Working memory and social competence in individuals with attention-deficit/hyperactivity disorder (ADHD) symptoms and autism spectrum disorder (ASD) traits

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ABSTRACT

Attention Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD) are heterogeneous neurodevelopmental disorders with similar functional impairments. Specifically, working memory (WM) deficits have been found in studies of both ADHD and ASD and social competence has been identified as an area in which these individuals also struggle. The purpose of this study was (a) to identify which components of working memory (WM; based on Baddeley's 2000 model) are deficient and (b) to explore how WM deficits contribute to social problems in individuals with varying levels of ADHD symptoms and ASD traits. It was hypothesized that visuospatial (VS) WM deficits would be evident in the three analogue clinical groups, phonological (PH) WM and central executive (CE) deficits would be more evident in groups with high ADHD symptoms, all three analogue clinical groups would have lower social competence, and WM abilities would moderate the relationship between ADHD symptoms and social competence. In Phase I, 1311 undergraduate students participated in an online survey on general psychopathology, ADHD symptoms, and ASD traits. From this sample, a subgroup (n = 60) completed Phase II, an in-lab session that included WM tasks, a brief cognitive assessment, and social conversation task. Although WM deficits were not identified for any group, all participants demonstrated worse performance on the VS WM task than the PH WM task. However, WM abilities did not moderate the relationship between ADHD symptoms and social competence. Exploratory analyses were conducted with similar results. Limitations and suggestions for future research are discussed.

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Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a heterogeneous neurodevelopmental disorder characterized by developmentally inappropriate levels of inattention, hyperactivity, and impulsivity (American Psychiatric Association [APA], 2013). The prevalence of ADHD is estimated to be 5% in children and 2.5% in adults, with more males than females meeting criteria for the disorder (APA, 2013). Overall, gender differences range from 6.4:1 to 3:1, males greater than females (Keen & Ward, 2004; Szatmari, Offord, & Boyle 1989). Autism spectrum disorder (ASD), another heterogeneous neurodevelopmental disorder, is defined by persistent deficits in social communication and social interaction as well as restricted, repetitive patterns of behavior, interests or activities (APA, 2013). The prevalence of ASD is 0.9-1% in the US, with similar estimates for children and adults (APA, 2013; Centers for Disease Control and Prevention [CDC], 2012). As with ADHD, gender differences are also found in ASD, with rates of males to females estimated to be 4-5:1 (APA, 2013; World Health Organization, 1992). ADHD symptoms were previously thought to be part of the presentation in individuals with ASD and not distinct from it; however, with recent changes to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), comorbidity between ADHD and ASD as separate disorders is allowed. Prevalence estimates of comorbidity of ADHD in individuals with ASD vary from 1:3 (Simonoff, Pickles, Charman, Chandler, Loucas, & Baird, 2008; Leyfer, Folstein, Bacalman, Davis, Dinh, Morgan, et al., 2006) to 1:2 (Holtmann, Bolte, & Poutska 2006; Sinzig, Walter, & Doepfner, 2009) depending on sampling, diagnostic criteria, and methodology. For example, in a recent study specifically examining ADHD symptoms from both parent and teacher report in children with a diagnosis of ASD, it was found that less than 16% of the ASD youth met clinically significant levels of ADHD symptoms (Hanson, Cerban,

Slater, Caccamo, Bacic, & Chan, 2013). Therefore, the "true" rate of comorbidity between ASD and ADHD is not clear at this time.

The National Institute of Mental Health (NIMH) has suggested that the focus of research shift away from diagnostic categories and instead examine mechanisms and dimensions across disorders (Insel, Cuthbert, Garvey, Heinssen, Pine, Quinn, Sanislow, & Wang, 2010; Sanislow, Pine, Quinn, Kozak, Garvey, Heinssen, Wang, & Cuthbert, 2010). The NIMH proposed research domain criteria (RDoC), including five domains that were proposed to account for endophenotypes, or the expression of the genetic liability, of psychological disorders (see Doyle, Faraone, Seidman, Willcutt, Nigg, Waldman, Pennington, Peart, & Biederman, 2005; Insel & Cuthbert, 2009). The five domains are cognitive systems, negative valence systems, positive valence systems, systems for social processes, and arousal/regulatory systems. Working memory, one area of the cognitive systems domain, is defined as an individual's ability to simultaneously process and temporarily store information for use toward a goal (Baddeley, 2007). Working memory is differentiated from short-term memory such that working memory is the process requiring attention whereas short-term memory is the component which taps specialized storage and rehearsal processes (Alloway, Gathercole, Kirkwood, & Elliott, 2009). Specifically, according to multiple models (e.g., Baddeley, 2007; Unsworth & Engle, 2007), working memory involves not only the temporary storage and rehearsal of information, but also control of attention (i.e., central executive) to ensure that task goals are maintained in an active state and to reduce interference (Unsworth & Spillers, 2010).

Working Memory

Baddeley (2007) proposed a model of working memory (WM) that includes four components: the visuospatial sketchpad, the phonological loop, the central executive, and the

episodic buffer. As the name suggests, the visuospatial sketchpad is primarily used for the temporary storage of visual and spatial information and is associated with spatial working memory; on the other hand, the phonological loop is proposed to processes auditory information and is associated with verbal working memory. The central executive (CE) is responsible for dividing attention among different stimuli, and essentially regulating the information that is being attended to and used at a particular point in time. That is, the central executive does not involve storage of information; rather, it acts as the controller of attention, such that tasks involving more cognitive control place more demands on the central executive (Engle & Kane, 2004, Unsworth & Spillers, 2010). Individual differences in WM capacity are attributable to the individual's ability to control attention in order to maintain goal-relevant information when interference or competition for attention is present (Engle & Kane, 2004). Finally, the episodic buffer organizes the visual, verbal, and auditory information into the correct chronological sequence. All of these components are hypothesized to work together for individuals with intact WM abilities. Although other models of WM have been proposed (e.g., the dual-component model; Unsworth & Engle, 2007), Baddeley's (2007) model of the storage/rehearsal and CE components will be examined in this study as it has been widely studied in relation to WM deficits in both ADHD and ASD (see Figure 1). Due to lack of research on the episodic buffer, it will not be investigated here.

WM Deficits in ADHD

Evidence for WM deficits in individuals with ADHD have been found in the three components of WM. That is, individuals with ADHD have difficulty with storage of visual-spatial information (e.g., Murphy, Barkley, & Bush, 2001), storage of phonological information

(e.g., Alderson, Hudec, Patros, & Kasper, 2013), and controlling attention to maintain both visual-spatial and phonological information (e.g., Alderson, et al., 2013).

Specifically, Martinussen, Hayden, Hogg-Johnson, and Tannock (2005) conducted a meta-analysis and found that children with ADHD showed more impairment in maintaining and manipulating visual-spatial (VS) information than in verbal information. Additionally, Willcutt and colleagues (2005) found that children with ADHD exhibited weaknesses in visual-spatial information in a separate meta-analysis. Additionally, neuropsychological profiles for individuals with ADHD tend to show greater right (spatial) than left (verbal) hemisphere involvement (Karatekin, 2004). Other studies have also found WM deficits for VS information in children with ADHD (Barnett, Maruff, Vance, Luk, Costin, Wood, & Pantelis, 2001; Brocki, Randall, Bohlin, & Kerns, 2008; Martinussen & Tannock, 2006).

In studies of adults with ADHD, evidence is mixed for the continued presence of VS WM deficits. For example, in a study of young adults with ADHD, auditory (phonological) working memory was found to be intact but nonverbal (visual-spatial) working memory was impaired (Murphy, Barkley, & Bush, 2001). On the other hand, Alderson, Hudec, Patros, and Kasper (2013) found that adults with ADHD performed similarly to healthy adults on a VS WM task, suggesting that VS WM deficits in adults with ADHD may improve over time as compared to children with the disorder. However, the task purity on VS WM performance needs to be considered in understanding these apparent differences. Murphy and colleagues (2001) used the Simon game, which presented the stimuli with both a colored light and a tone corresponding to the color, as a measure of nonverbal working memory. Although the sequence should be remembered visually (i.e., colored light pattern), it is possible that some participants were using the different tones (i.e., phonological working memory) to rehearse the information. Therefore,

the results may not directly reflect pure VS WM deficits. On the other hand, Alderson and colleagues used a task adapted from Rapport and colleagues' (2008) study of WM deficits in children with ADHD that required frequent attentional shifts between concurrent processing of new information and rehearsal/maintenance of information temporarily held in the buffer/storage component and did not find any differences between the VS WM performance of adults with ADHD and healthy controls (Alderson et al., 2013). Nonetheless, evidence for VS WM deficits in adults is mixed despite the number of studies demonstrating impairments in children with ADHD.

In contrast to Martinussen and colleagues' (2005) meta-analysis of WM deficits in children with ADHD, Boonstra and colleagues (2005) conducted a meta-analytic review of WM in adults with ADHD and found deficits in adults were primarily in phonological working memory (PH). As noted above, Alderson and colleagues (2013) used an adaptation of Rapport and colleagues' (2008) working memory tasks to investigate working memory deficits in adults with and without ADHD. The tasks they used required frequent attentional shifts and rehearsal/maintenance of information temporarily held in the buffer/storage component and found that the central executive and phonological storage/rehearsal processes of adults with ADHD were both significantly impaired relative to healthy adults. Furthermore, other studies have demonstrated auditory WM deficits in adults with ADHD using tasks such as the Paced Auditory Serial Addition (PASAT) and digit span (Karatekin & Arsanow, 1998; Lineweaver, Kercood, O'Keeffe, O'Brien, Massey, Campbell, & Pierce, 2012; Murphy, Barkley, & Bush, 2001). However, studies of forward and backward span tasks have been shown to be measures of short-term memory rather than assessments of working memory as they do not place sufficient demand on the "working," or central executive, component (see Cantor, Engle, & Hamilton,

1991; Engle, Tuholski, Laughlin, & Conway, 1999). Therefore, deficits in PH WM for adults with ADHD may be reflective of auditory short-term memory difficulties or in the storage/rehearsal of auditory information within WM. As such, PH WM deficits in adults with ADHD warrant further investigation.

Alderson and colleagues (2013) also found that adults with ADHD were significantly more impaired in central executive (CE) processes relative to healthy control adults. Similar deficits in CE processes were found for boys with ADHD (Rapport, Alderson, Kofler, Sarver, Bolden, & Sims, 2008). It is possible that such deficits are more related to attention difficulties, as Unsworth, Spillers, and Brewer (2009) have suggested that the ability to control attention in order to maintain goal relevant information when there is substantial distraction and interference is responsible for individual differences in working memory capacity. That is, working memory capacity is the efficiency of the CE component, often tested using complex span tasks and requiring attentional control (Engle et al., 1999; Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004). Although results are mixed, there is some evidence to suggest that all three components of WM (i.e., VS, PH, and CE) are deficient in individuals with ADHD.

WM Deficits in ASD

Evidence for WM deficits in individuals with ASD has been found primarily in the visual-spatial component of WM. That is, individuals with ASD have difficulty with storage of visual-spatial information (e.g., Morris, Rowe, Fox, Feigenbaum, Miotto, & Howlin, 1999); however, storage of phonological information seems to be intact (e.g., Williams, Goldstein, Carpenter, & Minshew, 2005). The central executive has not yet been investigated within the context of WM deficits in individuals with ASD, so it is not known if these individuals show deficits in this area.

Williams and colleagues (2005) investigated verbal and spatial WM in children, adolescents, and adults with autism and found a dissociation between verbal and spatial WM. That is, individuals with autism performed at a similar level to cognitive- and age-matched controls on tasks that involved the phonological loop (i.e., verbal WM) but performed poorer than controls on tasks that involved the visuospatial sketchpad (i.e., spatial WM). They suggested that this dissociation may be due to underlying neurobiologic substrates that may be impaired in one form of WM (e.g., visuospatial sketchpad) but not the other (e.g., phonological loop; Williams et al., 2005). However, Ozonoff and Strayer (2001) did not find deficits with individuals with ASD in comparison to a group with Tourette Syndrome and typically developing children. Conversely, Minshew, Luna, and Sweeney (1999) found that individuals with autism were significantly impaired compared to controls, showing more response suppression errors and impaired precision in reaching the target following a delay on an oculomotor response task.

Steele, Minshew, Luna, and Sweeney (2007) suggested that inconsistent evidence for spatial WM deficits in individuals with autism may be due to insufficient task difficulty relative to the ability level of the participants. That is, individuals with autism may only show spatial WM deficits when the memory load is sufficiently taxed and exceeds a threshold. For example, Morris and colleagues (1999) used a spatial WM task with a high memory load and found deficits in individuals with Asperger's syndrome compared to an age- and IQ-matched control group. Additionally, abnormal prefrontal cortical functioning has been documented in autism that may suggest visual-spatial WM systems are compromised (see Horowitz, Rumsey, Grady & Rapoport, 1988; Luna, Minshew, Garver, Lazar, Thulborn, Eddy, & Sweeney, 2002; Ohnishi, Matsuda, Hashimoto, Kunihiro, Nishikawa, Uema, & Sasaki 2000; Zilbovicius, Garreau,

Samsom, Remy, Barthelemy, Syrota, & Lelord, 1995). For example, Luna and colleagues (2002) investigated fMRI results of adults with autism during an oculomotor spatial working memory task and a visually guided saccade task. They suggested that spatial WM was impaired as a result of decreased activation (i.e., abnormalities in the neocortical circuitry) in the dorsolateral prefrontal cortex and posterior cingulate cortex during the task (Luna et al., 2002).

Verbal or auditory (i.e., phonological) WM abilities have generally been found to be intact in individuals with ASD (see Koshino, 2005; Mottron, Morasse, & Belleville, 2001; Williams et al., 2005; Williams, Goldstein, & Minshew, 2006). However, Bennetto and colleagues (1996) found verbal WM was impaired in comparison to clinical controls on counting and sentence span tasks. That is, adolescents and young adults in the autistic group (i.e., meeting DSM-III-R criteria for Autistic Disorder or Pervasive Developmental Disorder Not Otherwise Specified), performed worse than the verbal IQ-matched comparison group (Bennetto, Pennington, & Rogers, 1996). Additionally, Minshew and Goldstein (2001) found verbal WM to be intact in individuals with autism (mean age = 22), but as the complexity of the span task increased (i.e., greater semantic complexity), deficits in this area were more apparent, which they attributed to a reduced use of contextual structure and organizational strategies (i.e., from letters to words to sentences). This finding suggests that verbal WM deficits are apparent in individuals with ASD only when task demands are high, such that the task requires more cognitive resources to complete. Researchers have also found that individuals with ASD have difficulty in retaining and/or manipulating the temporal order of verbal material using oral recall of digits, written recall of words, and recognition of change in temporal sequence (Poirier, Martin, Gaigg, & Bowler, 2011). Although there is some evidence to suggest that individuals with ASD have difficulty with verbal WM tasks, both studies that found impairments used tasks (i.e., span tasks)

that are considered tests of short term memory rather than measures of WM (due to the lack of the combination of storage and mental manipulation of information; see Cantor et al., 1991; Engle et al., 1999).

Therefore, VS WM deficits appear to be established in multiple studies in adults with ASD (Luna et al., 2002; Minshew, Luna, & Sweeney, 1999; Williams et al., 2005). However, given the mixed evidence regarding PH WM deficits in individuals with ASD, it remains to be seen if the results are due to choice of task (i.e., span tasks), insufficient task demands, or there are simply no deficits in this area. Additionally, no studies to date have investigated if central executive (CE) WM deficits are present in individuals with ASD; although, the deficits that are evident in the VS component may be due to difficulty controlling attention to successfully maintain information "on-line" for use in the task. Therefore, more targeted investigation of potential WM deficits in individuals with ASD is needed.

Social Competence

Not only do individuals with ADHD and individuals with ASD have deficits in WM, they also show impairment in their social interactions. Specifically, these individuals often show lower social competence than healthy adults. Social competence is defined as the "skills that facilitate interpersonal interaction in the social environment, including the expression and control of nonverbal communication" (p. 50, Friedman, Rapport, Lumley, Tzelepis, VanVoorhis, Stettner, & Kakaati, 2003). Individuals with ADHD have difficulty relating to their peers and much of the research in this population has focused on social outcomes such as peer acceptance or friendships (e.g., Hoza, 2007). Individuals with ASD also have trouble relating to their peers; however, the focus of investigation in this population often concentrates on social cognition and theory of mind deficits as well as communication problems (e.g., Frith & Happe, 1994; Sigafoos,

Schlosser, Green, O'Reilly, & Lancioni, 2008). Given that these two populations have difficulty in social interactions (e.g., Bauminger, Solomon, Aviezer, Heung, Gazit, Brown, & Rogers, 2008; Friedman et al., 2003; Scheeren, Koot, & Begeer, 2012; Whalen & Henker, 1992), it follows that examining what behaviors individuals with ADHD and individuals with ASD display in common in social situations would be informative in understanding how such problems develop.

ADHD

Abikoff and colleagues (2002) found that children with ADHD are more likely to be rated as inappropriately intrusive during conversations or when playing with their peers. Furthermore, children with ADHD have difficulty shifting between giving and receiving in dyadic interactions with a peer (Guevremont & Dumas, 1994; Saunders & Chambers, 1996). Additionally, Clark and colleagues (1988) found that dyads with one ADHD child engaged in less reciprocal verbal interactions than comparison dyads with no ADHD child. Based on these studies, children with ADHD have difficulty both initiating and engaging appropriately in dyadic social interactions. Furthermore, when interacting with their friends, children with ADHD were found to show a self-centered and insensitive approach (Normand, Schneider, Lee, Maisonneuve, Kuehn, & Robaey, 2011). Finally, children with ADHD tend to show intense and overly intrusive behaviors in social exchanges, such as being loud, energetic, and forceful (Whalen & Henker, 1992).

In one interesting study by Landau and Milich (1988), children with ADHD were assigned to roles as either a host or a guest in a television talk show game. Children with ADHD were found to ask too many questions as a guest and too few questions as a host, evidencing communication difficulties or misunderstanding of their roles in this context. In this way, these

children appeared to be less adaptive in their ability to shift their social communication patterns according to task cues. The authors attributed this difficulty to a possible inability to respond to social or environmental cues for appropriate behaviors for the role they were assigned. They also suggested that the communication difficulties in children with ADHD may elicit negative responses from peers (Landau & Milich, 1988). Additionally, in a later study, Landau and Moore (1991) found that children with ADHD have difficulty responding appropriately to continually changing cues and demands that are typical of social interactions. Therefore, children with ADHD show difficulty with social communication as well as reading and appropriately responding to social cues.

Some have suggested that social impairments associated with ADHD are due to hyperactive and impulsive symptoms. For instance, behaviors that may be perceived as rude and obnoxious by others such as interrupting conversations, being intrusive, blurting comments, and being impatient may be due to behavioral disinhibition, a core feature of ADHD (Barkley, 1997; Friedman et al., 2003). Furthermore, symptoms of inattention (i.e., being easily distracted, having difficulty listening to others) may be viewed as indifferent and uncaring. In fact, adults with ADHD have rated themselves as less socially skilled at regulating their social behavior than non-ADHD adults (Friedman et al., 2003). Specifically, they reported difficulty with their skills to engage others in conversation as well as their self-presentation skills, including tactfulness and the ability to adjust their behavior to be appropriate to the situation. Therefore, social difficulties in individuals with ADHD are not confined to childhood; in fact, adults with ADHD continue to be impaired in their social interactions in comparison to healthy individuals.

ASD

According to DSM-5 criteria, individuals with mild forms of ASD show social impairment in the areas of social interaction, in that their social skills are less well developed relative to typically-developing peers (APA, 2013). These individuals may have difficulty perceiving peers' social cues and may show more concrete or immature styles of communication, conversation, and language.

As children with ASD get older, they experience additional social problems including: difficulties with initiation of social interactions, maintaining reciprocity, shared enjoyment, perspective-taking, and inferring the interest of others (Bellini, Peters, Benner, & Hopf, 2007). Furthermore, youth with ASD are unlikely to initiate social interactions with their peers and adults (Hauck, Fein, Waterhouse, & Feinstein, 1995). On the other hand, individuals with ASD who have higher intelligence, better adaptive behaviors, and lower autism severity scores tend to seek interactions with others, often in an unusual way such as by holding a monologue about a particular interest or standing too close to a conversation partner (Scheeren, Koot, & Begeer, 2012). Therefore, individuals with ASD either have trouble initiating interactions or initiate interactions in a strange way, including difficulties in communication.

Further problems individuals with ASD experience in the area of social communication include difficulty initiating and sustaining conversations, often talking in monologues without giving others a chance to contribute, having difficulty building and developing on comments made by others, and engaging in less chatting for purely social purposes (Pennington & Ozonoff, 1996). Moreover, individuals with ASD may seem disengaged in conversation as a result of their nonverbal behaviors, having difficulty coordinating their eye gaze, facial expression, and gesture with their speech (Pennington & Ozonoff, 1996). Other social behaviors that are impaired in

individuals with ASD include difficulties with social use of eye contact; greeting in a natural manner (i.e., not stiff); giving and receiving comfort; fitting behaviors to the immediate social context; and verbal interaction (Gillberg, Santosh, & Brown, 2009; Hauck, Fein, Waterhouse, & Feinstein, 1995).

In a study measuring reciprocal behavior, children with high-functioning ASD were less collaborative and less tolerant of an experimenter's input than typical children (van Ommeren, Begeer, Scheeren, & Koot, 2012). In addition, individuals with ASD tend to show inadequate use of eye contact, problems initiating social interactions, difficulty interpreting verbal and nonverbal social cues, inappropriate emotional responses, and a lack of empathy to distress in others (Weiss & Harris, 2001). Deficits in theory of mind, or understanding that other people have different thoughts, desires, and feelings, have also been proposed as underlying many of the difficulties in social interactions in individuals with ASD. These deficits have been found to predict difficulties in reciprocity and empathic prosocial behaviors such as caring and listening (Tager-Flusberg, 2001).

Bauminger and colleagues (2008) coded goal-directed behavior (i.e., cooperative behaviors directly related to performance of the task), sharing behaviors (i.e., experiences or emotions), prosocial behavior (i.e., comforting and behavior), conversation (i.e., small talk and negotiation), nonverbal interaction (i.e., combined eye gaze and smile), affect (i.e., shared laughter and positive affect), and play (i.e., parallel or coordinated play) in children with high functioning ASD. They found that children with high functioning ASD demonstrated fewer goal-directed behaviors and less positive affect, and received lower ratings on conversational flow and social conversation than the typical group (Bauminger, Solomon, Aviezer, Heung, Gazit, Brown,

& Rogers, 2008). Therefore, there is sufficient evidence to suggest that individuals with ASD are not as socially competent as typically developing individuals.

WM Deficits and Social Competence

Few studies have investigated the association between WM deficits and social competence in individuals with ADHD or ASD. However, one recent study examining social problems in children with ADHD found that the CE component had a direct effect on social problems (Kofler, Rapport, Bolden, Sarver, Raiker, & Alderson, 2011). Additionally, Kofler and colleagues found that the PH and VS WM components were indirectly related to social problems through hyperactivity/impulsivity and inattention, respectively. Similarly, Huang-Pollock and colleagues (2009) found that executive function accounted for 40-50% of the variance in memory for conversation in a chat room task in children with ADHD. Although this study did not examine the effect of working memory specifically on social competence, it suggests that performance in a conversational setting may be impacted by executive functions such as working memory. Furthermore, one study of college students with ADHD investigated executive dysfunction, including WM difficulties, and found evidence for impaired social functioning; however, this study did not directly link executive dysfunction with the social problems noted (Weyandt, DuPaul, Verdi, Rossi, Swentosky, Vilardo, O'Dell, & Carson, 2013).

Similar to literature in ADHD, there is a lack of research investigating how WM deficits relate to social competence in individuals with ASD. However, Reed (2002) suggested that symptoms of autism, such as pragmatic language impairment, social interactions, and desire for sameness, might be explained by a deficit in working memory. That is, pragmatic language, such as when to change topics or take turns in conversation, depends on complex information and transient cues, which would be difficult for individuals with working memory deficits to process

efficiently. Furthermore, working memory deficits in individuals with ASD would impact social interactions, which require the integration of a large number of elements. Reed (2002) described social stimuli as being transient and the behavior of people being more difficult to predict than the actions of objects (e.g., blocks) for individuals with ASD. Despite the dearth of studies examining the link between WM deficits and social competence in individuals with ASD, it is likely that similar results to those found in the ADHD literature in that WM deficits may contribute more to lower social competence than that found in neurotypical peers.

Specific Aims

This project has two aims: (a) to identify which components of working memory are deficient in individuals with varying levels of ADHD symptoms and ASD traits; and (b) to explore how working memory deficits contribute to social problems in individuals with varying levels of ADHD symptoms and ASD traits.

Hypotheses

Hypothesis 1: We anticipate that VS WM will be deficient in individuals with high levels of ADHD symptoms and ASD traits.

Hypothesis 2: We anticipate that PH WM and the CE component will be deficient in individuals with high levels of ADHD symptoms.

Hypothesis 3: We hypothesize that individuals with high ADHD symptoms, high ASD traits, and those high in both will display lower social competence than neurotypical controls.

Hypothesis 4: We anticipate that WM abilities will moderate the relationship between ADHD symptoms and social competence. Specifically, we hypothesize that individuals with high levels of ADHD with better WM abilities will have better social competence.

Method

Participants

Individuals were recruited from the Virginia Tech undergraduate student community. Interested participants completed screening questionnaires via an online system (SONA) to initially determine eligibility. Participants were included if they were 18 years or older and had a full scale IQ > 80. A total of 1311 individuals (324 male; mean age = 20.12, SD = 1.69, range = 18-48) completed the screening questionnaires during Phase I. Groups for Phase II were determined by clinical cut-off scores on the Adult Self-Report Scale V1.1 Screener (ASRS; Kessler, Adler, Gruber, Sarawate, Spencer, & Van Brunt, 2007) and on the Broad Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007). Participants whose scores were above the clinical cutoff on both the ASRS (≥ 14 ASRS total score) and the BAPQ (≥ 3.15 BAPQ total score) were placed in the high ADHD/high ASD group. Participants whose scores were below the clinical cutoff on both the ASRS and the BAPQ were placed in the low ADHD/low ASD group. Finally, participants whose scores were high on one screening measure but not the other were placed in one of the other two groups. Four hundred forty-three participants (196 males, 247 females) were randomly chosen and emailed who met screening criteria for one of the four groups (95 low ADHD/low ASD, 116 low ADHD/high ASD, 111 high ADHD/low ASD, 121 high ADHD/high ASD). Although 84 participants (32 males, 52 females) indicated interest in participating in the in-lab appointment, a total of 62 individuals (26 males; mean age = 20.32, SD = 1.35, range = 18-23.57) actually participated in Phase II of the study. Reasons for not participating included: being unresponsive to follow-up emails, unable to schedule appointment (too busy, lack of availability), and not interested in participating. One of the 62 participants was excluded due to difficulty comprehending task instructions, which

interfered with the participant's ability to complete the CASS (see below) and one participant was excluded due to video malfunction, resulting in a total of 60 participants. Therefore, four groups were established: 15 low ADHD/low ASD, 15 low ADHD/high ASD, 15 high ADHD/low ASD, and 15 high ADHD/high ASD.

Phase I measures

Demographic Questionnaire. The demographic questionnaire (Appendix A) was used to collect information about all participants' gender, age, race/ethnicity, declared or expected academic major, class year, expected years to completion of degree, and grade point average (GPA). Participants also reported whether they struggled with or have formally received any psychological diagnoses by a mental health professional by endorsing a checklist of various disorders (e. g., Anxiety Disorder, ADHD, ASD, Depression, Learning Disorder).

Adult ADHD Self-Report Scale V1.1 Screener (ASRS; Kessler, Adler, Gruber, Sarawate, Spencer, & Van Brunt, 2007). The ASRS (Appendix B) is a screening tool for adult ADHD that was developed in conjunction with the World Health Organization (WHO) and the Workgroup on Adult ADHD. It is composed of six questions rated on a 5-point Likert scale from 0 (never) to 4 (always) that are consistent with DSM-IV criteria and address the manifestations of ADHD symptoms in adults. The ASRS takes less than five minutes to complete. The clinical cutoff for the ASRS was determined by summing participant's responses (range 0-24). As suggested by Kessler et al. (20070, participants whose responses totaled 14-24 were determined to have symptoms consistent with adult ADHD. This scoring approach was found to have sensitivity of 64.9% and specificity of 94.0% (Kessler et al., 2007). Although diagnosis of ADHD is recommended to come from multiple reports (interviews, parents, spouses, etc.), studies have suggested that ADHD symptoms can be assessed reliably based on the individual's

account of his/her own behavior (see Murphy & Schachar, 2000). Reliability in the current study was acceptable (Cronbach's α = .77).

Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001). The AQ (Appendix C) is a 50-item self-report measure of characteristics of ASD, originally designed to identify ASD among adults with normal intelligence. The AQ is comprised of five domains: social skills, attention switching, attention to detail, communication, and imagination. All items are rated on a 4-point Likert scale from 1 (definitely agree) to 4 (definitely disagree). Approximately half of the items are worded to produce a "disagree" response and half an "agree" response in a high-scoring person with ASD. AQ items are typically scored in a binary manner, meaning that a response is scored as a one if it is characteristic of ASD (i.e., poor social skill, poor attention-switching, exceptional attention to detail, poor communication skill, and poor imagination) and a zero if it is not characteristic of ASD. Item scores are then summed for a total score ranging from 0 to 50. Higher scores are indicative of more ASD traits. A clinical cut-off score of 32 has been determined (Baron-Cohen et al., 2001). The AQ has been utilized extensively with adults, yielding reliability across time and culture (Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010). It has good internal consistency and test-retest reliability with college students; however, recent estimates of the internal consistency of the subscales have been less than acceptable (e.g., Austin, 2005; Hurst et al., 2007; Ingersoll et al., 2011). In terms of convergent validity, the AQ has been found to be correlated in the predicted direction with a number of theoretically related constructs, but to a somewhat lesser degree than the BAPQ (Ingersoll et al., 2011). In the current study, internal consistency was acceptable (Cronbach's α = .77).

Broad Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007). The BAPQ (Appendix D) is a 36-item self-report questionnaire designed to

identify individuals with the Broad Autism Phenotype (BAP). The BAPQ is comprised of three theoretically-based subscales thought to represent key components of the BAP including: Aloof, Rigidity, and Pragmatic Language. Each item is rated on a 6-point scale from 1 (very rarely) to 6 (very often). Several items are reverse scored to limit the potential for response bias. Scoring is determined by calculating an average of items. ROC analyses determined an average total item score of 3.15 as a clinical cut-point, with 81.8% sensitivity and 78.1% specificity (Hurley et al., 2007). The internal consistency for both the subscales and total measure is acceptable (Hurley et al., 2007). Total scores for the BAPQ have been found to be normally distributed in a college sample, and the proposed three-factor structure has been replicated via exploratory factor analyses (Ingersoll et al., 2011; Wainer et al., 2011). Convergent validity for the BAPQ has been established with direct clinical assessment of BAP, and the BAPQ has been found to correlate significantly with other BAP measures. Reliability in the current study was excellent (Cronbach's $\alpha = .91$).

Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987). The LSAS (Appendix E) is a self-report measure designed to assess anxiety related to social interactions and performance situations. It consists of 24 items rated on a 0-3 Likert scale according to the individual's fear/anxiety and avoidance of each situation. Cutoff scores of 60 are suggestive of social anxiety disorder. The LSAS has good internal consistency (alpha = .96; Heimberg et al., 1999) and convergent validity with other self-report measures of social anxiety. In the current study, internal consistency was excellent (Cronbach's $\alpha = .96$). It was used as a descriptive measure for Phase I respondents.

Phase II measures

Conners' Adult ADHD rating scale, self-report (CAARS: S; Conners, Erhardt, & Sparrow, 1999). The CAARS has 30 items measuring the frequency and severity of inattentive and hyperactive/impulsive dimensions of ADHD symptoms rated on a 4-point scale (0 = not at all, never to 3 = very much, very frequently; see Appendix F). Participant responses yielded five subscales: Total Symptoms, Total DSM-IV ADHD Symptoms, Inattention, Hyperactivity/Impulsivity, and ADHD Index (i.e., features of ADHD in adults that are not diagnostic criteria). The CAARS has demonstrated good reliability and validity (see Adler et al., 2008; and Erhardt et al., 1999). The CAARS was used in the current study as a descriptive measure in order to validate the screening/grouping of participants. It was also used as a continuous predictor of social competence in the exploratory analyses. The reliability of the ADHD Index of the CAARS in the current study was acceptable (Cronbach's $\alpha = .76$).

Social Responsiveness Scale, second edition, Adult Version (SRS-2-A; Constantino & Gruber, 2012). The SRS-2-A is a 65-item self-report measure of ASD-related social impairments, including social awareness, social information processing, reciprocal social communication, social motivation, and restricted interests/repetitive behaviors (see Appendix G). Originally validated for use with children (Constantino & Gruber, 2005), the second edition of the SRS includes an adult self-report (SRS-2-A), specifically normed for individuals age 19 and up. The SRS-2-A provided a total T-score and subscale T-scores about the degree of interference in everyday life situations. The SRS-2-A has a T-score range of 59 or less (normal range), 60 to 65 (mild range), 66 to 75 (moderate range), and 76 or greater (severe range). The SRS-2-A was used in the current study as a descriptive measure in order to validate the screening/grouping of the participants. Reliability in the current study was excellent (Cronbach's $\alpha = .94$).

Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-2; Wechsler, 2011). The WASI-2 provided an estimate of verbal, performance, and full scale IQ. The WASI-2 was comprised of two subtests: Vocabulary and Block Design (see Appendix H). It has demonstrated good reliability with individuals aged 6 to 89 years and can be completed in 15 minutes or less. The WASI-2 was used in the current study to determine inclusion criteria (IQ > 80; see Table 1).

Visuospatial working memory computer task (VS task). The visuospatial working memory computer task (VS) is a modified version of the task developed by Rapport and colleagues (2008) and used by Alderson et al. (2013) with adults. A series of 2.5 cm dots (4, 5, 6, or 7) were presented to participants sequentially for 800 ms each, in one of nine 3.2-cm squares arranged in three offset columns (see Figure 2). One dot was red, but the rest were black. The participant was asked to remember the location of each of the black dots, in order, and remember the position of the red dot last. Participants responded via a keypad resembling the columns on the screen. A trial was comprised of four to seven stimuli and each set-size block consisted of 12 trials (48 total trials). Participants were administered five practice trials prior to the experimental trials and were required to respond correctly to 80% of the practice trials to proceed. Participants did not receive feedback about their performance during practice or experimental trials.

Phonological working memory task (PH task). The phonological working memory task (PH) was similar to the Letter-Number Sequencing subtest in the Wechsler series of intelligence tests (Wechsler, 2011) and was a modified version of a measure developed by Rapport and colleagues (2008) and also used by Alderson et al. (2013) with adults. Participants heard a series of single digit numbers and one letter taken from a prerecorded stimulus bank. Participants were instructed to recall the numbers aloud from smallest to largest followed by the

letter. The experimenter then recorded the responses on an answer sheet and reliability of the recording of the response was later coded. The current study obtained excellent reliability between the original experimenter's recording and the reliability coder's recording of the participants' responses (set size 4 Cronbach's $\alpha = .98$, set size 5 Cronbach's $\alpha = .97$, set size 6 Cronbach's $\alpha = .94$, set size 7 Cronbach's $\alpha = .99$). A trial was comprised of four to seven stimuli and each set-size block consisted of 12 trials (48 total trials). Participants were administered five practice trials prior to the experimental trials and were required to respond correctly to 80% of the practice trials to proceed. Participants did not receive feedback about their performance during practice or experimental trials.

Contextual Assessment of Social Skills (CASS; Ratto, Turner-Brown, Rupp, Meisbov, & Penn, 2011). The CASS was a brief observational measure designed to assess conversational skills of adolescents and adults with ASD. This measure was unique from other measures, as it attempted to assess participants' ability to perceive nonverbal cues of their conversation partner and adjust their behavior in reaction to such responses. During this task, participants were observed during two 3-minute semi-structured role-plays, during which they interacted with two different confederates. Participants spoke only to confederates of the opposite sex. The social context was manipulated by modifying the confederate's level of interest in the conversation: during the first conversation the confederate demonstrated social interest and engagement, and during the second conversation the confederate demonstrated boredom and disengagement. Confederates were trained to modify their behavior to portray either boredom or interest. Also, confederates were given specific instruction regarding their participation in the conversation.

All conversations were videotaped and participants' verbal and non-verbal behaviors for each conversation were coded on nine dimensions: Asking Questions, Topic Changes, Vocal Expressiveness, Gestures, Positive Affect, Kinesic Arousal, Social Anxiety, Overall Involvement in the Conversation, and Overall Quality of Rapport. Two trained raters coded each set of videotaped role-plays. The items Asking Questions and Topic Changes were scored as behavioral counts and the remaining items were rated on a scale from 1 to 7 (1 = low, 7 = high). In previous research, the items: Asking Questions, Topic Changes, Overall Involvement, and Overall Quality of Rapport were examined as primary outcomes (Ratto et al., 2011). Change across these items was examined, comparing scores on the interested versus bored context: normal social adaptation in the bored context involves an increase in Asking Questions, Topic Changes, and Overall Involvement, and a decrease in Overall Quality of Rapport. A CASS total change score was calculated by standardizing and summing the scores on the previously mentioned four items for both the interested and bored contexts (Overall Quality of Rapport was reverse scored) and subtracting the interested total score from the bored total score. Higher scores were indicative of more normative adaptation between contexts.

In a pilot study of the CASS, across all items, internal consistency was high (standardized $\alpha = .83$) and inter-rater reliability was acceptable (ICC range of .50 to .70; $M = .68$; Ratto et al., 2011). Further, the measure was generally sensitive in evaluating differences between typical controls and individuals with ASD. In the current study, internal consistency was high (Cronbach's $\alpha = .81$) and inter-rater reliability across all items for both conditions was acceptable (ICC range of .40 to .96; $M = .65$). Inter-rater reliability scores are presented in Table 5.

Procedure

Participants learned about the survey phase of the study either through the psychology department's Sona system, an email using their respective department's distribution list, or flyers posted on campus. Then, participants signed up for the survey either through the psychology department's Sona system or by entering their email address into a separate Qualtrics survey, where additional information about the study was provided. Participants who signed up were contacted via email (either through the Sona system or using the blind carbon copy (BCC) option in order to protect participants' confidentiality) and given the URL to complete the survey. When they clicked the link provided, they were directed to the information sheet, and they entered their email address at the bottom of the page (email addresses were used to award Sona credit if applicable, to enter students into the cash prize raffle if applicable, to document who had completed the survey, to contact those selected for Phase II in-lab participation, and to verify if the participant completed the survey during the previous semester). After entering their email addresses, participants were automatically directed to the survey questions to complete. Students provided their answers electronically via a secure server. Participants who did not complete the survey were recontacted one week after they initially provided their email to participate in the study. They again received an email with the URL to complete the survey. The entire survey took approximately 20-30 minutes to complete. Before beginning the online survey, the students were informed of the chance that they may be contacted about participating in a second phase of the study that involves a single in-lab session on campus. All survey participants were provided with a list of local counseling resources at the end of the survey, with a statement encouraging participants to contact one of the agencies if they would like to talk to someone about personal problems or mental health services.

Participants who met screening criteria for one of the four groups (low ADHD/low ASD, low ADHD/high ASD, high ADHD/low ASD, high ADHD/high ASD) were emailed an invitation to participate in the in-lab phase (Phase II) of the study. The group status was masked to the study investigator to reduce any bias in interacting with participants. The study investigator sent participant responses to another co-investigator to determine group status and send back participant IDs that met criteria for Phase II in a random order. Participants who indicated interest in participating in Phase II and attended the session, as noted above, completed the following protocol. Upon arrival to the in-lab appointment, the co-investigator explained the procedures of the study to the participant and obtain informed written and verbal consent in one of the rooms at the Child Study Center (CSC). A list of resources, such as the campus counseling center and area mental health programs were available and provided to all participants. The participant received $10 if he or she was ineligible to receive Sona extra credit.

All participants completed the CASS interaction task (Ratto et al., 2011) and the working memory tasks (Rapport et al., 2008) in a counterbalanced order. The two working memory tasks were administered in a counterbalanced order but always together either before or after the CASS. Procedures described by Ratto and colleagues (2011) were followed for the CASS. Specifically, during the CASS, participants had two three-minute conversations with opposite-sex confederates. All conversations were videotaped via a computerized video recording system for later coding. These digital recordings were not marked with any identifying information (other than the participant's number), and they were stored on an encrypted remote server. Participants were seated in a room several feet away from a confederate. Prior to each conversation, the examiner read the following prompt to the participant and confederate:

"Thank you both so much for coming in. Right now we'd like each of you to act as if you had recently joined a new club or social group, and now you're sitting next to each other, waiting for the meeting to start. You will have 3 minutes to talk to each other, and then I will come back into the room" (Ratto et al., 2011).

The second interaction was identical to the first; however, during the first interaction the confederate conveyed interest (i.e., asked questions, elaborated on statements, waited 5 seconds to reinitiate conversation), and during the second interaction the confederate conveyed boredom (i.e., minimized initiation, kept statements brief, waited 7 seconds to reinitiate conversation). Following completion of the in-lab session, each videotaped CASS was coded by two independent trained raters.

Once the CASS and WM tasks were completed, all participants were administered the following measures in order: the WASI-2 (Wechsler, 2011), CAARS:S (Conners, Erhardt, & Sparrow,1999), and SRS-2-A (Constantino & Gruber, 2012).

At the end of the in-lab portion before the participant left, a short debriefing was conducted such that participants were told that they interacted with a trained confederate during the interaction task. Because of the need to minimize the risk of other potential participants learning about the nature of the social interaction task, the debriefing was not more extensive. Participants were also asked to not discuss the interaction task with others who might be interested in participating in the study.

Data Analytic Plan

Preliminary analyses were conducted to examine if working memory deficits or social competence differed as a function of participant gender, age, or IQ.

To investigate group differences in WM deficits (*Hypotheses 1 & 2*), this study followed the analytic plan of Rapport and colleagues (2008) and Alderson and colleagues (2013) such that the average stimuli correct at each set size (4, 5, 6, 7) was calculated to provide a measure of participants' VS and PH task performance separately. Then, separate VS and PH composite scores were created to address questions concerning overall VS and PH WM (i.e.,combined contribution of CE and storage/rehearsal processes) differences among groups, and computed as a mean of each participant's scores across the VS and PH set sizes.

Next, a regression approach described by Rapport et al. (2008) was employed to create three dependent variables that reflect the CE and separate PH and VS storage/rehearsal processes. The theoretical rationale of this procedure was based on findings that provided evidence of independent VS and PH subsystems and a single, domain-general CE (Alloway, Gathercole, & Pickering, 2006; Baddeley, 2007; Fassbender & Schweitzer, 2006; Smith, Jonides, & Koeppe, 1996). Shared variability between VS and PH composite scores was expected to reflect CE processes, while statistically removing shared variability between VS and PH scores was expected to reflect VS and PH storage/rehearsal processes, respectively (see Figure 1). Consequently, a VS storage/rehearsal variable was estimated using the following procedures. Phonological scores were regressed onto VS scores at each set size (4, 5, 6, 7) to covary common variance associated with the domain-general CE. The four unstandardized residual scores that result from this procedure were averaged to provide an overall measure of VS storage/rehearsal processes, independent of variance associated with the CE. Next, VS scores were regressed onto PH scores at each set size and the resulting unstandardized residual scores were averaged to create a variable that reflected PH storage/rehearsal processes, independent of variance associated with the CE. Finally, PH scores were regressed onto VS scores at each set size to

obtain unstandardized predicted scores that reflected shared variance between the variables. The process was repeated by regressing VS scores onto PH scores at each set-size and the eight total unstandardized predicted score were averaged to create a variable that reflected CE processes, independent of variability associated with PH or VS storage/rehearsal processes.

Additionally, one-tailed, independent samples t tests were conducted on the dependent variables representing VS storage/rehearsal, PH storage/rehearsal, and CE. To support the hypotheses related to WM deficits, significant differences should emerge between the neurotypical controls (i.e., low ADHD/low ASD) and individuals with ADHD (i.e., high ADHD/low ASD) on PH storage/rehearsal and CE (*Hypothesis 2*), such that the neurotypical controls score higher than individuals with ADHD suggesting PH WM deficits in individuals with ADHD. Additionally, differences should be found on VS storage/rehearsal between the analogue clinical groups and the neurotypical controls (*Hypothesis 1*), suggesting that all the analogue clinical groups show VS WM deficits in comparison to neurotypical controls.

To investigate the contribution of WM deficits to social competence, hierarchical multiple linear regressions were conducted (*Hypotheses 3 & 4*). Specifically, dummy codes for the groups being compared were entered into the first step, WM scores were entered into the second step, and the interaction of group with WM scores was entered into the final step to predict CASS change score. Separate regressions were run for each WM component (i.e., PH, VS, and CE).

Results

Power

Previous studies have investigated WM deficits in adults with ADHD compared to neurotypical controls and have found effect sizes ranging from 0.44 to 0.64 (Alderson et al.,

2013; Boonstra et al., 2005). In this study, the low ADHD/low ASD group was used as the healthy control. The effect size for this study was expected to be closer to the average effect size found in a previous meta-analytic review (Boonstra et al., 2005), so the effect size of 0.44 was used in an a priori power analysis, where a sample size of 60 participants was determined to be reasonable and feasible.

Post-hoc power analyses using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that the study was sufficiently powered to detect effects when examining differences between the groups. Specifically, given the effect sizes for the comparisons on the t-tests comparing WM performance on the two tasks, power ranged from 0.71 to 0.89, within range of what would be desirable (power = 0.80). Additionally, power ranged from 0.69 to 0.98 when comparing the groups on the three WM components (i.e., VS storage/rehearsal, PH storage/rehearsal, and CE). Power for the 2 (WM modality – VS or PH) x 4 (group) mixed model ANOVA was sufficient to detect the main effect for WM modality (power = 0.81), the main effect of group (power = 0.88), and the interaction between group and modality (power = 0.77). However, power for the regression analyses was low, ranging from 0.51 to 0.76.

Phase I Analyses

Descriptive analyses and correlations between measures administered at Phase I are presented in Table 1 for participants with complete data (n = 1101). All measures were significantly correlated with each other in the expected directions.

Participant Characteristics

No significant differences emerged between the four groups on age ($F(3, 56) = .82$, $p = .49$), gender ($\chi^2 = .21$, $p = .98$), or IQ ($F(3, 56) = .52$, $p = .67$). Sample race characteristics consisted of 45 Caucasian (75%), five Asian/Pacific Islander (8%), four Biracial (7%), two

African American (3%), two Latino/Hispanic or Chicano (3%), one Multiracial (2%), and one declined to report (2%). Participant characteristics overall and by group are reported in Table 2. Correlations for the main variables of interest for the overall sample are presented in Table 3.

WM Deficits

The first set of analyses examined differences in WM performance (i.e., PH and VS) between each of the analogue clinical groups and the neurotypical controls. As described above, the composite score for each of the WM tasks was computed using a mean of the participants' average stimuli correct at each set size. A 2x4 mixed model ANOVA revealed a significant main effect for WM modality ($F(1, 56) = 38.71$, $p < .001$, $\eta^2 = .41$) indicating that participants performed worse on the VS task relative to the PH task. However, there was not a significant main effect for group ($F(3, 56) = .32$, $p = .81$, $\eta^2 = .02$) or the interaction between group and modality ($F(3, 56) = 1.08$, $p = .37$, $\eta^2 = .06$). To explore whether WM deficits exist in any of the clinical groups, the regression procedure described in the method section above was conducted, producing variables for CE, PH storage/rehearsal, and VS storage/rehearsal. One-tailed, independent samples t tests comparing each of the analogue clinical groups with the healthy control group indicated that the three clinical analogue groups were not significantly different on their CE, PH storage/rehearsal, or VS storage/rehearsal scores from one another or from the healthy control group. Means, standard deviations and effect sizes are shown in Table 4.

Social Competence

Hierarchical linear regressions were completed to address Hypotheses 3 and 4 regarding the contribution of WM and group status to social competence in a social conversation task (i.e., CASS). Although the groups did not differ on their WM scores, the CE, PH storage/rehearsal, and VS storage/rehearsal scores were included as independent predictors of social competence as

well as moderators in separate regression analyses. The regression to address Hypothesis 3 included group status coded such that the healthy control group was contrasted with the analogue clinical groups (-3 = low ADHD/low ASD, 1 = low ADHD/high ASD, 1 = high ADHD/low ASD, 1 = high ADHD/high ASD). This contrast code was entered as a predictor of CASS change score in order to determine if the healthy control group performed better than the analogue clinical groups on social competence. The results from this regression showed that neurotypical controls did not perform significantly better than the analogue clinical groups on the CASS ($F(1,59) = 3.21$, $p = .078$, $R^2 = .052$). However, this trend was in the hypothesized direction, with the neurotypical controls performing better on the CASS (z-score = .97) than the analogue clinical groups (z-score = -.32). CASS scores for each group are presented in Table 5.

To address Hypothesis 4, the raw scores from the ASRS (range 0-24) were entered into step 1 of the regression. Step 2 of the regression included CE, PH storage/rehearsal, or VS storage/rehearsal (separate regressions were run for each component). Step 3 of the regression included the interaction term of ASRS scores with CE, PH storage/rehearsal, or VS storage/rehearsal. The dependent variable was again CASS change score (computation described in the method section above).

For the regression with CE, the full model did not predict the CASS change score ($F(3,56) = 1.14$, $p = .34$) and did not account for significant variance ($R^2 = .06$). For the regression with PH storage/rehearsal, the full model also did not predict the CASS change score ($F(3,56) = .81$, $p = .49$) and did not account for a significant proportion of the variance ($R^2 = .04$). Similarly, the full model for the regression with VS storage/rehearsal was not significant in that it did not account for a significant proportion of the variance ($R^2 = .05$) and did not predict the CASS change score ($F(3,56) = 1.07$, $p = .37$).

Overall, results of the regression analyses suggest that neurotypical controls did not perform significantly better than the analogue control groups, nor was working memory performance a moderator of social competence for individuals with high ADHD symptoms.

Exploratory Analyses

Although the original study was designed using clinical cut-offs from the ASRS and the BAPQ to determine group membership, categorical predictors are often ill-advised when continuous predictors are available (see Royston, Altman, & Sauerbrei, 2006; West, Aiken, & Krull, 1996). Therefore, exploratory analyses were conducted using continuous scores from the CAARS ADHD Index and the SRS Total score to address Hypotheses 3 and 4.

The exploratory regression to address Hypothesis 3 included the CAARS ADHD Index T-score, centered in Step 1. Step 2 of the regression included the SRS Total T-score and Step 3 of the regression included the interaction term. The dependent variable was the CASS change score, as above. The results from the full model showed that the participants' ADHD symptoms, ASD traits, or the interaction did not predict performance on the CASS ($F(3,56) = 0.89$, $p = .45$, $R^2 = .046$). Power for this analysis was determined to be 0.76.

To address Hypothesis 4, the CAARS ADHD Index T-score was entered into step 1 of the regression. Step 2 of the regression included CE, PH storage/rehearsal, or VS storage/rehearsal (separate regressions were run for each component). Step 3 of the regression included the interaction term of CAARS scores with CE, PH storage/rehearsal, or VS storage/rehearsal. The dependent variable was again CASS change score (computation described in the method section above).

For the regression with CE, the full model did not predict the CASS change score ($F(3,56) = .63$, $p = .60$) and did not account for a great deal of variance ($R^2 = .03$). Power for this

analysis was determined to be 0.78. For the regression with PH storage/rehearsal, the full model also did not predict the CASS change score ($F(3,56) = 1.06$, $p = .37$) and did not account for a significant proportion of the variance ($R^2 = .05$). Power for this analysis was determined to be 0.72. Similarly, the full model for the regression with VS storage/rehearsal did not predict the CASS change score ($F(3,56) = 1.29$, $p = .29$) and did not account for a significant proportion of the variance ($R^2 = .07$). Power for this analysis was determined to be 0.73.

Discussion

The current study was the first to investigate the connection between working memory and social competence in a sample of individuals with varying levels of ADHD symptoms and ASD traits. Specifically, this study investigated working memory differences between individuals with ADHD symptoms and ASD traits, using a well-studied WM task (see Alderson et al., 2013; Kofler et al., 2011; Rapport et al., 2008). Additionally, it was the first to systematically examine individuals with varying levels of ADHD symptoms and ASD traits compared to neurotypical controls in the same study.

Although previous studies have found VS WM deficits in individuals with high levels of ADHD symptoms (Murphy, Barkley, & Bush, 2001) and individuals with ASD traits (Williams, Goldstein, Carpenter, & Minshew, 2005), results from the current study did not find WM deficits in these individuals. In this study, WM deficits were defined as significantly worse performance on the working memory tasks compared to the neurotypical controls (low ADHD traits/low ASD symptoms) similar to previous studies (Alderson et al., 2013; Kofler et al., 2011; Rapport et al., 2008). In fact, our results might suggest that WM abilities are intact in college students with ADHD symptoms and ASD traits, supporting previous studies that found intact WM abilities.

For instance, Ozonoff and Strayer (2001) found that WM abilities in a sample of individuals with autism were not significantly impaired compared to both a clinical control group and a non-clinical control group. Additionally, few studies have examined WM abilities in adults with ADHD, but WM deficits may not be present as individuals with ADHD grow older (e.g., Alderson, et al., 2013). Therefore, results from our study suggest that WM abilities are intact in individuals with varying levels of ADHD symptoms and ASD traits, but the lack of support for our hypotheses about WM deficits must be discussed.

Several factors may have contributed to this result. First, this study investigated WM deficits in a sample of college students with ADHD symptoms and ASD traits. It may be the case that symptoms of these disorders were insufficient to result in performance differences when individuals completed the WM tasks. That is, previous studies that found WM deficits (Alderson et al., 2013; Minshew, Luna, & Sweeney, 1999) used samples consisting of clinical groups, carefully diagnosed with evidence-based measures, compared to neurotypical controls.

Furthermore, the participants in this study were college students, which may contribute to potentially milder impairments than students with clinical diagnoses of ADHD or ASD. Specifically, studies of emerging adults (i.e., college students) diagnosed with ADHD or ASD have found differences in outcomes for students with clinical diagnoses versus students without such diagnoses (e.g., Shaw-Zirt, Popali-Lehane, Chaplin, & Bergman, 2005; Shifrin, Proctor, & Prevatt, 2010). That is, college students with ADHD tend to have lower self-esteem and academic achievement than those without and students with ASD tend to be engaged in fewer extracurricular activities, especially those involving social interactions (Shaw-Zirt, Popali-Lehane, Chaplin, & Bergman; Shifrin, Proctor, & Prevatt, 2010; Taylor & Seltzer, 2011).

Therefore, the sample in this study may not have experienced the same level of impairment as individuals meeting diagnostic criteria often do.

Additionally, individual differences in the WM tasks may be masked by averaging group means. Specifically, both ADHD and ASD are heterogeneous neurodevelopmental disorders with various impairments and behavioral presentations, which may impact the results if individual scores are grouped together. That is, researchers have found that not all individuals with ADHD or ASD have WM deficits (see Geurts, Sinzig, Booth, & Happe, 2014; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005). Therefore, grouping individual profiles for one disorder may not adequately capture the WM deficits that individuals may have. Additionally, the control group was not without symptoms of either ADHD or ASD. Specifically, individuals in the low ADHD/low ASD group did not meet the cutoff required to be classified in any of the clinical groups, but it is possible the presence of ADHD symptoms and ASD traits in this "control" group contributed to the lack of differences between groups.

Another possible explanation for the lack of findings for working memory deficits is how deficits were defined in the current study. That is, we defined deficits as performance of the analogue clinical groups on the WM tasks as being significantly worse than the neurotypical controls, which has been done in past studies investigating WM deficits (e.g., Alderson et al., 2013; Kofler et al., 2011; Rapport et al., 2008). However, this approach may not be sufficient to claim that the groups are, in fact, deficient in their WM abilities. That is, most measures such as the WASI that identify individuals with deficits have been standardized on the general population, so researchers can be more confident in their ability to detect deficits if they are present. This study and others investigating working memory deficits often compare clinical groups to neurotypical controls within the same sample rather than comparing to a standardized

norm. Therefore, claiming that individuals are actually deficient in their WM abilities should be interpreted cautiously, until researchers are able to carefully examine psychometric properties of WM measures and determine typical performance for various developmental levels and symptom presentations.

Our hypothesis about the clinical control group performing better than the analogue clinical groups on social competence (Hypothesis 3) was also not supported, although the results of the regression suggested the relationship was in the right direction. It is possible that the lack of support for this hypothesis was due to the clinical control group also having symptoms of ADHD and ASD. That is, the clinical control group may have performed better on social competence than the analogue clinical groups, but the presence of ADHD symptoms and ASD traits likely masked the differences.

Finally, the hypothesis regarding the relationship between WM and social competence (Hypothesis 4) was not supported. While some researchers have suggested that WM may contribute to social difficulties (e.g., Huang-Pollock et al., 2009; Kofler et al., 2011), it was not found in this study to predict social performance in a conversation task. One possible explanation is that the CASS was designed for individuals with ASD, to capture the difficulties these individuals may display when interacting with a peer of the opposite sex (Ratto et al., 2011). Indeed, some have suggested that the social skill deficits that individuals with ASD and individuals with ADHD display are different. For example, individuals with ASD tend to have difficulty maintaining reciprocity in conversations and have difficulty taking another person's perspective in a social interaction (Bellini et al., 2007; Pennington & Ozonoff, 1996; Tager-Flusberg, 2001). However, individuals with ADHD may have difficulty focusing on their social partner's behaviors to respond appropriately or take turns in social interactions (Landau &

Milich, 1988; Friedman et al., 2003). Therefore, our choice for a social conversation task may not have been sensitive to the difficulties both groups of individuals display in social interactions.

Limitations and Future Directions

Several limitations to this study must be noted. First, the sample was comprised of college students, the majority of whom were Caucasian, which may not allow for generalizability to the community. Replicating this study using participants from the community would allow for a better understanding of difficulties young adults with symptoms of ADHD and ASD experience. Second, clinical groups were not carefully identified using evidence-based diagnostic interviews; rather, the groups were identified based on self-report from evidence-based screening questionnaires. Future research in this area should include a more thorough assessment of ADHD symptoms and ASD traits inasmuch as clinical features and symptoms of ADHD and ASD may not be sufficiently impairing for differences on measures of WM or social competence to be found unless those symptoms reach diagnostic threshold. Relatedly, using the BAPQ as a measure of ASD traits may be inappropriate as it was not intended to measure the defining characteristics of autism (Piven & Sasson, 2014). That is, the constructs measured in the BAPQ differ qualitatively and in the level of severity than characteristic of individuals with ASD (Piven & Sasson, 2014). Indeed, when examining the scores from the Autism Spectrum Quotient (AQ) collected in this study, the individuals with “high ASD traits” as measured by the BAPQ did not exhibit elevated scores on the AQ, suggesting that this sample is not similar to individuals with ASD. Rather, these individuals are better characterized as having characteristics of the broader autism phenotype. Further examination of these traits is necessary.

Additionally, information on medication status was not collected in this study, but it would be useful to control for medication status in analyses of the working memory tasks. Third, most measures used in this study were self-report, which may have introduced bias in the way the groups were determined as well as potential over- or under-reporting of symptoms. Although this study used measures of WM and social competence that were administered by computer or coded by an independent rater, respectively, future studies should incorporate multiple reporters in order to better identify behaviors or symptoms that are present.

Future research in this area should investigate more thoroughly whether the components of Baddeley's WM model are sufficient for the study of WM in heterogeneous disorders such as ADHD and ASD. Using WM models that account for when deficits occur and what they look like may be more clinically useful than Baddeley's model, which may simplify the complexities of WM. Specifically, Unsworth and Engle (2007) suggested that WM deficits result from a failure in the ability to actively maintain information in primary memory or from a failure in the ability to retrieve goal-relevant information from secondary memory. Although Unsworth and Engle's dual-component theory of WM does not specifically account for the different modalities (i.e., phonological and visual-spatial) like Baddeley's model, it may be more clinically useful in identifying WM difficulties. That is, WM involves the simultaneous storage and rehearsal of goal-relevant information, but dividing the information into specific modalities may not best capture the complexity of the skills required. Additionally, the capacity theory suggests that deficits occur when demands of the task exceed the limits of WM capacity, where there is a limited set of processing resources available (Just & Carpenter, 1992; Kane et al., 2004). This may have been the case in the current study, such that the demands of the task did not exceed the limits of the participants' WM capacity as was evident in the similarity of the scores across

groups of individuals with varying levels of ADHD symptoms and ASD traits. Therefore, using models (i.e., the dual-component theory and the capacity theory), that identify when WM deficits arise and what they look like may be more clinically useful than Baddeley's widely studied model (Baddeley, 2007; Just & Carpenter, 1992; Kane et al., 2004; Unsworth & Engle, 2007).

Additionally, response times on both the VS WM task and the PH WM task may be useful to examine as indicators of processing speed. That is, individuals who respond slowly and accurately on WM tasks may differ from individuals who respond quickly and accurately on their performance on the conversation task. For example, an individual who responds slowly on a WM task may have difficulty developing rapport with a conversation partner if they are constantly rehearsing the information in their mind before responding, even if the content exchanged is sufficient to maintain the conversation. In this way, examining other aspects of executive functioning may be useful in better understanding how such abilities affect social competence. Indeed, Huang-Pollock and colleagues (2009) found that executive functioning deficits (a composite measure of WM, planning, and inhibition) predicted social behaviors, such as the ability to pick up on subtle verbal cues and memory for the conversation, in children with ADHD. Other components of executive functioning may contribute more to social competence than WM, as was studied here.

Lastly, future studies should examine specific social behaviors rather than the broad concept of social competence. That is, this study used a brief social conversation task where independent well-trained coders rated each participant's behaviors in response to both an interested and a bored confederate. However, as noted above, individuals with ADHD and ASD may present with different skills deficits in social interactions that need to be examined more carefully. Thus, an examination of behaviors such as interruptions for individuals with ADHD

and reciprocity for individuals with ASD may better elucidate where difficulties arise in social situations. Additionally, WM abilities may not impact all aspects of social competence, so identifying and measuring discrete social behaviors may be more clinically useful.

Relatedly, the use of the CASS in this study to measure social competence may not have been the best to capture the difficulties individuals with both ADHD symptoms and ASD traits experience. That is, the CASS was designed to measure the social flexibility of individuals with high functioning ASD to detect and adapt to changing social contexts (Ratto, Turner-Brown, Rupp, Mesibov, & Penn, 2011). The nuances of social interaction for the individuals in this study may not be captured with a social flexibility measure, given that the individuals in this study did not meet clinical levels of ASD. In fact, many participants commented that they noticed the drastic change in the confederates' behaviors between the interested and bored conditions. This detection and subsequent adaptation to the changing social context for most participants would suggest that social flexibility was not problematic in this sample. Therefore, a different measure that captures specific social behaviors would be useful for future studies.

In conclusion, we found that individuals with varying levels of ADHD and ASD traits seem to perform similarly to neurotypical controls on measures of WM abilities. We also found that WM abilities did not predict social competence on a conversation task, nor did WM abilities moderate the relationship between ADHD symptoms and social competence. Despite the lack of significant findings, this study had several strengths including being the first to examine the relationship between WM abilities and social competence in individuals with varying levels of ADHD symptoms and ASD traits, to investigate differences between WM abilities in ADHD and ASD within the same study, and to examine the contribution of WM abilities to the relationship between ADHD and social competence.

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Table 1. *Phase I descriptives and correlations (n = 1101).*

	M (SD)	1.	2.	3.	4.	5.	6.
1. ASRS	10.56 (4.38)	--					
2. BAPQ Total	2.86 (1.01)	.17**	--				
3. LSAS total performance	22.67 (12.52)	.34**	.26**	--			
4. LSAS total social interaction	20.75 (12.22)	.32**	.30**	.82**	--		
5. LSAS overall total score	43.42 (23.61)	.35**	.29**	.96**	.95**	--	
6. AQ total score	17.47 (6.25)	.22**	.39**	.41**	.45**	.45**	--

Note. ASRS = Adult ADHD Self-Report Scale Screener; BAPQ = Broad Autism Phenotype Questionnaire; LSAS = Leibowitz Social Anxiety Scale; AQ = Autism Spectrum Quotient

*$p < .05$; **$p < .01$

Table 2. *Phase II participant characteristics overall and by group.*

	Overall (n = 60)	Group 1 (n = 15)	Group 2 (n = 15)	Group 3 (n = 15)	Group 4 (n = 15)
Age	20.28 (1.36)	20.02 (1.13)	20.02 (1.48)	20.67 (1.59)	20.42 (1.20)
IQ	109.82 (11.31)	109.53 (7.98)	109.73 (6.24)	112.60 (13.29)	107.40 (15.67)
Gender - male	25 (41.7%)	6 (40.0 %)	6 (40.0%)	7 (46.7%)	6 (40.0%)
Race - Caucasian	45 (75.0%)	10 (66.7%)	10 (66.7%)	13 (86.7%)	12 (80.0%)
ASRS Total	3.05 (1.82)	1.27 (1.22)	1.73 (.88)	4.47 (.74)	4.73 (.80)
BAPQ Total	3.21 (.65)	2.72 (.41)	3.69 (.61)	2.74 (.40)	3.69 (.32)
CAARS:S ADHD Index T-Score	55.55 (8.93)	50.73 (7.41)	53.67 (7.47)	53.67 (7.12)	64.13 (7.97)
SRS-2-A Total T-Score	58.62 (9.36)	50.73 (4.79)	63.07 (6.64)	53.33 (7.41)	67.33 (6.96)

Note. Group 1 = low ADHD/low ASD, Group 2 = low ADHD/high ASD, Group 3 = high ADHD/low ASD, Group 4 = high ADHD/high ASD; IQ = WASI-II FSIQ 2-Test Composite; ASRS = Adult ADHD Self-Report Scale Screener; BAPQ = Broad Autism Phenotype

Questionnaire; CAARS:S = Conners Adult ADHD Rating Scale, Short Form; SRS-2-A = Social Responsiveness Scale, 2nd Edition, Adult Form

Table 3. *Pearson correlation matrix between main variables of interest for Phase II (n = 60).*

	1.	2.	3.	4.	5.	6.
7. ASRS	--					
8. BAPQ Total	.07	--				
9. CE	.03	.07	--			
10. VS storage/rehearsal	.09	.15	.55**	--		
11. PH storage/rehearsal	-.04	-.08	.59**	-.33*	--	
12. CASS change score	-.14	-.01	-.00	.13	-.09	--

Note. ASRS = Adult ADHD Self-Report Scale
*$p < .05$; **$p < .01$

Table 4. *Composite and working memory components comparisons by group.*

	Group 1	Group 2		Group 3		Group 4	
	M (SD)	M (SD)	d[1]	M (SD)	d[1]	M (SD)	d[1]
Composite Scores							
PH	4.76 (.64)	4.58 (.46)	.32	4.69 (.54)	.12	4.90 (.33)	.27
VS	4.34 (.56)	4.26 (.64)	.13	4.30 (.57)	.07	4.24 (.55)	.18
WM Components							
CE	4.53 (.22)	4.47 (.19)	.29	4.50 (.21)	.14	4.54 (.22)	.05
PH storage/rehearsal	.00 (.54)	-.14 (.39)	.30	-.04 (.45)	.08	.18 (.37)	.38
VS storage/rehearsal	.04 (.45)	.04 (.57)	.01	.04 (.45)	.02	-.12 (.54)	.33

Note. Group 1 = low ADHD/low ASD, Group 2 = low ADHD/high ASD, Group 3 = high ADHD/low ASD, Group 4 = high ADHD/high ASD; PH = phonological, VS = visuospatial, CE = central executive.

[1] t-test comparisons vs. Group 1 (healthy control)

Table 5. *Contextual Assessment of Social Skills (CASS) subscale scores by group.*

		Group 1	Group 2	Group 3	Group 4
	Reliability	M (SD)	M (SD)	M (SD)	M (SD)
Interested					
Asking Questions[1]	0.93	7.40 (2.56)	8.40 (4.09)	7.07 (2.37)	7.20 (2.93)
Topic Changes[1]	0.53	5.33 (1.76)	5.00 (2.07)	4.40 (2.10)	4.87 (2.17)
Vocal Expressiveness	0.75	6.00 (0.54)	4.93 (1.83)	5.73 (0.88)	5.67 (1.23)
Gestures	0.74	5.53 (0.99)	3.47 (1.73)	5.40 (1.30)	4.87 (1.77)
Positive Affect	0.54	5.73 (0.59)	5.20 (1.15)	5.53 (1.13)	5.33 (0.98)
Kinesic Arousal	0.57	4.87 (0.74)	4.67 (0.98)	4.87 (0.92)	5.07 (1.03)
Social Anxiety	0.40	5.47 (0.64)	5.13 (1.25)	5.53 (1.13)	5.13 (1.36)
Overall	0.70	5.93 (.46)	5.47 (1.25)	6.07 (.80)	5.53 (.52)
Interest/Involvement[1]					
Overall Quality of Rapport[1]	0.73	5.73 (.70)	5.40 (1.18)	5.87 (1.19)	5.60 (.91)
Bored					
Asking Questions[1]	0.96	15.07 (4.23)	11.93 (5.05)	11.73 (4.54)	10.13 (2.85)
Topic Changes[1]	0.66	8.93 (2.92)	7.00 (2.07)	6.07 (3.54)	6.20 (3.19)
Vocal Expressiveness	0.56	6.07 (0.46)	4.87 (1.25)	5.20 (1.32)	5.73 (0.59)
Gestures	0.81	4.27 (1.87)	3.20 (1.70)	4.13 (2.03)	3.67 (1.84)
Positive Affect	0.58	5.40 (0.63)	4.73 (0.88)	5.13 (0.92)	5.07 (0.88)
Kinesic Arousal	0.52	5.00 (0.66)	4.60 (0.99)	4.40 (1.18)	4.33 (1.11)
Social Anxiety	0.63	5.67 (1.11)	4.73 (1.22)	4.80 (1.08)	4.67 (1.05)

Overall	0.75	6.07 (.88)	5.13 (1.46)	5.53 (1.19)	5.40 (.63)
Interest/Involvement[1]					
Overall Quality of Rapport[1]	0.42	5.20 (1.01)	4.47 (1.30)	4.67 (.90)	4.73 (.59)
CASS change score[2]	---	.97 (1.86)	-.39 (2.58)	-.09 (2.24)	-.49 (2.97)

Note. Group 1 = low ADHD/low ASD, Group 2 = low ADHD/high ASD, Group 3 = high ADHD/low ASD, Group 4 = high ADHD/high ASD

[1]Included in CASS change score

[2] Higher scores indicative of more normative adaptation between contexts

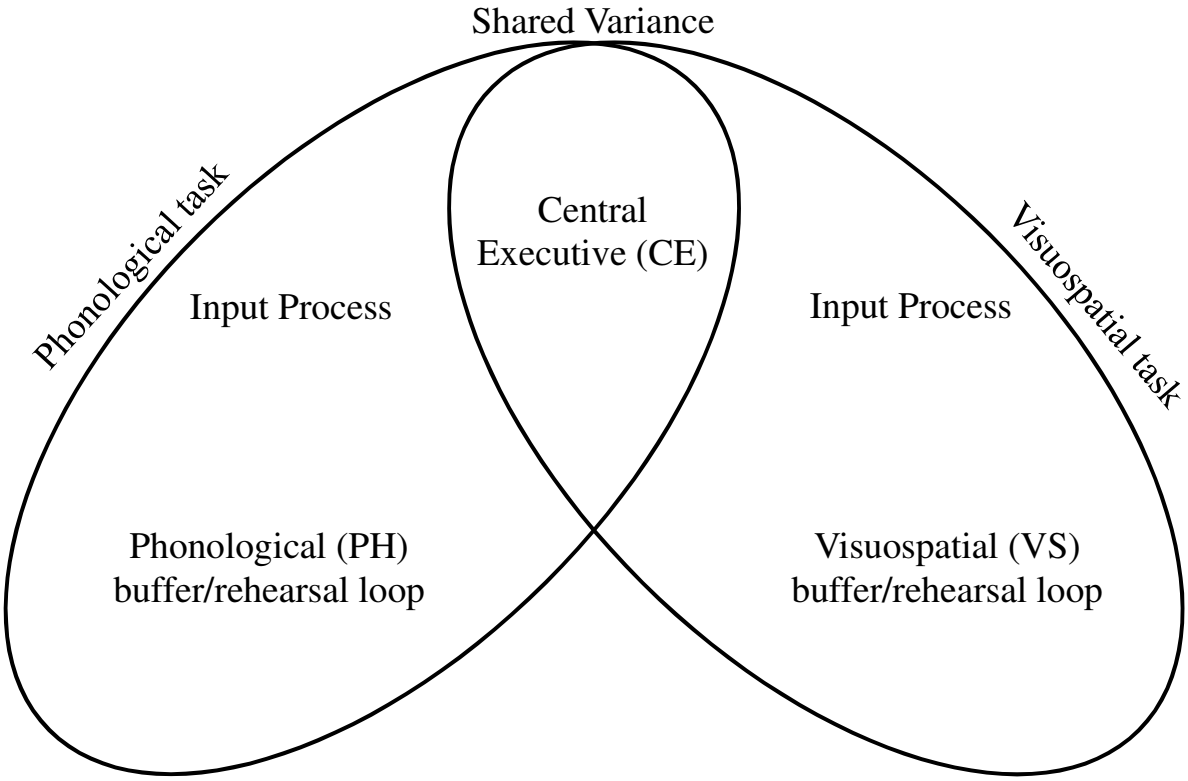


Figure 1. Baddeley's (2003) model of working memory, adapted by Rapport and colleagues (2008).

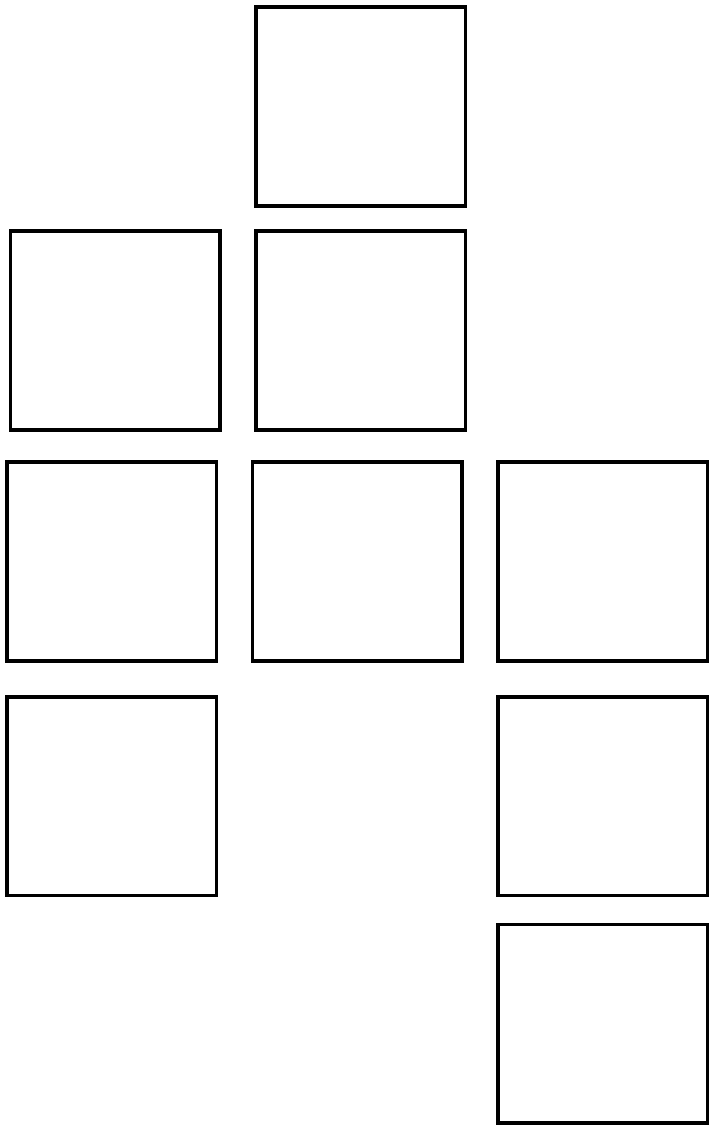


Figure 2. Grid for visual-spatial working memory task adapted from Rapport and colleagues (2008).

Appendix A.

Demographic Questionnaire

Please answer the following questions about yourself.

Gender

- □ Male
- □ Female

Age

_____ Years

_____ Months

Race/ethnicity (check all that apply)

- □ African American
- □ Asian/Pacific Islander
- □ Caucasian/European American
- □ Latino/Hispanic, or Chicano
- □ Native American
- □ Other

If you selected 'Other,' please specify: _____

Primary College Major (declared or expected)

- □ Agriculture and life sciences
- □ Architecture and urban studies
- □ Biological sciences
- □ Business, economics, finance, marketing, or hospitality
- □ Computer science
- □ Engineering
- □ Liberal arts and human sciences
- □ Mathematics
- □ Natural resources
- □ Physical sciences (e.g., physics, chemistry, geology)
- □ Psychology
- □ Other

If you selected 'Other,' please specify: _____

Class Year in College

- □ First year
- □ Second year
- □ Third year
- □ Fourth year
- □ Fifth year
- □ Sixth year
- □ Seventh year
- □ Beyond seventh year

Expected Years to Completion of Degree

- □ Three years
- □ Four years
- □ Five years
- □ Six years
- □ Seven years
- □ Beyond seven years

Have you ever taken time off of school for any reason other than financial?

- □ Yes
- □ No

Please enter an estimate of your current GPA: _____

Please indicate if you struggle with any of the following problems of have been diagnosed with any of the following disorders via an official assessment from a psychologist or doctor.

Anxiety disorder – worry that you cannot control, intense fear, very nervous in certain situations
Attention-deficit/hyperactivity disorder (ADHD) – inattentive, restless, hyperactive, impulsive
Autism spectrum disorder – social difficulties, intense or preoccupying interests
Depression – feelings of sadness, loss of interest in pleasurable activities, changes in appetite or sleep
Learning disorder – difficulty in acquisition and use of listening, speaking, reading, writing, or math abilities

	Struggle with problem	Received diagnosis
Anxiety disorder		
ADHD		
Autism spectrum disorder		
Depression		
Learning disorder		

Appendix B.

Adult ADHD Self-Report Scale V1.1 Screener (ASRS)

Check the box that best describes how you have felt and conducted yourself over the past 6 months.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
1. How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?					
2. How often do you have difficulty getting things in order when you have to do a task that requires organization?					
3. How often do you have problems remembering appointments or obligations?					
4. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?					
5. How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?					
6. How often do you feel overly active and compelled to do things, like you were driven by a motor?					
Four (4) or more checkmarks in the darkly shaded areas indicate symptoms that may be consistent with Adult ADHD.					

Appendix C.

Autism Quotient (AQ)

Below is a list of statements. Please read each statement very carefully and rate how strongly you agree or disagree with it.				
1. I prefer to do things with others rather than on my own.	definitely agree	slightly agree	slightly disagree	definitely disagree
2. I prefer to do things the same way over and over again.	definitely agree	slightly agree	slightly disagree	definitely disagree
3. If I try to imagine something, I find it very easy to create a picture in my mind.	definitely agree	slightly agree	slightly disagree	definitely disagree
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.	definitely agree	slightly agree	slightly disagree	definitely disagree
5. I often notice small sounds when others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
6. I usually notice car number plates or similar strings of information.	definitely agree	slightly agree	slightly disagree	definitely disagree
7. Other people frequently tell me that what I've said is impolite, even though I think it's polite.	definitely agree	slightly agree	slightly disagree	definitely disagree
8. When I'm reading a story, I can easily imagine what the characters might look like.	definitely agree	slightly agree	slightly disagree	definitely disagree
9. I am fascinated by dates.	definitely agree	slightly agree	slightly disagree	definitely disagree
10. In a social group, I can easily keep track of several different people's conversations.	definitely agree	slightly agree	slightly disagree	definitely disagree
11. I find social situations easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
12. I tend to notice details that others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
13. I would rather go to a library than a party.	definitely agree	slightly agree	slightly disagree	definitely disagree
14. I find making up stories easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
15. I find myself drawn more strongly to people than to things.	definitely agree	slightly agree	slightly disagree	definitely disagree
16. I tend to have very strong interests which I get upset	definitely	slightly	slightly	definitely

about if I can't pursue.	agree	agree	disagree	disagree
17. I enjoy social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
18. When I talk, it isn't always easy for others to get a word in edgeways.	definitely agree	slightly agree	slightly disagree	definitely disagree
19. I am fascinated by numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
20. When I'm reading a story, I find it difficult to work out the characters' intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
21. I don't particularly enjoy reading fiction.	definitely agree	slightly agree	slightly disagree	definitely disagree
22. I find it hard to make new friends.	definitely agree	slightly agree	slightly disagree	definitely disagree
23. I notice patterns in things all the time.	definitely agree	slightly agree	slightly disagree	definitely disagree
24. I would rather go to the theatre than a museum.	definitely agree	slightly agree	slightly disagree	definitely disagree
25. It does not upset me if my daily routine is disturbed.	definitely agree	slightly agree	slightly disagree	definitely disagree
26. I frequently find that I don't know how to keep a conversation going.	definitely agree	slightly agree	slightly disagree	definitely disagree
27. I find it easy to "read between the lines" when someone is talking to me.	definitely agree	slightly agree	slightly disagree	definitely disagree
28. I usually concentrate more on the whole picture, rather than the small details.	definitely agree	slightly agree	slightly disagree	definitely disagree
29. I am not very good at remembering phone numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
30. I don't usually notice small changes in a situation, or a person's appearance.	definitely agree	slightly agree	slightly disagree	definitely disagree
31. I know how to tell if someone listening to me is getting bored.	definitely agree	slightly agree	slightly disagree	definitely disagree
32. I find it easy to do more than one thing at once.	definitely agree	slightly agree	slightly disagree	definitely disagree
33. When I talk on the phone, I'm not sure when it's my turn to speak.	definitely agree	slightly agree	slightly disagree	definitely disagree
34. I enjoy doing things spontaneously.	definitely	slightly	slightly	definitely

	agree	agree	disagree	disagree
35. I am often the last to understand the point of a joke.	definitely agree	slightly agree	slightly disagree	definitely disagree
36. I find it easy to work out what someone is thinking or feeling just by looking at their face.	definitely agree	slightly agree	slightly disagree	definitely disagree
37. If there is an interruption, I can switch back to what I was doing very quickly.	definitely agree	slightly agree	slightly disagree	definitely disagree
38. I am good a social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
39. People often tell me that I keep going on and on about the same thing.	definitely agree	slightly agree	slightly disagree	definitely disagree
40. When I was young, I used to enjoy playing games involving pretending with other children.	definitely agree	slightly agree	slightly disagree	definitely disagree
41. I like to collect information about categories of things (e.g., types of car, types of bird, types of train, types of plant, etc.).	definitely agree	slightly agree	slightly disagree	definitely disagree
42. I find it difficult to imagine what it would be like to be someone else.	definitely agree	slightly agree	slightly disagree	definitely disagree
43. I like to plan any activities I participate in carefully.	definitely agree	slightly agree	slightly disagree	definitely disagree
44. I enjoy social occasions.	definitely agree	slightly agree	slightly disagree	definitely disagree
45. I find it difficult to work out people's intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
46. New situations make me anxious.	definitely agree	slightly agree	slightly disagree	definitely disagree
47. I enjoy meeting new people.	definitely agree	slightly agree	slightly disagree	definitely disagree
48. I am a good diplomat.	definitely agree	slightly agree	slightly disagree	definitely disagree
49. I am not very good at remembering people's date of birth.	definitely agree	slightly agree	slightly disagree	definitely disagree
50. I find it very easy to play games with children that involve pretending.	definitely agree	slightly agree	slightly disagree	definitely disagree

Appendix D.

Broad Autism Phenotype Questionnaire (BAPQ)

Below is a list of statements. Please read each statement very carefully and rate how often it applies to you by circling the number corresponding to your answer. Think about the way you have behaved the majority of the time rather than during selected time periods or transitory phases in your life. Note the items with asterisks: there is guidance about how to consider those statements at the bottom of the page.

Please do not leave any statements out. If unsure about an item, give your best guess.

1—Very rarely	3—Occasionally	5—Often
2—Rarely	4—Somewhat often	6—Very often

Questions:

1. I like being around other people	1	2	3	4	5	6
2. I find it hard to get my words out smoothly	1	2	3	4	5	6
3. I am comfortable with unexpected changes in plans	1	2	3	4	5	6
4. It's hard for me to avoid getting sidetracked in conversation	1	2	3	4	5	6
5. I would rather talk to people to get information than to socialize	1	2	3	4	5	6
6. People have to talk me into trying something new	1	2	3	4	5	6
7. I am "in-tune" with the other person during conversation ***	1	2	3	4	5	6
8. I have to warm myself up to the idea of visiting an unfamiliar place	1	2	3	4	5	6
9. I enjoy being in social situations	1	2	3	4	5	6
10. My voice has a flat or monotone sound to it	1	2	3	4	5	6
11. I feel disconnected or "out of sync" in conversations with others ***	1	2	3	4	5	6
12. People find it easy to approach me ***	1	2	3	4	5	6
13. I feel a strong need for sameness from day to day	1	2	3	4	5	6
14. People ask me to repeat things I've said because they don't understand me	1	2	3	4	5	6
15. I am flexible about how things should be done	1	2	3	4	5	6
16. I look forward to situations where I can meet new people	1	2	3	4	5	6
17. I have been told that I talk too much about certain topics	1	2	3	4	5	6

18. When I make conversation it is just to be polite ***	1	2	3	4	5	6
19. I look forward to trying new things	1	2	3	4	5	6
20. I speak too loudly or softly	1	2	3	4	5	6
21. I can tell when someone is not interested in what I am saying ***	1	2	3	4	5	6
22. I have a hard time dealing with changes in my routine	1	2	3	4	5	6
23. I am good at making small talk ***	1	2	3	4	5	6
24. I act very set in my ways	1	2	3	4	5	6
25. I feel like I am really connecting with other people	1	2	3	4	5	6
26. People get frustrated by my unwillingness to bend	1	2	3	4	5	6
27. Conversation bores me ***	1	2	3	4	5	6
28. I am warm and friendly in my interactions with others ***	1	2	3	4	5	6
29. I leave long pauses in conversation	1	2	3	4	5	6
30. I alter my daily routine by trying something different	1	2	3	4	5	6
31. I prefer to be alone rather than with others	1	2	3	4	5	6
32. I lose track of my original point when talking to people	1	2	3	4	5	6
33. I like to closely follow a routine while working	1	2	3	4	5	6
34. I can tell when it is time to change topics in conversation ***	1	2	3	4	5	6
35. I keep doing things the way I know, even if another way might be better	1	2	3	4	5	6
36. I enjoy chatting with people ***	1	2	3	4	5	6

*** Refer to casual interaction with acquaintances, rather than to special relationships such as those with close friends or family members.

Appendix E.

Liebowitz Social Anxiety Scale (LSAS)

Fear or Anxiety:
0 = None
1 = Mild
2 = Moderate
3 = Severe

Avoidance:
0 = Never (0%)
1 = Occasionally (1-33%)
2 = Often (33-67%)
3 = Usually (67-100%)

	Fear or Anxiety	Avoidance	
1. Telephoning in public. (P)			1.
2. Participating in small groups. (P)			2.
3. Eating in public places. (P)			3.
4. Drinking with others in public places. (P)			4.
5. Talking to people in authority. (S)			5.
6. Acting, performing or giving a talk in front of an audience. (P)			6.
7. Going to a party. (S)			7.
8. Working while being observed. (P)			8.
9. Writing while being observed. (P)			9.
10. Calling someone you don't know very well. (S)			10.
11. Talking with people you don't know very well. (S)			11.
12. Meeting strangers. (S)			12.
13. Urinating in a public bathroom. (P)			13.
14. Entering a room when others are already seated. (P)			14.
15. Being the center of attention. (S)			15.
16. Speaking up at a meeting. (P)			16.
17. Taking a test. (P)			17.
18. Expressing a disagreement or disapproval to people you don't know very well. (S)			18.
19. Looking at people you don't know very well in the eyes. (S)			19.
20. Giving a report to a group. (P)			20.
21. Trying to pick up someone. (P)			21.
22. Returning goods to a store. (S)			22.
23. Giving a party. (S)			23.
24. Resisting a high pressure salesperson. (S)			24.

Appendix F.

Conners Adult ADHD Rating Scale: Short Version (CAARS:S)

CAARS–Self-Report: Short Version (CAARS–S:S)

by C. K. Conners, Ph.D., D. Erhardt, Ph.D., & E. P. Sparrow, M.A.

Client ID:_____ **Gender:** M F (Circle One)

Birthdate: ____/____/____ (Month Day Year) **Age:**_____ **Today's Date:** ____/____/____ (Month Day Year)

Instructions: Listed below are items concerning behaviors or problems sometimes experienced by adults. Read each item carefully and decide how much or how frequently each item describes you recently. Indicate your response for each item by circling the number that corresponds to your choice. Use the following scale: 0 = Not at all, never; 1 = Just a little, once in a while; 2 = Pretty much, often; and 3 = Very much, very frequently.

	Not at all, never	Just a little, once in a while	Pretty much, often	Very much, very frequently
1. I interrupt others when talking.	0	1	2	3
2. I am always on the go as if driven by a motor.	0	1	2	3
3. I'm disorganized.	0	1	2	3
4. It's hard for me to stay in one place very long.	0	1	2	3
5. It's hard for me to keep track of several things at once.	0	1	2	3
6. I'm bored easily.	0	1	2	3
7. I have a short fuse/hot temper.	0	1	2	3
8. I still throw tantrums.	0	1	2	3
9. I avoid new challenges because I lack faith in my abilities.	0	1	2	3
10. I seek out fast paced, exciting activities.	0	1	2	3
11. I feel restless inside even if I am sitting still.	0	1	2	3
12. Things I hear or see distract me from what I'm doing.	0	1	2	3
13. Many things set me off easily.	0	1	2	3
14. I am an underachiever.	0	1	2	3
15. I get down on myself.	0	1	2	3
16. I act okay on the outside, but inside I'm unsure of myself.	0	1	2	3
17. I can't get things done unless there's an absolute deadline.	0	1	2	3
18. I have trouble getting started on a task.	0	1	2	3
19. I intrude on others' activities.	0	1	2	3
20. My moods are unpredictable.	0	1	2	3
21. I'm absent-minded in daily activities.	0	1	2	3
22. Sometimes my attention narrows so much that I'm oblivious to everything else; other times it's so broad that everything distracts me.	0	1	2	3
23. I tend to squirm or fidget.	0	1	2	3
24. I can't keep my mind on something unless it's really interesting.	0	1	2	3
25. I wish I had greater confidence in my abilities.	0	1	2	3
26. My past failures make it hard for me to believe in myself.	0	1	2	3

Appendix G.

Social Responsiveness Scale – Adult Self-Report (SRS-2-A)

WESTERN PSYCHOLOGICAL SERVICES
wps 12031 Wilshire Boulevard Los Angeles, CA 90025-1251
Publishers and Distributors

Social Responsiveness Scale –Adult Self-Report

John N. Constantino, M.D.

Name:_____ Administration Date: ___/___/___

Date of Birth: ___/___/____ Gender (circle one): Male Female

Instructions:

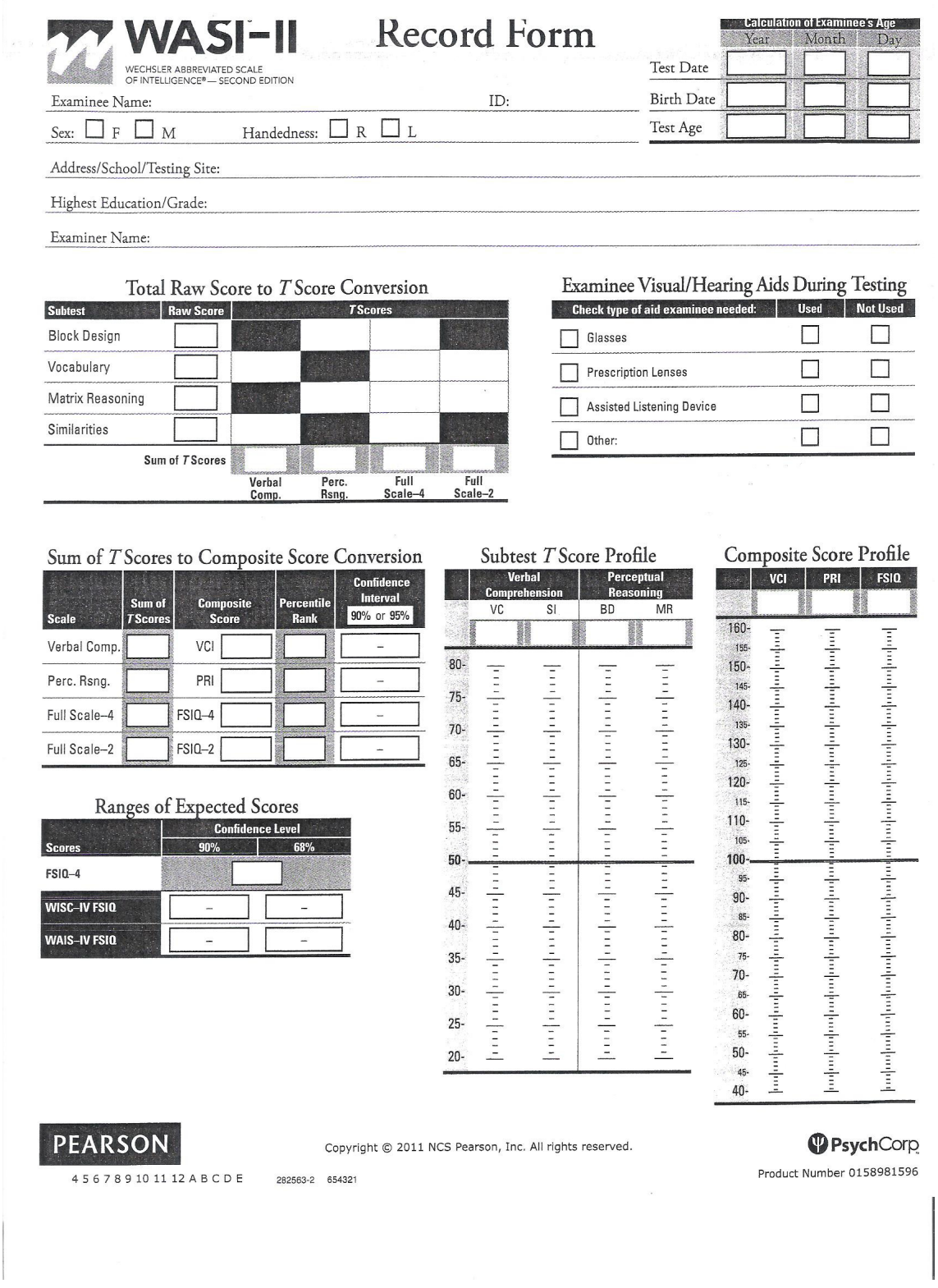
For each question, please check the box that best describes your behavior ***over the past six months.***

	Not True	Some-times True	Often True	Almost Always True
1. I am much more uncomfortable in social situations than when I am by myself	❑	❑	❑	❑
2. My facial expressions send the wrong message to others about how I actually feel	❑	❑	❑	❑
3. I feel self-confident when interacting with others	❑	❑	❑	❑
4. When under stress, I engage in rigid or inflexible patterns of behavior that seem odd to people	❑	❑	❑	❑
5. I do not recognize when others are trying to take advantage of me	❑	❑	❑	❑
6. I would rather be alone than with others	❑	❑	❑	❑
7. I am usually aware of how others are feeling	❑	❑	❑	❑
8. I behave in ways that seem strange or bizarre to others	❑	❑	❑	❑
9. I am overly dependent on others for help with meeting my everyday needs	❑	❑	❑	❑
10. I take things too literally, and because of that, I misinterpret the intended meaning of parts of a conversation	❑	❑	❑	❑
11. I have good self-confidence	❑	❑	❑	❑
12. I am able to communicate my feelings to others	❑	❑	❑	❑
13. I am awkward in turn-taking interactions with others (e.g., I have a hard time keeping up with the give-and-take of a conversation))	❑	❑	❑	❑
14. I am not well coordinated	❑	❑	❑	❑
15. When people change their tone or facial expression, I usually pick up on that and understand what it means	❑	❑	❑	❑
16. I avoid eye contact or am told that I have unusual eye contact	❑	❑	❑	❑
17. I recognize when something is unfair	❑	❑	❑	❑
18. I have difficulty making friends, even when trying my best	❑	❑	❑	❑
19. I get frustrated trying to get ideas across in conversations	❑	❑	❑	❑
20. I have sensory interests that others find unusual (e.g., smelling or looking at things in a special way)	❑	❑	❑	❑
21. I am able to imitate others' actions and expressions when it is socially appropriate to do so.	❑	❑	❑	❑
22. I interact appropriately with other adults	❑	❑	❑	❑
23. I do not join group activities or social events unless prompted or strongly urged to do so.	❑	❑	❑	❑
24. I have more difficulty than others with changes in my routine	❑	❑	❑	❑
25. I do not mind being out of step with or "not on the same wavelength" as others	❑	❑	❑	❑
26. I offer comfort to others when they are sad	❑	❑	❑	❑
27. I avoid starting social interactions with other adults	❑	❑	❑	❑
28. I think or talk about the same thing over and over	❑	❑	❑	❑
29. I am regarded by others as odd or weird	❑	❑	❑	❑

	Not True	Some-times True	Often True	Almost Always True
30. I become upset in situations with lots of things going on	❑	❑	❑	❑
31. I can't get my mind off something once I start thinking about it	❑	❑	❑	❑
32. I have good personal hygiene	❑	❑	❑	❑
33. My behavior is socially awkward, even when I am trying to be polite	❑	❑	❑	❑
34. I avoid people who want to be emotionally close to me	❑	❑	❑	❑
35. I have trouble keeping up with the flow of a normal conversation	❑	❑	❑	❑
36. I have difficulty relating to family members	❑	❑	❑	❑
37. I have difficulty relating to adults outside of my family	❑	❑	❑	❑
38. I respond appropriately to mood changes in others (e.g., when a friend's mood changes from happy to sad)	❑	❑	❑	❑
39. People think I am interested in too few topics, or that I get too carried away with those topics	❑	❑	❑	❑
40. I am imaginative	❑	❑	❑	❑
41. I sometimes seem to wander aimlessly from one activity to another	❑	❑	❑	❑
42. I am overly sensitive to certain sounds, textures, or smells	❑	❑	❑	❑
43. I enjoy small talk (casual conversation with others)	❑	❑	❑	❑
44. I have more trouble than most people with understanding chains of causation, i.e., how events are related to one another	❑	❑	❑	❑
45. When others around me are paying attention to something, I get interested in what they are attending to	❑	❑	❑	❑
46. Others feel that I have overly serious facial expressions	❑	❑	❑	❑
47. I laugh at inappropriate times	❑	❑	❑	❑
48. I have a good sense of humor and can understand jokes	❑	❑	❑	❑
49. I do extremely well at certain kinds of intellectual tasks, but do not do as well at most other tasks	❑	❑	❑	❑
50. I have repetitive behaviors that others consider odd	❑	❑	❑	❑
51. I have difficulty answering questions directly and end up talking around the subject	❑	❑	❑	❑
52. I get overly loud without realizing it	❑	❑	❑	❑
53. I tend to talk in a monotone voice (i.e., less inflection of voice than most people demonstrate)	❑	❑	❑	❑
54. I tend to think about people in the same way that I do objects	❑	❑	❑	❑
55. I get too close to others or invade their personal space without realizing it	❑	❑	❑	❑
56. I sometimes make the mistake of walking between two people who are trying to talk to one another	❑	❑	❑	❑
57. I tend to isolate myself	❑	❑	❑	❑
58. I concentrate too much on parts of things rather than seeing the whole picture	❑	❑	❑	❑
59. I am more suspicious than most people	❑	❑	❑	❑
60. Other people think I am emotionally distant and do not show my feelings	❑	❑	❑	❑
61. I tend to be inflexible	❑	❑	❑	❑
62. When I tell someone my reason for doing something, it strikes the person as unusual or illogical	❑	❑	❑	❑
63. My way of greeting another person is unusual	❑	❑	❑	❑
64. I am much more tense in social settings than when I am by myself	❑	❑	❑	❑
65. I find myself staring or gazing off into space	❑	❑	❑	❑

Appendix F.

Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-2)



WASI-II Record Form

WECHSLER ABBREVIATED SCALE OF INTELLIGENCE®— SECOND EDITION

Calculation of Examinee's Age (Year / Month / Day)

Examinee Name: ID:

Test Date / Birth Date / Test Age

Sex: ☐ F ☐ M Handedness: ☐ R ☐ L

Address/School/Testing Site:

Highest Education/Grade:

Examiner Name:

Total Raw Score to *T* Score Conversion

Subtest	Raw Score	*T* Scores			
Block Design					
Vocabulary					
Matrix Reasoning					
Similarities					
Sum of *T* Scores					
		Verbal Comp.	Perc. Rsng.	Full Scale–4	Full Scale–2

Examinee Visual/Hearing Aids During Testing

Check type of aid examinee needed:	Used	Not Used
☐ Glasses	☐	☐
☐ Prescription Lenses	☐	☐
☐ Assisted Listening Device	☐	☐
☐ Other:	☐	☐

Sum of *T* Scores to Composite Score Conversion

Scale	Sum of *T* Scores	Composite Score	Percentile Rank	Confidence Interval 90% or 95%
Verbal Comp.		VCI		–
Perc. Rsng.		PRI		–
Full Scale–4		FSIQ–4		–
Full Scale–2		FSIQ–2		–

Subtest *T* Score Profile

	Verbal Comprehension		Perceptual Reasoning	
	VC	SI	BD	MR
80				
75				
70				
65				
60				
55				
50				
45				
40				
35				
30				
25				
20				

Composite Score Profile

	VCI	PRI	FSIQ
160			
155			
150			
145			
140			
135			
130			
125			
120			
115			
110			
105			
100			
95			
90			
85			
80			
75			
70			
65			
60			
55			
50			
45			
40			

Ranges of Expected Scores

Scores	Confidence Level 90%	68%
FSIQ–4		
WISC–IV FSIQ	–	–
WAIS–IV FSIQ	–	–

PEARSON

4 5 6 7 8 9 10 11 12 A B C D E 282563-2 654321

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2. Vocabulary

Start
Ages 6–90: Item 4

Reverse
Ages 6–90: Does not obtain a perfect score on *either* Item 4 or Item 5, administer the preceding items in **reverse** order until two consecutive perfect scores are obtained.

Discontinue
After **3** consecutive scores of 0.

Stop
Age 6: After Item 22.
Ages 7–11: After Item 25.
Ages 12–14: After Item 28.

Record & Score
Items 1–3: Score **0** or **1** point.
Items 4–5: Score **0** or **2** points.
Items 6–31: Score **0**, **1**, or **2** points.
See the Manual for sample responses.

	Item	Response	Score
	1. Fish		0 1
	2. Shovel		0 1
	3. Shell		0 1
6–90	†4. Shirt		0 2
	5. Car		0 2
	6. Lamp		0 1 2
	7. Bird		0 1 2
	8. Tongue		0 1 2
	9. Pet		0 1 2
	10. Lunch		0 1 2
	11. Bell		0 1 2
	12. Calendar		0 1 2
	13. Alligator		0 1 2
	14. Dance		0 1 2

†If the examinee provides a 2-point response that requires feedback or gives an incorrect (0 point) response, provide corrective feedback as instructed in the Manual.

continue

Vocabulary *(continued)*

Discontinue after **3** consecutive scores of 0.

	Item	Response	Score
	15. Summer		0 1 2
	16. Reveal		0 1 2
	17. Decade		0 1 2
	18. Entertain		0 1 2
	19. Tradition		0 1 2
	20. Enthusiastic		0 1 2
	21. Improvise		0 1 2
	22. Haste		0 1 2
6 STOP	23. Trend		0 1 2
	24. Impulse		0 1 2
	25. Ruminate		0 1 2
-11 STOP	26. Mollify		0 1 2
	27. Extirpate		0 1 2
	28. Panacea		0 1 2
-14 STOP			

continue

2. Vocabulary *(continued)*

Discontinue after **3** consecutive scores of 0

Item	Response	Score
29. Perfunctory		0 1 2
30. Insipid		0 1 2
31. Pavid		0 1 2

Maximum Raw Score
Age 6: 41
Ages 7–11: 47
Ages 12–14: 53
Ages 15–90: 59

Vocabulary Total Raw Score ____

3. Matrix Reasoning

Start
Ages 6–8: Sample Items A & B, then Item 1
Ages 9–90: Sample Items A & B, then Item 4

Reverse
Ages 9–90: Does not obtain a perfect score on *either* Item 4 or Item 5, administer the preceding items in **reverse** order until two consecutive perfect scores are obtained.

Discontinue
After **3** consecutive scores of 0.

Stop
Ages 6–8: After Item 24.

Record & Score
Score **0** or **1** point.
Correct responses are in **color**.

	Item	Response					Score	
6–90	SA.	1	**2**	3	4	5		
	SB.	1	2	**3**	4	5		
6–8	1.	1	**2**	3	4	5	0	1
	2.	**1**	2	3	4	5	0	1
	3.	1	2	**3**	4	5	0	1
9–90	4.	**1**	2	3	4	5	0	1
	5.	1	2	3	4	**5**	0	1
	6.	**1**	2	3	4	5	0	1
	7.	1	2	**3**	4	5	0	1
	8.	1	2	**3**	4	5	0	1
	9.	1	2	3	**4**	5	0	1
	10.	1	**2**	3	4	5	0	1
	11.	1	2	**3**	4	5	0	1
	12.	1	2	3	**4**	5	0	1
	13.	**1**	2	3	4	5	0	1
	14.	1	2	3	**4**	5	0	1
	15.	1	**2**	3	4	5	0	1
	16.	1	2	3	4	**5**	0	1
	17.	1	2	3	**4**	5	0	1
	18.	1	**2**	3	4	5	0	1
	19.	1	2	3	**4**	5	0	1
	20.	1	**2**	3	4	5	0	1
	21.	1	2	**3**	4	5	0	1
	22.	1	2	**3**	4	5	0	1
	23.	**1**	2	3	4	5	0	1
6–8 STOP	24.	1	2	3	**4**	5	0	1
	25.	1	2	3	**4**	5	0	1
	26.	1	**2**	3	4	5	0	1
	27.	1	2	3	4	**5**	0	1
	28.	1	2	3	4	**5**	0	1
	29.	**1**	2	3	4	5	0	1
	30.	1	**2**	3	4	5	0	1

Maximum Raw Score
Ages 6–8: 24
Ages 9–90: 30

Matrix Reasoning Total Raw Score ____