & Kavale, 1996; Kolko, Loar, Sturnick, 1990; Pfiffner & McBurnett, 1997; Tiffen & Spence, 1986).

In response to this, researchers suggested that the reason social skills training is not effective is because children with ADHD fail to use their social knowledge during real life social

interactions, suggesting that their social problems are related to a performance deficit rather than a knowledge or skill deficit (de Boo & Prins, 2007; Huang-Pollock et al., 2009; Wheeler & Carlson, 1994). Researchers have begun exploring the possibility that this inability to apply social knowledge is in fact due to deficits in cognitive functioning. For example, observational studies reveal that children with ADHD demonstrate less frequent visual orientation to others and take longer to respond, consistent with cognitive attention deficits (Stroes, Alberts, & van der Meer, 2003). Similarly, one study found that children with ADHD encoded fewer social cues than other children (Matthys, Cuperus, Van, & Engeland, 1999), and several other studies have reported significant relations between parent and teacher ratings of social problems and executive functioning tasks measuring planning, strategy generation, organization (Clark, Prior, & Kinsella, 2002) and effortful control (Dennis, Britman, Huang, & Gouley, 2007). As such, there is a growing interest in cognitive deficiencies as the underlying cause of social dysfunction in children with ADHD (Hoza, 2007; Willcutt et al., 2005).

Contrary to the significant findings noted above, investigators have recently found non-significant results when examining cognitive functioning in relation to social impairments in children with ADHD. For instance, findings have indicated that executive functioning is unrelated to peer nominated social status (Diamantopoulou et al., 2007) and is not a significant mediator of ADHD symptoms and parent/teacher ratings of social problems (Huang-Pollock et al., 2009). Similarly, Biederman et al. (2004) found that children with ADHD with and without executive functioning deficits did not differ significantly in ratings of social impairment.

This discrepancy between positive and negative findings in these studies likely reflects conceptual issues. Specifically, the cognitive processes investigated and their measurement vary tremendously from one study to the next, resulting in disjointed studies that lack common

variables. For instance, these researchers have looked at cue encoding, working memory, individual executive functioning tasks, and/or composite executive functioning indexes, all of which measure vastly different processes (e.g., Clark et al., 2002; Diamantopoulou et al., 2007). In addition, this area of research lacks a distinct theoretical framework for conceptualizing how these types of cognitive tasks would affect social behavior or application of social skills. This lack of theoretical clarity is likely impacted by the continued discussions around the cognitive and theoretical underpinnings of ADHD as a disorder. Unfortunately, the result of this confusion is that there is a lack of effective intervention approaches for addressing social impairment among those with ADHD. Because of this, it is crucial to explore new perspectives on the social difficulties of those with ADHD that could lead to future intervention possibilities. In the section that follows, we will introduce event perception as a cognitive mechanism that provides an promising novel perspective on ADHD and its related impairments.

Event Perception: Empirical Evidence and Theory

As both the cognitive underpinnings of ADHD itself and its associated social impairments continue to evolve, event perception is a cognitive process that may provide meaningful insight into both. Event perception is “the process by which people parse a continuous stream of information into meaningful events” (Zacks & Swallow, 2007, p. 1). Event perception parallels the concepts of perceptual grouping proposed by Gestaltists, who suggested that the human nervous system is predisposed to group environmental stimuli based on common principles (e. g., movement or similarity; Köhler, 1967). Event perception is an extension of this concept to the grouping of complex, ongoing information, such as everyday events (Kurby & Zacks, 2008; Newtson, 1973; Newtson & Engquist, 1976; Tversky & Zacks, 2012; Zacks et al., 2001; Zacks & Swallow, 2007).

A key component of event perception is that it appears to be automatic. Event perception is typically measured by presenting a short movie clip and instructing participants to press a button when one meaningful event ends and another one begins, a procedure that results in remarkable consistency across viewers despite rather vague instructions (Boggia & Ristic, 2014; Newtonson & Enquist, 1976; Speer, Swallow & Zacks, 2003; Zacks & Swallow, 2007; Zacks, Tversky, & Iyer, 2001). More compelling are the results from neuroimaging studies. In one experiment (Zacks et al., 2001), participants viewed a series of movies while brain activity was recorded with fMRI, first passively and then later with active segmentation conditions. They found increases in brain activity during passive viewing in brain regions associated with this neural activity were those responsible for processing human motion and action and spatial attention shifting. These increases in brain activity corresponded to event boundaries identified during the active condition. This would suggest that brain activity corresponding to event boundaries reflect normal parts of perceptual processing of everyday events as opposed to specific changes due to the instructions or task itself.

Another core characteristic of event perception is that the process seems to contain an inherent hierarchical structure. When segmenting an event into meaning chunks, participants can be asked to identify small or large events, reflecting fine and coarse grain event boundaries. Results from event perception experiments utilizing this procedure demonstrate that fine-brain boundaries tend to fall within coarse-grain boundaries, and that coarse-grain boundaries are associated with larger increases in the brain activity in the areas mentioned above (Zacks et al., 2001; Zacks & Tversky, 2001; Zacks, 2007). It has been theorized that perceivers will tend to recognize and attend to both grains of events simultaneously, but that their attention can be drawn to one or the other based on instructions or task demands. For instance, when the content

that is being perceived is more discrepant with an observer's knowledge of that event, it is thought that fine-grained boundaries will be utilized due to the need for increased processing (Zacks, Speer, Swallow, Braver & Reynolds, 2007).

Event Segmentation Theory (EST) explains this grouping process. According to this theory, grouping ongoing information into discrete units this way is a normal, automatic part of perceptual processing that is central to cognitive control, working memory updating, and storage and retrieval from episodic memory (Zacks et al., 2007; Zacks & Sargent, 2010). At the core of event segmentation theory is the proposition that the most important results of perception and comprehension are predictions about what will happen in the near future, a belief that is echoed in many modern accounts of perception (Enns & Lleras, 2008), learning (Schultz & Dickinson, 2000), language (Elman, 2009) and cognitive control (Koziol & Lutz, 2013). Predictions are helpful because they facilitate efficient perceptual processing and allow one to plan actions more successfully.

EST suggests that predictions are the result of representations of discrete events called "event models" that are held within working memory and are maintained in the lateral prefrontal cortex (Grafman, 1995; Schwartz, 1995; Wood & Grafman, 2003). According to Zacks and Sargent (2010), event models may be thought of as representations of what is happening in the moment, that then aid the formation of predictions about what will happen next. As such, event models are informed by current ongoing perceptual information, while also guiding how subsequent information is processed. Event models are maintained and protected from small changes in incoming information, but are eventually updated when prediction errors increase. The hierarchical structure of event perception is produced by prediction error signals of different magnitudes, such that fine-grained representations are turned to update in response to small

increases in prediction error while coarse-grained representations are turned to update in response to larger increases in error (Zacks et al., 2007). As such, EST proposes that “smaller” event models arise from lower level aspects of an event representation that are sensitive to prediction error signals integrated over shorter time scales.

The change from one event model to the next is what results in the distinct, discrete events that are produced during the segmentation process. It has been further proposed that when an event model is updated, evidenced by an event boundary, there is an increase in processing that occurs that coincides with increases in prediction error. Likewise, while an event model is maintained, cognitive resources are downregulated and conserved. It has been suggested that increases in prediction errors are derived from a variety of critical features that, when they change unexpectedly, become discrepant with event models and lead to increased processing (Zacks et al., 2007). These critical features range from low-level sensory input such as color, sound, and movement, to higher-order conceptual components such as cause-and-effect interactions and actors’ goals (Zacks et al., 2007). Event perception, therefore, involves an interaction of both bottom-up and top-down processing, where events are perceived as meaningful wholes based on an observer’s prior knowledge of events (e.g. event models) that is compared to incoming information. As such, it appears that attention and memory mechanisms go hand in hand with changes in event models (Zacks et al., 2001), as the processing that occurs at event boundaries is linked to attention, through the tracking of incoming information, and memory, through the updating of the event models stored in working memory (Zacks et al., 2007; Zacks & Sargent, 2010).

In summary, event segmentation theory proposes that predictions about the near future are guided by working memory representations of the current event (e.g. event models), which

are updated in response to increases in prediction error. This updating arises through increased activation of perceptual processing pathways feeding into event models, which, to the person, is experienced as a boundary between meaningful events. The hierarchical structure of event perception is grounded in prediction errors of different magnitudes. Thus, event perception is an ongoing perceptual mechanism standing at the center of attention, cognitive control, and memory (Zacks & Sargant, 2010).

Importantly, event perception is a concept popular across various disciplines of cognition. Event theories, such as scripts and schemas, have been implicated in reading, computer science, music and auditory processing, and more (e.g. Gaver, 2010; Humphreys, Besner & Quinlan, 1988; Zacks, Speer & Reynolds, 2009; Zwaan, Radvansky, Hilliard & Curiel, 1998). For instance, event boundaries have been used in various discourse comprehension theories to understand how people parse the texts that they read, with fundamentally similar concepts underlying the theories (Zwaan, Langston & Graesser, 1999; Zwaan, Magliano & Graesser, 1995). As an example, some studies have found that reading time is increased during parts of the narrative that may be conceived of as event boundaries, such as when there are shifts in time, characters, goals, space, and causal contingencies (Rinck & Weber, 2003; Zwaan et al., 1998). In one study, including phrases that mark temporal discontinuity (e.g. “an hour later”) increased the likelihood that an event boundary would be identified at that spot during an event segmentation task (Speer & Zacks, 2005).

Event perception is a cognitive process involved in perceiving and comprehending events. It is theoretically similar to other theories in cognitive science across different disciplines, and represents a fundamental aspect of human experience. While event-related phenomena have been studied extensively in domains of cognitive science, to date there has been

very little research in applying event perception to clinical disorders. There is overlap in the proposed EST mechanisms and current known ADHD-related difficulties that make it likely that event perception may be impaired in those with ADHD: working memory, attention, cognitive control, tracking of incoming information, to name a few. Given the current need in the ADHD literature for continued exploration of cognitive underpinnings of the disorder, and this overlap, event perception provides a promising avenue for ADHD-related research.

Rationale for Current Research

As reviewed above, ADHD across the lifespan is associated with functional impairments in the academic, occupational, and socio-emotional domains. Of these, social difficulties are noteworthy because of they are pervasive, persistent, prevalent, and are predictive of long-term difficulties. Despite much research to date, it remains unclear what factors influence this social functioning and why. Explanations range from the core symptoms of ADHD themselves being to blame, to social skill deficits, to working memory and/or executive functioning impairments. Because of this, current interventions fail to produce lasting, meaningful improvements in social functioning.

One explanation that has gained momentum, and that also seems to tie together the various explanations that have emerged, is that cognitive deficits are at play. Cognitive deficits go hand-in-hand with the symptoms of ADHD themselves, and it is also conceivable they would interfere with various aspects of social functioning, such as picking up on social cues and regulating behavior. Perhaps not surprisingly given the continued queries into the cognitive deficits associated with ADHD, this approach has had theoretical, conceptual, as well as methodological challenges.

The measurement of event perception addresses many of these issues. First, the

methodology allows for real-time measurement of cognitive processing, in addition to providing opportunities for enhanced ecological validity and compelling options for future intervention. Second, event perception is guided by theory that specifically dictates how event models guide the processing of incoming information and perception of meaningful events, and these processes overlap those that are likely implicated in ADHD. Furthermore, applying this approach to the perception of social events does not require changing the theory or methodology; the same principles apply. This solves the issue that arises when examining the association between social cognition and maladaptive social behaviors, which often involves methods that do not fundamentally reflect the same cognitive factors that are of interest, such as working memory and inhibition in ADHD.

The ongoing debate and uncertainty in both the cognitive etiology of ADHD and of associated social impairments calls for continued exploration of novel approaches to investigate ADHD and social impairments. Event perception is a compelling choice for its methodology, theory, and originality. Therefore, the overarching theme of this dissertation is an investigation into the use of event perception to elucidate cognitive underpinnings of ADHD and associated social impairments.

Overview of Current Studies

This dissertation has been divided into two studies. The first study addresses event perception as a cognitive deficit among those with ADHD, and is currently in press in the *Journal of Attention Disorders*. The goal of this study was to document the event segmentation deficits of individuals with ADHD. 75 undergraduates with ADHD and 79 without ADHD were recruited from the University of Ottawa and performed an event segmentation task. Symptoms of inattention and hyperactivity were confirmed with a Conner's CBRS-SR. Results revealed

specific event segmentation deficits amongst the ADHD group in comparison to the non-ADHD group, suggesting explicit disturbances in the event perception system amongst those with ADHD. These results support future research further investigating event perception deficits associated with ADHD, and their contribution to social impairments.

The second study addressed the relationship between event perception, symptoms of ADHD, and social functioning. This article is currently under review at the *Journal of Child Psychiatry and Human Development*. The goal of this study was to establish the relationship among event perception, symptoms of ADHD, and social skills in early and late adolescents. In a two part study, 83 late adolescents (38 with ADHD, 45 without ADHD) between the ages of 17 and 24, and 22 early adolescents between the ages of 11 and 17, performed an event perception task and completed self-report questionnaires assessing social functioning and symptoms of ADHD (The Social Skills-Improvement System and the Conner's CBRS-SR). Bootstrapping mediation analyses were used to test mediation models. Results revealed that symptoms of inattention and hyperactivity mediate the relationship between event perception and social skills for the late adolescent group, and that symptoms of hyperactivity mediate the relationship between event perception and negative social behaviours for the early adolescent group. Results highlight the applicability of event perception to understanding social impairment in association with symptoms of ADHD, replicate past research in this area, and demonstrate preliminary developmental effects.

**Chapter 2: Study 1: Event Segmentation Deficits in Attention-Deficit/Hyperactivity
Disorder**

Ryan, J. & Rogers, M. (in press). Event Segmentation Deficits in Attention Deficit Hyperactivity Disorder. *Journal of Attention Disorders*.

Abstract

Event segmentation is the automatic cognitive process of chunking ongoing information into meaningful events. Event Segmentation Theory (EST) proposes that event segmentation is a grouping process fundamental to normal, every-day perceptual processing, taking a central role in attention and action control. The neurocognitive deficits observed amongst individuals with ADHD overlap those involved in event segmentation, but to date no research has examined event segmentation in the context of ADHD. The goal of this study was to document the event segmentation deficits of individuals with ADHD. 75 undergraduates with ADHD and 79 without ADHD were recruited from the University of Ottawa and performed an event segmentation task. Symptoms of inattention and hyperactivity were confirmed with a Conner's CBRS-SR. Results revealed specific event segmentation deficits amongst the ADHD group in comparison to the non-ADHD group: undergraduates with ADHD appear to display disrupted event model updating, suggesting explicit disturbances in the event segmentation system amongst those with ADHD. Future research directions include further elucidating these deficits with more varied stimuli and establishing associations with functional impairments.

Introduction

Every day, humans must process a wealth of information in their environments. How does the human brain make sense of all of this input? One powerful organizational principle is chunking, the process of grouping information into one cognitive representation. This process was first proposed by Gestaltists, who suggested that the human nervous system is predisposed to group environmental stimuli based on common principles (e. g., movement or similarity; Köhler, 1967). Since then, researchers have extended this concept to the grouping of complex, ongoing information, such as every day events (Kurby & Zacks, 2008; Newtonson, 1973; Newtonson & Engquist, 1976; Zacks et al., 2001)

As an illustration, imagine being asked to recall an excursion to the movies with a group of friends. One might perceive this situation in separate events, such as driving to the cinema, meeting friends in line, buying tickets, buying snacks, watching previews, watching the movie, and then driving home. It has been proposed that this ability to organize ongoing information into meaningful events is a function of a network of brain regions automatically inserting boundaries between discrete events as they occur (Speer, Zacks, & Reynolds, 2007; Zacks & Sargent, 2010). Likewise, this grouping process is thought to be a fundamental element of normal perceptual processing, taking a central role in attention, action control, online memory updating, and episodic memory (Bailey, Kurby, Giovannetti, & Zacks, 2013; Cooper & Shallice, 2006; Kurby & Zacks, 2008; Radvansky & Zacks, 2017; Sargent et al., 2013; Schwartz, 1995; Zacks & Sargent, 2010). Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder with impairments in cognitive functions that overlap those central to event segmentation, namely attention and action control (e.g. hyperactivity). It is thus possible that individuals with ADHD may demonstrate deficits in event segmentation, and

elucidating these deficits may help to inform the cognitive underpinnings of the disorder as well as guide treatment and intervention. As such, in this study we investigate the event segmentation abilities of individuals with ADHD.

Event Perception

Methodologically, measuring event segmentation ability involves utilizing an event perception task, also known as a unit marking procedure first developed by Newton and Engquist (1976). In such a task, participants are presented with a movie clip and are asked to press a button when “one meaningful event ends and another begins.” What results are a series of timestamps representing a participants’ perception of events. This methodology has been used to measure event segmentation of various types of ongoing information, such as every day activities, dance movements, as well as visual and verbal narratives (Bläsing, 2014; Boggia & Ristic, 2015; Magliano, Radvansky, Forsythe, & Copeland, 2014)

Event Segmentation Theory (EST) describes this grouping process. According to this theory, grouping ongoing information into discrete units this way is a normal, automatic part of perceptual processing that is central to cognitive control, working memory updating, and storage and retrieval from episodic memory (Zacks, Speer, Swallow, Braver & Reynolds, 2007; Zacks & Sargent, 2010). At the core of event segmentation theory is the proposition that the most important results of perception and comprehension are predictions about what will happen in the near future, a belief that is echoed in many modern accounts of perception (Enns & Lleras, 2008), learning (Schultz & Dickinson, 2000), language (Elman, 2009) and cognitive control (Koziol & Lutz, 2013). Predictions are helpful because they facilitate efficient perceptual processing and allow one to plan actions more successfully.

According to event segmentation theory, predictions are the result of representations of

discrete events called “event models” that are held within working memory and are maintained in the lateral prefrontal cortex (Grafman, 1995; Schwartz, 1995; Wood & Grafman, 2003).

According to Zacks and Sergant (2010), event models may be thought of as representations of what is happening in the moment, that then aid the formation of predictions about what will happen next. As such, event models are informed by current ongoing perceptual information, while also guiding how subsequent information is processed. Event models are maintained and protected from small changes in incoming information, but are eventually updated when prediction errors increase. This change from one event model to the next is what results in the distinct, discrete events that are produced during the segmentation process. Zacks et al. (2007) aptly describe this process:

Here is an example of how the mechanism in EST might work when one observes an everyday activity: Imagine watching a man wash dishes. He takes one plate from a pile next to the sink, scrapes food from it, and then places it in the sink. He does the same with a second plate. At this point, a number of cues make it likely that he will continue to scrape the plates. First, continuing to scrape would maintain a coherent movement pattern. Second, it would be consistent with previous observations in which it was statistically likely that scraping a plate was followed by more scraping of plates. Third, the observer might infer that the man had the goal of scraping all of the plates. Thus, for the duration of the plate-scraping activity, affairs would be predictable. However, when the man scraped the last plate, things would become less predictable. The coherent movement pattern would cease, the statistical dependency would be broken, and the inference of the actor’s goal to scrape all of the plates would no longer have predictive value. At this point, perceptual prediction would decline, leading to the activation of the

gating mechanism and updating of the event model. (p. 275).

Based on research to date, it also appears that variations in predictability are to be expected on finer and coarser timescales (Zacks et al., 2007). At each of these timescales, it is suggested that the prediction error signal can be tuned to the appropriate grain, such that fine-grained representations are turned to update in response to small increases in prediction error while coarse-grained representations are turned to update in response to larger increases in error (Zacks et al., 2007). As such, EST proposes a hierarchical structural to event perception, such that “smaller” event models arise from lower level aspects of an event representation that are sensitive to prediction error signals integrated over shorter time scales.

The processing that occurs at event boundaries is linked to attention, through the input of new information, and memory, through the updating of the event models stored in working memory (Zacks et al., 2007; Zacks & Sargent, 2010). Therefore, attention and memory mechanisms go hand in hand with changes in event models (Zacks et al., 2001). In 2001, Zacks et al. conducted a study in which participants watched movies both passively and then later while performing active event segmentation, while simultaneously having their brain activity recorded using fMRI. Results from this study indicated transient changes in neural activity at event boundaries, both during initial passive viewing and later active segmentation. The brain regions associated with this neural activity were those responsible for processing human motion and action and spatial attention shifting (Brodmann’s area 6; Zacks et al., 2001).

In summary, event segmentation theory proposes that predictions about the near future are guided by working memory representations of the current event (e.g. event models), which are updated in response to increases in prediction error. This updating arises through increased activation of perceptual processing pathways feeding into event models, which, to the person, is

experienced as a boundary between meaningful events. Thus, event segmentation is an ongoing perceptual mechanism standing at the center of attention, cognitive control, and memory. These processes are central to every day functioning, and as such, segmentation impairments are associated with significant changes in cognition (Zacks & Sargant, 2010). For instance, disturbances in various forms of event segmentation have been documented in individuals with cognitive deficits stemming from schizophrenia (Zalla, Verlut, Franck, Puzenat, & Sirigu, 2004), Obsessive-Compulsive Disorder (Zor et al., 2009), Parkinson's Disease (Zalla et al., 2000), lesions of the prefrontal cortex (Zanini, 2008; Zanini, Rumiati, & Shallice, 2002), Alzheimer's Disease and normal cognitive decline in aging (Zacks, Speer, Vettel, & Jacoby, 2006).

Attention-Deficit/Hyperactivity Disorder: Neurocognitive Overview

Attention Deficit/Hyperactivity Disorder (ADHD) is defined by the DSM-V as a neurodevelopmental disorder characterized by chronic, developmentally inappropriate inattention and/or hyperactivity-impulsivity that causes impairment (American Psychiatric Association, 2013). ADHD typically emerges in childhood, with an approximate prevalence rate of 5% in children (American Psychiatric Association, 2013; Faraone, Sergeant, Gillberg, & Biederman, 2003; Luebke & Bell, 2013; Polanczyk, De Lima, Horta, Biederman, & Rohde, 2007) and can continue into adulthood for up to two thirds of those diagnosed as children (Barkley, 2006; Wender, Wolf, & Wasserstein, 2001).

ADHD has come to be known as a disorder with a myriad of functional and cognitive impairments that are centralized around executive functioning deficits (Barkley, 1997; Doyle, 2006; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). To this end, the literature on neurocognitive deficits associated with ADHD has been occupied largely by inquiries towards executive functions. For instance, children and adolescents with ADHD have been found to have

deficiencies in executive functions such as planning, inhibition, working memory, and attention shifting (Gau & Shang, 2010; Pennington & Ozonoff, 1996; Toplak et al., 2009). Such executive functions are thought to be subserved by the frontal lobes (Alvarez & Emory, 2006; Smith & Jonides, 1999; Stuss, 2011). In fact, the most influential of executive functioning theories of ADHD to date has been Barkley's (1997) executive functioning model of ADHD, which he founded on theories of the neuropsychological functions of the prefrontal lobes. In this theory, Barkley (1997) proposed that poor behavioral inhibition was the central deficiency in ADHD. He further suggested that behavioral inhibition was linked to other executive functions that together serve to bring behavior under the control of internally represented information and self-directed actions, ultimately resulting in greater goal-directed action and task persistence.

It is clear from the research to date that the executive function deficit model has come to be the dominant paradigm to understand the neuropsychology of ADHD among researchers and clinicians, spurring a comprehensive literature focused on inhibition as the core deficit in ADHD (e.g. Homack & Riccio, 2004; Lijffijt, Leon, Verbaten, & van Engeland, 2005; Romine et al., 2004; van Mourik, Oosterlaan, & Sergeant, 2005; Willcutt et al., 2005). However, there is debate regarding the validity of the executive functioning theory of ADHD (Castellanos, Sonuga-barke, Milham, & Tannock, 2006; Willcutt et al., 2005), compelling the research community to consider the neurocognitive deficits of ADHD more holistically.

Event segmentation theory is a promising avenue for continued investigations of the neurocognitive deficits displayed by individuals with ADHD for several reasons. First, event segmentation theory grounds event perception processes in the prefrontal cortex and related areas. Second, recent models of ADHD conceptualize the cognitive deficits as arising from impaired executive functions that subserve self-control and goal-directed behavior, resulting in

the behavior of those with ADHD being controlled more by the immediate context and its consequences, rather than internally represented information, such as forethought and future planning (Barkley, 1997). As reviewed previously, the central premise of EST theory lies in the predictive benefit of event models for enhancing perception and understanding, which maps directly onto the theoretical executive functioning impairments in ADHD. Finally, as EST theoretically links cognitive processing with action-control, it provides a means of measuring the executive functioning and action-control system in a unified task, representing an ecologically valid approach to understanding the cognitive deficits associated with ADHD. To date, no research has examined event perception deficits in ADHD. The goal of this study was to document the event segmentation deficits of individuals with ADHD. Please note that throughout the text, when referring to undergraduates with ADHD or individuals with ADHD, we acknowledge that their current diagnostic status has not been confirmed for this study, but rather that they have self-reported a diagnosis in the past. As such, these individuals are those with a previous diagnosis of ADHD, rather than “with” ADHD. The phrasing used to describe these individuals differs at times in order to promote conciseness and legibility.

Methods

Participants

154 undergraduates ($n=75$ with ADHD, $n=79$ without ADHD) were recruited from the University of Ottawa using the Integrated System of Participation in Research. This system provides students in first year psychology classes with the opportunity to participate in lab or internet-based research in exchange for course credit. As part of a pre-screening questionnaire administered to all students enrolled in this system, participants reported whether they had received a diagnosis of ADHD in the past. Participants were asked to refrain from taking any

ADHD medication on the day of the study to avoid effects caused by medication. The University of Ottawa Board of Ethics approved this research, and all participants gave their signed, informed consent to participate.

Materials

Event Segmentation Task.

Participants performed an event segmentation task with a 1-minute clip from the movie *The Good, the Bad, the Ugly*, which is the same as clips used in other research with event segmentation (Boggia & Ristic, 2012; Hasson, Nir, Levy, Fuhrmann, & Malach, 2004) in order to ensure consistency between this study and others done in the past. The clip involved a scene where the main character turns against his partner after working together to earn a bounty, abandoning him in the desert. The task involved having participants watch the same clip three times with different instructions. In the first viewing, instructions stated to press the spacebar when “one meaningful event ends and a new one begins”, a typical measure of event segmentation. The second and third viewings stated to press the spacebar when “one small meaningful event ends...” and when “one large meaningful event ends...”, reflecting fine and coarse-grain event models (as per Boggia & Ristic, 2015; Newtonson & Engquist, 1976). Specifically, the instructions for the first viewing were: “You will watch a movie clip. Please watch carefully and press the spacebar when one meaningful event ends and a new one begins.” The second and third viewing had identical instructions except for the addition of the word “small” and “large”. These conditions were counterbalanced. The definition of “meaningful” was not explicitly given, even when asked by participants, as the objective of the instructions is to elicit spontaneous event segmentation behavior. Previous findings support that this wording is

sufficient for that purpose (Boggia & Ristic, 2015; Newtonson & Engquist, 1976; Zacks, Braver, et al., 2001).

The data that was obtained from the event segmentation task was a participant's button pressing behavior over the course of the viewing in each condition, which can be represented in several different ways. The *total number of button presses* is a variable that indicates both the size of a participant's event models and the number of times an event model is updated. Thus, this variable reflects the number of different event models a participant forms, representing a generalized overview of a participant's event segmentation behavior, without sensitivity to event location or content. This represents a general aspect of event segmentation behavior and can be examined for events of fine- or coarse-grain, or no particular event size orientation. Importantly, *the hierarchical effect* can also be assessed by examining the number of button presses in the small and large segmentation conditions. This is a measure of the organizational, hierarchical structure of event segmentation ability with specific focus on a participant's ability to orient to events on a fine- and coarse-grain scale.

Another variable examined was the *number of prototypical events* selected. Previous research has found that observers tend to agree in where they place event boundaries (Boggia & Ristic, 2015; Zacks, Swallow, Vettel, & McAvoy, 2006). Thus, prototypical events represent the typical or normative events identified in a control group, and *the number of prototypical events* represents the number of those agreed upon events that were identified by any single participant. Prototypical events were determined using the results of a control group ($n=31$). These participants performed the exact same event perception task as those in the experimental group, and they were recruited from the same system without special attention to ADHD status. The clip was broken down into 1-second intervals, and the participants' button presses were coded

into these intervals. The average number of button presses per 1-second interval was determined, and prototypical events were identified by those 1-second intervals with the highest number of button presses (+2 standard deviations above the mean number of button presses per unit of time (as per Boggia & Ristic, 2015; Newtonson & Engquist, 1976; Zacks, Swallow, Vettel, & McAvoy, 2006). In the experimental groups, the *number of correct prototypical events* was established by calculating the number of prototypical events that each participant identified. This procedure was repeated for each condition (no size, fine- and coarse-grain).

Symptoms of ADHD: The Conner's Behavioral Rating Scale - Self Report.

The CBRS-SR (Conners et al., 1997) was used to assess the current level of ADHD symptoms among participants in order to verify the groups. The CBRS-SR is a questionnaire-based rating scale comprised of 187 items that assesses 9 areas of psychological dysfunction in individuals up to 18 years of age. The items consists of a sentence about a symptom, and participants rated how truly the item described applied to them: (0) Not true at all (Never, Seldom), (1) Just a little true (Occasionally), (2) Pretty much true (Often, quite a bit), (3) Very much true (very often, very frequently). The ADHD symptom subscales allow for the identification of symptoms of inattention and hyperactivity/impulsivity. Examples of items related to ADHD symptomology from the questionnaire are: "I have trouble waiting my turn", "I interrupt other people", "I make careless mistakes" and "I have trouble concentrating". The CBRS-SR has robust psychometric properties (Test-retest reliability: 0.86; Internal Validity: Cronbach's $\alpha = 0.88$; Criterion validity: Sensitivity = 81.4%, Specificity = 83.7%; Conners et al., 1997). This scale is a prominent measure of ADHD and has been used to establish convergent validity for other measures of ADHD. Furthermore, they have been used in diverse clinical and research applications (Collett, Ohan, & Myers, 2003). While some participants were older than

18, many were also 17 or 18, thus the measure was used for all participants to maintain consistency. Because some participants in the study were not of an age included in the validation of this measure, potential interpretation difficulties were avoided by using a symptom total raw score rather than a T-score.

Procedure

Participants were welcomed to the lab and asked to sign a consent form. From there, participants were seated at a computer and given instructions for the event segmentation task. Up to four participants at a time could complete the experiment simultaneously in the same room, separated by wall dividers. Afterwards, participants filled out the Conner's CBRS. Finally, participants were fully debriefed. Each experimental session lasted approximately half an hour.

Results

Participants

Of the 154 participants, 64 were male (33 without ADHD, 31 with ADHD) and 90 were female (46 without ADHD, 44 with ADHD). A Pearson Chi-Squared test revealed no significant differences between the groups based on gender ($\chi^2=0.03, p=0.96$). The participants ranged in age from 17-25, and a t-test revealed no significant differences in age between the two groups ($t(153)=-1.01, p=0.31$). While participants were placed in groups based on their self-report of a previous diagnosis of ADHD, the groups were verified by comparing symptoms of ADHD based on responses to the Conner's CBRS. The participants in the ADHD group reported significantly greater raw scores of inattention ($t(153)=-10.85, p<0.01$) and hyperactivity ($t(153)=-8.35, p<0.01$) compared to the non-ADHD group. Please see Table 1 for a summary of relevant statistical information for these variables.

Group Differences based on Event Segmentation Variables

Six event segmentation variables were examined: Total number of button presses in the regular, small, and large conditions, and the number of prototypical events in the regular, small, and large conditions. A Shapiro-Wilks test determined that all six of these variables were non-normally distributed ($p < 0.01$). A non-parametric statistical method was pursued.

A Mann-Whitney U test was used to analyze to compare the mean ranks between the two groups on each of these six variables, and the results are shown in Table 2. A Bonferroni correction was applied to the results and significance below .0083 are highlighted. Although the mean rank of the number of presses were the key statistical variable, results will be discussed in terms of the number of presses and the number of prototypical events identified for clarity.

In the regular condition, the ADHD group pressed fewer times compared to the non ADHD group (Mann-Whitney $U=2263.00$, $p < 0.05$), and also identified fewer prototypical events in this condition compared to the non ADHD group (Mann-Whitney $U=2610.00$, $p=0.055$), but these results were not statistically significant after a Bonferroni correction. This suggests that participants in the ADHD group, when not instructed to identify a certain size of event, did not significantly differ in their perception of events compared to the non-ADHD group.

In the small event condition, the ADHD group presses the button more times compared to the non ADHD group, but the effect was also not significant (Mann-Whitney $U=2883.00$, $p > 0.05$). Also in this condition, the ADHD group identified fewer prototypical boundaries compared to the non ADHD group, but again the effect was not significant (Mann-Whitney $U=2779.00$, $p > 0.05$). These nonsignificant results suggest that when oriented towards small events, participants in the ADHD group did not differ in their patterns of event segmentation.

In the large event condition, the number of presses for the ADHD group was significantly greater compared to the non ADHD group (Mann-Whitney $U=3456.00$, $p<0.0083$). The number of prototypical presses in this condition was also higher among the ADHD group, but the effect was not significant (Mann-Whitney $U = 3166.00$, $p>0.05$). This finding indicates that participants in the ADHD group identified a greater number of events than the non-ADHD group when oriented to large ones, but they did not differ in their identification of prototypical events.

Discussion

The goal of this study was to establish if there were any differences in the event segmentation behavior for those with ADHD compared to those without. Findings revealed that the ADHD group identified significantly more events in the large condition. These results indicate that individuals with a previous diagnosis of ADHD do exhibit deficits in event segmentation behavior compared to a sample with no history of ADHD diagnosis.

The total number of button presses is a measure of the number of events perceived. Within the EST model, the perception of events depends on both sensory cues and knowledge structures that represent previously learned information about event parts and inferences about actors' goals and plans (Zacks & Sergant, 2010). These knowledge structures are referred to as event models. Zacks and Sergant (2010) explained that event models may be thought of as representations of what is happening in the moment, that then aid the formation of predictions about what will happen next. Event models are maintained and protected from small changes in incoming information, but are eventually updated when prediction errors increase. Differences in the number of presses therefore reflects differences in event model updating, in theory due to the degree of prediction errors. Variations in prediction errors could be the result of faulty online monitoring of incoming information compared to the event model being held in working

memory, or it could be due to the event model itself being different in content due to differences in the development of these event models over time. Segmentation in the large and small conditions represents event model updating on a coarse- and fine-grain timescale respectively, and is theorized to be produced by prediction errors that are smaller or larger.

Results from this study highlight significant differences among those with ADHD in regards to the perception of events in the large condition, in which participants were specifically asked to identify large events. In this condition, participants in the ADHD group pressed the button a greater number of times, indicative of more event model updating compared to the non-ADHD group. When considering this result in light of EST, the ADHD group were experiencing prediction errors on a smaller timescale than the non-ADHD group during the large segmentation condition. It is unlikely that this finding is due to differences in the content of event models, due to the nonsignificant findings in the number of prototypical events. Rather, it is likely that for the ADHD group, event model updating is occurring in response to smaller increases in prediction error over shorter timescales.

There are several possible explanations for this that relate directly to known symptoms of ADHD and associated impairments. First, event segmentation theory proposes that during event boundaries, when incoming information is discrepant with event models, attention must be upregulated in order to adaptively process incoming sensory input (Coull & Nobre, 1998; Nobre, 2001). In the case of those with ADHD, it seems likely that the attention deficit symptoms themselves would be related to disturbances in this system, in particular over longer timescales, as is suggested by our results. Likewise, more frequent event model updating may be due to deficits in the ability to actively sustain event models in working memory and monitor incoming information over longer periods of time. This interpretation is supported by the known working

memory deficits associated with ADHD (Gau & Shang, 2010; Pennington & Ozonoff, 1996; Toplak et al., 2009), as well as by the results from the regular and small condition, which point to intact event model updating among those with ADHD on a shorter timescales. Similarly, it is possible that individuals with ADHD experience more frequent event model updating during the large condition due to deficiencies in their perception of time, as deficits in this ability among those with ADHD has been suggested by some researchers (Barkley, Koplowitz, Anderson & McMurray, 1997; Barkley et al., 2001).

There were no differences among the groups in the regular or small conditions, nor with regard to the prototypical events in any condition. The interpretation above accounts for why event perception over smaller timescales may remain intact, such as in the number of presses in the small and regular condition. However, it is also important to consider the non-significant findings in the number of prototypical events, a measure of the degree to which events perceived are normative. It is possible that those with ADHD do not differ from those without ADHD in this regard. However, it is also possible that the shortcomings of the current analytical approach restricts the adequate measurement of this phenomenon. For instance, the number of normative events was quite small per condition, between 2 and 5, resulting in a very small range of possible values. The range of values was indeed even lower than that, ranging from 0 to 2. This analysis may simply not be sensitive enough to detect true differences in event model content or the degree to which events perceived are normative.

In summary, these results demonstrate a specific event segmentation deficit amongst the ADHD group in comparison to the non-ADHD group: Increased prediction errors on a smaller timescale by those with ADHD when asked to look for coarse-grain events, and overall an intact event perception and updating system with regards to finer-grained events in the small and

regular condition. Thus, compared to a non-ADHD sample, those with ADHD appear to display disrupted event model updating. Overall, these findings point to explicit disturbances in the event model and updating system amongst those with ADHD.

Limitations

This study has a number of limitations worth noting. In terms of experimental design, only one movie clip was used, which may have resulted in a limited understanding of event segmentation behavior in the ADHD group. This area of research would be greatly improved by future work including a variety of movie clips to further elucidate event segmentation behavior among those with ADHD across movies of different lengths and with different content. Furthermore, utilization of the CBRS-SR in measuring symptoms of ADHD limited our ability to compare scores of inattention and hyperactivity with norms for this measure. However, given that symptoms of ADHD were not a main variable in this study but were used only to validate the groups, we do not expect that this affected our findings in any way.

There are also a number of factors that may contribute to event segmentation behavior that were not accounted for in this study. For instance, medication usage history could impact aspects of neurocognitive functioning, including event segmentation. Likewise, individuals may have been diagnosed at a young age or relatively recently, and this difference could impact an individual's present neurocognitive impairment. These are issues to be addressed in future research. Nonetheless, these results document for the first time the event segmentation behavior of a sample with a previous diagnosis of ADHD. It is clear that distinct event segmentation patterns arise in comparison to a non-ADHD sample, reflecting differences in the event model system. Namely, those with ADHD differ in their event model content as well as updating. These differences may have notable impacts on general functioning, such as through comprehension and memory of everyday events. As individuals with ADHD exhibit difficulties

in a number of functional domains, it is possible that event segmentation differences may in part contribute to these impairments. This is an important topic for future research.

Appendix

Table 1

Group Characteristics

	ADHD	Non-ADHD			
	<i>M(SD)</i>	<i>M(SD)</i>	<i>t</i>	<i>p</i>	<i>Cohen's d</i>
<i>Age</i>	19.96(2.80)	19.56(2.34)	-1.01	0.31	.160
<i>Inattention</i>	20.23(6.60)	9.85(4.77)	-10.85	.000	-1.82
<i>Hyperactivity</i>	14.25(7.43)	6.11(3.85)	-8.35	.000	-1.40

Table 2

Mann-Whitney U Test Statistics and Descriptives with Event Segmentation Variables

	ADHD		Non-ADHD		Mann-Whitney U	n^2	Cohen's d
	$M(SD)$	Mean Rank	$M(SD)$	Mean Rank			
<i>Regular</i>	1.11(.14)	67.87	1.56(.15)	81.49	2263	.025	.319
<i>Small</i>	3.08(.24)	76.61	2.90(.24)	73.54	2883	.001	.071
<i>Large</i>	2.29(.17)	84.68	1.73(.16)	66.19	3456**	.050	.438
<i>Prototypical Regular</i>	0.11(0.5)	71.36	0.19(.05)	78.31	2510	.007	.162
<i>Prototypical Small</i>	0.63(.09)	73.37	0.74(.11)	76.48	2653	.001	.072
<i>Prototypical Large</i>	0.44(.07)	78.19	0.36(.07)	72.14	2995	.005	.141

** $p < 0.083$

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**Chapter 3: Study 2: ADHD Symptoms, Event Perception and Social Skills in Early/Late
Adolescents**

Ryan, J., Dugan, N., & Rogers, M. (submitted). ADHD Symptoms, Event Perception and Social Skills in Early/Late Adolescents. *ADHD Attention and Hyperactivity Disorders*.

Abstract

Alongside the main symptoms of inattention and hyperactivity/impulsivity, Attention-Deficit/Hyperactivity Disorder is associated with functional impairments across many different domains (American Psychiatric Association, 2013; DuPaul & Stoner, 2014; Weyandt & DuPaul, 2008). Social impairments are particularly troubling due to their pervasive, lifelong nature and associated long-term negative outcomes. The underlying causes of social impairment among those with ADHD remain unclear. Event perception provides a promising, novel approach for investigating underlying cognitive mechanisms associated with symptoms of ADHD and social impairment. The goal of this study was to establish the relationship among event perception, symptoms of ADHD, and social skills in early and late adolescents. Method: In a two part study, 83 late adolescents (38 with ADHD, 45 without ADHD) between the ages of 17 and 24, and 22 early adolescents between the ages of 11 and 17, performed an event perception task and completed self-report questionnaires assessing social functioning and symptoms of ADHD (The Social Skills-Improvement System and the Conner's CBRS-SR). Results: Bootstrapping mediation analyses revealed that symptoms of inattention and hyperactivity mediate the relationship between event perception and social skills for the late adolescent group, and that symptoms of hyperactivity are positively correlated with event perception and negative social behaviours for the early adolescent group. Results highlight the applicability of event perception to understanding social impairment in association with symptoms of ADHD, replicate past research in this area, and demonstrate preliminary developmental effects.

Introduction

Attention Deficit-Hyperactivity/Impulsivity Disorder (ADHD) is a neurodevelopmental disorder characterized by chronic, developmentally inappropriate and impairing levels of inattention and/or hyperactivity/impulsivity (American Psychiatric Association, 2013). ADHD emerges in childhood, with an approximate prevalence rate of 5% in children (American Psychiatric Association, 2013; Faraone, Sergeant, Gillberg, & Biederman, 2003), and can continue into adulthood for up to two thirds of those who receive a childhood diagnosis (Barkley, 2006; Wender, Wolf, & Wasserstein, 2006). Prevalence rates in samples of adolescents worldwide appear to be similar to those in children and young adolescents (DuPaul et al., 2001; Eagan et al., 2014; McKee, 2008).

In addition to the main symptoms of inattention and hyperactivity/impulsivity, ADHD is associated with a number of functional impairments, including in the social domain (American Psychiatric Association, 2013; DuPaul & Stoner, 2014). A recent study demonstrated that between 26 and 85% of children with ADHD showed clinically significant impairment in social behavior (McConaughy, Volpe, Antshel, Gordon, & Eiraldi, 2011). Teacher reports consistently show that children with ADHD are less well liked, less popular, less cooperative, and more disruptive than their same-aged typically developing peers (Hoza et al., 2005). Results from the Multimodal Treatment Study of Children with ADHD (MTA) revealed that children with ADHD between the ages of 7 and 9 years old received lower scores on social preference, were indicated as being less well-liked, and had fewer dyadic friendships (Hoza et al., 2005). Social difficulties among those with ADHD also persist into adolescence. Studies demonstrate that adolescents with ADHD continue to lack social competence, have fewer friends, and experience high levels of peer rejection at school, just as their childhood counterparts do (Bagwell, et al, 2001; Barkley,

Fischer, Edelbrock, & Smallish, 1990). Similarly, research has found that older adolescents with ADHD continue to experience social skill deficits and difficulties with social adjustment at school (Shaw-Zirt, Popali-Lehane, Chaplin & Bergman, 2005; Weyandt et al., 2013). Given the developmental continuity of social difficulties for those with ADHD and the relation to long-term negative outcomes, identifying potential underlying mechanisms involved in social problems in those adolescents with ADHD is critical.

Underlying Causes

The underlying causes of social impairment among those with ADHD remain unclear. One commonly cited perspective is that the core symptoms of ADHD themselves are to blame. For instance, research indicates that inattentive symptoms have a significantly greater association with passive behavior, poorer social skills, as well as decreased prosocial behavior, while hyperactive/impulsive symptoms have a significantly greater association with aggressive behavior, frequent interruptions, emotional dysregulation, and being disliked by peers (Maedgen & Carlson, 2000; Wheeler & Carlson, 1994; Cunningham & Siegel, 1987). Some researchers have further suggested that symptoms of inattention may be related to social difficulties due to missed opportunities for observational learning (Cunningham, Siegel, & Offord, 1985) and missed social cues (Landau & Moore, 1991), while symptoms of hyperactivity may be related to social difficulties due to unrestrained, impulsive behaviors that are perceived as overbearing and aversive by peers (Whalen & Henker, 1992). Empirical support for the relationship between core behavioral symptoms of ADHD and social problems is derived from studies demonstrating significant correlations between social problems and behavior ratings of inattention ($r = 0.61$; Humphrey, Storch, & Geffken, 2007) and hyperactivity ($r = 0.53$ to 0.61 ; Andrade, Brodeur, Waschbusch, Stewart, & McGee, 2009).

Another common view is that social impairments among individuals with ADHD arise due to impaired social skills, a belief that led to a focus on social skills training as a core component of intervention efforts (Mrug, Hoza, & Gerdes, 2001; Nixon, 2001). Unfortunately, although social skills training has been effective for improving the social functioning of aggressive and antisocial children (Webster Stratton, Reid, & Hammond, 2001), the results have been mixed for children with ADHD (Forness & Kavale, 1996). In one study, children with ADHD who received methylphenidate and psychosocial intervention that included social skills training did not differ in terms of measures of social functioning from a control group of children with ADHD who received methylphenidate only (de Boo & Prins, 2007). It has also been suggested that children with ADHD fail to apply their knowledge during real life social interactions due to a performance deficit, rather than a fundamental lack of social knowledge or skills (de Boo & Prins, 2007; Huang-Pollock, Mikami, Pfiffner, & McBurnett, 2009; Wheeler & Carlson, 1994).

Researchers have begun to explore the possibility that this inability to apply social knowledge may be due to deficits in cognitive functioning. One study found that children with ADHD encoded fewer social cues than their peers without ADHD (Matthys, Cuperus, Van, & Engeland, 1999); several other studies have reported significant associations between parent and teacher ratings of social problems and executive functioning tasks, such as measuring, planning, strategy generation, organization (Clark, Prior, & Kinsella, 2002) and effortful control (Dennis, Britman, Huang, & Gouley, 2007). However, contrary to these significant findings, some researchers have also found that cognitive functioning is not significantly related to social impairments in children with ADHD. For instance, findings have indicated that executive functioning is unrelated to peer nominated social status (Diamantopoulou, Rydell, Thorell, &

Bohlin, 2007) and is not a significant mediator of ADHD symptoms and parent/teacher ratings of social problems (Huang-Pollock et al., 2009). Similarly, Biederman and colleagues (2004) found that children with ADHD both with and without executive functioning deficits did not differ significantly in ratings of social impairment.

The discrepancy in findings regarding the significance of the relationship between cognitive processing deficits and social problems in children with ADHD may reflect both methodological and conceptual issues. First, the cognitive processes investigated and their measurement vary tremendously from one study to the next, resulting in studies that lack common variables. For example, cognitive measures used in this domain of research have included visual attention, cue encoding, working memory, individual executive functioning tasks, and/or composite executive functioning indexes, each of which measure vastly different processes (e.g., Clark et al., 2002; Diamantopoulou et al., 2007). Second, while associations between cognitive functions, ADHD symptoms, and social impairment have been established, there is less research describing the theoretical mechanisms by which these variables are related (Huang-Pollock et al. 2009; Kofler et al. 2011; Rinsky and Hinshaw 2011; Tseng & Gau 2013).

Recently, Bunford et al. (2015) attempted to clarify these relationships by comparing potential theoretical pathways through which executive functioning deficits, ADHD symptoms, and social impairment operate. Their results supported a theoretical model in which symptoms of inattention mediated the relationship between working memory and social impairment, while symptoms of hyperactivity mediated the relationship between inhibition and social impairment. In addition, Bunford et al. (2015) also found that inhibition and working memory were related and acted collectively on symptoms of inattention and hyperactivity/impulsivity. The latter finding demonstrates the interrelatedness of cognitive processes in relation to symptoms of

ADHD, which suggests a potential benefit of using unified examinations of cognitive processes in this area of research. To date, the shortcomings of the research on this topic highlight the need for utilizing cognitive tasks that theoretically link cognition and social behaviour and that encompass a holistic view of cognitive processing rather than individual cognitive skills.

To address the needs of this area of research, we suggest turning to concepts from social cognition. Of the research to date, the social information processing model is one of the most prominent theories in the realm of social cognition research (SIP; Crick & Dodge, 1994). Studies investigating SIP in various populations of interest have typically utilized “hypothetical-reflective reasoning” tasks that present participants with videos or scripts of hypothetical vignettes and have afterwards asked them to answer questions regarding their interpretation of the cues or their hypothetical behavioral responses (Rubin & Krasnor, 1986). Unfortunately, although researchers have found that individual differences in this type of social cognitive task are associated with many forms of maladaptive social behaviors (Calvete & Orue, 2011; Crick & Dodge, 1994, 1996; Dodge et al., 2003; Hubbard, Cillessen, Dodge, Coie, & Schwartz, 2001), there is documented instability in these relationships and an overall lack of consistency in findings across different studies – an issue that has been attributed in part to the need for real-time assessment of cognitive processing (Castro, 2004; Rubin & Krasnor, 1986; Hoza, 2007).

Event Perception

We propose turning to event perception to further investigate the underlying cognitive nature of social dysfunction in ADHD. Event perception, also commonly referred to as event segmentation, is the perceptual grouping of ongoing information into meaningful chunks (Zacks & Sargent, 2010). Event Segmentation Theory (EST) describes this grouping process (Zacks, Speer, Swallow, Braver & Reynolds, 2007; Zacks & Sargent, 2010). According to EST,

grouping ongoing information into discrete units this way is a normal, automatic part of perceptual processing that is central to cognitive control, working memory updating, and storage and retrieval from episodic memory. At the core of event segmentation theory is the proposition that perception of everyday events is guided by event models held in working memory (Grafman, 1995; Schwartz et al., 1995; Wood & Grafman, 2003; Zacks & Sergant, 2010). According to Zacks & Sergant (2010), event models may be thought of as representations of what is happening in the moment, that then aid the formation of predictions about what will happen next. As such, event models are informed by current ongoing perceptual processing, while also guiding how subsequent information is processed. Event models are maintained and protected from small changes in incoming information, but are eventually updated when there are discrepancies between event models and incoming information. This change from one event model to the next is what results in the distinct, discrete events that are produced during the segmentation process. Similarly, event segmentation theory also proposes an underlying hierarchical structure to event perception, such that “smaller” event models arise from lower level aspects of an event representation that are sensitive to prediction error signals integrated over shorter time scales.

Methodologically, measuring event perception involves utilizing an event segmentation task, also known as a unit marking procedure, which was first developed by Newton and Engquist (1976). In such a task, participants are presented with a movie clip and asked to press a button when “one meaningful event ends and another begins.” What results are a series of timestamped event boundaries that reflect a participant’s perception of events. The processing that occurs at event boundaries is linked to attention, through the input of new information, and memory, through the updating of the event models stored in working memory (Zacks & Sargent,

2010). As such, attention and memory mechanisms go hand in hand with changes in event models.

Event perception has several advantages as a method for studying cognitive underpinnings of social difficulties in ADHD. By presenting movie clips, event perception tasks allows for the real-time assessment of cognition as suggested by Castro (2004), as well as providing a means for increased ecological validity through the presentation of movie stimuli that more closely replicate real-life social interactions.

Boggia & Ristic (2015) were first to apply event perception in the context of social cognition. Participants were asked to segment social and nonsocial events of a movie while their eye gaze was being tracked. Results demonstrated that participants segmented social events and nonsocial events differentially, and that this process was associated with visual attention to faces and eyes. This study was the first to demonstrate that event perception is not just a cognitive ability but also a social cognitive ability guided by attention to social stimuli (e.g. eyes and faces). This methodology also provides an advantage over other social cognitive tasks: the theory is directly applicable to social events without special alteration of the task; simply presenting social content taps into event perception in the same way as presenting nonsocial content (Boggia & Ristic, 2015).

Recently, event perception deficits have been documented amongst a sample of undergraduate students with ADHD (Ryan & Rogers, 2018), providing further evidence that this may be an important part of social functioning in this clinical population. Investigating event perception as an underlying cause of social impairment among those with ADHD is a promising and novel approach.

Current Study

The goal of the current study is to establish whether event perception as a social cognitive process is related to symptoms of ADHD and social impairment in adolescents. Importantly, this improves on past research in this domain by utilizing a task that extends our theoretical understanding of social difficulties among those with ADHD using a social cognitive framework that assesses social information processing in real-time using a task with increased ecological validity. Demonstrating the relationship between event perception, symptoms of ADHD, and social impairment is a necessary first step towards establishing this line of research.

Based on the findings of Bunford et al. (2015), it is expected in our study that event perception abilities will be related to social functioning via mediation by symptoms of ADHD. In a recent study by Ryan & Rogers (2018), individuals with ADHD perceived more events than those without ADHD. Based on these findings, it is further hypothesized that increased identification of meaningful events when presented with a socially relevant movie stimuli will be related to increased symptoms of ADHD, which in turn will be related to decreased social functioning. Part A of this study was completed with late adolescents, and Part B was completed with a small sample of younger adolescents in order to provide a preliminary investigation of developmental effects.

Part A: Methods

Participants

83 late adolescents were recruited from the University of Ottawa using the Integrated System of Participation in Research. This system provides students in first year psychology classes with the opportunity to participate in lab or internet-based research in exchange for course credit.

The University of Ottawa Board of Ethics approved this research, and all participants gave their signed, informed consent to participate. Undergraduate students were chosen as the demographic for this study to maintain consistency with Ryan & Rogers (2018) investigations of the event segmentation deficits in undergraduate students with ADHD.

Materials

Event segmentation task.

Consistent with previous research (Boggia & Ristic, 2012; Hasson, Nir, Levy, Fuhrmann, & Malach, 2004), participants performed an event segmentation task with a 1-minute clip from the movie *The Good, the Bad, the Ugly*. The clip involved a scene where the main character turns against his partner after working together to earn a bounty, and then abandons him in the desert. The participants were asked to watch the same short clip three times, with different instructions for each viewing. In the first viewing, instructions stated to press the spacebar when “one meaningful event ends and a new one begins”, a typical measure of event segmentation. The second and third viewings stated to press the spacebar when “one small meaningful event ends...” and when “one large meaningful event ends...”, reflecting fine and coarse-grain event models (as per Boggia & Ristic, 2015; Newtonson & Engquist, 1976). Specifically, the instructions for the first viewing were: “You will watch a movie clip. Please watch carefully and press the spacebar when one meaningful event ends and a new one begins.” The second and third viewing had identical instructions except for the addition of the word “small” and “large”. These conditions were counterbalanced. The definition of “meaningful” was not explicitly given, even when asked by participants, as the objective of the instructions is to elicit spontaneous event segmentation behavior. Previous findings support that this wording is sufficient for that purpose (Boggia & Ristic, 2015; Newtonson & Engquist, 1976; Zacks, Braver, et al., 2001).

The data that obtained from the event segmentation task was represented in several different ways. The *total number of button presses* is a variable that indicates both the size of a participant's event models and the number of times an event model is updated. Thus, this variable reflects the number of different event models a participant forms, representing a generalized overview of a participant's event segmentation behavior, without sensitivity to event location or content. This represents a general aspect of event segmentation behavior and can be examined for small or large events, or no particular event size orientation.

Another variable examined was the *number of prototypical events* selected. Previous research has found that observers tend to have high levels of agreement on where they place event boundaries (Boggia & Ristic, 2015; Zacks, Swallow, Vettel, & McAvoy, 2006). Thus, prototypical events represent the typical or normative events identified in a control group, and *the number of prototypical events* represents the number of those agreed upon events that were identified by any single participant. Prototypical events were determined using the results of a control group of undergraduates without ADHD ($n=31$). These participants performed the exact same event perception task as those in the experimental group, and they were recruited from the same system without special attention to ADHD status. The clip was broken down into 1-second intervals, and the participants' button presses were coded into these intervals. The average number of button presses per 1-second interval was determined, and prototypical events were identified by those 1-second intervals with the highest number of button presses (+2 standard deviations above the mean number of button presses per unit of time (as per Boggia & Ristic, 2015; Newton & Engquist, 1976; Zacks et al., 2006). In the experimental groups, the *number of correct prototypical events* was established by calculating the number of prototypical events that each participant identified. This procedure was repeated for each condition (regular, small, and

large).

Symptoms of ADHD: The Conner's Behavioral Rating Scale - Self Report.

The Conner's Behavioral Rating Scale-SR (CBRS-SR; Conners et al., 1997) was used to assess the current level of ADHD symptoms. The CBRS-SR is a questionnaire-based rating scale comprised of 187 items that assesses 9 areas of psychological dysfunction in individuals up to 18 years of age. The items consists of a sentence about a symptom, and participants rated how truly the item described applied to them: (0) Not true at all (Never, Seldom), (1) Just a little true (Occasionally), (2) Pretty much true (Often, quite a bit), (3) Very much true (very often, very frequently). The ADHD symptom subscales allow for the identification of symptoms of inattention and hyperactivity/impulsivity. Examples of items related to ADHD symptomology from the questionnaire are: "I have trouble waiting my turn", "I interrupt other people", "I make careless mistakes" and "I have trouble concentrating". The CBRS-SR has robust psychometric properties (Test-retest reliability: 0.86; Internal Validity: Cronbach's $\alpha = 0.88$; Criterion validity: Sensitivity = 81.4%, Specificity = 83.7%; Conners et al., 1997). This scale is a prominent measure of ADHD and has been used to establish convergent validity for other measures of ADHD. Furthermore, they have been used in diverse clinical and research applications (Collett, Ohan, & Myers, 2003). While some participants were older than 18, many were also 17 or 18, thus the measure was used for all participants to maintain consistency. Because some participants in the study were not of an age included in the validation of this measure, potential interpretation difficulties were avoided by using a symptom total raw score rather than a T-score. Use of a raw score was further deemed to be appropriate for the research question, since symptoms of ADHD would be examined continuously as a mediator and not used in a clinical context.

Social functioning: Social skills.

Social skills were assessed using the Social Skills Improvement System – Self-Report. The SSIS-SR has been shown to have good reliability (test-retest reliability = 0.81) and internal consistency (alpha = 0.8; Gresham, Vance, Elliot, & Cook, 2011). This scale is a multidimensional measure of various types of social skills (Gresham et al., 2011). Participants are asked to rate a series of statements on a 4 point Likert scale (N = not true, L = little true, A = a lot true, and V = very true) to assess the frequency at which they experience certain events or behaviors (Gresham et al., 2011). The SSIS-SR includes questions such as: “I feel bad when others are sad,” “I listen when others speak,” and “I exclude others.” The items of this measure result in a social skills total score (herein referred to as Social Skills), made up of a variety of subscales that assess prosocial behaviors (communication, cooperation, assertion, responsibility, empathy, engagement, and self-control), as well as a problem behavior score that assesses negative social behaviors (herein referred to as Problem Behaviors).

Procedure

Participants were welcomed to the lab and asked to sign a consent form. From there, participants were seated at a computer and given instructions for the event segmentation task. Up to four participants at a time could complete the experiment simultaneously in the same room, separated by wall dividers. Afterwards, participants filled out the Conner’s CBRS and the SSIS-SR. Finally, participants were fully debriefed upon completion of the data collection. Each experimental session lasted approximately an hour.

Part A: Results**Participants**

Of the 83 participants, 38 reported a previous diagnosis of ADHD, while 45 reported no previous diagnosis of ADHD. There were 15 males and 68 females. The participants ranged in age from 17-25, with a mean age of 18.95 years. In terms of first language, 76.6% reported English, 9.1% reported French, 3.9% Chinese, 7.8% Arabic, and 2.6% other. Due to the discrepant number of males and females, gender was used as a covariate in the mediation analyses to examine gender effects.

Data Preparation: Main Study Variables

The main study variables were symptoms of inattention and hyperactivity measured via raw scores of the inattention and hyperactivity/impulsivity subscales from the Conner's-CBRS, Social Skill and Problem Behaviors from the SSIS-SR, and six event segmentation variables from the event segmentation task: total number of button presses in the regular (variable 1a), small (variable 2a), and large conditions (variable 3a), and the number of prototypical events in the regular (variable 1b), small (variable 2b), and large conditions (variable 3b). A Shapiro-Wilks test determined that all six of these event segmentation variables were non-normally distributed ($p < 0.01$), determined to be due to outliers. To address this, a winsorization procedure was used to normalize the data. Mean and standard deviations of main study variables after this procedure are presented in Table 1.

Simple Correlations

To determine which event segmentation variables were related to both the outcome variable and the mediator variable, simple correlations were compared among all variables of interest (Table 2). Though there is debate in psychological sciences regarding the appropriateness of this approach, the initial inspection of correlations to determine which variables to include in the mediation was decided on in order to maximize power. Correlations

indicated that only the number of button presses in the regular condition (variable 1a) was both related to symptoms of inattention and hyperactivity as well as social skills total. Thus, these variables were used in the mediation analyses.

Mediation Analyses

To test whether event segmentation differences on variable 1a were associated with social skills through ADHD symptoms, a series of simple mediation analyses were conducted. A bootstrapping, bias corrected, 10000 sample method was used (Hayes, 2009). The first model we tested was with variable 1a as the predictor, inattention as the mediator, and social skills total as the outcome. We also tested the model with the other symptom (hyperactivity) as a covariate, and the reverse model, where the mediator and predictor variable were reversed. Next, we tested the second model with variable 1a as the predictor, hyperactivity as the mediator, and social skills total as the outcome. Again, we also tested the model with the other symptom (inattention) as a covariate, and a third model with the mediator and predictor variable reversed. In all models, we controlled for age and gender. The results of all of these analyses are presented in Table 3.

Mediation analyses revealed that symptoms of inattention and hyperactivity both independently acted as mediators in the relationship between event segmentation and social skills. Specifically, increased number of presses in the regular event segmentation condition predicted higher levels of both symptoms of inattention and hyperactivity, which each in turn predicted a lower social skill score. In the models where the other symptom was controlled for, these mediations became non-significant. When the mediator and the predictor were reversed, again the mediations become non-significant.

Part B: Methods

Participants

22 youth between the ages of 11 and 17 years old were recruited from the community via posters in approved community locations, Facebook advertisements, and word of mouth. The University of Ottawa Board of Ethics approved this research, and all participants gave their signed, informed consent to participate. Participants under the age of 14 provide their assent, while their parents provided consent.

Materials

Event segmentation task. Participants performed an event segmentation task with a 2-minute clip from *Degrassi*. The clip involved a scene where a character arrived at a pool party and joined a small group conversation, followed by a discussion among a group of boys about who had made it onto the basketball team after tryouts. This clip was chosen for its appropriateness with this age group and its inclusion of social scenes. The task was the same as in Part A, but instructions were slightly altered for the age group: “You will now see a clip from a TV show. Your job is to find important events. When you do, press the spacebar to show when one important event ends and another one begins.” The instructions for the large and small condition differ slightly from the normal condition; they read “This time, your job is to find BIG/SMALL important events. When you do, press the spacebar to show when one big/small important event ends and another one begins.” These conditions were counterbalanced. As in Part A, the definition of “important” was not explicitly given, even when asked by participants, as the objective of the instructions is to elicit spontaneous event segmentation behavior.

The data obtained from this event segmentation task mirror those found in Part A. However, due to the small sample size, only the event segmentation variable that was found to be

significantly correlated to symptoms of ADHD and social skills in Part A was included here: the *total number of button presses* in the regular condition.

Symptoms of ADHD: The Conner's Behavioral Rating Scale - Self Report.

The CBRS-SR was used to assess the current level of ADHD symptoms. An overview of the questionnaire was provided in Part A. Raw scores were used to maintain consistency with Part B, and again was deemed appropriate due to the research question.

Social functioning: Social skills.

Social skills were assessed using the SSSIS-SR. An overview of the questionnaire was provided in Part A.

Procedure

Participants and their parents were welcomed to the lab and asked to sign an assent and/or consent form. From there, participants were seated at a computer and given instructions for the event segmentation task. Up to four participants at a time could complete the experiment simultaneously in the same room, separated by wall dividers. Afterwards, participants filled out the Conner's CBRS and the SSIS-SR with assistance from the experimenter if needed. Finally, participants were fully debriefed upon completion of the data collection. Each experimental session lasted approximately an hour.

Part B: Results

Participants

A total of 22 participants ranging in age from 11-17 ($M=13.9$; $N_{male}=7$, $N_{female}=15$; $N_{ADHD}=8$, $N_{ADHD}=14$) were recruited. A t-test revealed no significant difference in age based on previous ADHD diagnosis ($t=-1.14$, $p>0.05$) or gender ($t=-0.8$, $p>0.05$). However, a Pearson

Chi-Squared test revealed significant differences between genders on previous ADHD diagnosis ($\chi^2=10.8, p<0.01; N_{maleADHD}=6, N_{femaleADHD}=2$).

Data Preparation: Main Study Variables

The main study variables were: 1) symptoms of inattention and hyperactivity measured via raw scores from the inattention and hyperactivity/impulsivity subscales from the Conner's-CBRS; 2) The total number of button presses in the regular condition (variable 1a) for event segmentation; 3) problem behaviors, positive behaviors, and total social skills based on the SSIS-SR subscales. A Shapiro-Wilks test determined all of these variables were normally distributed except for the raw hyperactivity symptom score variable and the event segmentation variable 1a ($p<0.05$), determined to be due to outliers. A winzorization procedure was used to address this. Means and standard deviations are presented in Table 4. Due to the size of the sample, including gender as a covariate in the analyses was not pursued, and results should be interpreted with caution. Also due to the sample size, exploration of simple correlations was used instead of a mediation approach.

Correlation Analysis

Simple correlations were used to explore the association between these variables in the early adolescent group (Table 4). Event segmentation in the regular condition was significantly associated with hyperactivity, but not inattention. In addition, this event segmentation variable was closely approaching significantly associated with problem behaviors ($p=0.051$), but was not significantly related to positive behaviors or the social skills total. Overall, these correlations demonstrate a similar trend to the relationships among these variables in the older adolescent group.

Discussion

The results of the mediation analyses with late adolescents revealed that increased inattention and hyperactivity mediated the relationship between event segmentation and self-reported social skills. Specifically, as the number of events perceived in the regular condition increased (represented by the number of button presses in that condition), symptoms of inattention and hyperactivity also significantly increased, which was then significantly associated with decreased social skills. What does this result signify? More frequent pressing in the event segmentation task is indicative of perception of an increased number of events. Additionally, in comparison to individuals who press the button less frequently, those who press the button more frequently perceive smaller events, over shorter timescales, which therefore contain less information. In our late adolescent sample, this was related to symptoms of inattention and hyperactivity. When considering the cognitive deficits of those with ADHD, several possible explanations for this emerge. Event perception deficits such as these may emerge due to faulty online-monitoring of incoming information and deficient working memory updating that affects the event perception system. It is also possible that individuals with ADHD experience these event segmentation deficits due to deficiencies in the sense of time, a notion that has been suggested by some researchers (Barkley, Koplowitz, Anderson & McMurray, 1997), which in turn could affect their perception of events across time.

Our findings support the notion that event perception deficits are related to symptoms of ADHD, but also clarify that it may be more apt to consider that these event perception disturbances predict symptoms of inattention and hyperactivity rather than vice versa, as evidenced by the non-significant finding when the role of the mediator and predictor were reversed, which is consistent with findings from Bunford et al. (2015). Although a longitudinal

design would be necessary to confirm this interpretation, Event Segmentation Theory helps to explain why increased perception of smaller events over shorter timescales may result in increased inattention and hyperactivity. According to EST, when incoming information is consistent with the event models held in working memory, there is no new event perceived. As such, the time between event boundaries provides an opportunity for the down regulation and conservation of cognitive resources, including attention. When incoming information is no longer consistent with the information contained in the event model, prediction errors increase, which is experienced by the individual as the perception of a new event. At these event boundaries, attention and other cognitive resources are up regulated once again in order to facilitate processing of incoming information. This phenomenon has been supported by fMRI research that has demonstrated increased changes in neural activity at event boundaries in brain regions associated with processing human motion and action (Zacks et al., 2001). In the case of individuals who perceive more events, their cognitive resources, including attention and behavior regulation, are likely to be redirected more frequently to events that contain less information. Thus, the event perception system is directly related to the regulation of attention and action control, which provides an explanation for the relationship between event perception and symptoms of ADHD in our results.

Furthermore, our results also indicate that the subsequent increases in inattention and hyperactivity are then associated with decreased social skills. In previous research, the notion that social difficulties amongst those with ADHD are directly related to the symptoms of ADHD has been somewhat in competition with the notion that these social difficulties may be related to cognitive processing. These results add to the emerging literature, such as the study by Bunford et al. (2015), that suggests that it is not either or, but rather a combination of both cognitive

deficits and symptoms of ADHD, that are related and act together to influence social functioning. In this study and in that of Bunford et al. (2015), results suggest a distinct direction of the relationship between these variables such that cognitive processing predicts symptoms of ADHD, which then go on to affect various aspects of social functioning.

Interestingly, when the other symptom was used as a covariate to control for its effects, the mediation models became non-significant, a finding that also replicates those of Bunford et al. (2015). One reason for this may be that the models became non-significant due to the high correlation (e.g. collinearity) between symptoms of inattention and hyperactivity in our sample. Another interpretation may be that event perception deficits do not have unique effects on symptoms of inattention and hyperactivity, but rather that there is a collective effect on both symptoms. The latter interpretation is consistent with both the notion that the symptoms themselves are related, and event segmentation theory itself, which demonstrates how attention and inhibition/behavior regulation (via action-control) may be related and affected simultaneously.

In many ways, our results replicate and support the findings of Bunford et al. (2015) insofar as our models similarly suggest that symptoms of inattention and hyperactivity mediate the relationship between cognitive functions and social impairment, as well as the reverse models and the models including the other symptom as a covariate being non-significant. However, our methodology did differ in a very meaningful way. In comparison to their measures of working memory and inhibition, our cognitive task of event segmentation captured social cognition, which includes both elements of working memory and inhibition (via action-control) in the context of social information processing. In addition, our task measured real-time processing, while also providing increased ecological validity through the presentation of stimuli with social

interactions. In addition to these methodological advantages, we were able to capture identical effects for both symptom types. This is beneficial because it provides a potential avenue for intervention that does not require separate strategies for each symptom type, but could rather be utilized for all individuals with ADHD regardless of which specific symptom type they experience. This is particularly appealing because of the diversity of symptom presentation among those with ADHD (APA, 2013). The nature of the event segmentation task itself makes it a promising avenue for intervention, as movie stimuli can be selected to be socially relevant and close to real-life interactions, while also providing a possible avenue for computer-based instruction and practice.

Developmental Effects

In a preliminary investigation of developmental effects, a small sample of early adolescents were recruited to the study. Aside from a selection of movie stimuli that were more appropriate to this age range, methodology was identical. Only correlation analyses were pursued, due to low power associated with the sample size. Interestingly, results revealed both similarities and notable differences. First, the correlational analyses with early adolescents revealed that symptoms of hyperactivity only were significantly associated with event perception and social behavior, rather than both symptoms. This may reflect age-expected variations in symptom presentation, as it is typical for younger individuals with ADHD to present with increased symptoms of hyperactivity, and for older individuals with ADHD to present with increased symptoms of inattention (APA, 2013). Similarly, it is common for symptoms of hyperactivity to be recognized more quickly and as more problematic in younger individuals with ADHD (APA, 2013). It is therefore possible that in our sample, those with ADHD

presented with more symptoms of hyperactivity than inattention, and that this is why we observed effects only for hyperactivity.

Furthermore, while event segmentation and symptoms of ADHD were significantly related to positive social skills in late adolescents, they were significantly related with problem behaviors in younger adolescents. This likely reflects the same phenomenon as mentioned above, as it is well established that symptoms of hyperactivity are more reliably related to difficulties with problem behaviors, while symptoms of inattention are more reliably related to problems with social skills. As reviewed in the introduction, research has supported that inattentive symptoms have a significantly greater association with passive behavior, more poor social skills, and decreased prosocial behavior, while hyperactive/impulsive symptoms have a significantly greater association with aggressive behavior, frequent interruptions, emotional dysregulation, and being disliked by peers (Maedgen & Carlson, 2000; Wheeler & Carlson, 1994; Cuningham & Siegel, 1987).

Despite these age-related differences, the results show a similar trend as those with older adolescents. Results supported associations between event perception, a symptom of ADHD, and a trend towards significance in associations with social behavior. Although this is a small sample and only a preliminary look at this phenomenon in younger adolescents, our findings suggest that the relationship between event perception, symptoms of ADHD, and social functioning are likely to operate in largely the same fashion as in older adolescents while also evidencing age-related differences that reflect those that are considered characteristic of the disorder.

Limitations and Future Research

The current study demonstrates for the first time the relationship between event perception, symptoms of ADHD, and social impairment. It departs from previous literature on social impairments among those with ADHD by utilizing novel methodology, using a social cognitive approach that assesses real-time processing and has increased ecological validity. The potential for this task to be used for intervention must be further explored, such as by studies that investigate whether event perception can be instructed, and whether such instruction leads to stable improvements over time that are related to changes in symptoms of ADHD and social impairment. In addition, it would be strongly recommended to consider replicating these findings using a greater number of movie stimuli with a variety of social content.

The current study consisted of a very restrictive sample of those with ADHD symptoms. First, the late-adolescent sample consisted of undergraduate students, which may be considered a higher functioning and older subset of the entire population of those diagnosed with ADHD. Second, the sample was biased towards females, potentially due to the recruitment strategy focusing on first year psychology courses. Second, the early adolescent sample was very small. While it is important to acknowledge the shortcomings of the samples used that may affect generalizability, in the case of the late adolescents, and power, in the case of the younger adolescents, it is also significant to note that the findings remained significant when controlling for age and gender, and that in spite of these sample biases, we were able to replicate the overarching findings of Bunford et al. (2015). The similarities in the findings between this study and that of Bunford et al. (2015) suggest both that the current study is likely to be valid in spite of limitations, and that the mediating effect of the symptoms of ADHD in the relationship between cognitive functioning and social impairment is replicable and robust across ages and sample types. Nonetheless, the results from this particular study would be strengthened from

future research investigating the relationships among event segmentation, symptoms of ADHD and social impairment in a wider sample of those with ADHD, including undergraduate students in different courses, samples recruited from clinics and the community, and a younger age group.

Summary

The goal of this study was to establish the relationship among event perception, a novel approach to social cognition, symptoms of ADHD, and social skills in early and late adolescents. Results revealed an association between increased event perception and decreased social skills in late adolescents, and increased problem behaviors in early adolescents. This relationship was mediated by both symptoms of inattention and hyperactivity for the late adolescents, and symptoms of hyperactivity for the early adolescents. This mediation model is consistent with prior research examining the cognitive mechanisms associated with symptoms of ADHD and social functioning (e.g. Bunford et al., 2015), which confirms past research while also introducing a novel approach to investigating this topic. While these results are cross-sectional and should be interpreted with caution, the findings point to the utility of the event perception perspective in examining impairments related to ADHD, and suggest further research on this topic.

Appendix

Table 1

Mean and Standard Deviation of Part A Main Variables

Variable	Mean	SD
Symptoms of Inattention Raw Score	15.74	7.60
Symptoms of Hyperactivity Raw Score	10.14	7.00
Social Skills (SSIS-SR)	69.29	27.05
Problem Behaviors (SSIS-SR)	28.91	12.64
Variable 1a	0.90	1.10
Variable 2a	2.94	1.77
Variable 3a	1.91	1.04
Variable 1b	0.03	0.18
Variable 2b	0.62	0.83
Variable 3b	0.38	0.55

Table 2

Bivariate Correlations Among Main Study Variables

	1	2	3	4	5	6	7	8	9	10
1. Inattention	x									
2. Hyperactivity	.72**	x								
3. Social Skills	-.66**	-.60**	x							
4. Problem Behaviors	.687**	.662**	-.498**	x						
5. Regular	.27**	.26*	-.24*	.207	x					
6. Small	.07	.19	-.14	.119	.42**	x				
7. Large	.19	.18	-.12	.115	.33**	.47**	x			
8. Prototypical Regular	.14	.15	-.12	.106	.30*	.14	.13	x		
9. Prototypical Small	.11	.15	-.08	.003	.29*	.54**	.28**	.42**	x	
10. Prototypical Large	.05	.05	-.15	.091	.22*	.25*	.23*	.10	.266*	x

*p<0.05, **p<0.01

Table 3

Bootstrapping Statistics for the Mediation Models with Inattention and Hyperactivity as Mediators Between Event Segmentation and Social Skills

	R^2	F	p	$b(MX)$	p	$b(YX, M)$	p	Indirect Effects			Indirect Effect of Reversed			Indirect Effect Controlling for Other Symptom		
								pe	SE	95% CIs	pe	SE	95% CIs	pe	SE	95% CIs
IA as Mediator																
Event Segmentation	0.45	16.05	0.0	1.99	0.01	-2.01	0.38	-4.53	1.90	[-8.30,-.90]	-0.00	0.00	[-.012,.00]	-0.07	0.86	[-2.39,1.07]
H/I as Mediator																
Event Segmentation	0.37	11.32	0.0	2.11	<0.01	-0.21	0.40	-4.43	1.78	[-8.16,-1.23]	-0.09	0.10	[-.37,.06]	-0.60	0.58	[-2.34,0.13]

The macros provide a 95% confidence interval around the indirect effect. When zero is not in the 95% confidence interval, it can be concluded that the indirect effect is significantly different from zero at $p < 0.05$ (two tailed)

$B(MX)$ is the effect of the predictor on the mediator, $b(MX)$ is the effect of the predictor on the outcome while controlling for the mediator, pe is point estimate, IA is Inattention, H/I is hyperactivity/impulsivity, *Event Segmentation* is the number of button presses in the regular condition.

Table 4

Mean and Standard Deviation of Part B Main Variables

Variable	Mean	SD
Symptoms of Inattention Raw Score	11.64	7.14
Symptoms of Hyperactivity Raw Score	8.41	5.80
SSIS-SR Total Score	69.59	31.60
SSIS-SR Problem Behavior Score	11.64	7.15
ES 1a	2.68	2.60

Table 5

Bivariate Correlations Among Main Study Variables Part B

	1	2	3	4	5
1. Inattention	x				
2. Hyperactivity	.758**	x			
3. Social Skills	-.29**	-.669**	x		
4. Problem Behaviors	.797*	.765**	-.793**	x	
5. ES 1a	.211	.438*	-.381	.420^	x

*p<0.05, **p<0.01, ^=.051

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Chapter 4: Conclusion

The overarching goal of this dissertation was to investigate ADHD symptoms and related social impairment from the perspective of event perception. Event perception is an emerging topic in cognitive science, with noteworthy potential applications in clinical psychology. In particular, the overlap between the mechanisms theorized to be involved in event perception and those known to be involved in ADHD (e.g. working memory, attention) made a compelling case for examining ADHD from this lens. As the scientific understanding of ADHD continues to evolve, it is crucial to examine this disorder using new approaches in order to continue to progress theories, methodologies, and conceptualizations of the disorder.

Indeed, the findings reported in the studies in this dissertation clearly point to potential event perception differences among undergraduates with ADHD, in addition to associations with both ADHD symptoms and social skills that persist when controlling for gender and age. Results from these studies suggest that undergraduates with a previous ADHD diagnosis have impaired ability to perceive large events over longer time frames, resulting in them breaking down social information into smaller event units than their peers when oriented to large events. While these group differences emerged in study 1, results from study 2 highlighted associations between ADHD symptoms, social impairment, and neutral event perception without any size orientation. Here, ADHD symptoms were significantly positively related to increases in the number of events perceived in this no-size condition, which was in turn significantly negatively related to social skills.

Across these two studies, the results are at the same time consistent and discrepant. In both cases, ADHD diagnosis and/or symptoms were associated with perceiving an increased number of events. However, in study #1 the association was with events in the large condition, and in study #2 it was with events in the no-size condition. One reason for this may be the

research design. In study #1, group differences were investigated based on previous ADHD diagnosis status, while in study #2, ADHD was examined as a continuous variable via symptom scores. Therefore, the difference in event perception deficits that emerged between these studies may be due to statistical differences related to the way ADHD was measured. Another reason may be related to the power of the statistical findings. Both studies suffered from power issues. In the first, the sample size was adequate only to detect a moderate effect size, such as the main significant result that was found in the large condition. This significant result in the large condition had a power of 75%, which is just shy of the generally acceptable 80%. The group differences in the regular condition also had a moderate effect (though smaller than the large condition), though they were nonsignificant, and the power here was only 48%. This leaves a considerable chance that a true effect was missed in this condition. If this was the case, the effects in the two studies would more closely replicate each other. A replication of Study 1 was attempted with the data from Study 2, by running an ANOVA to test the difference in means across the conditions. All of the results were nonsignificant, but this is also likely due to power, as the sample size in each group was about half that of the groups in Study 1.

Despite these differences in results, in both studies there was a clear pattern in which ADHD was related to increased event perception identification. This pattern was also observed in the preliminary youth group. As such, the main finding of this study is that those with ADHD tend to perceive a greater number of events over smaller timescales, and that this is related to symptom level and reduced social functioning. Clarifying the degree to which this effect emerges in different conditions and across different movies would be an excellent avenue for future research, which will be discussed further in the next section.

The phenomenon of increased event identification in relation to ADHD diagnosis or symptomatology has several potential explanations. First, event segmentation theory proposes that event perception is related to attentional processes (Kurby & Zacks, 2008). It is suggested that attention processes are up-regulated during event boundaries and down-regulated during events in relation to the need for processing of incoming stimuli (Coull & Nobre, 1998; Nobre, 2001). It has been found in past research that ADHD is characterized by deficits in attention regulation; as such, it is possible that the increased event identification that was observed across both of these studies is due to inappropriate attention regulation.

Similarly, another explanation lies in the role of working memory. According to EST, event models are held in working memory while the information that is being processed matches that event model. When the event perception system is working properly, event models are updated only when incoming information becomes discrepant with the event model in working memory. As working memory deficits are commonly documented among those with ADHD (Gau & Shang, 2010; Pennington & Ozonoff, 1996; Toplak et al., 2009), it is possible that poor working memory affects the event perception system by affecting the degree to which individuals with ADHD can maintain event models in working memory. This would result in individuals with ADHD perceiving more events due to more frequent event model updating that is caused by poor working memory abilities.

Finally, another possible explanation is that individuals with ADHD experience more frequent event model updating due to deficiencies in their perception of time. Temporal information processing, the perception and representation of time, is a cognitive ability that allows for the organization of events and actions, as well as prediction of future events (Toplak, Dockstader, & Tannock, 2006). This cognitive skill has overlap with aspects of event

perception, not just in the timing aspect that is involved in identifying small and large events, but also the perceptual organization and prediction components that are inherent within the EST model. Indeed, temporal information processing issues have been documented among those with ADHD, such as duration discrimination and finger tapping (Barkley, Koplowitz, Anderson & McMurray, 1997; Barkley et al., 2001; Toplak et al., 2006). The event perception differences in relation to ADHD that were observed in these studies may reflect either of these issues.

While three distinct interpretations of our results were offered above, it is likely that all ring true in some form. Cognition is not unilateral, but rather a complex interaction of processes. Indeed, what is particularly compelling about the event perception approach is the integration of many aspects of cognition, which arguably provides a holistic, unified perspective of cognitive functioning. This also lends itself well to potential interventions, as several aspects of cognition can be targeted in a single task. Currently, pharmacological intervention, parent-management training, and cognitive-behavioral interventions are viewed as most effective interventions for those with ADHD, but the degree to which each of these treatment options produces meaningful reductions in ADHD symptoms and associated impairments alone or in combination continues to be debated (Daley et al., 2014; Fabiano et al., 2015; Van der Oord et al., 2008 2008; Young et al., 2016).

However, none of these intervention options have reliable effects on social functioning, and only medication has a reliable effect on cognitive deficits. In terms of cognitive functioning, some studies do report short-term cognitive benefits of ADHD medication (e.. Barnett et al., 2001; Holmes et al., 2010; Mehta, Goodyer & Sahakian, 2004; Wong & Stevens, 2012), but the long-term effects are largely unstudied. In terms of social functioning, pharmacological interventions and social skills training do not produce consistent benefits on long-term social

functioning (de Boo & Prins, 2007; Greenhill et al., 1999; Langberg & Becker, 2012; Ryan et al., 2011; Whalen & Henker, 1991). Since then, researchers have been actively exploring and developing new interventions targeted at the cognitive and social difficulties of those with ADHD, such as working memory training (Klingberg et al., 2005), parent-delivered social skills interventions (Wilkes-Gillan et al., 2016), play-based interventions (Barnes et al., 2017), and peer-based interventions (Mikami et al., 2013).

At present, there is a need for continued investigation of the underlying nature of social difficulties among those with ADHD, as well as novel intervention methods to address these social difficulties across the lifespan. The findings from this dissertation point to event perception as a possible avenue for intervention in the social domain. For instance, computer-based event perception tasks may be implemented to practice identifying meaningful events. Alternatively, instruction on how to identify meaningful events and prompting to do so during social interactions may be suitable additions to current social skills training programs. In order to explore these possibilities, it will first be important to establish whether event perception skills can be improved upon with practice and/or instruction, and whether improvements are related to ADHD symptom reductions and/or social skill improvements. These, and other future areas of research, are addressed in the section below.

Limitations and Future Directions

Despite the novelty and significance of the findings presented in this research, there are limitations to these studies worth addressing to design and implement future studies.

Stimuli, Methodology & Design.

The study of event perception is relatively new, and may still be considered an emerging topic, particularly in the realm of clinical psychology. As such, this methodology would benefit

from continued rigorous experimentation. For instance, to our knowledge, it is unclear how event perception may differ among typically developing individuals across the lifespan and across different types of video stimuli. Therefore, it would be worthwhile to establish “normative” event perception patterns for different types of movies, of different lengths, in order to in future compare to individuals with ADHD. This particular set of studies would benefit substantially from use of a wider range of video stimuli to fully explore the deficits among those with ADHD and their relation to social impairments.

In these studies, we attempted to uncover event perception deficits among those with ADHD in relation to different sized events, a feature of event perception that relates to the hierarchical structure of events - that is, the degree to which individuals are able to identify small events in relation to large ones. Although our analyses allowed us to compare results across these conditions, future research would benefit from exploring approaches that allow for specific measurement of the hierarchical effect. In a recent email with Dr. Zacks, an active researcher in the domain of event perception, alternative mathematical approaches to measuring the hierarchical effect were suggested (personal communication, August 13th, 2018). For instance, alignment approaches would involve calculating the distance between small and large events. Investigating the validity of these approaches among those with and without ADHD would be a promising future study.

Study 2 was designed as a cross-sectional mediation analysis to investigate the relationship between event perception, ADHD symptoms, and social functioning. This is consistent with the design of Bunford et al. (2015), who conducted a study of similar design investigating the relationship among cognitive functioning, ADHD symptoms, and social functioning. A longitudinal study would be a necessary next step to support the mediation model

presented in Study 2 and determine causal relationships. Likewise, a longitudinal study would provide evidence for the utility of event perception as a future potential treatment option by determining whether event perception predicts symptoms of ADHD and social impairment over time. Furthermore, investigating the degree to which event perception can be improved with practice or specific instruction, whether improvements are stable across time, and whether those improvements lead to changes in symptomatology or social functioning at a later date would be a promising approach to further this line of inquiry.

Finally, in both studies, the design used involved having up to four participants in the testing room at once to complete the event perception task. While it is possible that this set up was problematic for individuals prone to distraction, measures were put in place to minimize these effects. The room is designed to minimize distractions, as there are individual sliding walls that can extend to block the view from one cubicle to the next. In addition, participants were wearing headphones to hear the movie clips that also served to block out extraneous noise. Finally, a research assistant was monitoring the participants through a visual system throughout the task in order to note if they appeared to remain on task. These notes were carefully considered during the data cleaning phase in the case that a participant was deemed too distracted to be engaged in the task.

Samples.

The large majority of participants included in these studies were undergraduate students in first year psychology classes. Undergraduates were chosen as the main focus of this dissertation for several reasons. First, undergraduates with ADHD are more frequently being recognized as an at-risk group: research has found that students with ADHD symptoms show decreased functioning in several areas of college adjustment, lower levels of self-reported social

skills and self-esteem, greater academic performance concerns, depressive symptoms, social concerns, emotional instability, and substance use (Blase et al., 2009; Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2008; Shaw-Zirt, Popali-Lehane, Chaplin, & Bergman, 2005). Because of these known risks, undergraduate students with ADHD are an important population to study. In addition, as these were the first set of studies to look at this topic among those with ADHD, it was deemed appropriate to begin these investigations with a sample consistent with samples used in recent research on event perception. The ISPR system used for recruitment would also ensure high levels of participation and larger sample sizes needed for statistical power. A significant effort was made to extend this research to a youth sample using community-based recruitment methods approved by the University of Ottawa Research Ethics Board: word of mouth and posters in approved community locations. Unfortunately, over the course of two years, these methods did not produce a large sample, and the findings from Study 2 Part B are considered very limited. Overall, the findings within Study 1 and Study 2 are not generalizable beyond an undergraduate sample. Given the compelling evidence in these studies showing event perception differences among those with ADHD, future research would benefit substantially from recruiting methods targeting a wider audience, including community, clinical, and youth populations.

ADHD Diagnosis and Self Report.

The most rigorous means of confirming an ADHD diagnosis in clinical research is to include a comprehensive clinical interview and administration of relevant self-report questionnaires. For these studies, the research questions and purpose of the project were carefully considered during the design phase to assess the cost and benefit of this approach. It was determined that given the aims of the project, the originality of the approach, and the need

for sizeable samples in each study, that it would be most appropriate to utilize self-report of previous diagnosis. Utilizing self-report of previous diagnosis remains a common approach for investigating undergraduates or college students (e.g. Rabiner et al., 2008; Reaser, Prevatt, Petscher, & Proctor, 2007). We made efforts to mitigate potential negative effects associated with using a self-reported diagnosis. For instance, in Study 2, diagnostic groups were confirmed using the raw scores from the CBRS-SR. In Study 2, ADHD symptoms were investigated continuously, making the diagnosis only useful for ensuring a representation of the full spectrum of symptom presentation.

In these studies, self-report was also used to assess current symptomatology and social functioning. Much research has documented that children with ADHD are not valid reporters of their own symptoms (e.g. Hoza et al., 2004; Hoza, Pelham, Dobbs, Owens, & Pillow, 2002; Owens, Goldfine, Evangelista, Hoza & Kaiser, 2007). For this reason, the use of self-report is a controversial approach in both research and clinical practice. In both settings, it is considered the gold standard to collect information about symptoms and impairment from adults, such as parents and teachers, who observe the child in various settings. This approach seemed less advantageous in research with undergraduates, for whom parent and teacher ratings would likely be 1) more difficult to collect and 2) less likely to be accurate, due to less frequent and close contact than would be expected of younger samples. In planning Study 2 Part B, which used a youth sample, efforts were made to obtain teacher and parent ratings of ADHD symptomatology and social impairment. However, there was a very high rate of missing data from these informants; therefore these findings were not reported.

When assessing the impact of using self-report in research, it is important to consider the nature of self-report bias. Studies with children and adolescents with ADHD have found that

they consistently under-report their own ADHD symptoms and impairments, demonstrating a “positive illusory bias” (Owens et al., 2007). In the case of the studies presented here, this type of self-reporting bias would thus underestimate the effects of event perception in relation to ADHD symptoms, rather than overestimate them. In contrast, some research has shown that adults with ADHD are actually the best reporters of their symptoms (Kooij et al., 2008). In undergraduates, students seeking a new diagnosis may be more likely to overestimate their symptoms and impairments (Barrett, Darredeau, Bordy, & Pihl, 2005; Harrison, 2006; Harrison, Edwards, & Parker, 2007), but in our study, we recruited undergraduates with previous ADHD diagnoses, making it less likely that they would benefit in any way from exaggerating their symptoms. All together, it is not entirely clear that our undergraduate sample would be likely to demonstrate self-report bias, or to what degree. However, it is believed that any self-report bias would have limited the scope of our full understanding of the effects of event perception in ADHD, as opposed to presenting an inflation of true effects.

Medication and Diagnosis History.

The effect of current or past medication use on event perception were not the focus of this study, nor were the event perception deficits cross different types of ADHD diagnoses (e.g. Inattentive, Hyperactive/Impulsive, or Combined). However, it is still important to consider the effects of these variables on the results. To control for any potential medication effects, we requested that participants refrain from taking the ADHD medication prior to the study. While it is theoretically possible that event perception differs based on long-term medication history due to the neurocognitive effects of ADHD medications, these potential effects are still very much unclear; while some studies do report short-term cognitive benefits of ADHD medication (e.. Barnett et al., 2001; Holmes et al., 2010; Mehta, Goodyer & Sahakian, 2004; Wong & Stevens,

2012), others only report small effects (Advokat, 2010; Lakhan, & Kirchgessner, 2012), and the long-term effects are largely unknown (eg. Konrad, Neufang, Fink, & Herpertz-Dahlmann, 2007; Vitiello, 2001). Likewise, the degree to which cognitive difficulties vary based on diagnostic subtype also remains unclear (Mayes, Calhoun, Chase, Mink, & Stagg, 2009; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005), as does the validity of the subtypes themselves (Bell, 2011). Now that event perception has been linked to ADHD diagnosis and symptoms in these studies, investigating the effects of medication and diagnosis presentation on event perception would be a valuable topic for future research to further our understanding of ADHD.

Other Mental Health Symptoms.

Although it is common for those with ADHD to have comorbidities (APA, 2013), it is currently unclear to what degree other mental health symptoms associated with ADHD contribute to social impairment. Although we collected symptomatology of other mental health disorders via the CBRS-SR, including these in our mediation model as covariates was not possible due to needs for statistical power. As such, it is possible that event perception may have also been affected by other mental health symptoms. Before addressing the effect of other mental health issues on the relationship between ADHD, event perception, and social functioning, it is first important to broadly address the degree to which social impairment among those with ADHD is related to other mental health issues, as well as the effects of other mental health issues on event perception.

Summary

Aside from the main symptoms of ADHD, the disorder is also associated with a range of functional impairments, such as social, emotional, and academic/occupational difficulties. The social problems that are related to ADHD are of particular interest because of their lifelong

impact. The cognitive processes underlying both the disorder and these associated social impairments are still being carefully investigated. Introducing new approaches is an important part of this scientific process. Event perception provides a unique perspective on the cognitive and social deficits in ADHD and how they might be related, while also improving on previous methodologies. The primary goal of this dissertation was to apply event perception to capture the cognitive difficulties of ADHD and associated social impairments.F

The first study investigated whether event perception differed among those with ADHD compared to those without, and results ultimately revealed that individuals with ADHD tend to segment activity into a greater number of events. The second study sought to elucidate the social difficulties associated with ADHD among early and late adolescents by examining the relationship between event perception, symptoms of ADHD and social functioning. Findings from this study supported a mediation model, where symptoms of ADHD mediated the relationship between event perception and social skills. Results differed somewhat between early and late adolescents, but overall supported the same conclusion. Altogether, results of the two studies point to event perception differences associated with ADHD, as well as symptoms of ADHD acting as mediators in the relationship between event perception and social impairment.

While there are limitations to the studies here, together they are the first attempt to use event perception in the context of ADHD. The results contribute to current theoretical conceptualization of ADHD, as well as suggest exciting potential avenues for future ADHD-related inquiries and interventions.

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