Exploring Social Attention in Attention-Deficit/Hyperactivity Disorder: A Dimensional Approach

by

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The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

Rebecca Trossman was the sole author for the General Introduction and the General Discussion, which were written under the supervision of Dr. Tara McAuley and were not written for publication.

This thesis consists in part of three manuscripts written for publication. Each manuscript was based on originally collected data. As lead author of these studies, Rebecca Trossman was responsible for conceptualizing study designs, collecting data, carrying out data analyses, and drafting and submitting manuscripts.

As co-author and supervisor, Dr. Tara McAuley contributed intellectual input on study design and analyses and provided feedback and editing for each manuscript.

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Abstract

There is a well-established finding that individuals with ADHD experience social impairment in their daily lives. This likely arises from symptoms of the disorder coupled with deficits in cognitive factors important for effective social function. However, the exact nature of the social impairment remains poorly understood. That is, despite a substantial literature documenting the existence of social problems in daily life, it remains unclear which social cognitive processes may underlie these deficits. Because we lack a clear understanding of the mechanism behind social deficits in ADHD, extant social skills interventions have proven ineffective in ameliorating social functioning for individuals with ADHD. This is particularly notable given the detrimental effect of social impairment on overall wellbeing for those with ADHD. The complexity of social interactions places a high demand on attentional skills; thus, it is plausible that social attentional processes may subserve social impairment in ADHD. The current dissertation aims to elucidate the relationship between ADHD and two core social attentional constructs: self-referential processing and orienting to gaze cues. In line with the RDoC, this dissertation conceptualizes ADHD through a dimensional lens, measuring traits of ADHD along a continuum in three large undergraduate samples. Traits of Autism Spectrum Disorder were also included (and measured dimensionally) given commonalities between the disorders. In Study 1, I examined self-referential processing in a large sample of undergraduates (n=265) varying in ADHD traits. Self-referential processing was assessed online using the self-referential encoding task (SRET), a common implicit memory paradigm. Contrary to hypotheses, neither ADHD traits (nor ASD traits) influenced SRET performance. The self-reference effect also did not

emerge when memory was assessed using the most robust metric from the SRET, recognition sensitivity (*d*'), despite adequate power and careful quality control of data. These findings question self-referential processing as a mechanism underlying social impairment in ADHD and, more broadly, highlight the need for further evaluation of the SRET. Building upon these findings, in Study 2 I adapted the SRET to explore self-referential processing in a socially evaluative context to determine whether prioritization of self-referential information was reduced in ADHD in situations of social threat. This study employed another large undergraduate sample (n=302) expressing a varying level of ADHD traits. Consistent with Study 1, traits of ADHD and ASD did not modulate the self-reference effect, providing further support that ADHD and ASD traits do not impair prioritization of self-relevant information. Additionally, an unexpected finding emerged whereby participants with higher levels of neurodevelopmental traits demonstrated better overall performance on the implicit memory task. Finally, Study 3 (n=169) focused on a different core social attentional process: orienting towards eye gaze cues. This study employed an online adaptation of the classic gaze cueing paradigm to investigate whether ADHD and ASD traits modulate orienting to both neutral and emotional eye gaze cues. Results did not support a modulation in gaze orienting by ADHD (nor ASD) traits; that is, participants demonstrated spontaneous orienting towards eye gaze cues across all levels of neurodevelopmental trait expression. Further, there was no indication of reduced emotional modulation of gaze orienting in ADHD or ASD. Overall, the studies presented in this dissertation suggest that ADHD traits do not modulate two core social attentional processes. However, across the three studies – and over 700 participants – results consistently demonstrate a correlation between ADHD and ASD traits and social impairment in daily life, as measured through a self-

report questionnaire of everyday social problems (e.g., getting into arguments, difficulty maintaining friendships, etc.). Thus, although real-world social outcomes are negatively impacted by traits of both disorders, the two social attentional skills evaluated here do not appear to account for these deficits. Findings of this work address a gap in our understanding of the state of social cognitive abilities – specifically social attentional skills – in ADHD, with the ultimate aim of contributing to the literature seeking to develop successful interventions to remediate social impairment in this population.

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Chapter 1: General Introduction

This thesis investigated social attention in the context of individual differences in attention-deficit/hyperactivity disorder (ADHD) symptom expression. ADHD is a highly prevalent and persistent neurodevelopmental disorder that is characterized by academic, occupational, and interpersonal challenges along with hallmark symptoms of inattention, hyperactivity, and impulsivity (American Psychiatric Association, 2013; Ayano et al., 2023; Barkley et al., 2010; Faraone et al., 2006; Murphy & Barkley, 1996). Presently, our field is limited insofar as understanding the root causes of social impairment that is commonplace in ADHD (Nijmeijer et al., 2008). This lack of understanding may at least partly explain why there are not efficacious interventions to ameliorate social impairment in this clinical population, as evidenced by poor long-term efficacy of extant social skills interventions (Morris et al., 2021). My work aimed to address this gap in the literature by contributing to our understanding of social attention along a continuum of ADHD traits, which is an important and logical next step in intervention science (e.g., Pacheco et al., 2022). Self-referential processing and orienting to eye gaze are two foundational aspects of social attention that were examined in my work. Self-referential processing refers to the well-established finding that individuals devote greater resources to processing information of relevance to the self – an adaptive social skill that allows one to select out the most important information in social settings that contain vast amounts of information (Gray et al., 2004; Humphreys & Sui, 2016; Symons & Johnson, 1997). I examined whether ADHD traits reduced this typical prioritization for self-referential information, a novel contribution to the literature as this question has yet to be thoroughly explored (Chapter 2). To expand this line of inquiry, I then investigated whether heightening the social salience of self-

referential information additionally impacts the identification of self-relevance as an important cue for individuals with ADHD (Chapter 3). Orienting to the direction of someone else's eye gaze develops very early in life and subserves core social processes such as joint attention and theory of mind (Itier & Batty, 2009). Deficits in orienting to eye gaze have been associated with poor social competence, and while atypical gaze orienting has been identified in other neurodevelopmental disorders with significant social impairment (i.e., Autism Spectrum Disorder), findings regarding gaze orienting in ADHD are mixed (Groom et al., 2017; Hayward & Ristic, 2017; Klin et al., 2002; Marotta et al., 2017). This work aimed to elucidate the nature of gaze orienting in ADHD using the well-replicated gaze cueing task adapted to an online environment (Chapter 4). The findings from my three studies are discussed in terms of a broader framework regarding the mechanism behind social impairment in ADHD, and the implications with respect to social skills interventions are explored.

Dimensional Approach to Assessing ADHD Symptomology

Approximately one decade ago, the National Institute of Mental Health created the Research Domain Criteria (RDoC), a research framework that proposes an alternative nosology of mental disorders (Insel, 2014). RDoC is rooted in the principles of precision medicine, and aims to enhance our ability to accurately diagnose (and ultimately treat) psychopathology (Insel, 2014). To do so, the RDoC approach evaluates different domains of functioning (including attentional and social processes) that cut across current diagnostic categories (Cuthbert, 2022). Importantly, RDoC focuses on integrating evidence from different levels of analysis, ranging from the genetic and molecular level, to brain circuits, to behaviour and self-report, when

understanding these transdiagnostic domains (Cuthbert, 2022). By doing so, RDoC aims to develop a better understanding of the neurobiological underpinnings of psychopathology.

One important tenant of the RDoC framework is that psychopathology is best understood when symptoms are measured dimensionally (Cuthbert, 2022). This contrasts with the more traditional categorical approach to conceptualizing disorders taken by the DSM, where diagnosis is made based on presenting with a certain number of (often heterogeneous) symptoms that surpass the predetermined threshold for diagnosis. Those that do not meet this threshold, even those falling just one symptom short, are not eligible for diagnosis, even if there may be similarities between those who do and do not meet criteria at other levels of analysis (e.g., at the genetic level, or in brain circuitry that underlies behaviour). Not surprisingly, there is accumulating evidence that setting arbitrary diagnostic cut-offs in this manner results in systems with limited clinical utility for prognosis and treatment (Conway et al., 2019). RDoC aims to address this exclusive focus on current symptom manifestation at the expense of investigating underlying causes of behavioural expressions, while also tackling other problems inherent in categorical diagnostic systems, including high levels of comorbidity due to high degree in symptom overlap across distinct diagnostic categories, and phenotypic diversity within single diagnostic categories (Insel, 2014).

ADHD, in particular, contains much heterogeneity in symptom presentation (e.g., Nigg et al., 2020). Adoption of an RDoC-informed, dimensional approach to ADHD has proven to be useful for understanding functioning within this heterogeneous single category (Musser & Raiker Jr, 2019; Nigg et al., 2020; Pacheco et al., 2022). Further, a dimensional approach better captures the true distribution of ADHD symptoms amongst the general population, given that extensive

evidence from large samples demonstrates a normal distribution of these traits in the population (Crosbie et al., 2013; Greven et al., 2016; Larsson et al., 2012).

In this dissertation work, I adopted a dimensional approach to measuring symptoms of ADHD by assessing symptoms along a continuum. That is, instead of categorizing participants into two groups in a binary fashion based on the presence or absence of a clinical diagnosis of ADHD, I asked participants to report on the extent to which they possess a variety of traits of ADHD. As well, I focused on outcome measures (i.e., areas of social attention) that align with a key domain within the RDoC framework: social cognition (Gur & Gur, 2016). This method of symptom measurement is in alignment with the RDoC framework and allowed me to capture the entire spectrum of presentation of ADHD traits (i.e., the normal distribution of ADHD symptoms) as they occur in the population.

Social Functioning in ADHD

Impaired social function is commonly experienced by individuals with ADHD: children are rated as less popular by peers, have fewer reciprocated friendships, and are prone to more frequent peer victimization than their typically developing counterparts, while adults report poorer relationship quality, are less likely to marry, and experience higher divorce rates (Bagwell et al., 2001; Barkley et al., 2010; Blachman & Hinshaw, 2002; Hoza, 2007; Ros & Graziano, 2018; Spender et al., 2023). College students with ADHD also report high levels of social impairment, with difficulties building and maintaining interpersonal relationships being self-identified as one of the main difficulties they experience in daily life (Kwon et al., 2018; Sacchetti & Lefler, 2017).

Although the link between ADHD and impaired social function is well-established, little is known about underlying mechanisms that are involved in the emergence and/or maintenance of the social difficulties experienced by many individuals with the disorder. There is some evidence that social impairment is directly related to core symptoms of the disorder (Mary et al., 2016). In line with this hypothesis, studies find that hyperactivity and impulsivity may particularly impact social functioning in early childhood (Zoromski et al., 2015). That is, youth with high levels of hyperactivity and impulsivity display more aggressive behaviour, emotion dysregulation, and interruptions in the classroom (Nijmeijer et al., 2008). As children move into adolescence, research indicates that symptoms of inattention significantly contribute to social outcomes (Sibley et al., 2010; Zoromski et al., 2015). Specifically, inattention is thought to impact emotional learning and knowledge, reducing opportunities to learn through social observation or causing people to miss important social cues (Andrade et al., 2009; Hoza, 2007; Zoromski et al., 2015). Together, these features impact popularity of youth with ADHD amongst peers (Andrade et al., 2009). Similarly, other work looks at the role that executive function (EF) deficits – which are known to characterize ADHD – play in social outcomes. EF refers to the set of higher order cognitive processes that enable goal directed behaviour, including self-regulation. Some work identifies intact social cognition in ADHD when attentional and EF factors are statistically controlled (Mary et al., 2016). Other work shows that EF may mediate the relationship between ADHD and social problems, pointing towards the role that core ADHD symptoms (in this case EF deficits) play in causing downstream social consequences (Kofler et al., 2011; Kofler et al., 2018; Nilsen et al., 2015; Tseng & Gau, 2013).

Others, however, hypothesize that social dysfunction in fact represents a component of the broader ADHD clinical phenotype, as opposed to a downstream consequence of other ADHD symptoms. In line with this hypothesis, some research indicates that deficits exist in empathy, theory of mind (ToM), neural processing of faces, and the ability to recognize and label emotional expressions in others (Aydin et al., 2023; Bora & Pantelis, 2016; Romani et al., 2018; Uekermann et al., 2010). Some work hypothesizes that deficits in facial emotion recognition may underlie some of the social impairment seen in ADHD (Romani et al., 2018). However, there are mixed findings regarding whether social cognitive skills are impaired in ADHD, with other contradictory evidence indicating that individuals with ADHD actually possess similar social cognitive skills as typically developing peers when measured in a laboratory setting (Ioannou et al., 2020). This literature riddled with contradictory findings has led to confusion as to whether knowledge deficits in social skill areas are truly the root cause of social impairment (Morellini et al., 2022). At this point, no single social cognitive skill has emerged as an area of consistent deficit in ADHD.

Lacking a clear understanding of the cause of widespread social impairment in ADHD has had direct implications on the ability to remediate these deficits through clinical intervention. Studies of social skills interventions designed to improve social functioning in ADHD largely fail to identify sustained improvement in social skills (Morris et al., 2021; Pfiffner & McBurnett, 1997). While some studies of social skills interventions in ADHD identify specific areas of improvement (e.g., in assertion skills), they also find little generalizability to other domains of social functioning (Antshel & Remer, 2003). Further, although some studies identify moderate benefits immediately after intervention, evidence for long-term, sustained gains is lacking

(Storebø et al., 2019; Willis et al., 2019). Many believe the inability to develop effective social skills interventions for individuals with ADHD is a consequence of the lack of knowledge about the mechanism behind social impairment, as it is as of yet unknown what specific skills are in need of remediation.

Social Attention

Social interactions are highly complex: any one social scenario contains a multitude of incoming information sources. Therefore, social engagement places considerable demands on our attentional skills (e.g., Capozzi & Kingstone, 2024; Capozzi & Ristic, 2018). Social attention refers to the skills needed to engage in this process of allocating attentional resources appropriately in social situations. While the construct of social attention lacks one coherent definition in the literature, it is generally thought to consist of myriad processes that work together to allow individuals to identify and attend to the information most important in that moment for efficient and successful social interaction (Salley & Colombo, 2016). In Crick and Dodge's (1994) foundational model of social information processing, encoding of social cues is the model's first step – a step which is necessary for successful engagement in higher level processes that comprise social interaction (e.g., interpreting social cues to make a judgment about a peer's intentions). This dissertation sought to investigate the relationship between ADHD symptoms and two foundational social attentional skills: prioritization of self-relevant information and utilizing eye gaze as a cue for attentional orienting.

Self-Referential Processing

Personal relevance represents an important feature of certain environmental stimuli that can assist the attentional system in selecting out information worthy of further processing from

the vast amounts of incoming input we are constantly receiving during social interactions (Humphreys & Sui, 2016). Accordingly, it has been widely demonstrated that individuals devote greater attentional resources to processing information that is relevant to the self, an effect known as the self-reference effect (SRE; Golubickis & Macrae, 2021; Gray et al., 2004). Prioritization of self-relevant information in the attentional system is an adaptive social cognitive process, as it guides us towards information most likely to be significant in a given social situation, and self-referential processing allows us to rely on our own experiences to interpret and understand the mental states of others (Mitchell et al., 2005).

Experimentally, various methods have converged to demonstrate that self-relevant information is typically attended to more readily, processed more deeply, and remembered better than information of less consequence to the individual (Gray et al., 2004; Humphreys & Sui, 2016; Symons & Johnson, 1997). Beginning several decades ago, early studies demonstrated this phenomenon using a variety of tasks; for example, on dichotic listening tasks, participants are more distracted from their instructed task when presented with self-relevant words through a channel that is supposed to be ignored, while other work shows that individuals can pick up self-relevant information, for example their own names, from unattended conversations – findings that have since been replicated and expanded upon (Bargh, 1982; Cherry, 1953; Humphreys & Sui, 2016). Neuroimaging techniques such as electroencephalograph (EEG) have also been used to demonstrate that individuals exhibit heightened attention towards self-relevant information at the neural level (Gray et al., 2004; Turk et al., 2011). Increases in amplitude of event related potentials (ERPs) indicative of attention, including the P300, have been reported in response to self-relevant stimuli (e.g., one's own name; Gray et al., 2004). The late positive potential (LPP),

an ERP thought to reflect more effortful, elaborate encoding and sustained engagement with stimuli, has been found to respond more strongly to self-relevant stimuli, suggesting that type of information is also processed more deeply than other types of information (Auerbach et al., 2015). In turn, heightened attention and more elaborate encoding of self-referential information appear to lead to memory benefits for this type of information.

Substantial evidence for the heightened processing of and memory for self-referential information comes from an experimental paradigm called the Self-Referential Encoding Task (SRET), a task that has frequently been used to demonstrate improved memory towards self-relevant stimuli (Symons & Johnson, 1997). In this task, participants are presented with target words and asked to evaluate these words in relation to the self, in relation to others, or regarding a property of the word (e.g., meaning, rhyming with another word, etc.; Symons & Johnson, 1997). Following this encoding phase, participants complete an incidental memory test and are asked to recall the adjectives they had previously seen. Findings from this task demonstrate that individuals remember more words that are encoded in reference to the self, compared to words encoded in reference to other people. Further work has demonstrated that this memory advantage is indeed linked to increased attention towards and more elaborate encoding of self-relevant information (Turk et al., 2013).

Bias in processing towards self-relevant information is thought to be important for competent social functioning. Consistent with this, the SRE has been linked to social cognitive ability at both the behavioural level and the neural level. People who demonstrate typical patterns of self-referential processing correspondingly perform better on tasks measuring social cognitive skills such as Theory of Mind (ToM) and empathic accuracy (Dinulescu et al., 2021).

As well, self-referential processing activates similar brain regions as several other important social cognitive tasks, indicating that it is strongly linked with other important social cognitive domains that guide competent interpersonal functioning in daily life (Mitchell et al., 2005).

To date, self-referential processing is relatively unexamined in the context of ADHD, and preliminary evidence regarding the SRE in ADHD is mixed (Klein et al., 2011). That is, while one experiment found no differences in the SRE between participants with and without ADHD, a second experiment demonstrated reduced memory bias for self-referential information in participants with ADHD relative to controls (Klein et al., 2011). Experimentally, evidence suggests that depleting attentional resources through experimental manipulation reduces prioritization of self-relevant information (Turk et al., 2013). As such, it is plausible that difficulties with attentional control inherent in ADHD will reduce the typical attentional boost given towards this important social information. In addition, emerging research findings point towards executive control as the main attentional system that is relevant to self-referential processing (rather than alerting and orienting; Svensson et al., 2023). Given that this is similarly an important attentional process impacted in the case of ADHD, there is further theoretical basis to hypothesize that self-referential processing may be impacted in ADHD (Mullane et al., 2010). Moreover, the known neural correlates of self-referential processing are also brain areas associated with differences in ADHD. Specifically, self-referential processing has been associated with medial prefrontal cortex (mPFC) function in a number of functional neuroimaging studies (Leshikar & Duarte, 2014; Northoff et al., 2006; Yamawaki et al., 2017). The mPFC plays a central role in important brain networks, including the default mode network (DMN) which is activated during times of introspection and the absence of an externally driven

task (Gusnard et al., 2001; Raichle et al., 2001). Neuroimaging studies show developmental differences in the DMN and mPFC in the context of ADHD relative to typically developing individuals, including disrupted connectivity within the DMN and disrupted connections between the DMN and other neural networks important for executive and attentional control (Sidlauskaite et al., 2016; Sripada et al., 2014; Wilson et al., 2013). Alterations in DMN architecture in ADHD have been demonstrated to underlie other behavioural deficits in ADHD, namely poor decision making (Sonuga-Barke & Fairchild, 2012). Similarly, because DMN structures underlie typical self-referential processing, this may point towards self-referential processing being an important social cognitive skill worthy of further investigation in ADHD. Thus, while the state of self-referential processing in the context of ADHD remains unclear at this time, its high level of dependence on the allocation of attentional resources, its relationship with competent social functioning in everyday life, and its overlap with neural areas implicated in ADHD make it a logical candidate for further investigation.

Here I sought to identify whether prioritization of self-relevant information was a social attentional process with deficits in the context of ADHD. In accordance with the hypothesis that ADHD may alter the detection and utilization of relevant social cues, it was proposed that self-relevance of social information may represent another important social cue that is not attended to preferentially in ADHD, resulting in reduced memory benefits for self-relevant information.

Orienting to Gaze

The visual world contains information far in excess of human processing capabilities. Thus, it is essential that individuals possess a mechanism that allows for some information to be selected for further processing while other interfering stimuli are ignored. Orienting, one

component of attention, is responsible for the alignment of attention with stimuli in the environment to allow for further processing of select information deemed important or relevant to the present situation (Frischen et al., 2007). Environmental cues can elicit orienting of visual attention towards specific locations in space, helping direct individuals towards locations with potentially important information (Frischen et al., 2007; Posner, 1980). The Posner cueing task is a common experimental paradigm used to demonstrate that cues can indeed elicit shifts in attentional orienting towards a specific spatial location (Posner, 1980). In this paradigm, participants fixate at the center of a screen and respond to a target stimulus that appears either to the left or the right of the central fixation point. The presence of a cue (e.g., an arrow, a change in lighting) prior to the onset of the target results in faster responses to targets appearing in previously cued locations, highlighting that attention had been shifted towards the cued location. In the naturalistic world, different types of cues exist in the environment that similarly influence attentional orienting.

The eyes are amongst the most salient social stimuli for humans (Emery, 2000). Because eye gaze conveys important information about one's thoughts and emotions, we are drawn towards the location of another person's eyes (Itier & Batty, 2009). Since the eyes afford important clues about others' attention and intentions, in a social context eye gaze serves as a central cue for attentional orienting. When combined with other information (e.g., emotional facial expressions), gaze direction serves as a particularly powerful clue to infer others' mental states (Lassalle & Itier, 2015). The Posner cueing paradigm described above has been modified to evaluate social attention by substituting averted eye gaze as the critical orienting cue prior to the onset of a target (Frischen et al., 2007; McKay et al., 2021). Studies using gaze cueing tasks

demonstrate that individuals typically spontaneously orient attention in the direction of another's eye gaze, as evidenced by faster reaction times to targets that appear in a location previously cued by eye gaze (Friesen & Kingstone, 1998; Frischen et al., 2007; McKay et al., 2021). Moreover, adding certain emotional expressions (i.e., fear, surprise, happiness, and anger) to the face following the gaze cue further strengthens the gaze cueing effect, likely because of the additional information being conveyed (Lassalle & Itier, 2015; McCrackin & Itier, 2018). In certain clinical populations (e.g., Autism Spectrum Disorder, schizophrenia), deficits in the ability to utilize eye gaze as a cue for attentional orienting has been strongly linked with several of the social deficits present in these disorders, and some evidence suggests that the ability to understand the social meaning of eye gaze direction is predictive of social competence (Frischen et al., 2007; Hayward & Ristic, 2017; Klin et al., 2002).

Despite indications of gaze processing deficits in other clinical disorders with notable social deficits, to date, research evaluating the ability to utilize eye gaze as a cue for attentional orienting in the context of ADHD is characterized by mixed results (Akiyama et al., 2008; Gillespie-Lynch et al., 2013; Kliemann et al., 2010). Some studies have demonstrated deficits in orienting to gaze in ADHD, finding that participants with ADHD do not respond faster to targets cued by eye gaze direction and do not demonstrate interference from invalid gaze cues (Marotta et al., 2014; Marotta et al., 2017). One recent study comparing adults with and without ADHD identified a smaller gaze orienting effect (GOE) in ADHD relative to non-ADHD participants (Uono et al., 2023). Together, these studies indicate that participants with ADHD do not spontaneously orient to gaze cues in a typical fashion, and further, that this deficit is specific to gaze cues, rather than a more global attentional orienting deficit. These findings are further

supported by EEG evidence of abnormal alpha modulations in children with ADHD while performing gaze cueing tasks, and indications of atypical response in the attention-sensitive P200 event-related potential (ERP) in adults with ADHD when viewing pictures of a direct eye gaze, together suggesting atypicalities in gaze orienting at the neural level that in turn predict behavioural level performance on gaze cueing tasks (Guo et al., 2019; Mauriello et al., 2022).

On the other hand, results from other work suggest that individuals with high levels of ADHD traits do spontaneously orient towards gaze cues; in one study, participants high in ADHD symptomology committed errors on a task requiring inhibition of saccadic movements in the direction of the gaze cue, suggesting that gaze did capture attention and interfered with task performance (Lee et al., 2015). In another study, children with ADHD showed atypical EEG activity in early visual processing (i.e., P1 ERP), but not in face specific neural indicators (i.e., N170 ERP) suggesting abnormalities at early visual attention stages, but intact face processing (Tye et al., 2013). Other work investigating gaze orienting in ADHD identifies a more general deficit in orienting to stimuli in participants with ADHD, finding that participants with ADHD perform worse than controls on a cueing task regardless of whether the cue was of a social or non-social nature (Groom et al., 2017). However, this finding is inconsistent with the broader literature that generally does not identify basic attentional orienting to non-social cues as a core attentional deficit in ADHD, instead finding that orienting of attention is a relatively spared attentional process in this population (Mullane et al., 2011). Taken together, the literature thus far is riddled with contradictory findings regarding the state of orienting to eye gaze in ADHD.

As discussed above, evidence suggests that the addition of emotional expression to gaze cues in experimental paradigms strengthens the typical GOE, referred to as emotional

modulation of gaze cueing. This is likely because the addition of emotional expression confers even more information about the mental state of another person, providing even more insight than just the direction of that person's gaze. Emotional modulation of gaze cueing has not been explored extensively in the context of ADHD to date. Of the limited literature that has examined this question thus far, some evidence suggested that adding an angry facial expression to the gaze cue interfered with gaze cueing for adults with ADHD, and inattentional symptoms were correlated with modulated saccadic response to angry gaze cues in non-clinical participants (Manoli, 2019; Motomura et al. 2023). While another study did not detect emotional modulation of gaze cueing in ADHD, they also did not demonstrate this finding in their non-ADHD participants, either, in contrast to the typically robust (though small) effect that emotional gaze cues do facilitate faster reaction time to congruent targets in non-ADHD samples (Uono et al., 2023). While emotional modulation of gaze cueing remains relatively poorly understood in ADHD, a more significant literature has characterized broader emotional processing deficits in ADHD. This body of research consistently reports atypicalities related to the processing of threat-related emotions in ADHD (Uekermann et al., 2010). For example, youth with ADHD perform worse than typically developing peers at identifying threat-related emotional faces (e.g., angry faces), and show differences in ERPs at the neural level during such tasks (Pelc et al., 2006; Williams et al., 2008). Further, greater difficulty in emotional facial recognition in youth with ADHD is associated with self-reported behavioural level interpersonal problems (Pelc et al., 2006).

Overall, orienting to gaze cueing in ADHD, and the emotional modulation of gaze cueing more specifically, require further investigation to determine whether they constitute a core social

attentional impairment in the case of ADHD. In this work, I aimed to address the discrepancy in the literature regarding gaze orienting in ADHD by using a large sample expressing a continuum of ADHD traits to investigate whether ADHD traits modulate orienting towards gaze cues. I also sought to address the relatively novel question of whether emotional expression modulates the GOE in ADHD.

Overlap with ASD

ASD is a neurodevelopmental disorder that is characterized by substantial deficits in social functioning (American Psychiatric Association, 2013). Co-morbidity between ASD and ADHD is common – recent estimates suggest that 42% of children diagnosed with ASD also meet criteria for ADHD (Stevens et al., 2016). While the converse is less common, one large cohort study found that one in eight children with ADHD also meet criteria for an ASD diagnosis, while a meta-analysis reported an even higher level of overlap, with results indicating that 21% of children with ADHD met the threshold for ASD (Hollingdale et al., 2020; Zablotsky et al., 2020). Individuals with ADHD also demonstrate significantly more ASD traits than those without ADHD (Hollingdale et al., 2020). Accordingly, there has been growing recognition that ASD and ADHD share many similar features, including social impairment, along with indications that they also possess shared genetic heritability (Antshel & Russo, 2019; Mikami et al., 2019). Identification of this overlap in presentation across the neurodevelopmental disorders has led to the emergence of the idea of underlying transdiagnostic features that explain both the high rates of co-morbidity and overlap in symptomology between ASD and ADHD (Ameis, 2017). This perspective also aligns well with the RDoC framework, which promotes the method

of looking at domains of function (in this case, social attention), instead of remaining limited within traditional diagnostic categories.

With respect to social functioning in particular, it seems that social cognitive impairment is evident in both ADHD and ASD to some degree, with differences emerging in severity or magnitude of difficulty (Aydin et al., 2023; Baribeau et al., 2015; Demopoulos et al., 2013; Mikami et al., 2019). That is, although social cognitive deficits of a greater magnitude are typically seen in ASD, impairment in social cognition has been conceptualized as a transdiagnostic factor across ADHD and ASD, suggesting that the difference between the disorders is more of quantity rather than quality (Baribeau et al., 2015; Mikami et al., 2019). Neuroimaging evidence further supports this theory by demonstrating that ASD and ADHD share common associations between patterns of activation at the neural level and behavioural performance on social skills tests, suggesting that the underlying biological mechanism behind impaired performance on social skills measures is common across these neurodevelopmental disorders (Baribeau et al., 2019). Accordingly, this dissertation also measured ASD traits dimensionally, in addition to the continuous measurement of ADHD symptoms, in order to investigate whether there was overlap in performance across traits of neurodevelopmental disorders on the social attentional tasks studied here.

Summary of Thesis Objectives

As reviewed above, ADHD is characterized by prevalent and impairing social challenges. However, there is still much we do not know about the integrity of important social cognitive skills in individuals with ADHD, which has limited the ability to develop successful social skills interventions for this population. Specifically, gaps in our understanding remain regarding

whether deficits in core social attentional skills underlie behaviourally-evident social impairment in ADHD, and which social cognitive skills may be at play. This dissertation presents three studies that aimed to address this gap in the literature by exploring specific social cognitive skills in individuals expressing a range of ADHD traits. The extant literature contains mixed findings regarding the integrity of these social attentional skills in ADHD. There are various methodological reasons that may result in these conflicting findings, including small sample sizes in many studies, variability in task designs (e.g., variable stimulus onset asynchronies and use of real versus computer generated face images in gaze orienting studies, reliance on free recall outcome measures in SRET studies), and dichotomizing ADHD into clinical versus control groups. In line with RDoC principles, I chose to measure ADHD traits dimensionally in a sample of undergraduate participants, rather than taking a categorical approach, as the latter ignores the continuous distribution of ADHD symptoms in the general population and may further contribute to a literature that ignores the phenotypic diversity and high levels of comorbidity inherent in ADHD research when it is studied as a categorical phenomenon (Musser & Raiker Jr, 2019). Additionally, each study measured everyday social impairment (e.g., getting into arguments, problems forming and maintaining friendships) using a self-report questionnaire, and examined the relationship between ADHD traits and social problems in everyday life to explore whether the current samples demonstrate the hypothesized relationship between elevated symptoms of ADHD and social impairment.

To begin, in Chapter 2, I focused on self-referential processing, and examined whether ADHD (and ASD) traits measured along a continuum would predict a reduction in the self-reference effect (SRE) on the self-referential encoding task (SRET). I predicted that participants

would demonstrate better memory for words encoded in a self-referential context relative to an other-referential context. However, I hypothesized that this pattern would be moderated by ADHD and ASD traits, such that those with high levels of symptoms would not demonstrate the same memory boost for self-relevant information. This would be among the first evidence to demonstrate that ADHD traits interfere with self-referential processing. As an additional goal, I examined whether the SRET paradigm could translate to online delivery, hypothesizing that the SRE would still emerge with sufficient quality control, given that previous literature has described the SRE as quite robust.

Next, in Chapter 3, I sought to replicate the previous study examining the status of self-referential processing in ADHD, however this time looking at self-referential processing in a more socially evaluative context. Specifically, this study employed a modified version of the SRET whereby trait adjectives were encoded embedded within socially evaluative statements about either the self or an unspecified other person (e.g., McCrackin et al., 2021). I again measured ASD traits alongside ADHD symptoms. I hypothesized that ADHD and ASD traits would interact with self-relevance, such that those reporting lower levels of symptoms would demonstrate better memory for information encoded within self-referential socially evaluative statements relative to other-referential socially evaluative statements, whereas those with high levels of traits would not derive the same memory boost from self-relevance. Once again, as a tertiary goal, this study sought to validate the online adaptation of the SRET.

Finally, in Chapter 4, I shifted the focus to attentional orienting to gaze cueing in an online study investigating orienting to gaze and arrow cues in ADHD. This study used an online adaptation of the classic gaze cueing paradigm. I also investigated emotional modulation of gaze

cueing by comparing the GOE in response to neutral, happy, and angry eye gaze cues. I hypothesized that participants would demonstrate a faster reaction time and greater accuracy in their responses when targets were congruent with the cued location, replicating the classic arrow and gaze cueing pattern in an online environment. I further predicted that this boost in speed and accuracy for valid cues would benefit all participants equally for arrow cues; however, I hypothesized that individuals with high levels of ADHD and ASD traits would not benefit as much from congruent gaze cues, relative to participants with lower levels of symptoms. With respect to modulation by emotional gaze cues, I hypothesized that participants would typically display faster reaction times when a target is preceded by a congruent, emotionally-valenced gaze cue relative to a neutral cue. Based on the literature suggesting deficits in threat-related processing in ADHD, I also explored whether participants reporting high levels of ADHD symptoms displayed the same facilitation in gaze orienting afforded by fearful gaze cues. Finally, this study additionally aimed to test whether the classical gaze cueing task findings would replicate when administered online.

Chapter 2: Is the self-reference effect modulated by ADHD traits?

Attention-deficit/hyperactivity disorder (ADHD) is characterized by developmentally atypical and impairing symptoms of inattention, hyperactivity, and impulsivity (American Psychiatric Association, 2013). Social challenges are commonly experienced by individuals with ADHD: children are rated as less popular by peers, have fewer reciprocated friendships, and are prone to more frequent peer victimization than their typically developing counterparts, while adults report poorer relationship quality, are less likely to marry, and experience higher divorce rates (Bagwell et al., 2001; Barkley et al., 2010; Blachman & Hinshaw, 2002; Hoza, 2007). Although some of the social impairment experienced by individuals with ADHD is directly related to core symptoms of the disorder (Mary et al., 2016), there are several aspects of cognition implicated in the broader clinical phenotype that may further contribute to varied interpersonal outcomes. For example, there is evidence that individuals with ADHD have deficits in theory of mind, empathy, and the ability to recognize and label emotional expressions in others – all of which have implications for social function (Bora & Pantelis, 2016; Uekermann et al., 2010). Importantly, however, other work has found that executive functions mediate the association of ADHD and social difficulties (Tseng & Gau, 2013) and that group differences in social cognition disappear once executive functions and attention are controlled for (Mary et al., 2016). Consequently, further exploration of attentional processes may help elucidate the etiology of social impairment in individuals with this disorder.

Self-Referential Processing

Information relevant to the self is attended to more readily, processed more deeply, and remembered better, an effect known as the self-reference effect (SRE) (Gray et al., 2004; Humphreys & Sui, 2016; Symons & Johnson, 1997). Self-relevance assists our attentional system in selecting information for further processing from the vast amount of input received during social interactions (Golubickis & Macrae, 2021; Humphreys & Sui, 2016). Prioritization of self-relevant information in the attentional system is thus an adaptive process, as it guides us towards information most likely to be significant in a given social situation, and it allows us to rely on our own experiences to organize, interpret, and understand the mental states of others (Mitchell et al., 2005).

The SRE has been studied extensively using the self-referential encoding task (SRET; Symons & Johnson, 1997). In this incidental memory paradigm, participants typically demonstrate superior recall of adjectives they previously evaluated in relation to the self (e.g., 'are you kind?') compared with others (e.g., 'is he kind?') or in relation to the words themselves (e.g., 'does kind rhyme with mind?'). Positive vs. negative adjectives about the self are even more likely to be recalled and thus may be particularly meaningful, although it has been demonstrated that this positivity bias is modulated by mood (Auerbach et al., 2016; Durbin et al., 2017). Nonetheless, the basic SRE is a robust empirical finding linked to increased attention towards and more elaborate encoding of self-relevant information at both behavioural and neural levels (Gray et al., 2004; Hudson et al., 2020; Turk et al., 2013). The SRE is also associated with better performance on social cognitive tasks assessing Theory of Mind (ToM) and empathic accuracy (Dinulescu et al., 2021; Lombardo et al., 2007), suggesting that the processing of self-

relevant information may be important vis-a-vis competent interpersonal functioning in daily life.

Self-Referential Processing and ADHD

Self-referential processing is relatively unexamined in the context of ADHD, but its high level of dependence on the allocation of attentional resources and its relationship with other important social cognitive skills important for competent social functioning in everyday life make it a logical candidate for further investigation (Dinulescu et al., 2021). Experimental work has shown that depleting attentional resources by manipulating demands on attention with difficult tasks during encoding reduces prioritization of self-relevant information (Turk et al., 2013). As such, it is plausible that difficulties with attentional control inherent in ADHD will reduce the typical attentional boost given towards this important social information. At present, I am aware of only one study that examined the SRE in a sample of undergraduate students and it produced mixed findings: SRE profiles were comparable in those with and without ADHD in one experiment, but in another experiment students with ADHD showed a reduced memory bias for self-referential information relative to controls (Klein et al., 2011). Thus, identifying whether self-referential processing serves as a core social deficit in the context of ADHD, and a possible explanatory mechanism behind behavioural social impairment, represents a gap in the literature.

The Present Study

In line with an RDoC-informed approach to conceptualizing psychopathology through a dimensional lens, this study utilized a large sample of undergraduate students expressing varying levels of ADHD traits along a continuum (e.g., Morris et al., 2022). Thus, instead of comparing between two discrete groups (i.e., ADHD vs. no ADHD), we can observe whether self-referential

processing changes dimensionally along with other traits characteristic of ADHD (i.e., inattention, hyperactivity). This is particularly relevant given that aspects of self-referential processing have been proposed as possible transdiagnostic domains of relevance in this framework (Mennin & Fresco, 2013). Given phenotypic overlap with autism spectrum disorder (ASD), common social impairment in ADHD and ASD, and prior work identifying an SRE deficit in young adults with high levels of ASD symptomatology, a secondary goal was to look at the joint influence of ASD and ADHD traits on self-referential processing (Ameis, 2017; Henderson et al., 2009; Mikami et al., 2019). I hypothesized that greater symptom burden for both ADHD and ASD would be associated with more social impairment in daily life.

With respect to performance on the SRET task, I hypothesized that individuals reporting low levels of ADHD and ASD traits would demonstrate the expected SRE, whereby words encoded in a self-referential context are remembered better than words encoded in an other-relevant context. However, I hypothesized that the SRE would be weaker in participants with higher levels of self-reported ASD and ADHD traits, such that they would not demonstrate the typical memory boost for words encoded in a self-referential context because they are not preferentially attending to self-referential information in a typical manner. Thus, I predicted a two-way interaction between word referent and ASD/ADHD traits. I predicted that traits of both ASD and ADHD would similarly influence the SRE, reducing the salience boost typically afforded to self-referential words.

Because the COVID-19 pandemic precluded in-person research at the time of this study, a tertiary goal was to assess whether the typical SRET pattern would emerge when the task was administered online. To my knowledge, only a few studies have adapted this task for online

delivery (e.g., Bentley et al., 2017; Dainer-Best et al., 2018), thus I sought to add to this growing literature. I hypothesized that the strong claims associated with the robustness of the SRE (i.e., better memory performance for words encoded in a self-referential relative to other-referential context) would transfer, so long as stringent quality control of online data was enforced.

Methods

Participants

Three hundred and forty-six (346) undergraduates from the University of Waterloo were recruited via the Department of Psychology participant pool and volunteered in the study for course credit between the fall 2020 term and the summer 2021 term. Data from eighty-one (81) participants were rejected (see Procedure and Data Analysis sections below). The final sample (N = 265; 182 - 69% - females) ranged in age from 17 to 46 (M = 20.22[1], SD = 3.18) and was racially diverse (34% Caucasian, 24% East Asian, 20% South Asian, 6% mixed ethnicity, 16% other, including Black, Indigenous, Arab, and Caribbean). The majority (84%) of participants indicated that they had been exposed to English since birth. Only participants familiar with the character Harry Potter were eligible to participate in the study. Eighteen participants (6%) indicated having received a clinical diagnosis of ADHD.

Materials

Strengths and Weaknesses in ADHD Symptoms and Normal Behaviours (SWAN; Swanson et al., 2001)

[1] Only 3 participants were above 30 years old.

Consistent with a dimensional perspective of ADHD (e.g., Lubke et al., 2009) the SWAN was utilized to measure 9 symptoms of inattention and 9 symptoms of hyperactivity-impulsivity along a continuum. The SWAN has demonstrated high convergent validity with other measures of ADHD, and high sensitivity and specificity for identifying ADHD, as well as high internal consistency and moderate test-retest reliability (Burton et al., 2019; Lakes et al., 2012). For each item, participants rated themselves along a seven-point Likert scale ranging from *far below average (-3)* to *far above average (3)*. Wording was modified to be more appropriate for an undergraduate population (e.g., ability to follow through on instructions & finish schoolwork/chores). Responses were summed to create an ADHD total score ranging from -54 to 54, with higher scores indicating more ADHD symptomatology.

Autism Quotient (AQ; Baron-Cohen et al., 2001)

The AQ is a 50-item self-report questionnaire assessing ASD characteristics and traits across several domains, including attention to detail, attention switching, social skills, imagination, and communication. Previous work assessing the psychometric properties of the AQ yielded high internal consistency and test-retest reliability, and specifically found this to be a suitable tool for assessment of ASD traits in neurotypical college samples (Stevenson & Hart, 2017). Participants were asked to rate how well each statement applies to them on a 4-point Likert scale ranging from *definitely disagree* (1) to *definitely agree* (4). After reversing appropriate items, responses were summed to create a total score out of 200 such that higher scores denote more ASD symptomatology.

Weiss Functional Impairment Rating Scale – Self Report, Social Subscale (WFIRS-S; Weiss et al., 2018)

This 9-item self-report questionnaire asks participants to rate how often they have encountered a variety of interpersonal problems (e.g., getting into arguments, problems maintaining friendships, etc.) over the previous month on a 4-point Likert scale ranging from *never or not at all* (0) to *very often or very much* (3). Responses were summed to create a total score out of 27 such that higher scores reflect greater social impairment.

Center for Epidemiological Studies Depression Scale – Revised (CESD-R; Eaton et al., 2004)

Because depression has been shown to modulate SRET performance (e.g., Auerbach et al., 2016), this 20-item self-report questionnaire was used to assess participants' experience of low mood – as reflected in feelings of sadness, anhedonia, and guilt – over the past two weeks. Participants responded on a 4-point Likert scale ranging from "*Not at all or less than one day*" (0) to "*Nearly every day for 2 weeks*" (3) and items were summed to create a total score out of 60. Scores above 16 represent moderate to severe depressive symptomology (Eaton et al., 2004). This measure of depression was initially included in this work in order to screen for participants meeting criteria for current depression and subsequently exclude their data from analyses, in line with similar work in the SRET literature (e.g., Hudson et al., 2020). However, the unanticipated high levels of depression reported by the current sample (discussed in more detail below) precluded this application of the depression data because of the large number of participants falling above the clinical cutoff score. As a result, descriptive statistics of CESD data are reported below to describe levels of low mood in the current sample. As well, supplemental analyses with a subset of the sample falling below the clinical cut-off were conducted to ensure similar patterns of results in this non-depressed subgroup (see Appendix 1). However, CESD data were not included as a predictor in SRET regression models for parsimony in statistical

models and because the relationship between depression and SRET has been examined thoroughly elsewhere and was outside the scope of the current study aims.

With respect to this scale, previous work investigating the CESD has identified excellent validity and reliability in very large community samples as well as samples of college students, indicating that it is an accurate and appropriate measure of depression in the general population (Van Dam & Earleywine, 2011).

Self-Referential Encoding Task

The online SRET consisted of two phases. In the endorsement phase, participants were presented with a set of target words on a screen and for each one, were instructed to make either a self-referential judgment (i.e., does this adjective describe you?) or an other-referential judgment (i.e., does this adjective describe Harry Potter?). Endorsement scores were calculated as the number of 'Yes' responses by referent (self vs. other) and valence (positive vs. negative). In the next phase, participants completed two surprise memory tasks. First, they were asked to enter any adjectives they could recall from the endorsement phase (free recall task). Recall data were visually inspected to correct for clear typographical and spelling errors, and the number of words correctly recalled was summed. Next, participants were asked to identify whether or not a word had appeared in the endorsement phase (recognition task). Recognition scores were calculated in two ways. Firstly, I calculated the number of hits on recognition trials (i.e., the number of adjectives that had previously been presented that were correctly identified as 'old'). As well, memory sensitivity (*d'*) was calculated to account for false alarms. This metric was computed using the R package 'psycho' (version 0.6.1) and reflects the standardized hit rate

minus the standardized false alarm rate, with adjustment for extreme values made following the recommendations of Hautus (1995).

The SRET was designed using PsychoPy (version 2020.1.2) and administered online via Pavlovia. Trait adjectives were presented in lower case Arial font. Three lists of word consisting of 24 words each (12 positive, 12 negative) were selected from a previous study (Hudson et al., 2020). Selected words were trait adjectives 3 to 8 characters long, categorized as either positive or negative based on valence ratings from Warriner et al (2013) that ranged from 1 (highly negative) to 9 (highly positive). I defined positive trait adjectives as having a mean affective valence score of 7 or higher, and negative trait adjectives as having a mean score of 3 or lower. Descriptive statistics for each word list are reported in Table 1. The three word lists were statistically equivalent in terms of valence for both positive, $F(2,33) = 1.79$, $p = .182$, and negative, $F(2,33) = 2.69$, $p = .083$, trait adjectives, as well as for arousal, $F(2,69) = 2.03$, $p = .139$, dominance, $F(2,69) = 0.15$, $p = .862$, average word length, $F(2,69) = 1.98$, $p = .146$, and word frequency, $F(2,69) = 2.41$, $p = .097$, which was calculated based on logarithmic values of current word frequency norms published by Brysbaert & New (2009). Within each list, positive and negative adjectives were not statistically different in length, arousal, or word frequency (ps > .05), although positive words were rated higher in dominance (ps < .001). Two lists of words were used to generate adjectives in SRET experimental trials, while the third list provided the distractors in the recognition task following the SRET.

Table 1

Descriptive Statistics for Each Word List.

	Length		Valence		Arousal		Dominance		Frequency	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
List 1										
Positive	6.35	1.41	7.54	0.41	5.03	0.95	6.90	0.37	2.44	0.59
Negative	6.67	1.44	2.67	0.22	4.69	0.72	4.04	0.87	2.15	0.37
List 2										
Positive	6.00	1.12	7.41	0.38	4.22	1.15	6.71	0.39	2.51	0.50
Negative	6.40	1.17	2.60	0.34	5.33	0.76	4.09	0.44	2.56	0.79
List 3										
Positive	6.70	1.05	7.25	0.25	4.41	0.34	6.88	0.50	2.95	0.75
Negative	6.21	1.76	2.59	0.30	4.35	0.67	4.04	0.62	2.43	0.59

Note. Length is reported in number of letters. Valence, arousal, and dominance reflect the normative ratings taken from Warriner et al. (2013). Word frequency represents $\log_{10}$ values from Brysbaert & New (2009).

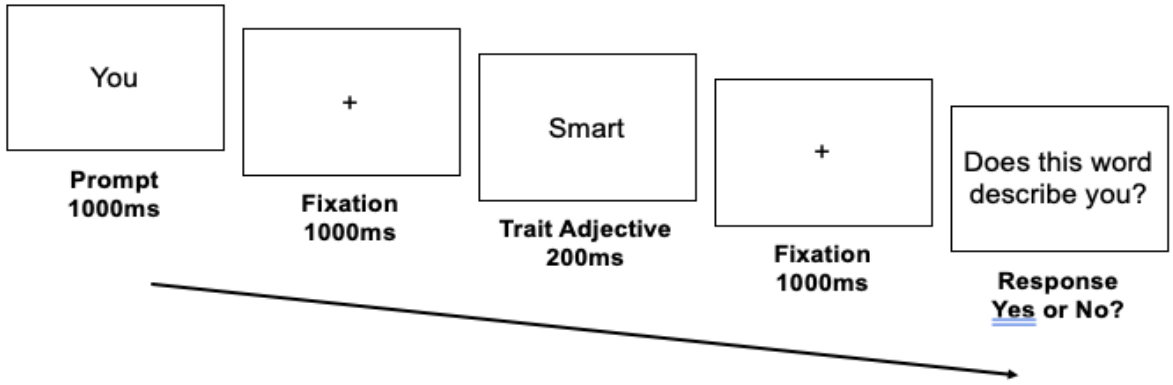
Procedure

Participants were informed that the purpose of the study was to assess how individual differences impacted adjective endorsement and were not initially informed of the memory component. Participants completed self-report questionnaires online administered via Qualtrics

in the following order: SWAN, AQ, CESD, WFIRS-S, and were then provided with instructions for the SRET. Following a practice round to ensure they understood task instructions, participants completed two blocks of 24 trials of the endorsement task with a mixed design such that each block included an even number of self-referential and other-referential trials and an equal number of positively-valenced and negatively-valenced trait adjectives mixed in a random fashion. In each trial, participants were presented with a prompt informing them whether this trial would ask them to make a self or other related judgment (1000ms), followed by a fixation cross for 1000ms (see Figure 1). The target adjective was then presented on screen for 200ms, followed by another 1000ms fixation cross and finally the judgment question, to which the participant was asked to make a response (yes or no) with a keypress. The judgment question remained on the screen until participants made a response. Participants then completed a brief distractor task (counting backwards from 50), and then entered the surprise memory phase of the task. They began with the free recall task, typing in any target adjectives they remembered from the encoding phase. Then, in the recognition task, they were presented with 72 trait adjectives, including the 48 target words from the encoding blocks and 24 matched distractor items, and asked to indicate whether or not each adjective appeared in the encoding phase. After completing the entire SRET, participants were debriefed, provided written consent again due to the deceptive nature of the surprise memory component (23 participants did not re-consent after being debriefed on the deception, and therefore their data were excluded from analysis), and were remunerated.

Figure 1

Example of Self-Referential Encoding Task (SRET) Trial.



Data Analysis

Stringent quality control procedures were utilized to optimize data quality. To check that sufficient attention was devoted to both the computerized task and self-report questionnaires, participants who completed the study in less than 20 minutes were excluded from the study (N = 24). This time cut-off was selected because the computerized task required 15 minutes to complete, and it was deemed unlikely that participants could complete both this task and several self-report questionnaires in an attentive manner in fewer than twenty minutes. To minimize the impact of missing data on parameter estimates, participants missing more than 20% of data on any scale were dropped from analysis (N = 22). To check for response bias or lack of variability in responding, standard deviations on questionnaires were calculated and participants with a standard deviation of zero on more than one questionnaire were removed from analyses (N = 6). Finally, anticipatory errors on the SRET were defined as trials with a reaction time of less than 150ms. Participants with an elevated number of anticipatory errors (i.e., more than 3 standard deviations above the mean number of anticipatory errors) on the task were excluded (N = 6). For

all other participants, individual trials with response times less than 150ms were excluded (on average 1.58 trials per participant).

To investigate the relationship between neurodevelopmental traits and social impairment within our sample, bivariate Pearson correlations between ADHD traits and social impairment on the WFIRS-S, and ASD traits and social impairment were calculated. Next, a series of 2 x 2 repeated-measures ANOVAs with referent (self, other) and valence (positive, negative) as within subject factors were conducted on endorsement, free recall, recognition, and memory sensitivity data. Finally, repeated measures multiple regression was used to test the effects of ADHD and ASD symptoms, word valence and word referent on performance on the SRET task. In the first regression model, ADHD symptoms, word referent, and word valence served as predictors. A second multiple regression model was run with ASD symptoms as an additional predictor, in addition to those used in the previous model (i.e., ADHD traits, word referent, word valence). ADHD and ASD symptoms were entered together into the model to investigate the unique contribution of ADHD on the SRET outcome variable when removing the variance of ASD traits, in line with the aims of this work (whereas the relationship between ASD traits alone and the SRE is beyond the scope of the present work). Recognition sensitivity served as the outcome variable in both regression models because it accounts for false alarms and correct rejections of distractor words (relative to just evaluating how many trait adjectives from encoding were later correctly recognized). The regression models were run in a hierarchical fashion: in the first step of each regression model, main effects of word referent, word valence, and symptom variables were entered, and 2-way interaction terms were then entered in the second step based on *a priori*

hypotheses (i.e., interaction terms between symptom variables and referent). Variables were mean-centered prior to computing interaction terms.

Results

All data were normally distributed, with skew less than 3 and kurtosis less than 10. One univariate outlier was detected on the AQ, 2 univariate outliers were detected on the WFIRS-S, and 16 outliers were detected on SRET data (1 on recall, 11 on recognition hit rate, 4 on recognition sensitivity); data were winsorized to eliminate these univariate outliers, operationalized as 3 standard deviations above or below the sample mean. No multivariate outliers were identified. Descriptive statistics are presented in Table 2.

Table 2

Descriptive Statistics on Self-Report Questionnaires.

	M	*SD*	Max	Min	Cronbach's *a*
SWAN	-12.17	15.05	25	-50	.90
AQ	113.86	13.44	155.07	77	.80
WFIRS-S	6.30	5.23	22.07	0	.86
CESD	22.75	12.88	56	1	.82

Table 3

Bivariate Correlation Matrix Between Self-Report Questionnaires.

	AQ	WFIRS-S	CESD
SWAN	.07	.16*	.23**
AQ	-	.31**	.33**
WFIRS-S	-	-	.68**

Note. *$p < .05$ ** $p < .001$

Association Between Neurodevelopmental Traits and Social Impairment

Bivariate correlations were significant and positive between ADHD traits and social impairment, $r(263) = .16$, $p = .011$, and ASD traits and social impairment, $r(263) = .31$, $p < .001$, indicating that higher levels of self-reported neurodevelopmental traits were associated with greater self-reported social problems in daily life (Table 3).

Online Replicability of the SRET

Table 4 displays the means and standard deviations for the four conditions across each variable analyzed while Figure 2 shows the distribution of scores for each variable.

Adjective Endorsement

There were significant main effects of valence, $F(1,264) = 893.46$, $MSE = 8.50$, $p < .001$, $\eta^2_p = 0.77$, and referent, $F(1,264) = 5.78$, $MSE = 2.59$, $p = .017$, $\eta^2_p = 0.02$, indicating that participants endorsed more positively- than negatively-valenced words and more other-referential words than self-referential words. This was qualified by a significant referent by valence interaction, $F(1,264) = 6.65$, $MSE = 6.62$, $p = .010$, $\eta^2_p = 0.03$. Post-hoc tests revealed that positively-valenced adjectives were endorsed at a higher rate than negatively-valenced adjectives in both self-referential ($p < .001$) and other-referential ($p < .001$) contexts, though participants were more likely to endorse positively-valenced adjectives in reference to Harry Potter relative to the self ($p = .001$).

Free Recall

With the caveat that free recall scores were very low overall (less than 3 words on average, out of the possible 12 in each condition, see Table 4 and Figure 2), there were

significant main effects of referent, $F(1,264) = 88.33$, $MSE = 1.54$, $p < .001$, $\eta^2_p = 0.25$, and valence, $F(1,264) = 5.01$, $MSE = 1.21$, $p = .026$, $\eta^2_p = 0.02$. As hypothesized, participants recalled more adjectives in reference to the self than other and more adjectives that were positively- vs. negatively-valenced. The referent by valence interaction was not significant, $F(1,264) = 3.75$, $MSE = 1.61$, $p = .054$, $\eta^2_p = 0.01$.

Recognition Hit Rate

There were significant main effects of referent, $F(1,264) = 4.70$, $MSE = 2.22$, $p = .031$, $\eta^2_p = 0.02$, and valence, $F(1,264) = 4.35$, $MSE = 2.30$, $p = .038$, $\eta^2_p = 0.02$ that were qualified by a significant interaction, $F(1,264) = 11.83$, $MSE = 1.87$, $p < .001$, $\eta^2_p = 0.04$. As predicted, words encoded in a self-referential context were more likely to be recognized if they were positively- rather than negatively-valenced ($p < .001$), whereas words encoded in an other-referential context were recognized equally well irrespective of valence ($p = .460$). As well, positively-valenced words were equally likely to be recognized regardless of whether they were encoded in a self- or other-referential context ($p = .428$), whereas negatively-valenced words were more likely to be recognized when encoded in an other-referential context rather than a self-referential context ($p < .001$).

Recognition Memory Sensitivity (d')

There were significant main effects of referent, $F(1,264) = 5.70$, $MSE = 0.16$, $p = .018$, $\eta^2_p = 0.02$, and valence, $F(1,264) = 81.44$, $MSE = 0.44$, $p < .001$, $\eta^2_p = 0.24$, with better memory sensitivity for other-referential words and negatively-valenced words. This was qualified by a significant interaction, $F(1,264) = 13.77$, $MSE = 0.14$, $p < .001$, $\eta^2_p = 0.05$. Contrary to expectation, post-hoc tests showed that positively-valenced words were recognized equally well

whether they were encoded in a self-referential or other-referential context (p = .393), while negatively-valenced words were recognized better when encoded in an other- vs. self-referential context (p = .001). As well, negatively-valenced words were recognized better than positively-valenced words for words encoded in both self-referential (p = .001) and other-referential (p = .001) contexts.

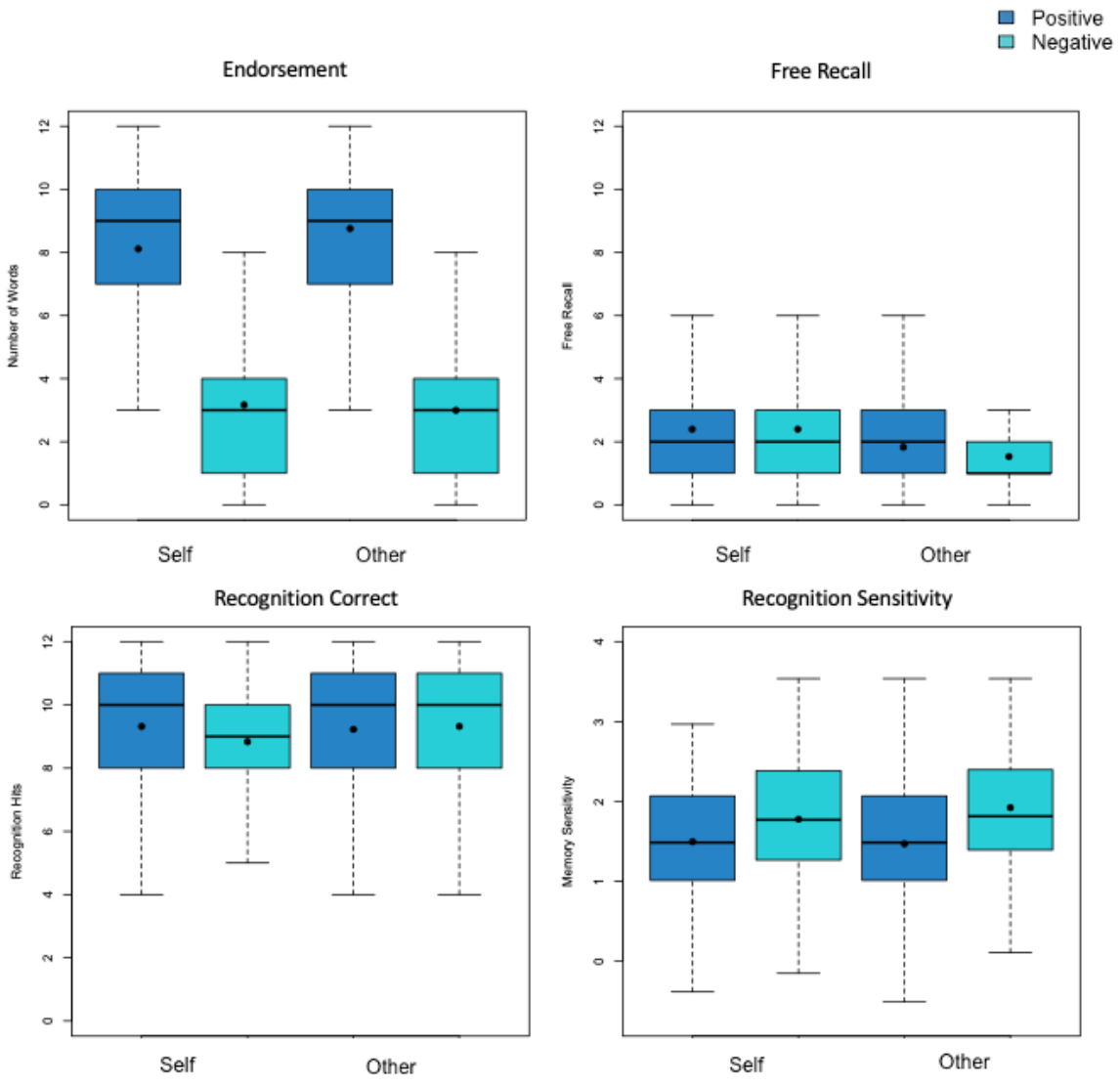
Table 4

Means and Standard Deviations for each SRET Condition.

		Self		Other	
		M	*SD*	*M*	*SD*
Endorsement	Positive	8.11	2.78	8.76	2.21
	Negative	3.17	2.57	3.00	2.18
Recall	Positive	2.40	1.48	1.83	1.32
	Negative	2.40	1.38	1.53	1.20
Recognition - Hits	Positive	9.32	1.96	9.23	2.01
	Negative	8.83	2.11	9.32	2.03
Recognition - Sensitivity	Positive	1.49	0.75	1.47	0.77
	Negative	1.78	0.75	1.92	0.78

Figure 2

Results for Mean Endorsement, Free Recall, Recognition, and d' Score.



Note. Dark blue represents positively-valenced words while light blue represents negatively-valenced words. The total possible number of words in each endorsement, recall, and recognition condition is 12. d' of 0 indicates chance level. The black line in each box represents the median, black dots represent the mean, and the tops and bottoms of each box represent the interquartile range between the 25th and 75th percentile.

SRE and ADHD Traits

A hierarchical regression model evaluating the effect of referent, valence, and ADHD symptoms on memory sensitivity produced a statistically significant model, $F(3, 1056) = 21.79$, $R^2 = 0.06$, $p < .001$. Neither referent ($B = -0.06$, $SE = 0.05$, $p = .209$) nor ADHD symptoms ($B = 0.002$, $SE = 0.002$, $p = .134$) were significant predictors of memory sensitivity. Valence did significantly predict memory sensitivity ($B = -0.37$, $SE = 0.05$, $p < .001$), with negatively-valenced words recognized better than positively-valenced words. To investigate the hypothesis that ADHD traits would interact with word referent, this interaction term was entered in the second step of the model. The addition of this interaction term did not explain significantly more variance in recognition sensitivity ($\Delta F(1, 1055) = 0.35$, $p = .555$), and the interaction term was not significant ($B = -0.002$, $SE = 0.003$, $p = .555$), so this interaction was not probed further.

SRE and ADHD with ASD Traits

Next, we evaluated the impact of both ADHD and ASD traits on memory sensitivity. The overall model was significant, $F(4, 1055) = 16.38$, $R^2 = 0.05$, $p < .001$. Again, ADHD symptoms ($B = 0.002$, $SE = 0.002$, $p = .127$) and referent ($B = -0.06$, $SE = 0.05$, $p = .209$) did not significantly predict memory sensitivity. ASD traits were also not a significant predictor of memory sensitivity, $B = -0.001$, $SE = 0.002$, $p = .659$. Negative valence again predicted superior memory sensitivity, $B = -0.37$, $SE = 0.05$, $p < .001$. In the second step of the model, interaction terms were entered to test a priori hypotheses regarding the interactions between ADHD symptoms and word referent and ASD symptoms and word referent. The addition of these interaction terms to the model did not explain significantly more variance in our outcome measure ($\Delta F(2, 1053) = 0.30$, $p = .739$). The interaction between ADHD symptoms and word

referent (B = -0.002, SE = 0.003, p = .580) and ASD symptoms and word referent (B = -0.002, SE = 0.003, p = .611) were both non-significant, and the main effect of word valence remained the only statistically significant predictor of memory sensitivity, B = -0.37, SE = 0.05, p < .001.

Discussion

Although social impairment is prevalent in ADHD, the potential contribution of attentional processes to social function is understudied and thus poorly understood. Self-referential processing was examined in this study because it is rooted in attention and is supported by neural underpinnings that are known to be atypical in individuals with ADHD (Humphreys & Sui, 2016; Sonuga-Barke et al., 2016). I administered an online version of the SRET to a large undergraduate sample to test whether self-referential processing varies along a continuum of ADHD and ASD symptoms. Although the former was the primary focus of investigation, I included the latter in accordance with the transdiagnostic approach to understanding neurodevelopmental disorders which recognizes a degree of phenotypic overlap across distinct diagnostic categories (Mikami et al., 2019) and because some studies have reported atypical SRET results in autistic groups (Henderson et al., 2009). As well, I elected to measure traits of both ADHD and ASD along a continuum in a non-clinical sample (rather than comparing a clinical sample to a comparison group) in accordance with the RDoC approach to studying psychopathology, which posits that dimensional measurement better captures the distribution of ADHD traits in the broader population, and reduces problems inherent in categorical measurement of mental health phenomena, such as high incidences of co-morbidity and within-diagnosis phenotypic diversity which are inherent in categorical measurement of mental health phenomena (Cuthbert & Insel, 2013; Insel, 2014).

Consistent with hypotheses, ADHD and ASD symptomology was correlated with social impairment in everyday life. However, contrary to hypotheses, there were no significant main effects or interactions involving ADHD or ASD on SRET performance. The one extant study of self-referential processing in ADHD yielded mixed findings (Klein et al., 2011) and recent studies in the ASD literature have also failed to identify a deficit in self-referential processing (Lind et al., 2020; Williams et al., 2018). Whilst it may be the case that traits of neurodevelopmental disorders have little to no bearing on the prioritization of self-relevant information, interpretation of my null findings is complicated by inconsistent evidence of the SRE in this sample.

The SRET paradigm is well-established, having been used in social cognitive research for over 40 years (Symons & Johnson, 1997). A consistent finding is that information encoded in a self-referential context is processed more deeply and remembered better than information encoded in reference to someone else. This study, undertaken with a large sample, yielded mixed results regarding the SRE: it was evident in free recall and recognition hit rate, but not in recognition sensitivity (which showed the opposite pattern). Emotional valence of trait adjectives emerged as the most salient predictor of memory performance, with negatively-valenced words most likely to be remembered – especially when encoded in reference to others. This finding contrasts with the typical SRET pattern in two ways: firstly, referent at encoding is typically the strongest predictor of later memory, and secondly, SRET findings typically reveal a positivity bias (Symons & Johnson, 1997; Moses-Payne et al., 2022).

Due to these inconsistent and unexpected findings in the context of adequate statistical power from this large sample and careful quality control of the data, I evaluated the existing

SRET literature to try and identify possible sources of differing patterns of results. Consistently, other work has begun to highlight that little research has been conducted to evaluate the psychometric properties of the SRET, highlighting that there is great variety in the types of outcome variables (e.g., free recall vs. hits on a recognition task vs. *d*') from the SRET evaluated across studies, as well as many parameters within the task design that impact individual study results, despite the fact that they are investigating the same theoretical construct (Dainer-Best et al., 2018; Klein, 2012). For example, in a large meta-analysis of the SRE by Symons and Johnson (1997), the majority of studies reviewed employed only free recall memory tests, which can produce floor effects (e.g., Hudson et al., 2020). While other studies utilize recognition tests, they typically evaluate only hit rates and therefore do not take errors into account (e.g., Auerbach et al., 2016). In my work, while I did find evidence for the SRE in free recall and recognition hit rate data, this effect disappeared when I accounted for errors by looking at recognition memory sensitivity. Other subtle methodological factors that can modulate the SRE include the use of blocked versus mixed design for the referent, whether a distractor task is used, and the degree of familiarity with the other referent used in the task (Hudson et al., 2020; Klein, 2012; Symons & Johnson, 1997). Overall, Klein (2012) and others suggest that we may need to exercise some caution when making inferences about the construct of self-referential processing from an experimental paradigm that produces variable results when small study details are changed. This study, which employed a traditional SRET paradigm adapted to an online context, introduced another variable that may additionally highlight the susceptibility of SRET results to highly specific methodological parameters.

Thus far, only a handful of studies have evaluated whether the SRET translates to an online environment (Bentley et al., 2017; Dainer-Best et al., 2018). One study (Dainer-Best et al., 2018) focused more specifically on SRET endorsement data rather than memory outcomes, precluding comparison regarding whether the SRE emerged. However, trends on endorsement data are similar to those presented here (i.e., endorsement of significantly more positively-valenced adjectives relative to negative adjectives). The other study that has adapted the SRET for use online (Bentley et al., 2017) does replicate the SRE (as well as the traditional positivity-bias on the SRET) in an online environment. Of note, their paradigm did not compare self- to other-referential encoding, instead comparing self-referential encoding to semantic and structural encoding and utilized free recall as their primary outcome measure – further indicating that the SRET may be quite sensitive to specific parameters of the experimental paradigm, which can influence whether the SRE emerges.

To probe findings regarding the importance of negative emotional valence of trait adjectives for later memory, I considered the sample used for this study and the timeframe during which the data were collected. Specifically, data were collected from the fall of 2020 until the fall of 2021 in Ontario; during this time, strict COVID-19 infection control measures were in place that significantly impacted college students, including severely limiting in-person academic and social activities. Emerging evidence suggests that these measures may have particularly impacted mood in Canadian university students, and, consistent with this, the present sample demonstrated high levels of depression symptoms on mood screening questionnaires (King et al., 2022). A significant literature has demonstrated that depression impacts the pattern of performance seen on the SRET, such that the typical positivity bias disappears and

participants with depression instead show a preference for negative self-referential information (Auerbach et al., 2016; Benau et al., 2019; Dainer-Best et al., 2017; Shestyuk & Deldin, 2010). Thus, to probe whether high levels of depression symptoms in this sample amplified the importance of negative valence, I conducted additional exploratory analyses with data from participants scoring below the clinical cut-off for depression on the CESD (see Appendix A). Results from this subgroup were consistent with findings from the whole sample, again revealing a strong effect of negative valence of trait adjectives on later memory, and, importantly, the SRE remained absent in regression analyses with memory sensitivity as the outcome measure, indicating that the importance of negative valence for later memory is not being driven solely by a highly depressed sample. Instead, it seems that affective information rather than self-referential information is serving as the strongest cue for deeper processing in this sample. This finding may be in line with findings from the memory literature indicating a memory boost for affectively arousing, negative information (Nadarevic, 2017; Talmi & McGarry, 2012). Research has also described that there might be shared mechanisms between using emotional valence and self-reference as salient cues for processing, and both are often deeply intertwined in our everyday world and work together to drive our attentional resources towards information of social relevance, seemingly indicating that both emotional valence and self-relevance ought to be considered in tandem when conceptualizing SRET results (Gutchess & Kensinger, 2018).

While the present study afforded the opportunity to assess the SRE online and offered an interesting opportunity to explore a traditionally laboratory-based paradigm in a relatively novel context, it also limited control over the environment of participants during testing. Stringent quality control procedures and significant visual inspection of data were utilized to try to

minimize the impact of poor quality data. Overall, regression models can only explain about 5% of variance in recognition sensitivity metrics on our SRET task, indicating that it is possible that there may be extra noise introduced by variables such as the lack of control over the testing environment. Other limitations include the self-report nature of symptom questionnaires. Symptoms of neurodevelopmental disorders and depression were all assessed using self-report questionnaires. While these questionnaires offer information about trait levels of symptoms along a continuum, research does suggest that self-reporting on ADHD symptoms produces higher rates of individuals who fall into a clinical range relative to individuals who have a clinical diagnosis of the disorder from a medical professional (Garnier-Dykstra et al., 2010). Self-report data is further vulnerable to bias in response style and requires a high level of self-reflection and insight into one's own day to day functioning.

In sum, the present study fails to detect a relationship between self-referential processing and ADHD (or ASD) traits. At the same time, this work highlights vulnerability of the SRET to slight methodological variations and casts doubt on its ability to capture the self-reference effect in an online environment. As such, further investigation is needed with other tasks to more definitively determine whether attentional processes contribute to the social challenges that many individuals with ADHD experience. At the same time, this line of inquiry will move forward in potentially illuminating ways by widening its focus to other putative underlying mechanisms – such as other social cognitive skills. Doing so will equip our field with a better understanding of the causes of social deficits in ADHD and ideally lead to more targeted interventions to ameliorate these challenges.

Chapter 3: Self-referential processing is not modulated by dimensional symptoms of ADHD

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder affecting 8 percent of youth globally (Ayano et al., 2023), with most continuing to experience impairing symptoms into adulthood (Faraone et al., 2006). In addition to the core diagnostic symptoms of inattention and hyperactive-impulsive behaviours, impaired interpersonal functioning is commonly experienced by individuals with the disorder (American Psychiatric Association, 2013; Ros & Graziano, 2018). Young adults with ADHD identify difficulties in building and maintaining interpersonal relationships as one of the main difficulties they experience (Kwon et al., 2018; Sacchetti & Lefler, 2017), which has a direct negative impact on their quality of life (Wehmeier et al., 2010). Despite the high prevalence of and considerable costs associated with social impairment in ADHD, social function has proven resistant to extant interventions (Morris et al., 2021; Willis et al., 2019). The identification of mechanisms that give rise to and/or perpetuate impaired social function in individuals with ADHD may facilitate the development of more effective treatments (Storebø et al., 2019).

Although social function has been conceptualized as a multifaceted construct, an important component is being able to effectively engage in interactions with others (e.g., Junge et al., 2020). Social interactions are inherently complex, characterized by many processes that place formidable demands on attention, such as detection of verbal and nonverbal cues and filtering of irrelevant information (Capozzi & Ristic, 2018). Information that is relevant to the self is attended to more readily, processed more deeply, and remembered better than information about others, termed the self-reference effect (SRE; Gray et al., 2004; Humphreys & Sui, 2016; Symons & Johnson, 1997). The prioritization of self-relevant information in attention is adaptive

because it allows us to rely on our own experiences to organize, interpret, and understand the mental states of others (Humphreys & Sui, 2016; Mitchell et al., 2005). Indeed, bias towards self-referential information is positively associated with empathy and theory of mind (Dinulescu et al., 2021), suggesting that it is important for competent interpersonal functioning in daily life.

Self-referential processing may be relevant to understanding social impairment in ADHD. Experimental work has shown that the prioritization of self-relevant information can be reduced in typical young adults by depleting their attentional resources (Turk et al., 2013), which raises the possibility that the SRE may be attenuated in clinical groups in whom attention is compromised (e.g., ADHD). At a neural level, self-referential processing is supported by brain regions that have also been implicated in ADHD – such as the medial prefrontal cortex and other midline structures that form the default mode network (Leshikar & Duarte, 2014; Wilson et al., 2013). Disruptions to the default mode network have been implicated in other behavioural impairments in ADHD (e.g., poor decision making; Sonuga-Barke & Fairchild, 2012); it is therefore plausible that they may similarly interfere with typical self-referential processing. To date, only one study has directly examined self-referential processing in young adults with the disorder and results were mixed (Klein et al., 2011). In one experiment, SRE profiles were statistically comparable in the ADHD and control groups; however, in a second experiment, the ADHD group had a reduced SRE compared with the control group. Although the authors offer an interpretation of their findings based on methodological differences between the experiments (a point I return to in the discussion), they also caution that replication is needed given their small sample size.

The Research Domain Criteria (RDoC), developed by the National Institute of Mental Health as a nosological alternative to the categorical classification of psychopathology used in the DSM, posits that adopting a dimensional approach to mental health disorders better captures the range and diversity of presentations of these disorders (Insel, 2014). That is, compared to a traditional categorical approach that relies on surpassing a threshold of a wide assortment of symptoms to meet criteria for a diagnosis, the RDoC approach aims to guide research into the neural and biological underpinnings of psychopathology by identifying domains of functioning that cut across diagnostic categories (Cuthbert, 2022; Insel, 2014; Pacheco et al., 2022). Ultimately, this approach aims to reduce problems of comorbidity, within-diagnosis heterogeneity, and ignorance of underlying causes of psychopathology (Insel, 2014; Pacheco et al., 2022). Here, I assessed self-referential processing in a large sample of undergraduate students expressing a range of ADHD symptomology, in accordance with a dimensional, RDoC informed approach. Specifically, I evaluated how functioning in a certain domain (i.e., self-referential processing) varied along a continuum of ADHD traits. Further in line with the RDoC framework, along with the transdiagnostic view that acknowledges phenotypic similarity between ADHD and ASD (Mikami et al., 2019), symptoms of ASD were additionally measured here in a dimensional manner. I hypothesized that self-reported symptomology of neurodevelopmental disorders would positively correlate with reports of social problems experienced in daily life (e.g., difficulties forming and maintaining interpersonal relationships, as measured by a self-report questionnaire described below).

I used a modified version of the self-referential encoding task (SRET; Symons & Johnson, 1997), in which participants rated their feelings in response to socially evaluative

statements about either themselves or another unnamed person and then completed an incidental memory test for adjectives that had been embedded within the statements. This modification heightens the social component of the traditional SRET by increasing its social relevance and introducing potential social threat. This is done by creating an encoding scenario where the participant must read an evaluative statement from an (unknown) other person about themselves. That is, rather than simply judging whether an adjective describes themselves, in this study, trait adjectives are embedded within evaluative statements about themselves. This heightens the threat involved in the situation because it involves reading a direct judgment from another person, instead of simply self-reflecting about personal relevance of adjectives. This modified SRET paradigm has been used to replicate the SRE in research with young adults, and may be particularly relevant when evaluating self-referential processing in ADHD given that threat-related emotion processing appears to be of particular relevance in ADHD (McCrackin & Itier, 2018; McCrackin et al., 2021; Williams et al., 2008).

Because the SRE is well-established, I hypothesized that participants in this study would demonstrate better memory for adjectives that were evaluated in relation to the self compared with an other. Additionally, given work identifying a positive bias in the SRE (e.g., Auerbach et al., 2016), I also hypothesized that memory would be further enhanced for trait adjectives about the self that were positive rather than negative in affective valence. Lastly, I hypothesized that participants with high levels of ADHD and ASD traits would not prioritize self-relevant information to the same extent as their peers with low levels of these traits, resulting in an interaction between referent (self vs. other) and traits of both disorders. Given the modification

to the SRET protocol to enhance social relevance, it was further hypothesized that these effects may be enhanced relative to the traditional SRET.

Methods

Participants

Three hundred and forty-one (341) undergraduate students (who did not take part in Study 1) from the University of Waterloo were recruited via the Department of Psychology participant pool and volunteered in the study for course credit. Data were collected in the fall 2021 and winter 2022 terms. Thirteen participants withdrew consent after the deceptive nature of the task was revealed and an additional 26 were excluded from analyses due to poor quality data (see below). The final sample (N = 302) ranged in age from 17 to 52 (M = 20.42, SD = 4.70) and consisted of mostly female participants (71%). The sample was racially diverse: 45% of participants identified as Caucasian, 20% identified as South Asian, 15% identified as East Asian, with the remaining 20% identifying other ethnicities, such as Black, Indigenous, Arab, Caribbean, and mixed ethnic background. A majority (86%) of participants indicated that they had been exposed to English since birth. Seventeen participants reported a clinical diagnosis of ADHD.

Materials

Strengths and Weaknesses in ADHD Symptoms and Normal Behaviours (SWAN; Swanson et al., 2001)

Consistent with a dimensional understanding of ADHD (e.g., Lubke et al., 2009), the SWAN was used to measure symptoms of inattention and hyperactivity-impulsivity along a continuum. For each item, participants rated themselves along a seven-point Likert scale ranging

from *far below average (-3)* to *far above average (3)*. Wording was modified to be more appropriate for an undergraduate population (e.g., ability to follow through on instructions & finish schoolwork/chores). Responses were summed to create an ADHD total score ranging from -54 to 54, with higher scores indicating greater ADHD symptomatology (M = -13.06, SD = 14.58, Range = -51 to 31.04, α = .91).

Autism Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001)

The AQ is a 50-item self-report questionnaire assessing ASD characteristics and traits across several domains, including attention to detail, attention switching, social skills, imagination, and communication. Participants were asked to rate how well each statement applies to them on a 4-point Likert scale ranging from *definitely disagree* (1) to *definitely agree* (4). After reversing appropriate items, responses were summed to create a total score out of 80 such that higher scores denote more ASD symptomatology (M = 114.49, SD = 13.45, Range = 80 to 155.67, α = .72).

Weiss Functional Impairment Rating Scale – Self Report, Social Subscale (WFIRS-S; Weiss et al., 2018)

This 9-item self-report questionnaire asks participants to rate how often they have encountered a variety of interpersonal problems (e.g., getting into arguments, problems maintaining friendships, etc.) over the past month on a 4-point Likert scale ranging from *never or not at all* (0) to *very often or very much* (3). Responses were summed to create a total score out of 27 such that higher scores reflect greater social impairment (M = 5.07, SD = 4.17, Range = 0 to 17.90, α = .83).

Center for Epidemiological Studies Depression Scale – Revised (CESD-R; Eaton et al., 2004)

Because depression has been shown to modulate SRET performance (e.g., Auerbach et al., 2016), this 20-item self-report questionnaire was used to assess participants' experience of low mood – as reflected in feelings of sadness, anhedonia, and guilt – over the past two weeks. Similar to the prior study, a measure of depression was initially included in a SRET study in order to exclude those presenting with clinically significant levels of depressive symptoms. As with the previous sample, unanticipated high levels of endorsement of depression precluded this application, and thus participants with all levels of depression symptomology were included in further analyses. Associations between depression and other variables are reported (see below), however the direct impact of depression on SRET performance is beyond the scope of the present work. Participants responded on a 4-point Likert scale ranging from "*Not at all or less than one day*" (0) to "*Nearly every day for 2 weeks*" (3) and items were summed to create a total score out 60 (M = 21.61, SD = 12.80, Range = 0 to 59, α = .82). Scores above 16 represent moderate to severe depressive symptomology (Eaton et al., 2004).

Self-Referential Encoding Task (SRET)

The online SRET task consisted of two phases: the rating phase and the surprise memory phase. In the rating phase, participants were presented with socially evaluative statements. These statements were either self- or other-referential and contained either a positive or negative trait adjective (e.g., "he thinks she is mean", "she thinks you are kind"). In response to these statements, participants were asked to rate their subjective emotional valence ("how positive or negative did this make you feel?") and emotional arousal ("how calm or excited did this make you feel?") on a 7-point Likert scale, where 1 indicated very negative valence or very low arousal and 7 indicated very positive valence or very high arousal (Figure 3). Ratings of

emotional valence and arousal were averaged for each of the four conditions (i.e., self-positive, self-negative, other-positive, other-negative). Participants then completed the incidental (surprise) memory tasks. In the free recall task, participants were asked to enter any trait adjectives they could recall from the endorsement phase. Recall data were visually inspected to correct for clear typographical and spelling errors, and number of words correctly recalled was calculated. In the recognition task, participants had to identify whether or not a word appeared in the endorsement phase. Recognition scores were then calculated in two ways. Firstly, we calculated the number of hits on recognition trials (i.e., the number of adjectives that had previously been presented that were correctly identified as 'old'). As well, memory sensitivity (*d'*) was calculated to account for false alarms. This metric was computed using the R package 'psycho' (version 0.6.1) and reflects the standardized hit rate minus the standardized false alarm rate, with adjustment for extreme values made following the recommendations of Hautus (1995).

The SRET was designed using PsychoPy (version 2021.2.3) and administered online via Pavlovia. Based on words used in a prior study (Hudson et al., 2020), we created 3 lists that each consisted of 24 trait adjectives (12 positive: valence score of 7 or higher; 12 negative: valence score of 3 or lower) presented in lower case Arial font. The lists were compared on word length (ranging from 3 to 8 characters), valence, arousal, and dominance ratings from Warriner et al. (2013), and word frequency based on log10 values from Brysbaert & New (2009). Descriptive statistics are reported in Table 5. The word lists were statistically equivalent in terms of valence for both positive, $F(2,33) = 3.23$, $p = .053$, and negative, $F(2,33) = 1.24$, $p = .303$, trait adjectives, as well as for arousal, $F(2,69) = 1.04$, $p = .359$, dominance, $F(2,69) = 0.17$, $p = .848$ and average word length, $F(2,69) = 0.95$, $p = .390$. Word frequency, which was calculated based

on logarithmic values of current word frequency norms published by Brysbaert & New (2009), did differ significantly between lists, $F(2,69) = 3.81$, $p = .027$. Within each list, positive and negative adjectives were not statistically different in length or arousal (ps > .05), although positive words were rated higher in dominance (ps < .001). While lists one and two were equivalent for word frequency (ps > .05), positive words were significantly more frequent than negative words for list three, $t(21.95) = 2.70$, $p = .013$. Bonferroni-corrected paired t-tests indicated that only lists one and three differed in word frequency, with words on list three being significantly more frequent than words included on list one ($p = .016$). Two lists of words were used to generate adjectives for the SRET rating phase, while the third list provided the distractors in the recognition task, determined randomly per participant and condition.

Table 5

Descriptive Statistics for Each Word List.

	Length		Valence		Arousal		Dominance		Frequency	
	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*
List 1										
Positive	6.58	(1.31)	7.37	(0.30)	4.74	(0.83)	6.95	(0.37)	2.46	(0.49)
Negative	6.33	(1.44)	2.61	(0.30)	5.16	(0.53)	3.98	(0.78)	2.24	(0.37)
List 2										
Positive	6.58	(1.31)	7.33	(0.31)	4.47	(0.99)	6.67	(0.39)	2.55	(0.56)
Negative	5.58	(1.31)	2.56	(0.24)	4.99	(0.91)	4.05	(0.51)	2.66	(0.71)

List 3

Positive	5.92	(1.24)	7.66	(0.42)	4.81	(1.03)	6.90	(0.43)	3.19	(0.67)
Negative	5.92	(1.68)	2.73	(0.26)	4.37	(0.67)	4.31	(0.67)	2.48	(0.63)

Note. Length is reported in number of letters. Valence, arousal, and dominance reflect the normative ratings taken from Warriner et al. (2013). Word frequency represents $\log_{10}$ values from Brysbaert & New (2009).

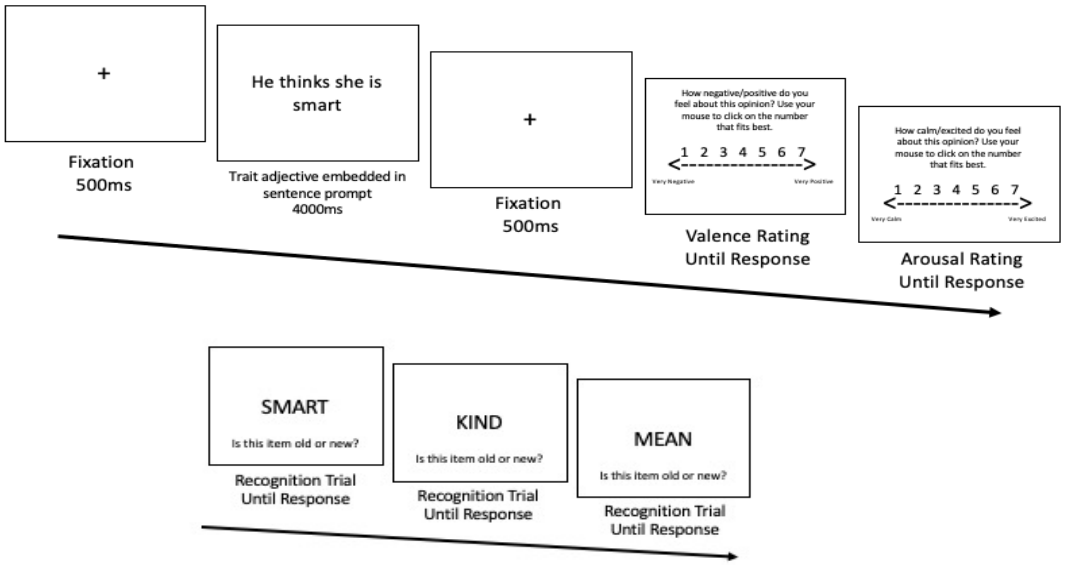
Procedure

Participants were informed that the purpose of the study was to assess how individual differences impacted adjective ratings and were not informed of the memory component at the outset. After providing consent, participants completed self-report questionnaires via Qualtrics and were then provided with instructions for the SRET. Following a brief practice round to ensure that participants understood task instructions, participants completed two blocks of 24 trials in the implicit encoding/rating phase. Each block included an even number of self- and other-referential trials and an equal number of positively- and negatively-valenced social evaluative statements that were intermixed and presented in a random fashion. As seen on Figure 3, each trial began with a central fixation cross (500ms), followed by the social evaluative statement (4000ms). After another central fixation cross (500ms), participants completed the valence and arousal ratings. The ratings remained on the screen until participants made a response by using the mouse to select the appropriate number on the scale that appeared on screen. Participants then completed a brief distractor task (counting backwards from 50) and entered the incidental memory phase. First, participants were instructed to type in any target

adjectives they remembered from the social evaluative statements in the first phase of the task (free recall). Next, they were presented with 72 trait adjectives, including the 48 target words from the encoding blocks and 24 matched distractor items, and were asked to indicate via keypress whether each adjective had been embedded in an evaluate statement they read earlier in the study (recognition). After completing the SRET, participants were debriefed, provided written consent again due to the deceptive nature of the surprise memory component, and were remunerated.

Figure 3

Example of SRET Encoding Trial (Upper Panel) and Recognition Trials (Lower Panel).



Data Analysis

Stringent quality control procedures were utilized to optimize data quality in this online study. To check that sufficient attention was devoted to both the computerized task and self-report questionnaires, participants who completed the study in less than 20 minutes were

excluded from the study ($N = 8$), as it was deemed unlikely that participants could complete the task and questionnaires in an attentive manner in fewer than twenty minutes. To minimize the impact of missing data on parameter estimates, participants missing more than 20% of data on any scale were dropped from analysis ($N = 9$). To check for response bias or lack of variability in responding, standard deviations on questionnaires were calculated and participants with a standard deviation of zero on more than one questionnaire were removed from analyses ($N = 9$). All data were normally distributed, with skew less than 3 and kurtosis less than 10. One univariate outlier was detected on the SWAN, two univariate outliers were detected on the AQ, four univariate outliers were detected on the WFIRS-S, and 16 outliers were detected on the SRET (11 on recognition hit data and five on recognition sensitivity data); data were winsorized to eliminate univariate outliers, operationalized as 3 standard deviations above or below the sample mean. No multivariate outliers were identified.

To test the relationship between neurodevelopmental traits and social impairment in daily life, bivariate correlations between WFIRS-S and ADHD traits, and WFIRS-S and ASD traits were computed. Next, a series of 2 x 2 repeated-measures ANOVAs with referent (self, other) and statement valence (positive, negative) as within subject factors were conducted on subjective valence and arousal ratings, as well as free recall, recognition, and memory sensitivity data. Multiple regression with repeated measures data was then used to test the effects of ADHD and ASD symptoms, word valence and word referent on performance on the SRET task. As with the previous study, models were run separately for ADHD traits alone, and then ADHD and ASD traits together (in order to evaluate the relationship between ADHD and SRET performance while accounting for the variance of ASD traits). Recognition sensitivity served as the outcome

variable, as it accounts for false alarms of distractor words (relative to just evaluating how many trait adjectives from encoding were later correctly recognized). In the first step of the regression, main effects of word referent, word valence, and symptom variables were entered. Two-way interaction terms were entered in the second step based on *a priori* hypotheses (i.e., the interaction between neurodevelopmental traits and word referent). Finally, to investigate whether self-reported social impairment predicted SRET performance, an additional multiple regression model was run with WFIRS-S, word referent, and word valence as predictors in the first step, and the interaction term between WFIRS-S and word referent in the second step. Variables were mean-centered prior to computing interaction terms.

Results

Correlation between Neurodevelopmental Traits and Social Impairment

Bivariate correlations revealed significant, positive correlations between ADHD traits and social impairment, $r(300) = .30$, $p < .001$, and ASD traits and social impairment, $r(300) = .28$, $p < .001$, supporting the hypothesis that traits of neurodevelopmental disorders would be associated with social functioning deficits in daily life (see Table 6).

Table 6

Bivariate Correlation Matrix Between Self-Report Questionnaires.

	AQ	WFIRS-S	CESD
SWAN	.11*	.30**	.27**
AQ	-	.28**	.25**
WFIRS-S	-	-	.64**

Note. *$p < .05$ ** $p < .001$

Online Replicability of the SRET

Table 7 displays the means and standard deviations for the four conditions across each variable analyzed while Figure 4 shows the distribution of scores for each memory variable.

Subjective Ratings

Valence ratings. There was a significant main effect of valence, $F(1,301) = 2632.09$, $MSE = 1.23$, $p < .001$, $\eta^2_p = 0.90$, such that participants rated their subjective feelings as more positive following positive evaluative statements relative to negative evaluative statements. The main effect of referent was not significant, $F(1,301) = 1.13$, $MSE = 0.07$, $p = 0.289$, $\eta^2_p < .01$. There was a significant referent by valence interaction, $F(1,301) = 210.04$, $MSE = 0.20$, $p < .001$, $\eta^2_p = 0.41$. Post hoc t-tests revealed that for positive evaluative statements, participants rated their valence more positively in response to self-referential statements than other-referential statements, $t(301) = 12.75$, $p < .001$; similarly, for negative evaluative statements, participants rated their valence more negatively for self-referential relative to other-referential statements, $t(301) = -12.04$, $p < .001$.

Arousal ratings. There was a significant main effect of referent, $F(1,301) = 55.38$, $MSE = 1.62$, $p < .001$, $\eta^2_p = 0.16$, such that participants reported higher levels of subjective arousal after reading self-referential evaluative statements relative to other-referential evaluative statements. The main effect of statement valence, $F(1,301) = 178.59$, $MSE = 0.35$, $p < .001$, $\eta^2_p = 0.37$, was also significant, with participants reporting higher subjective arousal in response to positive relative to negative evaluative statements. This was qualified by a significant valence by referent interaction, $F(1,301) = 25.67$, $MSE = 0.19$, $p < .001$, $\eta^2_p = 0.08$, such that positive evaluative statements were rated more emotionally arousing than negative ones for both self- and other-

referential statements (*p*s < .001), however this valence effect was stronger for self-referential than other-referential statements.

Free Recall

With the caveat that free recall scores were quite low overall (on average about 2 words out of the possible 12 in each condition), there was a significant main effect of referent, $F(1,301) = 77.74$, $MSE = 1.30$, $p < .001$, $\eta^2_p = 0.21$, with self-referential words recalled more frequently than other-referential words. The main effect of valence was not significant, $F(1,301) < 0.01$, $MSE = 1.01$, $p = .977$, $\eta^2_p < 0.01$, and there was no significant valence by referent interaction, $F(1,301) = 0.18$, $MSE = 1.63$, $p = .669$, $\eta^2_p < 0.01$.

Recognition Hit Rate

There were significant main effects of referent, $F(1,301) = 74.08$, $MSE = 2.45$, $p < .001$, $\eta^2_p = 0.20$, and valence, $F(1,301) = 17.00$, $MSE = 2.53$, $p < .001$, $\eta^2_p = 0.05$, such that self-referential words were recognized more often than other-referential words, and negatively-valenced words were recognized more often than positively-valenced words. The referent by valence interaction was not significant, $F(1,301) = 0.12$, $MSE = 1.77$, $p = .730$, $\eta^2_p < 0.01$.

Recognition Memory Sensitivity (d')

There were significant main effects of referent, $F(1,301) = 58.19$, $MSE = 0.17$, $p < .001$, $\eta^2_p = 0.16$, and valence, $F(1,301) = 74.99$, $MSE = 0.39$, $p < .001$, $\eta^2_p = 0.20$, with better memory sensitivity for self- than other-referential and for negative than positive evaluative statements. The referent by valence interaction was not significant, $F(1,301) = 1.18$, $MSE = 0.14$, $p = .277$, $\eta^2_p < 0.01$.

Table 7

Means and Standard Deviations for Each SRET Condition.

		Self		Other	
		M	*(SD)*	*M*	*(SD)*
Subjective Valence Ratings	Positive	5.80	(0.63)	5.41	(0.69)
	Negative	2.15	(0.67)	2.50	(0.70)
Subjective Arousal Ratings	Positive	4.36	(1.22)	3.78	(1.25)
	Negative	3.69	(1.14)	3.36	(1.01)
Recall (average number of words)	Positive	1.92	(1.40)	1.37	(1.15)
	Negative	1.94	(1.38)	1.34	(1.13)
Recognition – Hits (average number of words)	Positive	9.27	(1.95)	8.47	(2.19)
	Negative	9.62	(1.96)	8.87	(2.25)
Recognition - Sensitivity (*d*')	Positive	1.44	(0.75)	1.23	(0.76)
	Negative	1.72	(0.89)	1.56	(0.85)

Note. The total possible number of words in each recall and recognition condition is 12.

SRE and ADHD Traits

The previous analyses involving implicit memory performance demonstrated that our online modified SRET gave rise to the expected self-reference effect. We next evaluated a hierarchical regression model with the contribution of referent, valence, and ADHD symptoms on memory sensitivity, which was statistically significant, $F(3, 1204) = 22.59$, $R^2 = 0.05$, $p < .001$. Self-reference ($B = 0.18$, $SE = 0.05$, $p < .001$) and negative valence ($B = 0.31$, $SE = 0.04$, $p < .001$) were both significant predictors of better memory sensitivity. ADHD symptoms were

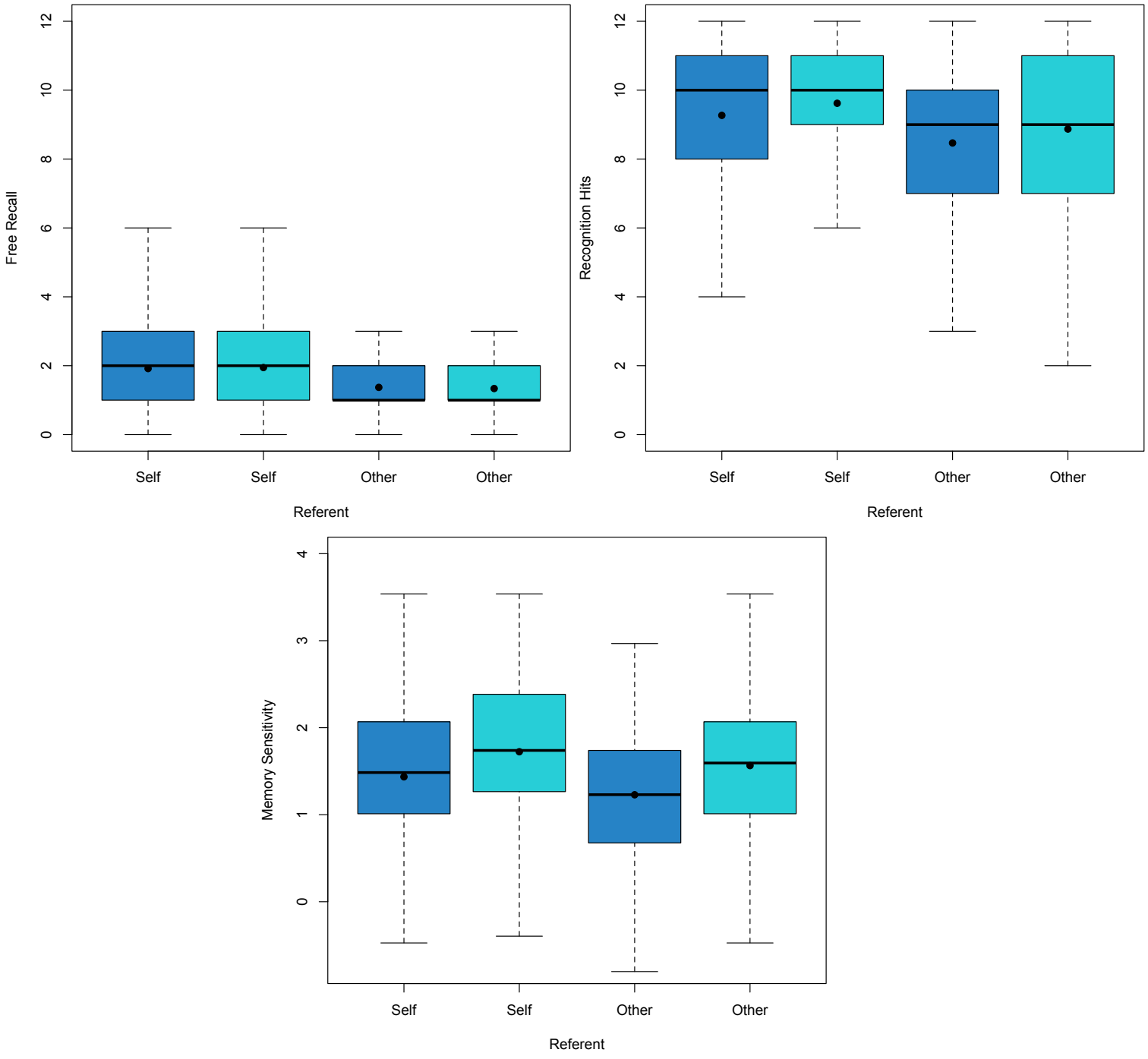
also a significant predictor of memory sensitivity, $B = 0.004$, $SE = 0.01$, $p = .005$, with higher self-reported ADHD symptoms predicting better performance. To investigate the hypothesis that ADHD traits would interact with word referent, this interaction term was entered in the second step of the model. The addition of this interaction term did not explain significantly more variance in memory sensitivity ($\Delta F(1, 1203) = 0.05$, $p = .815$), and the interaction term was not significant ($B < 0.001$, $SE = 0.003$, $p = .815$), so this interaction was not probed further.

SRE and ADHD with ASD Traits

Next, I evaluated the impact of both ADHD and ASD traits on memory sensitivity. The overall model was statistically significant, $F(4, 1203) = 18.32$, $R^2 = 0.05$, $p < .001$. Again, higher ADHD symptoms ($B = 0.004$, $SE = 0.002$, $p = .011$), self-reference ($B = 0.18$, $SE = 0.05$, $p < .001$), and negative valence ($B = 0.32$, $SE = 0.05$, $p < .001$) all predicted better memory sensitivity. ASD traits were also a significant predictor of memory sensitivity, $B = 0.004$, $SE = 0.002$, $p = .022$, in the same manner as ADHD symptoms (i.e., higher self-reported ASD traits predicted better memory sensitivity). In the second step of the model, interaction terms were entered to test a priori hypotheses regarding the interactions between ADHD symptoms and word referent and ASD symptoms and word referent. The addition of these interaction terms to the model did not explain significantly more variance in the outcome measure ($\Delta F(2, 1201) = 0.09$, $p = .913$). The interaction between ADHD symptoms and word referent ($B = 0.001$, $SE = 0.003$, $p = .784$) and ASD symptoms and word referent ($B = -0.001$, $SE = 0.003$, $p = .722$) were both non-significant, so this was not probed further.

Figure 4

Results for Free Recall, Recognition Hits, and Recognition Sensitivity Scores.



Note. Dark blue represents positively-valenced words while light blue represents negatively-valenced words. The total possible number of words in each endorsement, recall, and recognition condition is 12. *d*' of 0 indicates chance level. The black line in each box represents the median, black dots represent the mean, and the tops and bottoms of each box represent the interquartile range between the 25th and 75th percentile.

SRE and Social Impairment

To explore whether self-reported social impairment predicted reductions in the SRE, I ran a multiple regression model with WFIRS-S score, word referent, and word valence as predictors and memory sensitivity as the dependent variable. In the first step of the model where main effects of these variables were entered as predictors, the overall model was statistically significant, $F(43\ 1204) = 27.05$, $R^2 = 0.06$, $p < .001$. Self-reference ($B = 0.18$, $SE = 0.05$, $p < .001$) and negative valence ($B = 0.31$, $SE = 0.05$, $p < .001$) again predicted better memory sensitivity, while lower self-reported social impairment predicted better memory sensitivity ($B = 0.03$, $SE = 0.01$, $p < .001$). To test whether self-reported social impairment reduced the SRE, the interaction between WFIRS-S and word referent was entered into the second step of the model. However, the addition of this interaction term did not explain significantly more variance in memory sensitivity ($\Delta F(1, 1203) = 0.17$, $p = .685$). As well, the interaction between self-reported social impairment and word referent ($B = 0.005$, $SE = 0.01$, $p = .685$) was not significant.

Discussion

This study sought to address a gap in our understanding of self-referential processing in ADHD. Self-referential processing guides attention and is supported by neural underpinnings that are shared with ADHD, a clinical disorder characterized by attentional challenges (American

Psychiatric Association, 2013; Gray et al., 2004; Leshikar & Duarte, 2014; Sonuga-Barke & Fairchild, 2012; Wilson et al., 2013). Only one study has directly examined the prioritization of self-relevant information in ADHD and no studies that have done so in conjunction with ASD, which has some phenotypic similarities with ADHD and has been linked to atypical self-referential processing (Henderson et al., 2009). My approach was informed by the RDoC framework, which proposes that adopting a dimensional rather than categorical understanding of psychopathology enhances the clinical utility of our research by providing better understanding of root causes of disease that may cut across currently distinct diagnostic categories (Cuthbert, 2022; Cuthbert & Insel, 2013). As such, I focused the research question on a large sample of young adults expressing a continuum of both ADHD and ASD traits using a validated task and stringent data quality procedures. Doing so more accurately reflects the (normal) distribution of ADHD traits amongst the general population (Crosbie et al., 2013).

There is accumulating evidence that the SRET may not be as robust as previously thought and is instead sensitive to minor changes to the task format (Dainer-Best et al., 2018). Though administered online, the self-reference effect was replicated in this version of the SRET that was modified to have a stronger social element. As expected, participants demonstrated superior memory of trait adjectives that had previously been evaluated in relation to themselves compared with an abstract other person. Contrary to predictions, however, trait adjectives were more likely to be remembered when they were negatively-valenced rather than positively-valenced. This may reflect a developmental trend whereby negative self-evaluations increase throughout adolescence, peaking at age 19 then decreasing with age (Moses-Payne et al., 2022). Given that the mean age of this sample is approximately 20 years old, participants may be most attuned to

negative evaluations in the encoding phase, enhancing later memory for this information in particular. It may alternatively relate to some indications in the memory literature that suggest a memory benefit for negatively-valenced information (e.g., Nadarevic, 2017), which contrasts the positivity-bias typically discussed in the SRET literature. As well, although referent and valence did not interact in my study, work with adolescent females who are clinically depressed has shown that memory is enhanced for negative self-referential information (Auerbach et al., 2015). Participants in this study were mostly female and endorsed high levels of depressive symptoms, consistent with other samples of Canadian undergraduate students during the COVID-19 pandemic (King et al., 2022). Whilst I replicated the established SRE in this study, these findings highlight the importance of mood when considering the ways in which emotional valence of information interacts with memory.

Consistent with my hypothesis, I identified a significant, positive correlation between ADHD and ASD traits and behavioural-level social impairment. Despite this, and contrary to the hypothesis, I found significant main effects of ADHD traits and ASD traits on memory sensitivity (see below) but no significant interactions between either of these traits and referent. Rather, participants in this sample generally remembered self-relevant information better than information that is not relevant to the self – mirroring the typical SRE found in the general population. This null result is consistent with findings reported by Klein et al. (2011) in their first experiment in which participants with and without ADHD produced a reliable SRE. In a second experiment using a modified SRET paradigm where participants had to produce a personal example of each trait adjectives (instead of just making a judgment about the adjective as was done in experiment 1, and in the traditional SRET), they found an attenuated SRE in participants

with ADHD. The authors posited that this may reflect atypical episodic, rather than semantic, processing in ADHD, as well as reduced benefit from elaborative processing associated with more in-depth SRET encoding activities. Thus, the present results may further lend support to an intact SRE in ADHD, as they also demonstrate in their more traditional application of the SRET paradigm. However, the mixed findings inherent in the ADHD SRET literature may instead reflect more poorly organized or impoverished episodic self-knowledge in ADHD, rather than deficits in attending towards self-referential knowledge. I also note that recent studies in the ASD literature have failed to identify a deficit in self-referential processing; two recent studies found no reduction in the SRE in a clinical ASD sample, nor did they identify a relationship between ASD traits in a community sample and self-referential processing (Lind et al., 2020; Williams et al., 2018). Thus, accumulating evidence hints towards the lack of SRE modulation by ADHD and ASD traits.

Following from the above, a surprising finding was that memory sensitivity significantly improved with increasing traits of ADHD and ASD – reflecting a general tendency to do better on the SRET with greater self-endorsement of symptomatology. These small but significant effects are puzzling, particularly in the context of high levels of reported memory complaints in individuals with ADHD and meta-analytic evidence suggesting difficulties with verbal memory encoding in ADHD (Skodzik et al., 2017). In ASD, the literature similarly suggests a reduction in verbal memory compared to peers, though this effect is small and is more prevalent in free recall memory relative to recognition (Desaunay et al., 2020). The gender skew of the current sample (which is heavily female – in direct contrast to the distribution of ADHD and ASD in the population; Adak & Halder, 2017; Espinet et al., 2022) may underlie this unexpected finding.

That is, a substantial literature suggests that females with ASD are more likely to adopt strategies to compensate for and mask autistic characteristics (e.g., Hull et al., 2020). Emerging evidence suggests that adults with ADHD may similarly adopt camouflaging behaviours, albeit to a lesser extent than those with ASD (van Der Putten et al., 2024). Given that the present sample comprises mostly females and consists of undergraduate students – who are more likely to represent a higher functioning subset of the broader population (Wild et al., 2022) – it is possible that individuals in this sample with high levels of neurodevelopmental traits have been particularly successful at developing strategies to camouflage ASD and/or ADHD traits. Such strategies may include being particularly attuned to opinions of other people, which is what they are confronted with in the present study, thereby enhancing attention (and later memory) of emotionally threatening stimuli. It is also plausible that this finding may stem from the strong correlation between neurodevelopmental traits and depressive symptoms in this sample, as it may reflect the finding in other work indicating that low mood increases attention to and memory for social information, particularly negative and threat-related information, and heightens sensitivity to social rejection, which may have been triggered by the paradigm utilized here (Kupferberg et al., 2016; Leppänen, 2006). While these are possible explanations of this finding, it ultimately remains unclear why this main effect emerges.

In addition to the absence of the hypothesized interactions between neurodevelopmental traits and word referent, I did not detect an interaction between self-reported social impairment and word referent. While a significant main effect did emerge, suggesting that those with fewer social problems in everyday life generally remembered the adjectives in this task better than those with higher levels of social impairment, the absence of a significant interaction with word

referent indicates that SRET performance does not appear to relate to self-reported social problems in everyday life in this study in the predicted manner (i.e., interfering with prioritization of self-relevance). Because previous work has identified that bias towards self-referential information predicts better performance on tasks of ToM and empathic accuracy, it has been thought that the SRET is of relevance for social competence more broadly (Dinulescu et al., 2021). However, the absence of this interaction here may indicate that the SRET might not have as much bearing on competent social function as previously hypothesized.

The current findings should be interpreted within the context of several limitations. First, the sample consisted mostly of females in an undergraduate institution, which prevents assessing the generalizability of our findings to a more diverse population (e.g., males, youth, individuals recruited from the community). Enhancing the diversity of participants will be an important next step for future studies examining self-referential processing. Second, I assessed ADHD traits along a continuum via self-report questionnaire, though doing so has been shown to produce higher rates of individuals who fall into a clinical range relative to individuals who have a clinical diagnosis of the disorder from a medical professional (Garnier-Dykstra et al., 2010). Though logistically difficult, assessment of ADHD traits may be enhanced in future work by incorporating ratings from informants into participants' self-report. Lastly, pivoting to an online format was necessary due to public health restrictions related to the COVID-19 pandemic, but doing so limited my ability to control participants' environments during testing. Stringent data quality control measures were undertaken in an effort to mitigate the impact of possible poor data; however, even the most robust regression models still only explained roughly 5% of the

variance in SRET performance, perhaps indicating that the online environment introduced additional noise into the data.

In sum, the above findings suggest that in a socially evaluative context, individuals with high levels of ADHD and ASD symptomology pick up on self-relevant information that is embedded in evaluative statements that are expressed by unknown others – an important component of social interactions and, ultimately, competent social function. The RDoC framework provides a potentially fruitful framework for future investigations into mechanisms that may explain the nature of social impairment in ADHD. Gaining a better understanding of which cognitive and/or social-emotional abilities are and are not implicated in ADHD will ideally allow for the development of more targeted interventions to ameliorate social impairment in ADHD in the future.

Chapter 4: Do neurodevelopmental traits modulate the gaze orienting effect?

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder defined by developmentally atypical and impairing symptoms of inattention, hyperactivity, and impulsivity (American Psychiatric Association, 2013). Individuals with ADHD also frequently demonstrate a range of social challenges, including fewer reciprocated friendships in childhood, more frequent peer victimization, and poorer relationship quality in adulthood (Bagwell et al., 2001; Barkley et al., 2010; Blachman & Hinshaw, 2002; Hoza, 2007). While social impairments in ADHD are well-documented, underlying mechanisms remain poorly understood which has had implications for the development of efficacious interventions to remediate social functioning in individuals with this disorder. Some posit that social impairment is a downstream consequence of core ADHD symptoms and associated deficits in executive functioning (Mary et al., 2016; Tseng & Gau, 2013). There is also evidence, however, that social impairment may be attributable to impairments in some aspects of social cognition – including theory of mind and the ability to recognize and label others' emotional expressions (Bora & Pantelis, 2016; Uekermann et al., 2010).

Social functioning is a multifaceted construct, and the elements of social cognition implicated above (i.e., theory of mind, emotion recognition) are quite complex. As such, there has been a push to focus on more elementary aspects of social attention in order to piece apart where the deficits in social skill may lie. In line with this, the Research Domain Criteria (RDoC) framework – a novel taxonomy of psychopathology proposed by the National Institute for Mental Health – proposes that effective mental health research should evaluate individual

domains of functioning using a dimensional approach in order to elucidate underlying neurobiological and behavioural mechanisms that underlie psychopathology and may cut across current diagnostic categories (Cuthbert, 2022; Insel, 2014; Pacheco et al., 2022). Social communication represents one such domain of functioning, and it is further broken down into low level skills, including orienting of attention to social information (Gur & Gur, 2016; Insel, 2014). This work utilizes an RDoC-informed dimensional approach to evaluate social attentional orienting in individuals with varying levels of ADHD traits.

Gaze Orienting

The visual world contains information far in excess of human processing capabilities. Thus, it is essential that individuals possess a mechanism that allows for some information to be selected for further processing while other interfering stimuli are ignored. Different cues exist in our environment that can elicit orienting of visual attention towards specific locations in space, helping direct individuals towards locations with potentially important information (Frischen et al., 2007). In a social context, the eyes are amongst the most salient stimuli for humans (Emery, 2000). Because eye gaze conveys important information about one's thoughts and emotions, we are drawn towards the location of another person's eyes (Itier & Batty, 2009; McKay et al., 2021). Since the eyes afford important clues about others' attention and intentions, in a social context eye gaze serves as a central cue for attentional orienting. When combined with other information (e.g., emotional facial expressions), gaze direction serves as a particularly powerful clue to infer others' mental states (Lassalle & Itier, 2015; McKay et al., 2021).

Experimentally, attentional orienting towards shifts in eye gaze direction has been studied using a gaze cueing experimental paradigm, where participants are presented with a face image

with an eye gaze shift to the left or right of the screen, followed by the presentation of a target (e.g., an asterisk) that participants are asked to respond to with a button press (e.g., McKay et al., 2021 for review). When the target appears on the same side of the screen as the gaze shift (i.e., a congruent trial), response times towards that target are faster than when the target appears on the opposite, non-gazed-at side of the screen (i.e., an incongruent trial); this is termed the gaze cueing effect or gaze orienting effect (GOE). From this body of work, significant evidence converges to show that people naturally orient towards the direction of others' eye gaze (Friesen & Kingstone, 1998; Frischen et al., 2007; McKay et al., 2021). When this paradigm is adapted to include an emotional expression along with the gaze cue, the GOE typically emerges to an even greater degree (e.g., McCrackin & Itier, 2019). Indeed, emotional modulation of gaze cueing is seen across several studies experimentally; that is, when certain emotions (e.g., fear, surprise, happiness, and anger) are expressed following the gaze cue, congruent targets are responded to even faster (Lassalle & Itier, 2015; McCrackin & Itier, 2018; McCrackin & Itier, 2019; Neath et al., 2013). The integration of emotional information to the gaze cueing paradigm enhances ecological validity, as faces in naturalistic settings are rarely looking around their surroundings with purely neutral expressions. Thus, the additional information being conveyed when someone's eyes look to the side and then the face expresses emotion mimics someone reacting to information that has captured their attention.

Deficits in orienting to gaze cues have been documented in certain clinical populations (e.g., ASD, schizophrenia), and deficits in the ability to utilize eye gaze as a cue for attentional orienting have been linked with the social deficits present in these disorders (Akiyama et al., 2008; Gillespie-Lynch et al., 2013; Kliemann et al., 2010). As well, evidence suggests that the

ability to understand the social meaning of eye gaze direction is predictive of social competence in nonclinical populations as well, suggesting that orienting to social gaze may be important for higher level social competence (Frischen et al., 2007; Hayward & Ristic, 2017). Thus, orienting to eye gaze appears to constitute a core social attentional skill that underlies more complex interpersonal interactions.

Gaze Orienting in ADHD

While indications of gaze processing deficits exist in other clinical disorders with notable social deficits, to date, the ability to utilize eye gaze as a cue for attentional orienting in the context of ADHD has not been extensively studied, and the existing literature exploring this question is characterized by mixed findings. Some studies have demonstrated deficits in orienting to gaze in ADHD, finding that participants with ADHD do not respond faster to targets cued by eye gaze direction and do not demonstrate interference from invalid gaze cues, while other work identifies a smaller, but still present, GOE in ADHD relative to non-ADHD participants (Marotta et al., 2014; Marotta et al., 2017; Uono et al., 2023). Additional evidence from electroencephalogram (EEG) data indicates abnormal alpha modulations in children with ADHD relative to non-ADHD controls when performing gaze cueing tasks, and demonstrates that atypical activity at the neural level predicted both behavioural accuracy on the cueing task and inattentive symptoms in daily life (Guo et al, 2019). Similarly, adults with ADHD demonstrate abnormal attention-sensitive P200 ERP signals when processing direct eye gaze (Mauriello et al., 2022). Notably, these studies specify that this deficit in gaze cueing is specific to eye gaze cues, rather than a more global attentional orienting deficit (Marotta et al., 2014; Marotta et al., 2017).

On the other hand, other work suggests that individuals with ADHD do orient towards gaze cues in a typical fashion (Lee et al., 2015; Tye et al., 2013). In one study, participants high in ADHD symptomology committed errors on a task requiring inhibition of saccadic movements in the direction of the gaze cue, suggesting that gaze did capture attention and interfere with task performance (Lee et al., 2015). In another study, children with ADHD showed atypical EEG activity in early visual processing (i.e., P1 ERP), but not in face specific neural indicators (i.e., N170) suggesting abnormalities at early visual attention stages, but intact neural indicators of face processing (Tye et al., 2013). While other works suggest a more general attentional orienting deficit in ADHD, finding that participants with ADHD perform worse than controls on a cueing task regardless of whether the cue was of a social or non-social nature, this is not consistently found in the literature and attentional orienting is generally thought to be an attentional process that is spared in the case of ADHD relative to other aspects of attention (Groom et al., 2017).

Of the limited literature that has examined emotional modulation of gaze cueing in ADHD, some evidence suggests that adding an angry facial expression to the gaze cue interferes with gaze cueing for adults with ADHD, and inattentional symptoms are correlated with modulated saccadic response to angry gaze cues in non-clinical participants (Manoli, 2019; Motomura et al., 2023). Other work does not detect emotional modulation of gaze cueing in ADHD, however notably they also do not demonstrate this finding in their non-ADHD participants, either, in contrast to the typically robust finding that emotional gaze cues do enhance reaction time in non-ADHD samples (Uono et al., 2023). While emotional modulation of gaze cueing remains relatively unexplored in ADHD, a significant literature has characterized

more broad emotional processing deficits in ADHD. This body of research consistently reports atypicalities related to the processing of threat-related emotions in ADHD (Uekermann et al., 2010). For example, youth with ADHD perform worse than typically developing peers at identifying threat-related emotional faces, and show differences in ERPs at the neural level during such tasks (Williams et al., 2008). Overall, orienting to gaze cueing in ADHD, and the emotional modulation of gaze cueing more specifically, require further investigation to determine whether they constitute a core social cognitive deficit in the case of ADHD.

The Present Study

This study investigated whether orienting toward gaze cues varied with individual differences in ADHD traits and the interplay of these traits with facial emotional expression. In accordance with an RDoC-informed approach to conceptualizing neurodevelopmental disorders, we also examined individual differences in traits of ASD – which, as previously noted, may influence orienting to gaze (e.g., Landry & Parker, 2013). The study was conducted in a large sample of undergraduate students who participated online due to COVID-19 public health restrictions. We hypothesized that traits of ADHD and ASD would be correlated with social impairment in daily life. Moreover, we hypothesized that participants would generally display faster reaction times and greater accuracy in their responses when the orienting cue is predictive of target location (i.e., a replication of the GOE). However, we further hypothesized that individuals expressing high levels of ADHD and ASD traits would be less effective than those with low levels of these traits in using these social cues to orient attention – reflected in a reduced reaction time and accuracy benefit on congruent trials. Lastly, we hypothesized that emotional facial expression would generally facilitate an even faster GOE, however participants

with high levels of ADHD traits may benefit less from this enhancement, particularly to fearful faces due to threat-related emotion processing differences in ADHD.

Methods

Participants

Two-hundred and five undergraduate students from the University of Waterloo were recruited via the Department of Psychology participant pool and volunteered in the study for course credit between January to November 2022. The final sample (N = 169) ranged in age from 18 to 67 (M = 19.97, SD = 4.18) and consisted of mostly female participants (77%) and was racially diverse (40% Caucasian, 24% East Asian, 13% South Asian, and 54% other, including Black, Indigenous, Arab, and Caribbean). Most participants (81%) indicated that they had been exposed to English since birth. For this study, participants who completed either SRET study were eligible to participate. 17 participants reported having been diagnosed with ADHD by a medical professional.

Materials

Strengths and Weaknesses in ADHD Symptoms and Normal Behaviours (SWAN; Swanson et al., 2001)

Consistent with a dimensional perspective of ADHD (e.g., Lubke et al., 2009) the SWAN was utilized to measure 9 symptoms of inattention and 9 symptoms of hyperactivity-impulsivity along a continuum. For each item, participants rated themselves along a seven-point Likert scale ranging from *far below average (-3)* to *far above average (3)*. Wording was modified to be more appropriate for an undergraduate population (e.g., ability to follow through on instructions &

finish schoolwork/chores). Responses were summed to create an ADHD total score ranging from -54 to 54, with higher scores indicating more ADHD symptomatology.

Autism Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001)

The AQ is a 50-item self-report questionnaire assessing ASD characteristics and traits across several domains, including attention to detail, attention switching, social skills, imagination, and communication. Participants were asked to rate how well each statement applies to them on a 4-point Likert scale ranging from *definitely disagree* (1) to *definitely agree* (4). After reversing appropriate items, responses were summed to create a total score out of 200 such that higher scores denote more ASD symptomatology

Weiss Functional Impairment Rating Scale – Self Report, Social Subscale (WFIRS-S; Weiss et al., 2018)

This 9-item self-report questionnaire asks participants to rate how often they have encountered a variety of interpersonal problems (e.g., getting into arguments, problems maintaining friendships, etc.) over the past month on a 4-point Likert scale ranging from *never or not at all* (0) to *very often or very much* (3). Responses were summed to create a total score out of 27 such that higher scores reflect greater social impairment.

Center for Epidemiological Studies Depression Scale – Revised (CESD-R; Eaton et al., 2004)

This 20-item self-report questionnaire was used to assess participants' experience of low mood over the past two weeks. Participants responded on a 4-point Likert scale ranging from "*Not at all or less than one day*" (0) to "*Nearly every day for 2 weeks*" (3) and items were summed to create a total score out. Because of the unanticipated high burden of depression symptoms encountered in the above studies, mood was again measured in this sample. However,

because there were no a priori hypotheses vis-à-vis depression and gaze cueing (e.g., McCrackin & Itier, 2019, which does not detect a relationship between depressive symptoms and the gaze cueing effect or emotional modulation of gaze cueing), results from this questionnaire are presented descriptively but not included in further statistical models.

Cueing Task

The cueing task was designed using Testable and administered via their online platform (https://www.testable.org/). In this task, participants were informed that they would be presented with images of faces and arrows, followed by a target stimulus (a black asterisk). They were instructed to make a speeded response using a button press on their keyboard as soon as the target appeared on the screen, indicating whether the target appeared on the left or right side of the screen with their key press. Reaction time (RT) and accuracy of responses were measured.

Four female and four male facial identities (#02, 03, 06, 09, 20, 22, 24, and 27) from the NimStim database2 were used for this experiment (Tottenham et al., 2009). For each facial identity, images of fearful, happy, and neutral expressions were used (see Figure 5). Images were grayscale and were cropped into an oval shape around just the face, with hair and ears removed. The pupils of each face were moved to the left and right corners of both eyes to produce an appearance of averted gaze. The mouth regions of the neutral faces with averted gaze were edited to simulate tongue protrusion, creating "neutral-tongue" expressions, in order to control for the change in mouth variations and apparent motion seen with fearful and happy expressions while maintaining a neutral expression (see McCrackin & Itier, 2018). For each trial, images of the same identity were used to create face sequences, each composed of three frames: (1) a neutral face looking straight was presented; (2) the same neutral face with an averted gaze to the left or

right; (3) the same averted-gaze face that either displayed a fearful, happy, or neutral-tongue expression (see Figure 5). This presentation sequence of images at a rapid pace gave the appearance of a person dynamically gazing to one side and then reacting with a fearful, happy, or neutral expression. Previous work has demonstrated that this sequence (neutral direct gaze, neutral averted gaze, then finally onset of emotional averted gaze) creates the appearance as if face stimuli are "reacting" to something in the gazed-at direction, and this enhanced ecological validity further facilitates gaze cueing (Capozzi & Ristic, 2020; Lassalle & Itier, 2015; McCrackin & Itier, 2019). Arrow cueing trials were also intermixed with gaze cue trials to create a comparison, 'non-social', condition. Arrow stimuli consisted of greyscale bars (i.e., a straight horizontal bar) and arrows pointing either to the left or the right side of the screen on scrambled backgrounds (see Figure 5). Scrambled backgrounds of arrow stimuli were matched in mean contrast and pixel intensity with the face stimuli. On these trials, participants would initially see the arrow bar, which provided no indication about direction to match the neutral direct gaze on gaze cue trials. The left or right arrow would then appear, followed by a second frame of an arrow pointing in the same direction with a shift in the scrambled background to match the motion of gaze cue trials.

Across all conditions (i.e., arrow, neutral, happy, and fearful), each trial began with a central fixation cross for 500ms that disappeared at the onset of the first face or arrow image. For gaze trials, the dynamic face sequence began with the onset of a neutral, face image with a direct gaze for 300ms, followed by the same neutral face with an averted gaze (i.e., the eyes shift to look either towards the right or left side of the screen) for 100ms, and then followed by an averted gaze emotional face or neutral-tongue image. For arrow trials, a straight bar appeared

immediately following the fixation cross for 300ms (to match the direct gaze, neutral face that begins gaze trials), followed by an arrow image pointing left or right. Following this gaze or arrow sequence, the target asterisk then appeared on either the right or left side of the screen, centered vertically. The target remained on screen for 500ms or until participants provided a response (see Figure 6).

Participants were instructed to respond as quickly as possible and indicate the location of the target (i.e., left or right side of the screen). When a target appeared on the side of the screen that the gaze is averted towards, it is considered a congruent trial, while incongruent trials refer to those where the target appeared on the non-gazed-at side of the screen. Half of the trials completed were congruent, and half were incongruent. Target location and stimulus type (neutral face/emotional face/arrow) were randomized in terms of order, with an equal number of congruent right, congruent left, incongruent right, and incongruent left trials within each condition. Participants were told to respond with the 'z' and 'm' keys on the keyboard to indicate the location of the target as soon as the target appeared on screen (target localization task).

Figure 5

Example of (A) Gaze Stimuli and (B) Arrow Stimuli.

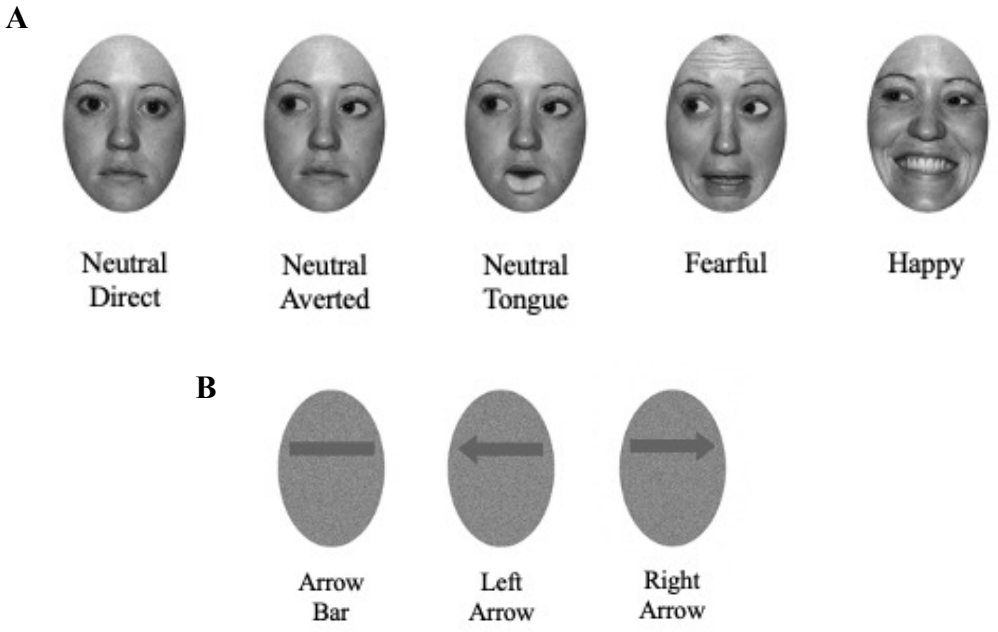
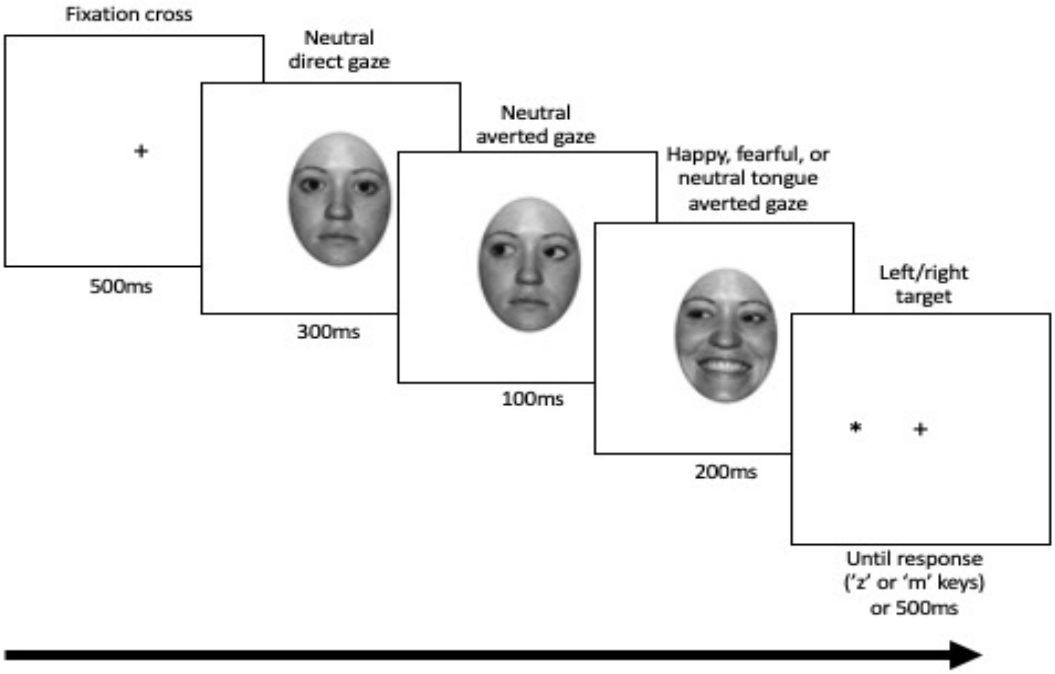
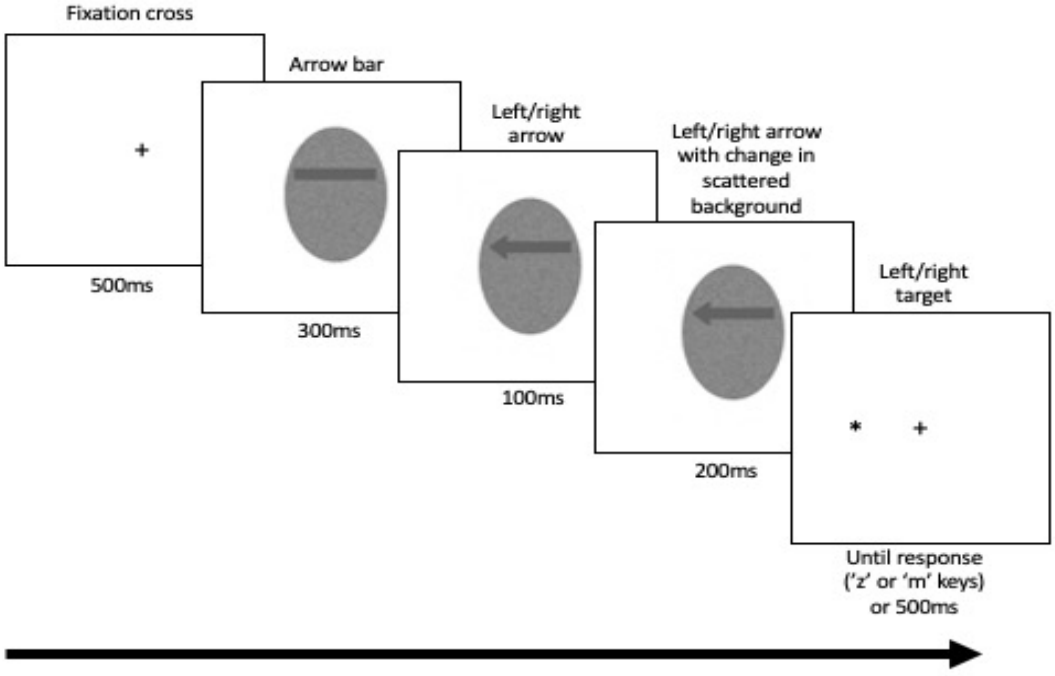


Figure 6

Sequence of One Trial for a Congruent Gaze Trial (Upper Panel) and a Congruent Arrow Trial (Lower Panel).


Fixation cross
Neutral direct gaze
Neutral averted gaze
Happy, fearful, or neutral tongue averted gaze
Left/right target
500ms
300ms
100ms
200ms
Until response ('z' or 'm' keys) or 500ms


Fixation cross
Arrow bar
Left/right arrow
Left/right arrow with change in scattered background
Left/right target
500ms
300ms
100ms
200ms
Until response ('z' or 'm' keys) or 500ms

Procedure

Participants were informed that the purpose of the study was to assess how emotional expression of faces interact with its gaze to cue attention. After providing consent, participants completed all self-report questionnaires online administered via Qualtrics. Participants were then provided with instructions for the gaze cueing task. Participants were required to complete this online computerized task on a laptop or desktop computer, and were instructed to be seated at a desk with their computer, and arrange their screen such that their eyes were aligned with the fixation cross in the centre of the screen. They were also informed that they would be required to maintain focus on the task for approximately 15 minutes without a break, and were asked to minimize distractions in their environment (e.g., silencing notifications on their devices). Participants were informed that their goal on this task was to respond to a target appearing on the screen using a keypress. Participants were told to respond as quickly and accurately as possible, indicating the location of the target on the screen. Following a block of practice trials to ensure participants understood the task, they completed one block of 320 trials of the cueing task as described above. After completing the task, participants were debriefed, provided written consent again after being de-briefed about the full purpose of the experiment (i.e., it was not previously disclosed that we were evaluating the impact of ADHD symptoms on gaze and arrow cueing) and were remunerated.

Data Analysis

Stringent quality control procedures were utilized to optimize data quality in this online study. To check that sufficient attention was devoted to both the computerized task and self-report questionnaires, participants who completed the study in less than 20 minutes were

excluded from the study ($N = 6$), as it was deemed unlikely that participants could complete the task and questionnaires in an attentive manner in fewer than twenty minutes. To minimize the impact of missing data on parameter estimates, participants missing more than 20% of data on any scale were dropped from analysis ($N = 14$). To check for response bias or lack of variability in responding, standard deviations on questionnaires were calculated and participants with a standard deviation of zero on more than one questionnaire were removed from analyses ($N = 6$).

For data on the gaze cueing task, responses were considered correct if the key response matched the side of the screen that the target was on, and if the response time was less than 2.5 standard deviations away from the mean for each condition (Van Selst & Jolicoeur, 1994). Average RTs were calculated for each condition using the correct responses only. For quality control purposes, participants with very low hit rates on the gaze cueing task (fewer than 50% trials correct) or participants who required the removal of a very high number of trials from analysis (i.e., due to RT outliers or incorrect responses, or trial timeouts with no response recorded within 500ms time limit) were excluded from analyses ($N = 10$ additional participants removed; of note, many participants removed based on criteria described above regarding self-report questionnaires were also deemed to have poor quality data on the gaze cue task using these criteria). Data from these participants was deemed to reflect poor engagement on the task, as most of the participants far exceeded cutoffs for good data quality (e.g., 5 of the 10 participants who were removed failed quality control criteria on over 90% of trials, meaning approximately 300 out of 320 total trials were responded to incorrectly, not responded to at all, or responded to with widely varying RTs).

To test the relationship between neurodevelopmental traits and social impairment in daily life, bivariate correlations between WFIRS-S and ADHD traits, and WFIRS-S and ASD traits were computed. To assess online replicability of the gaze cueing task, 4 (condition: arrow, neutral, happy, fearful) x 2 (congruency: congruent, incongruent) repeated-measures ANOVAs were run separately on hit rate and mean RTs. Next, to examine emotional modulation of gaze cueing, a repeated-measures ANOVA was run on RT data the above ANOVA on RT data was re-run comparing data from only gaze-cueing trials (i.e., a 3 x 2 repeated-measures ANOVA without the arrow condition). Arrow trials were removed from this analysis to allow for direct comparison with previous work (e.g., Chen et al., 2021, which did not utilize an arrow condition), in particular given that this effect has been shown to be small and may be diluted by the inclusion of additional factors in the model. For all repeated-measures ANOVAs, when Mauchly's Test of sphericity was significant, Greenhouse-Geisser corrected degrees of freedom are reported. Follow-up comparisons were carried out with Bonferroni corrected paired *t*-tests.

To test the association between neurodevelopmental traits and the GOE, two approaches were taken. First, I created the cueing effect score by calculating a difference score between average congruent and incongruent RTs (i.e., mean incongruent trial RT – mean congruent trial RT) for each participant. The cueing effect score was calculated separately for each condition (i.e., arrow, and each of the emotional face conditions), and an overall gaze cueing effect score was calculated by performing the same subtraction (i.e., mean incongruent trial RT – mean congruent trial RT) collapsed across all gaze trials. I then looked at the correlation between the cueing effect score and ADHD traits by performing Spearman correlations (as the Shapiro-Wilk normality test indicated that the distributions of cueing effect scores were not normally

distributed). Correlations between cueing scores and ASD traits and cueing scores and self-reported social impairment were also computed. Next, repeated measures multiple regression was utilized to test the effects of ADHD and ASD symptoms, condition, and congruence on RTs. To simplify interpretation of regression analyses and to align with procedures in previous work, mean RT on correct trials served as the outcome variable, and only arrow and neutral gaze conditions (i.e., not emotional face trials) were used. In the first step of the regression, main effects of condition, congruence, and symptom variables were entered. The 2-way interaction terms were entered in the second step based on *a priori* hypotheses (i.e., the interaction between congruence and neurodevelopmental traits). Variables were mean-centered prior to computing interaction terms. Finally, to explore how ADHD traits modulate emotional gaze cueing, hierarchical regression models were run separately for happy and fearful gaze cue performance using ADHD symptoms and congruence as predictors and RT on happy or fearful trials as the outcome variable.

Results

All data were normally distributed, with skew less than 3 and kurtosis less than 10. Two univariate outliers were detected on the WFIRS-S and 16 outliers were detected on mean RT data; these data were winsorized to be equivalent to three standard deviations above or below the mean. No other univariate or multivariate outliers were identified. Descriptive statistics are presented in Table 8.

Table 8

Descriptive Statistics for Self-Report Questionnaires.

	M	*SD*	Min	Max	Cronbach's *a*
ADHD Symptoms	-12.56	15.06	-51	32	.92
ASD Traits	116.58	12.91	83	151	.86
Social Impairment	5.54	4.53	0	19.29	.82
Depression Symptoms	23.29	14.04	1	52	.86

Table 9

Bivariate Correlation Matrix Between Self-Report Questionnaires.

	AQ	WFIRS-S	CESD
SWAN	.17*	.20*	.31**
AQ	-	.30**	.32**
WFIRS-S	-	-	.61**

Note. *$p < .05$ ** $p < .001$

Correlation Between Traits and Social Impairment

Bivariate correlations were significant and positive between ADHD traits and social impairment, $r(167) = .20$, $p = .008$, and ASD traits and social impairment, $r(167) = .30$, $p < .001$, indicating that higher levels of self-reported neurodevelopmental traits were associated with greater self-reported social problems in daily life (Table 9).

Online Replicability of the GOE

Because the COVID-19 pandemic precluded in-person research at the time of this study, the cueing task was administered online. Because this task is traditionally conducted in-lab, I first sought to assess whether typical patterns of findings emerge when this task is modified for

online delivery, prior to evaluating core research questions concerning neurodevelopmental traits.

Hit Rate

Overall accuracy on the gaze cueing task was very high, with an average of 93.20% correct responses, and only 6.80% of trials lost due to incorrect responses, misses, or timeouts (i.e., no response within 500ms window). The main effect of congruence on hit rate was significant, $F(1,166) = 21.02$, $MSE = 0.00$, $p < .001$, $\eta^2_p = 0.11$, such that hit rates were significantly higher on congruent relative to incongruent trials. A main effect of condition also emerged, $F(2.78,461.15) = 43.00$, $MSE = 0.00$, $p < .001$, $\eta^2_p = 0.21$. Pairwise comparisons revealed that arrow trials had a significantly lower hit rate than fearful trials ($p < .001$) but were not significantly different from neutral ($p = .359$) or happy ($p = .999$) trials. Within gaze cue trials, fearful trials had a significantly higher hit rate than neutral ($p < .001$) and happy trials ($p < .001$). Finally, neutral trials had a significantly higher hit rate than happy trials, $p = .018$. There was no significant congruence by condition interaction, $F(2.81,466.74) = 0.37$, $MSE = 0.00$, $p = .763$, $\eta^2_p = 0.002$.

Reaction Time

Consistent with predictions, a main effect of congruence emerged, $F(1,166) = 87.34$, $MSE = 533.84$, $p < .001$, $\eta^2_p = 0.35$, such that RTs were significantly faster on congruent relative to incongruent trials. A main effect of condition was also significant, $F(2.51,416.88) = 59.62$, $MSE = 263.86$, $p < .001$, $\eta^2_p = 0.26$. Pairwise comparisons revealed that arrow trials had a significantly slower RT relative to each gaze cue condition (all ps $< .001$). Within gaze cue conditions, happy trials had significantly faster RTs than neutral ($p < .001$) and fearful trials ($p =$

.024), while fearful trials were responded to significantly faster than neutral trials, $p < 0.001$. The congruence by condition interaction was not significant, $F(2.88,478.34) = 2.45$, $MSE = 146.38$, $p = .065$, $\eta^2_p = 0.02$. (see Figure 7 and Table 10).

Results from an ANOVA without the arrow condition again revealed main effects of congruence ($F(1,166) = 88.28$, $MSE = 383.17$, $p < .001$, $\eta^2_p = 0.35$) and condition ($F(1.94,322.68) = 37.20$, $MSE = 160.45$, $p < .001$, $\eta^2_p = 0.18$). In this case, main effects were qualified by a significant congruence by condition interaction, $F(1.94,322.25) = 3.85$, $MSE = 133.06$, $p = .023$, $\eta^2_p = 0.02$. Post hoc t-tests revealed that for congruent trials, neutral trials had significantly slower RTs than happy ($t(166) = 7.85$, $p < .001$) and fearful ($t(166) = 6.63$, $p < .001$) trials. RTs on happy and fearful trials did not differ, $t(166) = 1.94$, $p = .130$. On non-congruent trials, RTs were faster for happy trials relative to neutral trials ($t(166) = 5.01$, $p < .001$), but did not differ between neutral and fearful ($t(166) = 2.12$, $p = .089$) and happy and fearful ($t(166) = 2.26$, $p = .064$) trials.

Table 10

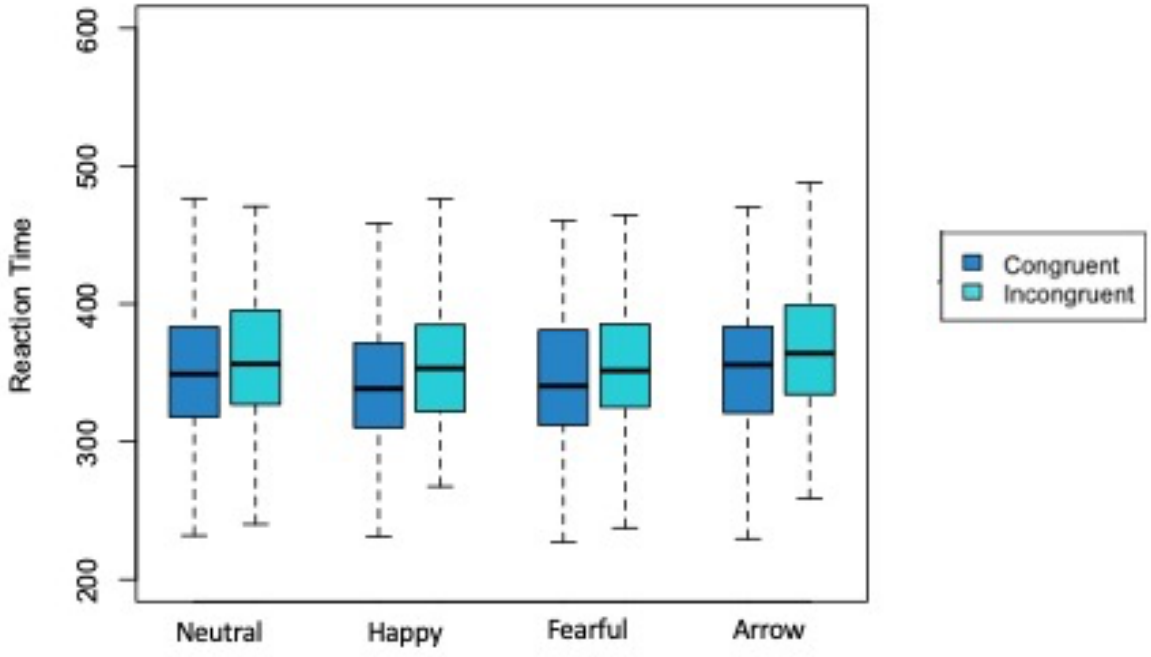
Mean Reaction Times (in ms) for Each Task Condition.

	Congruent		Incongruent		
	M	*SD*	*M*	*SD*	*p*
Neutral	355.04	52.57	363.96	54.12	0.13
Happy	345.00	50.56	357.78	51.55	0.02
Fearful	347.29	49.24	360.85	54.55	0.02
Arrow	359.20	52.02	371.83	58.36	0.04

Note. p-values represents results from t-tests comparing significance between congruent and incongruent trial reaction times within each condition.

Figure 7

Mean Reaction Time Data.



Note. Dark blue represents congruent trials while light blue represents incongruent trials. The black line in each box represents the median, and the tops and bottoms of each box represent the interquartile range between the 25th and 75th percentile.

GOE and ADHD Traits

Spearman correlation between ADHD traits and cueing effect score were non-significant for both face and arrow cueing scores (see Table 11). Taking a regression-based approach, main effects of ADHD traits, congruence, and condition (i.e., neutral gaze or arrow cue) were entered

into the model as predictors, while RT served as the outcome variable. The resulting model was statistically significant, $F(3,672) = 2.91$, $R^2 = 0.01$, $p = .034$. Congruence significantly predicted RT, $B = 10.78$, $SE = 4.18$, $p = .010$, such that congruent trials were responded to faster than incongruent trials. Arrow vs. gaze cue condition ($B = 6.02$, $SE = 4.18$, $p = .151$) and ADHD traits ($B = 0.02$, $SE = 0.14$, $p = .890$) did not significantly predict RT. To investigate the *a priori* hypothesis that ADHD traits would interact with congruence (i.e., ADHD traits predicting less of an RT boost on congruent trials), this interaction term was entered in the second step of the model. The addition of this interaction term did not explain significantly more variance in reaction time ($\Delta F(1,671) = 0.86$, $p = .355$), and the interaction term was not significant, $B = 0.26$, $SE = 0.28$, $p = .355$, so this interaction was not probed further. To summarize, no relationship emerged between self-reported ADHD traits and the GOE.

GOE and ADHD with ASD Traits

ASD traits were not correlated with gaze or arrow cueing scores (see Table 11). Using regression, the overall model evaluating the impact of both ADHD and ASD traits on RT was significant, $F(4, 671) = 4.72$, $R^2 = 0.03$, $p < .001$. Once again, congruence significantly predicted RT, $B = 10.78$, $SE = 4.15$, $p = .001$, such that congruent trials yielded faster response times than incongruent trials. Again, there was no main effect of arrow vs. gaze condition, $B = 6.02$, $SE = 4.15$, $p = .148$, or ADHD traits, $B = 0.05$, $SE = 0.14$, $p = .696$, on RT. However, there was a significant main effect of ASD traits on RT on the task, $B = 0.52$, $SE = 0.16$, $p = .002$, such that higher levels of ASD traits predicted overall slower mean RT on the task. In the second step of the model, interaction terms were entered to test *a priori* hypotheses regarding the interactions between ADHD traits and congruence, and ASD traits and congruence. The addition of these

interaction terms to the model did not explain significantly more variance in our outcome measure ($\Delta F(2, 669) = 0.44$, $p = .647$). The interactions between ADHD traits and congruence ($B = 0.26$, $SE = 0.28$, $p = .354$) and ASD traits and congruence ($B = 0.02$, $SE = 0.33$, $p = .954$) were both non-significant, and thus were not probed further. To summarize, endorsement of higher ASD traits directly predicted slower RT on the cueing task, regardless of whether the cues were social (i.e., eye gaze) or non-social (i.e., arrows). However, this was a main effect; that is, ASD traits were not correlated with the GOE.

Table 11

Correlation Between Self-Reported Traits/Social Impairment and Cuing Effect Scores for Each Condition.

	Neutral Cueing Effect	Happy Cueing Effect	Fearful Cueing Effect	Arrow Cueing Effect	Gaze Cueing Effect
ADHD Traits	$r_s = .09$, $p = .246$	$r_s = .07$, $p = .339$	$r_s = .05$, $p = .502$	$r_s = .03$, $p = .684$	$r_s = .13$, $p = .103$
ASD Traits	$r_s = .11$, $p = .169$	$r_s = -.08$, $p = .303$	$r_s = .15$, $p = .058$	$r_s = -.22$, $p = .144$	$r_s = .09$, $p = .262$
Social Impairment	$r_s = .05$, $p = .479$	$r_s = .04$, $p = .569$	$r_s = .03$, $p = .714$	$r_s = .01$, $p = .916$	$r_s = .08$, $p = .320$

Note. Spearman rho (r_s) is reported for each analysis.

Emotional Modulation of GOE and ADHD Traits

ADHD traits were not correlated with the cueing effect score in either the fearful or happy emotional gaze cueing conditions (see Table 11). Using a regression-based approach, a model exploring whether ADHD traits and congruence predict RT in only fearful trials did not yield a significant model, $F(2, 335) = 2.88$, $R^2 = 0.01$, $p = .057$. Congruence significantly predicted RTs ($B = 13.56$, $SE = 5.66$, $p = .017$), while ADHD traits did not ($B = 0.03$, $SE = 0.19$,

p = .874). When only happy trials were explored, the overall model was again non-significant, $F(2, 335) = 2.64$, $R^2 = 0.01$, p = .073, and congruence was the sole significant predictor of RT (B = 12.78, SE = 5.56, p = .022), while ADHD traits again did not predict RT (B = 0.01, SE = 0.19, p = .975). Thus, when emotional gaze cue trials are looked at on their own, no relationship emerges between ADHD traits and RT.

GOE and Social Impairment

To explore whether self-reported symptoms of social impairment correlated with the cueing effect, bivariate correlations between WFIRS-S and cueing effect scores were calculated (see Table 10). Self-reported symptoms of social impairment were not correlated with gaze or arrow cueing scores.

Discussion

Social impairment in everyday life has been identified as a pervasive feature in ADHD (Hoza, 2007; Nijmeijer et al., 2008; Uekermann et al., 2010), though underlying mechanisms remain poorly understood. Instinctual orienting of attention towards eye gaze is an important social attentional skill that emerges early in development and allows individuals to appropriately orient attention to the most relevant social information (McKay et al., 2021). This aspect of social attention is predictive of social competence and has shown atypicalities in other neurodevelopmental disorders with social impairment (e.g., Akiyama et al., 2008; Gillespie-Lynch et al., 2013; Hayward & Ristic, 2017; Frischen et al., 2007; Kliemann et al., 2010).

This work evaluated whether ADHD traits measured along a continuum in a non-clinical sample predicted the strength of the GOE. While I identified a correlation between higher ADHD symptomology and greater social impairment in everyday life, contrary to my hypothesis,

results showed a stable GOE across varying levels of ADHD symptomology (see also Lee et al., 2015). This finding differs from my hypothesis, and from another recent study that utilized a similar paradigm and did identify a reduced GOE in adults with ADHD (Uono et al., 2023). Findings also contradict previous work that has demonstrated absence of the GOE in children with ADHD (Guo et al., 2019; Marotta et al., 2014; Marotta et al., 2017). It is unclear why results from the present study did not replicate other studies that employ similar cueing tasks, however it may relate to methodological differences (e.g., online study delivery), the larger sample size used here, or population (e.g., non-clinical sample) differences, discussed in more detail below. Nonetheless, my results do continue to highlight the inconsistencies seen when trying to answer the question of the status of spontaneous orienting to gaze cues in ADHD.

Secondarily, I sought to test whether ADHD traits influenced emotional modulation of the gaze orienting effect. Adding emotional expression as a variable in the gaze cueing paradigm has generally demonstrated that creating the perception of an emotional reaction to the gazed-at location on the screen creates faster reaction times towards congruent targets (e.g., McCrackin & Itier, 2018). This is thought to be due to the enhanced ecological validity of the added emotion, given that real-world social information most often integrates both shifts in gaze direction and emotional reactions (Capozzi & Ristic, 2020; Lassalle & Itier, 2015). In this study, I found that participants responded faster to happy and fearful faces relative to neutral faces, in keeping with previous work (Chen et al., 2021). However, symptoms of ADHD did not interact with this pattern. While extant findings on this topic are sparse, there is a considerable literature documenting atypical processing of threat-related emotions in ADHD (e.g., Uekermann et al., 2010; Williams et al., 2008). Consistently, one study identified that angry facial expressions in

particular interfered with gaze cueing for adults with ADHD (Manoli, 2019). Accordingly, I hypothesized that this pattern may particularly impact orienting to fearful faces for those with high levels of ADHD traits; however, I did not in fact see any relationship between ADHD symptomology and the GOE to fearful gaze cues. Overall, these findings contribute to a small but growing literature investigating the interaction between emotional processing and gaze cueing in ADHD, and are consistent with one other recent study that did not identify a relationship between ADHD and emotional modulation of gaze cueing (Uono et al., 2023).

In order to adopt an approach consistent with the transdiagnostic conceptualization of neurodevelopmental disorders, I measured ASD traits in addition to ADHD traits in this work. Like ADHD traits, endorsement of more ASD traits was positively correlated with everyday social problems. With respect to the GOE, extant findings are mixed regarding whether ASD interferes with orienting to gaze cues, with some work indicating atypical gaze cueing and other studies suggesting intact basic cueing but more difficulty emerging with gaze orienting under more demanding circumstances (e.g., a more complex social environment; Zhao et al., 2017). In this work, I did not find evidence of a relationship between ASD traits and the GOE, mirroring other similar findings which suggest equivalent performance between ASD and non-ASD participants on laboratory gaze cueing tasks, and perhaps lending further support to the notion that orienting to gaze cues is intact in ASD on simple tasks such as this gaze cue paradigm but becomes more implicated in social attentional problems in social environments with greater complexity (Zhao et al., 2017).

Despite not identifying support for hypothesized relationships with respect to ASD and the GOE, an unexpected finding did emerge whereby participants who endorsed higher levels of

ASD traits demonstrated a main effect of overall slower performance on our cueing task across both social and non-social cueing trials. While the present work had initially set out hypotheses vis-à-vis social cues in particular, this result of a main effect of slower orienting is consistent with meta-analytic results in children, which also demonstrated overall general slower RTs on cueing tasks compared to controls across both arrow and gaze cueing trials (Landry & Parker, 2013). In that meta-analysis looking specifically at studies on childhood ASD, they identified increases in the overall slower orienting with older age within childhood. Here, I found evidence for this same pattern emerging in a sample of young adults when ASD is measured dimensionally, lending additional evidence to their findings in an extended age range. Overall, these findings lend support to the idea that visual orienting more broadly, not purely to social stimuli, may be of relevance in ASD.

Previous literature has indicated that gaze cueing appears to have important predictive value vis-à-vis social competence (e.g., Hayward & Ristic, 2017). Thus, I additionally investigated whether there was a correlation between the GOE and self-reported problems with social functioning in everyday life. Within the present sample, social impairment in daily life did not correlate with the GOE. The findings presented here may indicate that performance on gaze cueing tasks has less bearing on competent social abilities in everyday life than previously thought. Similarly, other work has indicated that the GOE does not correlate with other important social cognitive abilities, such as Theory of Mind (Neath et al., 2013).

Because restrictions associated with the COVID-19 pandemic necessitated online administration of the gaze cueing task, this afforded the opportunity to assess whether the gaze cueing task would replicate when delivered in an online environment. The gaze cueing task is a

classical experimental paradigm, however it is almost exclusively administered in-lab, and to our knowledge it has not been administered online to date. My results replicate several expected patterns of performance on the gaze cueing task, most notably both faster RTs and higher hit rates were identified on congruent relative to incongruent trials, suggesting participants are benefiting from the gaze cue to orient attention. As well, I replicate other findings suggesting that participants benefit preferentially from gaze cues over arrow cues, and from emotionally valenced gaze cues over neutral gaze cues (e.g., McCrackin & Itier, 2018). Taken together, these findings suggest that similar patterns of performance emerge on the task regardless of delivery method, so long as stringent quality control of data is enacted.

While the present study afforded the opportunity to assess the gaze cueing task online and offered an interesting opportunity to explore a traditionally laboratory-based paradigm in a relatively novel context, it also limited control over the environment of participants during testing. Stringent quality control procedures and significant visual inspection of data were utilized to try to minimize the impact of poor quality data. Overall, the regression models can only explain about 5% of variance in task performance, indicating that it is possible that there may be extra noise introduced by variables such as the lack of control over the testing environment. The self-report nature of symptom questionnaires represents another limitation of the present work. While assessing traits of neurodevelopmental disorders in a dimensional fashion is an overall strength of this work in many ways, employing self-report questionnaires to assess ADHD does also come with limitations. Specifically, research suggests that self-reporting on ADHD symptoms produces higher rates of individuals who fall into a clinical range relative to individuals who have a clinical diagnosis of the disorder from a medical professional (Garnier-

Dykstra et al., 2010). Self-report data is further vulnerable to bias in response style and requires a high level of self-reflection and insight into one's own day to day functioning. Other limitations of this work include a narrow age range of the sample and a gender breakdown of participants that does not reflect the split typically seen in the broader population.

In sum, the present study did not detect a relationship between orienting to gaze cues and ADHD traits. Instead, this work demonstrated that attentional orienting seems to benefit from gaze cues, in terms of both accuracy and speed of gaze shift, regardless of ADHD or ASD symptom burden. This work further replicated findings regarding emotional modulation of gaze cueing, demonstrating that emotional faces – and fearful faces in particular – facilitate gaze orienting even more than neutral eye gaze cues. However, I did not find a relationship between ADHD or ASD symptoms and emotional modulation of gaze cueing. Future work may wish to explore whether other factors are important for understanding gaze cueing in ADHD, for example the complexity of the task or the complexity of the environment, which may help explain apparent inconsistencies in the ability to allocate social attention in individuals with ADHD. Furthermore, expanded scope of study to other core social attentional skills in ADHD is warranted in future work in order to continue the search for social skills in need of remediation in ADHD in order to aid in the development of effective, targeted social skills interventions for this population.

Chapter 5: General Discussion

ADHD is a prevalent neurodevelopmental disorder characterized by impairing symptoms of inattention, hyperactivity, and impulsivity. Although social impairment is commonly reported by individuals who have ADHD, the reason or reasons why are unclear. Some work attributes social impairment as secondary to symptoms of inattention (e.g., inattention would cause individuals with ADHD to miss out on important social learning opportunities) or hyperactivity/impulsivity (e.g., children with ADHD might be intrusive in class or not properly follow the rules of a game, causing ostracization from classmates). On the other hand, other work suggests that cognitive deficits may underlie social impairment in the context of ADHD, mirroring the etiology of social impairment in other neurodevelopmental disorders (e.g., ASD). This perspective proposes that problems with the core building blocks needed to properly engage in the social world exist in ADHD and lead to downstream behavioural consequences such as lower popularity amongst peers and fewer reciprocal friendships. While attempts have been made to improve social function in individuals with ADHD, such as social skills training, as of yet these interventions have not been found to be efficacious. Without a clear understanding of the etiology of social impairment in ADHD, it is likely that intervention programs are unable to identify the specific target for intervention, thus limiting effectiveness. This dissertation aims to contribute to the literature clarifying the nature of social impairment in ADHD by evaluating two core social attentional skills – self-referential processing and gaze orienting – in individuals with varying levels of ADHD traits. Importantly, ADHD traits are measured in a dimensional fashion

in accordance with the RDoC framework and in recognition of the normal distribution of ADHD traits amongst the general population.

This dissertation also measured dimensional traits of ASD, in addition to ADHD traits, given the growing acknowledgement of ADHD and ASD as neurodevelopmental disorders that frequently co-occur and share a high degree of phenotypic overlap (Mikami et al., 2019). Specifically, while social functioning is a core area of deficit in ASD according to diagnostic criteria, recognition of the prevalence of social impairment in ADHD has added to the understanding that viewing common symptoms of neurodevelopmental disorders (e.g., social skill impairment) through a transdiagnostic lens may add value in research, in line with the RDoC approach. As a secondary aim, this work sought to additionally assess how ASD traits impact the core social attention skills evaluated here. It was hypothesized that individuals reporting high levels of ASD traits would show a similar pattern of performance on social cognitive tasks as individuals with only high levels of ADHD traits, however the magnitude of social cognitive difficulties may differ.

Self-Referential Processing in ADHD

In Chapter 2, I shared findings from a study investigating self-referential processing in individuals with varying levels of ADHD traits. Although there is a paucity of research examining self-referential processing in ADHD, it is an important social cognitive skill that relies heavily on attentional resources and is subserved by the very same neural substrates that are implicated in ADHD, making it a logical candidate for further inquiry in ADHD (Mitchell et al., 2005; Sidlauskaite et al., 2016; Turk et al., 2013; Yamawaki et al., 2017). I employed the SRET, a classical social cognitive task initially developed in the 1970s and used widely for over

five decades, to understand how individuals process self-relevant information (Symons & Johnson, 1997). I adapted this task to an online environment because of infection control measures associated with the COVID-19 pandemic. Results of this study did not support the hypothesis of deficits in self-referential processing in the case of ADHD, nor did I identify a relationship between ASD traits and self-referential processing. However, interpretation of these results was complicated by the overall lack of a consistent SRE in our greater sample. This finding led to a more thorough investigation into the SRET literature, finding other recent work that has questioned the replicability of this task (e.g., Dainer-Best et al., 2018; Klein, 2012).

In a follow up study, Chapter 3 explored similar questions regarding self-referential processing in ADHD with an important adaptation to the experimental paradigm aimed to increase the social relevance of the task. Previous work adapting the SRET in this manner demonstrates similar patterns of findings regarding prioritization of self-referential information in memory (e.g., McCrackin et al., 2021). Unlike the prior study, the anticipated SRE did emerge in this online study, perhaps due to the increased social relevance created in this task. However, once again, ADHD traits did not interfere with the SRE, as demonstrated by equivalent memory benefit afforded to words encoded in a self-referential context across the continuum of ADHD traits. ASD traits also did not modulate the SRE. Surprisingly, ADHD and ASD traits did emerge as a significant predictor of overall performance on the SRET; however, instead of interacting with self-relevance as predicted, a main effect was found, such that higher self-reported levels of ADHD and ASD traits predicted better memory performance on the SRET, regardless of referent at encoding. Finally, self-reported social impairment in daily life did not interact with self-

relevance on the SRET, in contrast to the hypothesis that higher levels of social problems in everyday situations would reduce the SRE.

Together, findings from Chapters 2 and 3 converged to suggest that ADHD (and ASD) traits do not interfere with or reduce self-referential processing. Results contradicted the hypothesized role that high levels of ADHD symptoms may play in impairing the utilization of self-relevance as a salient social cue by not affording this type of information the enhanced attentional resources it usually receives. Instead, results suggested that individuals reporting even very high levels of ADHD symptoms can recognize that self-relevance is an important cue that warrants greater attention and deeper processing, resulting in a memory boost for this information. Results from these studies suggested that this is the case in both more neutral tasks (i.e., just judging whether an adjective describes you) and more socially evaluative tasks (i.e., reading opinion statements about you from another person). In both cases, ADHD traits appear unrelated to the adaptive ability to zone in on self-relevant information.

Unfortunately, interpretation of some of these findings is complicated by inconsistencies in the emergence of the SRE, which may stem from the sensitivity of the SRET to small methodological changes, as discussed in more detail in Chapter 2. In this body of work, this same trend may manifest; that is, the two studies utilized very similar experimental procedures, with the exception of a relatively small modification to the SRET encoding method. Thus, the inconsistent emergence of the SRE may further indicate that the SRET is highly sensitive to small methodological changes. In this case, a simple adjective judgment task, delivered online, may not be sufficient to induce the SRET, whereas a more socially threatening, socially evaluative task can elicit this effect. To further support this interpretation, I conducted t-tests to

ensure equivalence between both samples in terms of average age ($p = 0.541$), exposure to English language ($p = 0.814$), ADHD traits ($p = 0.494$), and depression symptoms ($p = 0.293$). Chi-square testing also confirmed equivalence between samples in terms of participant gender ($p = 0.411$). These analyses ensured no significant differences between the two samples, and that differences in the social evaluative nature between tasks may explain the inconsistent findings between studies.

In addition to inconsistencies in results, my findings indicated that the SRE was not related to self-reports of social problems encountered in everyday life. This result further complicates the interpretations of the findings here, as it introduces the idea that rather than my results not identifying a core social attentional deficit in ADHD, instead I may have not selected a task sensitive to detecting this type of deficit. That is, the absence of an association between the SRE and a more face-valid indicator of social function (i.e., self-reported social functioning) may suggest that the SRET has less robust implications for higher level social outcomes than previously hypothesized.

Overall, this dissertation contributes to the literature suggesting that further work may be needed to re-evaluate whether the SRET is quite as robust as previously thought, as well as whether it has bearing on everyday social competence. Future work may wish to consider these implications when using this task to assess self-referential processing and social cognitive abilities more broadly. Despite complications in interpretation due to task-related limitations, findings from two studies across over 500 unique participants converge to demonstrate that self-reported levels of ADHD and ASD traits do not modulate self-referential processing.

Gaze Orienting in ADHD

Chapter 4 explored a different social skill: orienting to eye gaze cues. Spontaneous orienting of attention in the direction of another person's eye gaze is a foundational social attentional skill that typically develops early in life and subserves important social abilities (Itier & Batty, 2009). Existing work regarding the state of gaze orienting in ADHD has produced conflicting findings, with some - albeit inconsistent – evidence of atypical gaze cueing in ADHD (Marotta et al., 2014; Marotta et al., 2017; Uono et al., 2023). With respect to the replication of this experimental paradigm online, this study did detect the typical gaze orienting effect. That is, I found significantly higher accuracy and faster reaction times to congruent rather than incongruent gaze cues. As well, eye gaze cues facilitated attentional orienting better than arrow cues, and congruent emotional gaze cues were responded to faster than neutral gaze cues. These findings were consistent with hypotheses, lending support to the notion that the gaze cueing paradigm can transfer to online administration. I did not identify a significant association between gaze orienting and self-reported social impairment in daily life. With respect to ADHD-related hypotheses, however, I did not identify evidence of impaired gaze orienting in ADHD. These findings are consistent with some other studies that identify typical patterns of performance on gaze cueing tasks in individuals with ADHD (Lee et al., 2015; Tye et al., 2013). This is also consistent with the orienting of attention to non-social cues in ADHD, where research generally demonstrates that this aspect of attention is intact in ADHD (e.g., Mullane et al., 2011).

While it was initially hypothesized that ADHD traits may interfere with orienting to gaze (but not arrow) cues, results did not support this hypothesis. As discussed in more detail in Chapter 4, prior literature on this subject has produced mixed findings. It is unclear exactly why

there are discrepant findings on the topic, as there is significant overlap in methodological approaches across studies evaluating this research question. When reviewing the literature that does find GOE abnormalities in ADHD, one notable observation is that there are frequently quite small sample sizes used in these studies. For example, Marotta and colleagues (2017) included only 38 total participants (19 with ADHD), while Marotta (2014) involved 44 total participants (22 with ADHD). Uono and colleagues (2023), who identified a smaller (but still present) GOE in ADHD relative to non-ADHD participants, included 45 participants in each group (i.e., 90 total participants). In contrast, the present sample consisted of almost 200 participants, and is significantly greater than the samples used in those studies that do find an effect. While it remains unclear why there is inconsistency in the literature, it is worth noting that certain studies may lack sufficient power to make strong claims about impaired gaze orienting in ADHD, especially in light of difficulty with consistent replication of this finding.

Implications for Underlying Mechanism Behind Social Impairment

To summarize, this dissertation work selected two core social attentional skills – self-referential processing and orienting to eye gaze – and investigated whether they differed among young adults expressing differing levels of ADHD symptomology. The findings from this dissertation aim to contribute to the literature exploring circumscribed social cognitive skills in the context of ADHD to elucidate why social impairment is evident at the behavioural level in ADHD. Taken together, the results presented in this dissertation suggest that the core aspects of social attention selected for investigation do not subserve social impairment seen in ADHD.

A possible interpretation of these findings is that they signal intact low level social attentional skills in ADHD. Accordingly, this interpretation also suggests that the mechanism

behind social impairment evident at the behavioural level in ADHD may not be due to deficits in circumscribed social attentional skills; individuals with ADHD may indeed possess intact low-level social attentional abilities and can perform equivalently to others when these skills are measured on controlled laboratory tasks. Instead, impairment emerges at another level of the social information processing system: recruiting and using these low-level skills in highly complex social environments. This interpretation is consistent with work suggesting that social impairment in ADHD is not a reflection of a deficit in social skill knowledge, but rather a problem with implementing these social skills (Aduen et al., 2018; Cervantes et al., 2013). Many factors have been proposed that may interfere with the application of these skills to real world social situations. These include symptoms of inattention, hyperactivity, and impulsivity; deficits in executive function (EF); and emotion regulation challenges. Indeed, there is evidence to support the notion that inattentive symptoms interfere with children's ability to learn and attend to rules of a games and activities, impacting their social engagement with peers (Mrug et al., 2007). Hyperactivity/impulsivity symptoms have similarly been linked to real-world social functioning consequences. For example, one study identifies that young boys with high levels of hyperactive/impulsive behaviours were rated as less popular by peers and as being less socially proficient by observers (Ronk et al., 2011). With respect to EF, EF deficits have been found to play a mediating role in the relationship between ADHD and social functioning, suggesting that deficits in this domain may account for social dysfunction (Tseng & Gau, 2013). Consistently, other work finds that working memory abilities – an important component of EF – explain poorer social communication abilities in those with high levels of ADHD symptoms (Nilsen et al., 2015). In terms of emotion regulation, it has been well documented that emotion regulation

deficits are pervasive in ADHD and are often linked with adverse social outcomes, although heterogeneity in emotion dysregulation is documented within ADHD (Bunford et al., 2018; Musser et al., 2013). Work examining the impact of emotion dysregulation on social functioning in ADHD identifies that, when considered in conjunction with factors discussed above, emotion dysregulation may play an important role in social outcomes; for example, one study identifies that emotion regulation problems mediate the relationship between inattentive symptoms and social impairment in college studies (Ryan et al., 2016). The work presented in this dissertation did not directly assess these factors. However, lack of evidence for deficits in social attentional skills studied here may be interpreted as supporting any of these other proposed mechanisms as the root cause of social dysfunction. Future research may wish to continue to explore how, and to what extent, these features of ADHD explain social impairment.

In addition to inattention, hyperactivity/impulsivity, EF, and emotion dysregulation, another alternative mechanism that may explain social impairment in ADHD is the high burden of comorbidities that are quite common in ADHD. While comorbidity with ASD is considered here, there are also high levels of comorbidity between ADHD and other neurodevelopmental disorders, such as oppositional defiant disorder (ODD), which also carry deficits to social functioning and frequently co-occur with ADHD (Gnanavel et al., 2019). Indeed, there is evidence to suggest additional symptom burden in ADHD with other comorbidities, for example one study identifies that individuals with ADHD and ODD, but not ADHD alone, possess deficits in facial emotional recognition (Noordermeer et al., 2020). The results presented in this dissertation, which do not identify a link between ADHD and social attentional deficits, may

lend support to the notion that other mechanisms, including possibly EF, emotion dysregulation, and co-morbidity, explain social impairment evident in ADHD.

Alternatively, instead of outright dismissing the contribution of low level social attentional skills to social impairment in ADHD, the result presented in this dissertation may also be interpreted as indicating that the present work did not identify the correct social skills that may be the root cause of impairment in ADHD, or utilized tasks that do not have as much bearing on social competence as initially hypothesized. Initially, this dissertation chose to select social skills that are highly reliant on attentional processes, hypothesizing that the deficits in attentional processes inherent in ADHD may make these social skills particularly worthy of investigation in ADHD. However, because findings from the three studies presented here do not point towards deficits in either of these areas, it remains possible that other core social skills serve as the underlying mechanism. For example, a meta-analysis exploring the social skill of facial emotion recognition in ADHD does identify evidence for a deficit in this skill, however heterogeneity in findings across the literature does remain (Romani et al., 2018). Thus, it remains possible that impairment in other core social skills outside of those selected in this dissertation cause social dysfunction in ADHD, however additional work is still needed to identify which of these skills produce replicable findings of impairment. Moreover, there are indications in the data presented here that neither the SRE nor the GOE are related to self-reports of social problems in everyday life. Accordingly, it is possible that these tasks are not sensitive to problems in social function at a higher level of analysis, and thus obstruct the ability to detect a relationship between ADHD and social abilities in these studies. Overall, future work looking for more consensus findings on the nature of the many other very important social cognitive abilities

in ADHD is warranted. Further work evaluating the sensitivity of social attentional laboratory tasks to everyday social problems is also needed. Work evaluating these questions would contribute greatly to furthering the understanding of the social cognitive profile of ADHD.

Social Skills Interventions

Other important implications that stem from my work relate to designing interventions that can improve day to day social functioning for individuals with ADHD. Thus far, the literature exploring extant social skills interventions in ADHD has not revealed consistent evidence for improved interpersonal concerns in youth with ADHD (Mikami et al., 2017; Morris et al., 2021; Storebø et al., 2019; Willis et al., 2019). One meta-analysis concluded that there was not sufficient evidence to indicate that social skills training can improve teacher- or parent-rated social skills, another meta-analysis evaluating the existing literature of social skills interventions specifically in adolescents with ADHD found no evidence for improvement in parent or teacher rated social skills following participation in the intervention programs; overall, almost all recent meta-analyses on the topic converge to suggest that there is little evidence to support the efficacy of social skills interventions in ADHD (Mikami et al., 2017; Morris et al., 2021; Storebø et al., 2019). While there is one meta-analysis evaluating social skills training in a broader age range of ADHD patients that does find some promising results, they do identify several limitations, most notably that any gains made during the intervention do not last long-term (Willis et al., 2019). Because of the state of findings on social skills interventions, one author suggests that most promising way to improve efficacy of social outcomes may be via peer counselling for classmates of children with ADHD on acceptance – suggesting that the intervention itself is not improving social skills amongst children with ADHD (Mikami et al., 2017).

While it is unclear why exactly a clearly effective social skills intervention has yet to be developed, one potential reason is difficulty choosing appropriate treatment targets because of a lack of understanding of what skills need remediation. This work can help contribute to this literature by providing further evidence of some social skills that do not seem to be appropriate targets for remediation. Results from this dissertation point towards perhaps either other social skills or a higher level of analysis as the intervention.

Dimensional Conceptualization and Assessment of Neurodevelopmental Disorders

This work sought to contribute to the growing literature studying psychopathology such as ADHD from a dimensional rather than categorical perspective. This work adopted a dimensional approach to measuring traits of both ADHD and ASD. As discussed previously, this approach aligns with principles of the NIMH's RDoC, which posits that a dimensional approach to studying mental health in research may be more appropriate than a categorical approach, as it allows researchers to look at varying degrees of dysfunction in different domains of functioning outside the confines of individual categorical diagnoses, and understand how these behavioural phenotypes relate to underlying biological systems. Across the studies presented here, I have collected three large samples of participants who were asked to self-report on their own ADHD symptoms burden using this dimensional approach. Across the three studies, I consistently identified that endorsement of these traits was approximately normally distributed. This aligns with other work that has used this approach to explore traits of ADHD – including findings from a very large community sample of over 16000 youth which similarly finds that these traits are normally distributed in the general population (Crosbie et al., 2013).

The work presented in this dissertation lends further support to the notion that viewing ADHD traits along a continuum, instead of conducting research through a categorical lens, may add value in understanding ADHD traits and their associations with important psychosocial and biological features, and functional outcomes. Indeed, other work examining the link between ADHD traits and certain cognitive variables have found that they are related in a linear fashion along the entire continuum of ADHD traits, including what would be 'sub-threshold' ADHD from a categorical diagnostic perspective, and aligns with neuroimaging data identifying profiles of resting state functional brain connectivity that vary dimensionally along with symptoms of inattention and hyperactivity measured along a continuum (Pruim et al., 2019; Salum et al., 2014). In this work, I consistently identified a correlation between ADHD traits and social impairment in everyday life, lending further support to the idea that there is merit in evaluating ADHD-related outcomes from a dimensional perspective.

Overall, while the RDoC framework represents a relatively novel taxonomy of psychopathology, the work presented here adds to the quickly growing body of literature suggesting that is a fruitful avenue for further research that will broaden our understanding of ADHD, and psychopathology more generally, by allowing researchers to gain a better understanding of domains that cut across traditional diagnostic categories and may be related to important underlying neurobiological factors at the heart of the development and maintenance of psychopathology. The work presented here serves as one example of an application of this approach to research into functioning in neurodevelopmental disorders.

Online Adaptation Due To COVID-19 Pandemic

This research was conducted in the context of the COVID-19 pandemic, leading to two potential important implications regarding our findings. Firstly, infection control measures precluded in-lab data collection, requiring a pivot to online delivery of traditional in-lab experimental paradigms. As a result, I had the opportunity to investigate whether two popular experimental paradigms in the social cognitive literature are able to be adapted to online delivery. While this represents a limitation as it reduced experimental control over the data relative to when this study is typically conducted in-lab, it also represented an opportunity to explore a relatively novel adaptation to these important paradigms. With respect to the SRET, thus far only a small number of studies have administered this paradigm online, with only one study examining the memory component of the SRET. That study was able to replicate the traditional SRET findings online. My work, on the other hand, was varied: while one study did replicate a traditional SRET pattern (i.e., better memory for self- relative to other-referential information), the other study did not detect this pattern. As discussed above, this is consistent with other work demonstrating that the SRET appears to be vulnerable to slight alterations to the experimental paradigm, perhaps suggesting it is not as robust as previously thought. With respect to the online adaptation of the gaze cueing task, I have not identified previous work attempting to administer this task online. My work suggests that this task can translate to online delivery. In order to try and replicate in-lab findings, several measures were taken, such as providing participants with specific instructions regarding their setup while doing the task. Specifically, it was required that participants complete the study on a computer (i.e., they were not allowed to use a mobile device), and they were required to be seated at a desk or table with the screen in a specific position. Compliance with these instructions was assessed through self-report, with

participants being told that their answers would have no bearing on remuneration. While an in-lab setting does offer more experimental control around this setup, my findings indicate that the GOE is robust enough to be detected even without ideal experimental conditions.

Moreover, it has been documented that the pandemic and associated infection control measures had a significant impact on the mental health of Canadian university students (King et al., 2022). This was reflected in all three of the samples I collected, where I saw very high self-reported levels of depression, anxiety, and stress symptoms. This persisted across data collected over the course of several terms (i.e., between September 2020 when data collection commenced for Study 1 to November 2022 when collection of Study 3 participants concluded) with varying levels of infection control measures in place. Emerging evidence suggests that the prevalence of low mood across my studies is consistent with other samples assessed during this unique time period. However, my work included unique considerations regarding the role of depression symptoms, particularly in light of the well-established impact that depression exerts on self-referential processing. Specifically, individuals with depression have been demonstrated to show a negativity bias in self-referential processing (Auerbach et al., 2016; Benau et al., 2019; Dainer-Best et al., 2017; Shestyuk & Deldin, 2010). That is, while people typically process positive, self-referential information most readily, individuals with depression instead demonstrate a self-negativity bias, a notable pattern given that our paradigm investigating self-referential processing included valence as a variable. As a result, separate analyses are included as an Appendix for Chapter 2, given that I was unable to identify the expected SRE in this study. In this appendix, I examined the same research questions using only a subset of the larger sample that falls below the clinical threshold for depression on the CESD. Results from this subgroup are consistent with

findings from the whole sample with respect to SRET performance. This suggests that while higher-than-expected rates of depression is an important consideration in my work, it is unlikely to fully explain some of the unexpected null results with respect to the SRE. Nonetheless, depression is clearly a key variable that must be considered in this work, particularly given its consistently high correlation with self-reported social problems in daily life across samples presented here. Further work using samples outside the context of pandemic-related restrictions would likely help understand whether these findings generalize.

Limitations and Future Directions

Other important limitations of this work include the use of self-report measures to capture symptoms of neurodevelopmental disorders and social impairment in daily life. Self-reporting on one's behaviour requires a high degree of insight in order to accurately judge whether and to what extent something applies to you. While it was outside the scope of the present work, future work collecting collateral reports of neurodevelopmental disorder symptoms or social problems in daily life may help address this limitation. As well, as reviewed previously, ADHD symptoms are measured along a continuum in this work, which I believe is an overall strength of the work as this more accurately reflects how ADHD traits present in the general population and aligns with the RDoC framework. However, it does not allow for a comparison between individuals who have received a clinical diagnosis of ADHD by a trained medical professional versus a control group. However, although the work presented here was guided by a dimensional framework, I nonetheless elected to collect data on formal ADHD diagnoses across all studies. These data revealed that a small number of participants in each sample endorsed having a clinical diagnosis of ADHD (a total of 52 participants across all studies – albeit a high number of

participants also endorsed being unsure about whether they had a diagnosis or preferred not to answer this question). Given the approach taken in this dissertation, while these data were collected, they were not used in subsequent analyses related to social impairment or social attention, as this was outside the scope of the current research questions. While the lack of a clinical ADHD sample is not necessarily a limitation of my work given the above-mentioned advantages of a dimensional approach, adoption of a categorical approach would have allowed for more direct comparison between this work and other similar literature that does traditionally use a categorical framework when comparing social attentional skills between participants in an ADHD group versus a non-ADHD group. The small percentage of participants endorsing a clinical ADHD diagnosis in these samples (relative to previous work that recruits clinical vs. control groups of relatively equivalent size) does suggest that some caution may need to be used when comparing these results to previous work.

The lack of demographic diversity with respect to gender and age in the sample may further limit generalizability of the findings and represents a potentially fruitful avenue for future research. Specifically, in all three studies presented in this dissertation, the samples are highly skewed towards female rather than male participants. It is notable that this does not reflect the demographic breakdown of ADHD and ASD: The distribution of ADHD and ASD in the population is more heavily skewed towards male, with some estimates suggesting the prevalence is twice as high in males relative to females (Adak & Halder, 2017; Ayano et al., 2023; Espinet et al., 2022). As well, there may be phenotypic differences in presentation between genders of ADHD symptoms and social impairment (Loyer Carbonneau et al., 2021). For these reasons, further investigation with a sample that more closely represents the gender distribution of ADHD

in the population may yield more insights about social attention in ADHD. As well, my samples consisted of undergraduate university students specifically. This is a notable limitation of my work to consider for two important reasons: Firstly, the age range of all samples used was mostly limited to young adults, meaning the samples did not capture whether these social skills may have differences at other developmental stages, particularly at a younger age. It remains possible that individuals with ADHD demonstrate a different developmental pattern acquiring these skills but catch up by the time they reach young adulthood, which is when they are captured here in my work. Future research investigating similar questions using a sample of children or adolescents may shed light onto this possibility. Secondly, because the participants used in this work are all university students, they may not be representative of the general population – a concern which is brought forward by a recent meta-analysis that demonstrates that convenience samples of undergraduate students may not be representative of the broader population (Wild et al., 2022). Thus, even at the high end of the continuum of ADHD, these studies are capturing individuals who are high functioning enough to achieve admission to a competitive postsecondary institution. Therefore, these samples may be missing some of the true range of variability in symptoms, in particular at the higher end of impairment.

Conclusions

Overall, the work presented in this dissertation furthers our understanding of social skill deficits in the context of ADHD. Specifically, I sought out to determine whether two specific core social attentional skills – self-referential processing and gaze orienting – were different in the case of ADHD. Over the three studies presented here, I identified that these core skills do not seem to be implicated in the disorder. This helps shed light on the question as to why

behaviourally evident and impairing social impairments in ADHD exist, and helps further our understanding of some low level social attentional processes that are unlikely to be at the root of social problems. This work demonstrated that at this level of analysis, there was no difference in self-referential processing or spontaneous gaze orienting at varying levels of ADHD trait presentation. These results, while somewhat complicated due to online administration of tasks, point towards the need for future research to evaluate other contributors to social impairment in ADHD in the search to identify what factors are at play in order to develop appropriate and effective intervention programs.

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Appendix A: Supplemental Analyses of SRE in Low Depression Sub-Sample

Due to unanticipated high levels of depression symptomology in the present sample, analyses were re-run on participants who were self-reporting symptoms below the clinical threshold for depression (i.e., a score below 20 on the CESD, which has been found to provide the best trade-off between sensitivity and specificity when screening for depression in the general population; Vilagut et al., 2016). This subgroup of the dataset consisted of 123 participants ranging in age from 18 to 46 (M = 20.72, SD = 4.17) and was mostly female (68%). Data cleaning and analysis procedures were the same as described in the manuscript.

Online Replicability of the SRET

Adjective Endorsement

There was a significant effect of valence, $F(1,122) = 1158.58$, $MSE = 5.05$, $p < .001$, $\eta^2_p = 0.90$, indicating that participants endorsed significantly more positive than negative words. The main effect of referent was not significant, $F(1,122) = 2.87$, $MSE = 1.50$, $p = .09$, $\eta^2_p = 0.02$. However, there was a significant referent by valence interaction, $F(1,122) = 4.93$, $MSE = 4.46$, $p = .03$, $\eta^2_p = 0.04$. Post-hoc tests revealed that participants endorsed positive words with equivalent frequency for both themselves and others ($p = .32$), but were more likely to endorse negative words in reference to others than the self ($p = .003$).

Free Recall

A main effect of referent emerged as hypothesized, $F(1,122) = 27.25$, $MSE = 1.50$, $p < .001$, $\eta^2_p = 0.18$, with self-referential trait adjectives recalled more often than other-referential words. The main effect of valence $F(1,122) = 3.66$, $MSE = 1.39$, $p = .06$, $\eta^2_p = 0.03$, and the

referent by valence interaction, $F(1,122) = 0.25$, $MSE = 1.62$, $p = .62$, $\eta^2_p = 0.002$, were not significant.

Recognition Hit Rate

There was a significant main effect of valence, $F(1,122) = 6.17$, $MSE = 2.79$, $p = .01$, $\eta^2_p = 0.05$, with negative words recognized better than positive words. The main effect of referent was not significant, $F(1,122) = 1.03$, $MSE = 1.78$, $p = .31$, $\eta^2_p = 0.01$. There was a significant interaction between valence and referent, $F(1,122) = 9.73$, $MSE = 1.54$, $p = .002$, $\eta^2_p = 0.07$, reflecting that self-referential words were better recognized if they were positive rather than negative ($p < .001$), whereas other-referential words were remembered equally well regardless of whether they were positive or negative ($p = .89$).

Recognition Memory Sensitivity (d')

The main effect of referent was not significant, $F(1,122) = 1.44$, $MSE = 0.14$, $p = .23$, $\eta^2_p = 0.01$. There was a significant main effect of valence, $F(1,122) = 26.95$, $MSE = 0.50$, $p < .001$, $\eta^2_p = 0.18$, which was qualified by a significant referent by valence interaction, $F(1,122) = 11.73$, $MSE = 0.13$, $p < .001$, $\eta^2_p = 0.09$. Post-hoc tests indicated that positive words were recognized equally across referent ($p = .11$), whereas negative words were recognized better when they were other-referential ($p = .002$).

SRE and ADHD Traits

The first step of the hierarchical regression model evaluating the effect of referent, valence, and ADHD symptoms on memory sensitivity resulted in a statistically significant model, $F(3, 488) = 11.15$, $R^2 = 0.06$, $p < .001$. Referent was not a significant predictor of memory sensitivity, $B = -0.04$, $SE = 0.06$, $p = .536$. Valence did significantly predict memory

sensitivity, B = -0.33, SE = 0.06, p < .001, with negative words recognized better than positive words. Finally, ADHD symptoms significantly predicted memory sensitivity in this group, B = 0.01, SE = 0.002, p = .010, with higher levels of ADHD symptoms predicting better performance on the recognition task. To investigate the hypothesis that ADHD traits would interact with word referent, this interaction term was entered in the second step of the model. The addition of this interaction term did not explain significantly more variance in recognition sensitivity (ΔF(1, 487) = 0.28, p = .596), and the interaction term was not significant (B = -0.002, SE = 0.005, p = .596), so this interaction was not probed further.

SRE and ADHD with ASD Traits

Next, we evaluated the impact of both ADHD symptoms and ASD traits on memory sensitivity. The overall model was significant, F(4, 487) = 8.36, R^2 = 0.06, p < .001. Once again, higher levels of ADHD symptoms (B = 0.01, SE = 0.002, p = .01) and negative valence (B = -0.33, SE = 0.06, p < .001) significantly predicted better memory sensitivity, while referent was not a significant predictor of memory sensitivity, B = -0.04, SE = 0.06, p = .54. ASD traits were also not a significant predictor of memory sensitivity, B = -0.001, SE = 0.002, p = .83. In the second step of the model, interaction terms were entered to test a priori hypotheses regarding the interactions between ADHD symptoms and word referent and ASD symptoms and word referent. The addition of these interaction terms to the model did not explain significantly more variance in our outcome measure (ΔF(2, 485) = 0.27, p = .765). The interaction between ADHD symptoms and word referent (B = -0.002, SE = 0.004, p = .582) and ASD symptoms and word referent (B = -0.002, SE = 0.005, p = .614) were both non-significant.