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Perceptual Asymmetries and Lateralization in Adults with Attention Deficit Hyperactivity Disorder

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Perceptual Asymmetries and Lateralization in Adults with Attention Deficit Hyperactivity Disorder

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Dedication

I would like to dedicate this thesis to my mother, Deborah, who shared with me her love of reading, helped me to understand the importance of education, and instilled in me a strong work ethic. A promise between us brought me back to college and sustained me through its many challenges.

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Abstract

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurobehavioral disorder characterized by one or more of the following: poor attention, impulsivity, and kinetic over-activity. Many studies have found support for the theory that ADHD is the result of right hemisphere dysfunction. Additionally, those with ADHD often resemble older adults or patients with right hemisphere lesions who show clear signs of left hemi-spatial neglect. Several studies have attempted to identify differences in lateralization between the ADHD subtypes, although the results have been conflicting. The current study aims to clarify these conflicting results by controlling for a number of relevant factors including age, gender, and ADHD sub-type. In part 1 of the study, participants completed a screening task comprised of both ADHD and handedness measures. In part 2, participants found to be eligible completed a number of lateralization measures. Results of a line bisection task were not significant, however the overall trends were consistent with those found in previous research, indicating evidence of a slight leftward perceptual bias in controls known as pseudo-neglect, a stronger leftward bias in ADHD-I groups, and a contrasting rightward bias in ADHD-C/H groups. On a cancellation task, participants with ADHD-C/H made significantly more left- than right-sided omissions, as well as more left-sided omissions than the ADHD-I group. Results of the lateralization drawing task indicated that both ADHD groups showed a tendency to draw objects more toward the right side than controls. Implications of the current study and ideas for future research are discussed.

Perceptual Asymmetries and Lateralization in Adults with Attention Deficit Hyperactivity Disorder

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurobehavioral disorder characterized by signs of disruption in executive function, including poor attention and impulsivity, and over-activity (American Psychiatric Association, 2000; The ADHD Molecular Genetics Network, 2002; Centers for Disease Control, 2010). The Diagnostic and Statistical Manual of Mental Disorders (4^{th} edition, text revised; DSM-IV-TR) categorizes ADHD into three subtypes: Predominantly Inattentive type (ADHD-I), Predominantly Hyperactive-Impulsive type (ADHD-H), and Combined type (ADHD-C) (American Psychiatric Association, 2000). Research suggests that approximately 5.6 - 15.6% of children aged 4 - 17 have ADHD, although the actual rates vary by gender, age, and subtype with males being two to three times more likely to be affected than females; additionally, the largest difference in subtype diagnoses by gender occurs in ADHD-Combined type as males are significantly more likely to be diagnosed than females (Centers for Disease Control, 2010; Mental Health in the United States, 2005; Froehlich et al., 2007). According to the National Institute of Mental Health (2009), approximately 4.1% of adults in the United States have a diagnosis of ADHD, and among adults aged 18 to 29, the lifetime prevalence is 7.8%.

Although the prevalence rates of ADHD in children are relatively high, research suggests that a developmental resolution is common, resulting in substantially lower rates in adults. In one longitudinal study, only 35% of male children and adolescents with ADHD continued to meet the DSM criteria for the disorder as adults; however, 76% of the adult participants met the criteria for at least one of the four definitions of ADHD persistence: syndromatic persistence, symptomatic persistence, functional persistence, and medicated (Biederman, Petty, Evans, Small, & Faraone, 2010; Biederman, Petty, Clarke, Lomedico, & Faraone, 2011). Two additional studies found that 36-46% of adults retrospectively diagnosed with childhood ADHD continued to meet the DSM criteria for ADHD (Kessler et al., 2005; Lara et al., 2009). Biederman et al. (2010) reported that increasing age was associated with decreases in overall ADHD, particularly hyperactive/impulsive symptoms, in adolescence. Additionally, adults with persistent ADHD were significantly more likely than those who were fully remittent to have a comorbid disorder, a family history of psychiatric disorders, and a history of educational challenges (Biederman et al., 2010). In the retrospective studies, persistence of ADHD into adulthood was related to both subtype and severity; those with a childhood diagnosis of ADHD-C had the highest rates of persistence (Kessler et al., 2005; Lara et al., 2009). Although ADHD is often thought of as a childhood disorder, this research suggests that, for many, it continues to pose problems and challenges in adulthood.

ADHD Subtype Classification

Despite the current classification of ADHD into three subtypes by the DSM IV-TR, behavioral studies on children with ADHD suggest that the disorder may be better characterized as only two subtypes: ADHD- Inattentive type (ADHD-I) and ADHD-Combined type (ADHD-C, integrating the Hyperactive-Impulsive and Combined types (Barkley, DuPaul, & McMurray, 1990; Booth, Carlson, & Tucker; 2007; Lockwood, Marcotte, & Stern, 2001; Mullins, Bellgrove, Gill, & Robertson, 2005). The two subtypes display different patterns of attentional impairments in educational settings. Those with ADHD-C are also at an increased risk (two to three times higher) for aggressive and antisocial behavior over those with ADHD-I (Barkley et al., 1990). Additional differences between subtypes in prevalence rate, age, and gender (Romano, Baillargeon, & Tremblay, 2002), as well as in medication response (Hale, 2006) have been documented.

Pathogenesis of ADHD

Many studies have found support for the theory that the pathogenesis of ADHD is related to anomalies in brain structures, including differences in the volumes of the total brain, the superior prefrontal, and the right superior prefrontal areas, as well as in several of the cerebellar lobules, the corpus callosum, and the splenium (Arnsten, 2009; Hill, Yeo, Campbell, & Vigil, 2003). These studies have also implicated neurochemical differences, including weak catecholamine signaling, reduced dopamine production, and reduced norepinephrine production in the prefrontal cortex (Arnsten).

In particular, ADHD is often associated with right hemisphere dysfunction (Arnsten, 2009; Heilman, Voeller, & Nadeau, 1991; Hill et al., 2003; Klimkeit & Bradshaw, 2006; Stam & Bakker, 1990). Neuroimaging studies have found decreased regional cerebral blood flow (rCBF) in the right hemisphere areas of the orbitofrontal cortex and middle temporal gyrus (Lee et al., 2004) and reduced brain activation in the right parietal lobe and fronto-striatal network observed in both children and adults when completing mental rotation and continuous performance tests (Schneider et al., 2010; Silk et al., 2005; Vance et al., 2007). Additionally, functional magnetic resonance imaging (fMRI) studies have shown atypical right-hemisphere perisylvian morphology in some patients with ADHD (associated with lower social comprehension scores) (Miller, Miller, Bloom, Hynd, & Craggs, 2006). Finally, one longitudinal study comparing MRI images from 218 children with ADHD and 358 neurotypically developing children found that the ADHD group displayed age-appropriate gains in relative cortical thickness of the left hemisphere and posterior region of the right hemisphere; however, the right frontal cortex failed to show these same gains in relative thickness resulting in atypical anterior brain asymmetry (Shaw et al., 2009).

ADHD is strongly related to deficits in executive functioning including disturbances in response inhibition, divided attention, phonological working memory, and visual object working memory (Pasini, Paloscia, Alessandrelli, Porfirio, & Curatolo, 2007). The prefrontal cortex has been implicated as a dominant area in executive functioning, with the particular evidence for the role of the right pre-frontal cortex. However, research by Pasini et al. (2007) found some relationship between the dorsolateral left prefrontal cortex and divided attention, although this neurobehavioral relationship appears to be weaker than that of the right prefrontal cortex (Collette et al., 2005).

Additional evidence for the implication of the right hemisphere in ADHD comes from the literature on patients with right-hemisphere lesions, as these patients display many of the behavioral and selective attention symptoms (including left hemi-neglect) observed in those with ADHD (García-Sánchez, Estévez-González, Suárez-Romero, & Junqué, 1997). Although patients with lesions in both hemispheres show evidence of asymmetric exploration of space, making more errors on the side of space contralateral to the hemispheric damage, only patients with right-hemisphere damage showed clear evidence of hemi-spatial neglect across different tasks of spatial attention (Gainotti, D'Erme, Monteleone, & Silveri, 1986; Halligan, Burn, Marshall, & Wade, 1992; Heilman

& Van Der Abell, 1980; Kinsella, Olver, Ng, & Packer, 1993; Voeller & Heilman, 1988). In addition to right-hemisphere lesions, lesions to the frontal cortex have also been related to left hemi-spatial neglect (Jewell & McCourt, 2000). Finally, lesions to the right-hemisphere and prefrontal areas have been shown to cause similar visuo-spatial, emotional, behavioral, and attentional symptoms to those evident in ADHD (Heilman, Bowers, Valenstein, & Watson, 1986; Max et al., 2005).

Neuropsychological Assessment of Lateralization

Several neuropsychological methods have been used to measure hemispheric functioning and lateralization, including visual line bisection and cancellation tasks (Bowers & Heilman, 1980; Bradshaw, Nettleton, Nathan, & Wilson, 1985; Voeller & Heilman, 1988; Sandson, Bachna, & Morin, 2000). Line bisection tasks require participants to mark the perceived midpoint of a series of lines that may vary by length, thickness, justification, orientation, and vertical placement. A meta-analysis of line bisection studies by Jewell and McCourt (2002) found that neurotypical controls, when presented with horizontal lines, show evidence of pseudo-neglect, a slight but significant leftward bias, in their bisections; however, the extent of this bias is dependent both on handedness and the hand used. Bisections made using the left hand were farther to the left of center than were bisections made using the right hand. In cancellation tasks, participants must circle or cross out all of the relevant target letters or shapes in a given array. Previous research has shown that the number of omissions of neurotypical adults does not differ significantly from zero and that the number of omissions on the left and right sides do not differ significantly from each other (Mesulam, 2000).

ADHD and Perceptual Biases

Studies of perceptual biases via the line bisection task in patients with right hemisphere damage have shown an ipsilateral spatial neglect resulting in bisection errors to the right of center (Harvey & Milner, 1999; Urbanski, 2008). Several studies have determined that participants with ADHD, collapsed across subtype, mimicked the pattern of neglect patients, bisecting lines significantly to the right of center (Rolfe, Hausman, & Waldie, 2006; Rolfe, Hamm, & Waldie, 2008) and making more left- than right-sided errors on cancellation tasks (Jones, Craver-Lemley, & Barrett, 2008). Other studies have failed to find the same connection between ADHD and perceptual asymmetries (Klimkeit, Mattingly, Sheppard, Lee, & Bradshaw, 2003). However, these conflicting results may be due in part to the failure to include comparisons between ADHD subtypes. A study published in 1998 found that the Combined and Hyperactive-Impulsive types of ADHD account for approximately 70% of all cases, with the Inattentive type accounting for the remaining 30% (Faraone, Biederman, Weber, & Russell, 1998). Since the different ADHD subtypes appear to have different, and sometimes opposite, neurobehavioral patterns, failure to account for these patterns is likely to create inconsistent results dependent on the proportion of each subtype in the sample.

Lateralization tudies utilizing the letter cancellation task have uncovered similar patterns of perceptual asymmetry and hemi-neglect. According to Voeller and Heilman (1988), boys with Attention Deficit Disorder missed more overall targets in a letter cancellation task than their non-affected peers. Additionally, the boys with ADD made more left-sided errors than the controls, consistent with prior research indicating left hemi-neglect in ADHD (Landau, Gross-Tsur, Auerbach, Van der Meere, & Shalev, 1999). Sandson et al. (2000) conducted a similar study with adults and found that participants with ADHD had higher mean error rates on the left than on the right and were more likely to make errors in the left visual field than were the controls.

Lateralization by Subtype

Several studies have attempted to identify differences in lateralization between the subtypes of ADHD. In two separate studies, researchers compared the line bisection judgments of neurotypical children, children with ADHD-I, and children with ADHD-C (combining the Hyperactive-Impulsive type and Combined type) (Rolfe et al., 2006; Rolfe et al., 2008). They found that neurotypical children displayed a symmetrical bias dependent on hand use; irrespective of the hand used, children diagnosed with ADHD-C bisected lines significantly to the right of center and children with ADHD-I bisected significantly to the left of center. Taken together, these results suggest that ADHD-I and ADHD-C are two similar but distinct pathologies. People with ADHD-C more closely resemble patients with right hemisphere lesions; this similarity suggests that right hemisphere dysfunction is more closely linked to ADHD-C, than to ADHD-I in childhood.

Unlike children, adults are more likely to be diagnosed with ADHD-I. Despite the high proportion of ADHD-C/H in children (Faraone et al., 1998), the reverse pattern of relative subtype rates documented in adults (Clarke, 2001; Heilman et al., 1991) is related to decreasing hyperactive/impulsive symptoms seen with increasing age throughout adolescence (Beiderman et al., 2010). No research has been conducted to investigate whether changes in brain morphology thought to underlie ADHD subtypes with hyperactive/impulsive features accompany the observed behavioral changes and symptom resolution observed by adulthood. Additionally, little research has investigated the presence of perceptual asymmetries and the differences between subtypes in adult ADHD samples (Clarke, 2001; Heilman et al., 1991).

Research Aims

The current study aims to clarify and resolve some of the conflicting results concerning ADHD, brain lateralization, and perceptual asymmetries found in the existing literature. More specifically, the relationships between ADHD, anomalous lateralization, and perceptual asymmetries are tenuous at best. While many studies have controlled for factors such as gender, handedness, other dimensions of lateralization, hand use, ADHD subtype, age, and the effect of previous trials on subsequent line bisections, no single study has controlled for all of these factors.

The goals of the current study are: 1) to determine whether participants with ADHD-Combined/Hyperactive-Impulsive type show evidence of left hemi-neglect in line bisection, letter-cancellation, and drawing tasks; 2) to determine whether participants with ADHD-Inattentive type show evidence of right hemi-neglect in line bisection, letter-cancellation, and drawing tasks; 3) to examine the effects of gender and hand use on measures of lateralization in the ADHD and control samples; 4) and to investigate whether a predictive relationship exists between ADHD and the direction and/or degree of lateralization.

Method

Participants

Participants were 90 individuals (80 female) between the ages of 18 and 29 recruited via Facebook and campus email at Bates College. Criteria for exclusion from the study included abnormal vision, left-handedness, a history of arm injury or surgery with impairment, and the presence of a documented learning disability (excluding ADHD). Nine participants met one or more of the exclusionary criteria. Additionally, five participants were excluded for failing to complete one or more screening measures, completing the screening survey more than once, or having foreknowledge of the study.

The gender composition of the remaining 76 participants was 10.5% male (*n* = 8) and 89.5% female (*n* = 68). The mean age for males was 21.38 years (SD = 2.72) and the mean age for females was 19.69 years (SD = 1.88). Due to an error in the online survey, information on racial and ethnic composition was lost. Additionally, 3.9 % of the sample (*n* = 3) indicated a diagnosis of ADHD. Of the remaining 76 participants, 46 returned for the second half of the study (8.70 % male, n = 4; 92.30 % female, n = 42) with mean ages of 19.67 (SD = 2.082) and 19.74 (SD = 2.220) respectively. The means and standard deviations for each of the psychometric tests are presented in Table 1.

Materials

All participants completed an online survey including a handedness questionnaire, three ADHD measures, and a set of questions on demographic information and exclusionary criteria; those who met the criteria for inclusion were asked to come into the lab to complete the second part of the study, including a line bisection task, letter and shape cancellation tasks, and a lateralization drawing task.

Screening measures.

Handedness scale.

The Edinburgh Handedness Inventory (EHI) is a 20-question survey used to determine dominant hand use (see Appendix A). Participants indicated their preferred hand for common activities by putting '+' signs in the "left hand" or "right hand" columns ('+' in the column of the preferred hand, '++' if one would never use the non-preferred hand unless forced, and '+' in each column if one's hands are used equally or there is no preference). Common activities assessed in the survey included writing, throwing, using scissors, and brushing one's teeth. The direction and degree of handedness is scored as [(right hand marks - left hand marks) / (right hand marks + left hand marks)] × 100. Negative scores indicate a degree of left-handedness and positive scores indicate a degree of right-handedness, with higher scores indicating the greatest overall preference for one hand over the other. Additionally, the survey includes two questions to address foot and eye preference. Internal consistency for the EHI is high (coefficient alpha=.93) (Oldfield, 1971; Williams, 1991).

ADHD measures.

The Wender Utah Rating Scale (modified form; WURS) is a 25-item version of the larger 61-item scale (see Appendix B). This questionnaire is designed to retrospectively assess the presence of ADHD behaviors from childhood via self-report including irritability, anger, moodiness, immaturity, etc. The selected 25 items have been shown to differentiate between adults with ADHD and controls. Participants identified the extent to which each item described them as a child (not at all or very slightly, mildly, moderately, quite a bit, or very much). The current study used a cutoff score of 46, as recommended by Ward, Wender, and Reimherr (1993), which correctly classified 96% of participants. The WURS was moderately correlated with the Parents' Rating Scale for normal subjects and adults with ADHD respectively ($r=0.49$ ($p\leq0.0005$, $df=98$) and $r=0.41$ ($p\leq0.0005$, $df=65$) (Ward, Wender, & Reimherr, 1993).

To assess for a current ADHD diagnosis and to determine subtype, the 18-item Adult ADHD Self-Report Symptom Checklist (ASRS-v 1.1) was given (see Appendix C). The scale consists of two subscales with questions that measure inattentive symptoms (How often are you distracted by activity or noise around you?) and hyperactive / impulsive symptoms (How often do you feel restless or fidgety?) independently. Participants rated the frequency with which they engage in the listed behaviors (never, rarely, sometimes, often, or very often) (Adler et al., 2006), resulting in subscale scores for inattentive, hyperactive-impulsive, and total ADHD symptoms as well as an ADHD index score utilizing the following cutoff scores respectively: 32, 33, 65, and 21.

The Conners Adult ADHD Rating Scale – Self-Report: Screening Version (CAARS-S:SV) is a 30-item self-report questionnaire for adults aged 18 and over. The CAARS includes subscales for inattentive symptoms, hyperactive-impulsive symptoms, total ADHD symptoms, and an ADHD index. Participants indicated the frequency with which certain items or behaviors occur on 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. The CAARS utilizes standardized t-scores with higher scores indicating higher levels of ADHD symptoms and overall likelihood of an ADHD diagnosis. Internal reliability of the CAARS ranges from .66 to .90 (Conners et al., 1999; Erherdt, Epstein, Connors, Parker, & Sitarenios, 1999). The factor analysis for the subscales of the CAARS S:SV met the criteria for good fit as described by Connors, Erherdt, and Sparrow (1998) (GFI = .989, AGFI = .986, NNFI = .990, CFI = .991).

Demographics and exclusionary criteria.

A short questionnaire was also administered to gather demographic information (gender, age, race / ethnicity) and determine the presence of potentially exclusionary criteria including uncorrectable vision problems, co-morbid learning disabilities, prior arm injuries or surgeries, current arm injuries, and alcohol and drug use in the previous 24 hours (see Appendix D).

Lateralization tasks.

Line bisection task.

Similar to the method used by Rolfe et al. (2008), participants completed a pen-and-paper line bisection task to assess for perceptual bias as an indication of hemi-neglect. The task included 102 horizontal lines with lengths ranging from 100 to 260 mm, of which one third were aligned to the left of the page, one third were aligned to the right, and one third were presented in the center. Each line appeared on a plain, white background presented in a landscape orientation on a single standard 8.3 by 11.7 inch sheet of paper. Participants were given a black ball-point pen and instructed to place a mark at the midpoint of each line. The stack of pages was placed face-down in front of each participant; one page at a time, the participant flipped the top page to face up, placed a mark on the line, and flipped it into another pile facing down. Participants complete 51 lines (17 of each justification) with each hand.

Cancellation tasks.

As a second method to assess the presence of hemi-neglect and the resulting perceptual bias, participants completed a series of cancellation arrays consisting of random arrangements of target letters and shapes (the letter ‘A’ and an open circle with a slanted line through it respectively) and non-target letters and shapes (Mesulam, 2000, p.

146). Each array, containing either 60 target letters and 300 non-target letters or 60 target shapes and 300 non-target shapes, was presented on a white background in landscape orientation on a standard 8.3 by 11.7 inch sheet of paper, consistent with the method employed by Jones, Craver-Lemley, and Barrett (2008). The left and right sides of the page each contained 180 objects including 30 target stimuli; the targets were arranged evenly so that 15 appeared in the upper half and 15 appeared in the lower half. In line with the original procedure, a new colored pencil was given after every 10 targets (this makes analysis of the origination and method of searching possible, although these factors are not relevant to the current study). The task was untimed; however, participants were asked to work quickly to complete the task, to scan the page only once and circle the target stimuli, and to indicate to the experimenter when finished.

Lateralization drawing task.

This task was included for exploratory purposes to determine whether the expected perceptual biases seen in previous studies employing line bisection and cancellation tasks could also be observed in the way that participants compose drawings. Each participant received one standard sheet of white paper (8.3 x 11.7 inches) and a box of eight Crayola crayons along with the following prompt:

> Please draw a scene using only one side of the paper including the following items: a house, a tree, and a person. You may include additional decorations, but your drawing MUST include all three of the items mentioned above. Do not use any materials other than those provided by the experimenter. When you are finished, please return your drawing, the written prompt, and the crayons to the experimenter.

After reading the prompt, participants were informed that the task had no time limit and asked if they had any questions. The following two questions were common among the first participants, - “Does ‘one side’ mean one half of the page?” “Are we limited to those three things?” - so the following answers were included as standard verbal instructions for subsequent participants: “One side means that you can use the entire surface of the page, but cannot turn it over;” “you may decorate your drawing as you wish, but it must include the house, tree, and sun.”

Procedure

A link to the initial online screening survey was posted on Facebook as a private event and sent out to the students, faculty, and staff of Bates College in several campus-wide emails containing a link to the survey. Before beginning the survey, participants were asked to review a list of medications and to confirm that they had not consumed any of the listed substances during the previous 24 hours (see Appendix E). Each participant then completed a consent form, the EHI, the WURS (modified form), the ASRS-v 1.1, the CAARS-S: SV, and questions about demographic information and exclusionary criteria. Upon completion of the survey, participants read a short debriefing letter and had the opportunity to claim course credit for their participation.

Participants who met the criteria for inclusion were contacted via their preferred method (email, text message, or phone) and asked to return for additional data collection. Criteria for inclusion in the current study included right-handedness, absence of co-morbid learning disabilities, no history of major arm injuries or surgeries, no current arm injuries, and normal or corrected-to-normal vision. Participants who indicated that they had abnormal vision or a history of arm injuries or surgeries were contacted via email for additional information. Those with a history of arm injuries or surgeries who indicated in follow-up emails that they experienced no significant effects and those who indicated that they misunderstood the initial vision question and actually had normal or corrected-to-normal vision were asked to return for additional data collection. Upon entry to the lab, participants were directed to a chair and instructed to place the legs of the chair evenly between lines of masking tape on the floor to either side of the chair. In this position, the midline of the chair lined up with the midline of a rectangle shape taped on the table (internal dimensions 8.3 ×11.7 inches).

Prior to completing the experimental procedure, participants were asked to review the medications list again and to confirm that they had not consumed any of the listed substances during the previous 24 hours and to read and sign the consent form. Due to an error in the online version of the EHI that only allowed a choice of left or right hand, excluding the ability to select both or indicate degree, 31 of the 46 returning participants were also asked to complete a paper-and-pencil version of the survey.

The experimenter explained that the paper materials for all of the subsequent tasks must be aligned within the rectangle and that it was important to keep each paper straight and centered. Participants began by completing the perceptual asymmetry tasks with the order of the task (line bisection vs. cancellation tasks), the order of the line orientation (left, center, and right), and order of the cancellation tasks (letter vs. shape) balanced across participants.

After completing the line bisection and cancellation tasks, each participant received the prompt for the lateralization drawing task. This task was completed with only one hand and the choice of which hand to use was left up to the participant. Finally, participants were thanked, debriefed, and given an opportunity to receive course credit for their participation in the study.

Data Analysis

Line bisections.

For each of the line bisections, a bias score was calculated to determine the degree and direction of the departure from the true center. The distance from the left end of the line to the participant's mark was measured for each line to the nearest 0.5 mm; the bias score was calculated as [(left half-true half) / true half]×100 (Rolfe, et al., 2008; Scarisbrick, Tweedy, & Kuslansky, 1987) resulting in possible scores ranging from -100 to 100, with negative scores indicating a bias to the left of center and positive scores indicating a bias to the right of center.

Cancellation task.

Each cancellation array was scored by dividing the array into left and right halves, and the number of targets circled on the left and right sides was counted for each of the four arrays (Jones, et al., 2008), resulting in eight bias scores. Four bias scores were computed for the right and left hands for each of the two types of arrays as [(right correct – left correct) / 30] × 100 and [(right total errors – left total errors) / 30] × 100. Negative scores indicate higher accuracy on the left side of the array and positive scores indicate higher accuracy on the right side of the array.

Lateralization drawing task.

All analyses of the drawings utilized only the three objects specified in the prompt - house, tree, and sun - regardless of the number and type of objects actually included. Drawings were scored by measuring the distance from the left and right sides of each of the three objects to the true center; negative numbers indicate that the measurement falls to the left of true center and positive numbers indicate that the measurement falls to the right of true center. Two bias scores were calculated for each drawing: an average bias score using the center point of the three objects, and an overall bias score using only the most extreme leftward and rightward measurements. The average bias score was calculated as [(tree left + tree right) / 2 + (sun left + sun right) / 2 + (house left + house right) / 2] / 3; negative scores indicate that more objects were drawn to the left of center and positive scores indicate that more objects were drawn to the right of center. The overall bias score was calculated as (farthest left measurement + farthest right measurement) / 2; negative scores indicate that the entire drawing was justified to the left of center and positive scores indicate that it was justified to the right of center (see Figure 5).

Results

Sample Characteristics

One participant who was left-handed was excluded from all further analyses for a final sample of $N = 45$ (three male). Additionally, the visual line bisection data were dropped for one participant due to failure to properly orient the stimuli, and the drawing data was excluded for one participant who misunderstood the instructions and drew only on the right side of the page.

A series of multivariate analyses of variance (MANOVA) were conducted to determine whether the use of drugs and/or alcohol within the 24 hours prior to taking the survey ($n = 4$) affected scores on the handedness and ADHD measures and whether a prior arm injury ($n = 5$) affected bias scores on the line bisection and cancellation tasks.

No differences between the groups were found; therefore, all remaining participants were included in the analyses. Multivariate analysis of variance (MANOVA) indicated no significant gender differences in either the visual line bisection or the cancellation tasks. The analyses did indicate selected gender differences for the two bias measures of the lateralization drawing task, however the results of subsequent one-way ANOVAs indicated that this difference was only significant for controls when using the extreme edge scoring method.

Within the returning sample ($N = 45$), 20% of the participants were classified as meeting the criteria for ADHD (as indicated by a score at least one standard deviation above the mean on at least one of the CAARS subscales); 11.1% were classified as ADHD-I ($N = 5$) and 8.9% were classified as ADHD-C/H ($N = 4$). This rate is substantially higher than the rate reported in the literature indicating a lifetime prevalence rate in adults aged 18 to 29 of 7.8% (National Institute of Mental Health, 2009); however, for the purposes of this study, participants were not required to fully meet the DSM-IV-TR criteria to be classified as ADHD-I or ADHD-C/H. Participants who scored at least one standard deviation above the mean on the CAARS S:SV subscale for Hyperactive/Impulsive symptoms (with or without Inattentive symptoms) were included in the ADHD-C/H group, and participants who scored at least one standard deviation above the mean only on the subscale for Inattentive symptoms were included in the ADHD-I group. Although we use the previously listed diagnostic categories throughout the current study, these titles do not reflect diagnosis based on DSM-IV TR criteria and the resulting groups include both clinical and subclinical presentations of ADHD. Mean scores for each group on the handedness and ADHD scales are presented in Table 1.

Between-Measure Correlations

Two versions of the Edinburgh Handedness Inventory.

A Pearson correlation was conducted for the participants who completed both versions of the scale (N = 31) to determine whether the limited online version adequately assessed handedness for the purpose of this study. A one-tailed test of significance was used for this analysis. Results showed a moderate positive correlation between the two versions ($r(29) = .59$, $p < .001$), and a subsequent pairwise comparison indicated that the means of the online and paper-and pencil-versions (M = 75.49, M = 70.51) did not differ from each other. Additionally, visual inspection of the lateralization quotients for both measures indicated differences in degree of handedness, but not in direction. The online version of the Edinburgh Handedness Inventory was used for all further analyses.

ADHD measures.

Pearson correlations were conducted to assess the extent of agreement between the three ADHD measures (WURS, ASRS-S, and CAARS S:SV). A one-tailed test of significance was used for all bivariate analyses because all three measures purportedly assess the presence of ADHD. Results showed a weak positive correlation between the WURS and the ASRS-S ($r(74) = .31$, $p = .003$), and moderate correlations between the WURS and the CAARS S:SV ($r(74) = .53$, $p < .001$), and the CAARS S:SV and the ASRS-S ($r(74) = .59$, $p < .001$). As a result of the relatively low correlations, the CAARS S: SV was used for all further analyses except where noted.

Order Effects

A series of MANOVAs (task order: line bisection/cancellation vs. cancellation/line bisection; line order: left/center/right vs. left/right/center vs.

center/left/right vs. center/right/left vs. right/left/center vs. right/center/left; cancellation array type order: letter/shape vs. shape/letter; and hand order: left/right vs. right/left) was conducted to test for order effects. Results indicated no effects of task order, line justification order, cancellation array type order, or hand order.

Cancellation Task Bias and ADHD Group

Several one-sample *t*-tests were performed to determine whether the number of left- and right-sided omissions differed significantly from zero. In the letter cancellation task, only the omissions for the control and ADHD-C/H groups were significantly different (control group: $t(35) = -3.83$, $p < .001$; $t(35) = -4.85$, $p < .001$; ADHD-C/H group: $t(3) = -2.94$, $p = .03$; $t(3) = -2.61$, $p = .04$).

As predicted, a 1-tailed, paired samples t-test indicated that in the letter cancellation task, the ADHD-C/H group ($M = 1.75$, SD = 1.19) omitted significantly more targets on the left side than on the right side ($M = 29.38$, SD = 0.48). A series of independent samples *t*-tests were conducted to assess between group differences by spatial location and array type. The ADHD-C/H group ($M = 1.75$, SD = 1.19) also omitted significantly more left-sided targets than the ADHD-I group ($M = 29.60$, SD = 0.89; $t(7) = 1.95$, $p = .046$) (see Figure 1). All other between-group differences for the letter cancellation task failed to reach significance. No significant differences were found between the three groups on the shape cancellation task.

Lateralization Drawing Task and ADHD Group

All participants included in these analyses completed the drawing with the right hand. A one-way ANOVA (ADHD group: none vs. ADHD-I vs. ADHD-C/H) was performed on the average bias scores. As expected, the ADHD-C/H group drew objects significantly further to the right (*M* = 39.04, *SD* = 24.39) than controls, whose average bias score did not differ significantly from zero (*M* = 2.30, *SD* = 26.95); contrary to predictions, the ADHD-I group also drew objects significantly more to the right of center (*M* = 34.25, *SD* = 5.38) than controls. The two ADHD groups did not differ from each other. A second one-way ANOVA was performed on the edge bias scores. Due to the significant effect of gender for control participants, males were excluded from this analysis. No significant effects were revealed, although the pattern and direction of the edge bias scores was consistent with that of the average bias scores. To determine whether the two scoring systems (average bias and edge bias) measure the same general effect, a Pearson correlation was conducted. Results indicated a strong positive correlation between the two systems, suggesting that they assess the same construct (r = .63, $p < .001$). Figure 2 displays a comparison of the means for each of the two scoring systems by ADHD subgroup.

Visual Line Bisection Task

To determine if the biases shown by each group were significantly different from zero as a function of the hand used, a series of one-sample *t*-tests was performed. As shown in Figure 3, the control group showed the expected marginally significant slight deviation to the left for both left- and right-hand use ($t(35) = -1.420$, $p = .083$, *Cohen's d* = .23; $t(35) = -1.486$, $p = .073$, *Cohen's d* = .24). The expected leftwards trend for the ADHD-I group also approached significance for both the left and right hands ($t(4) = -1.914$, $p = .064$, $d = .69$; $t(4) = -1.923$, $p = .064$, *Cohen's d* = .69).

Two two-way mixed factorial ANOVAs were conducted for bisections with the right and left hands with justification (left, right, center) as a within-subjects variable and group (control, ADHD-I, ADHD-C/H) as a between-subjects variable. A significant interaction of justification and group was found for bisections completed with the left hand ($F(3, 43) = 3.55$, $p = .01$), but not for bisections completed with the right hand. Three one-way repeated measures ANOVAs comparing the effects of justification on bisections completed with the left hand for each of the three groups indicated that the effect of justification was only significant among the control group. Subsequent paired-samples *t*-tests indicated that these participants bisected center-justified lines significantly farther to the left ($M = -1.95$, SD = 3.34) than either left- or right-justified lines ($M = -0.11$, SD = 3.23; $M = 0.26$, SD = 2.77). A non-significant trend also suggested that the ADHD-C/H group showed the expected bias to the right when lines are justified to the left or center of the page, but not when the lines are justified to the right (see Figure 3).

To allow comparison with the results of Rolfe et al. (2008), a two-way ANOVA was performed, collapsing across justification, with hand (right, left) as a within-subjects variable and group (control, ADHD-I, ADHD-C/H) as a between-subjects variable. The ANOVA did not reveal any significant effects; however, the trends were consistent with predictions based on the results of Rolfe et al. (2008) that the control group would show a slight leftward bias, the ADHD-I group would show a more extreme leftward bias, and the ADHD-C/H group would show a rightward bias, all irrespective of hand used (see Figure 4).

Lateralization Correlations

A series of Pearson correlations were conducted to determine the relationship between the lateralization drawing task and the other two lateralization measures. Results indicated that the lateralization drawing task was not correlated with any of the dimensions of the line bisection or cancellation tasks (Average Center Bias: $r(42) = .63$, $p < .001$).

Discussion

This study used three different tasks - a line bisection task, a visual cancellation task, and a lateralization drawing task - to investigate the presence of perceptual asymmetries in young adults with and without ADHD. Participants with ADHD as defined by the CAARS S: SV were classified into the following two subgroups: the ADHD-Inattentive group (ADHD-I) and the ADHD-Combined/Hyperactive group (ADHD-C/H), comprised of both the ADHD-Combined type (ADHD-C) and the ADHD-Hyperactive/Impulsive type (ADHD-H).

Letter Cancellation Task

In the letter cancellation task, a priori hypotheses predicted that participants in the ADHD-C/H group would omit significantly more targets on the left side of the letter array, and they would omit more left-sided targets than either the control or ADHD-I groups. Resulting trends were consistent with these hypotheses, however the difference between the ADHD-C/H and control groups failed to reach significance. As expected, no differences between groups on the shape cancellation task were found, consistent with previous research (Jones et al., 2008).

Further, research found that young adults with ADD/ADHD showed more evidence of asymmetrical performance on cancellation tasks than controls. The current study adds general evidence in support of these findings. However, we found that only the ADHD-C/H group displayed significant asymmetrical performance, in contrast to research by Garcia-Sanchez et al. (1997), who found the greatest asymmetrical performance in participants with Attention Deficit Disorder without hyperactivity, and Sandson et al. (2000), who found that ADHD subtype was not related to the presence of increased left-over-right omissions.

Several studies, including the current study, have found significant differences in the letter cancellation task, but not in the shape cancellation tasks. These findings suggest that the two tasks may activate different brain regions. Although the ADHD-I group failed to show the expected rightward bias observed in previous studies (Rolfe et al., 2006; Rolfe et al., 2008), the pattern of their mean omissions does appear to be less biased to the left than either the ADHD-C/H group or the control group. Further study with a larger sample is needed to investigate these potential effects.

Visual Line Bisection Task

Existing research on the line bisections of children with and without ADHD found that the three subgroups differed significantly in the direction and degree of their bisections. The ADHD-I group bisected lines significantly to the left of center and the ADHD-C/H group bisected lines significantly to the right of center irrespective of the hand used; the line bisections of the control group were dependent on the hand used, with bisections biased to the left when completed with the left hand and biased to the right when completed with the right hand (Rolfe et al., 2008). A meta-analysis by Jewell and McCourt (2000) found that neurotypical adults bisected lines to the left of center with both hands, although bisections completed with the left hand were biased further to the left than bisections completed with the right hand.

The current study replicated this pattern of results, finding that, irrespective of the hand used to complete the bisections, the ADHD-C/H group bisected lines to the right of center, and both the control and ADHD-I groups bisecting lines to the left of center, with the ADHD-I showing a larger degree of leftward bias than the controls. Unfortunately, this pattern did not reach significance.

Taken with the results of the letter cancellation tasks, these findings provide tentative support for a relationship between ADHD-Combined/Hyperactive type and left hemi-spatial neglect. The evidence for an association between ADHD-Inattentive type and the leftward perceptual bias observed in some prior studies was mixed. The ADHD-I group did show a non-significant trend toward the left in the line bisection task. However, in the letter cancellation task, this group made approximately equal errors on the right and left sides of the array, a clearly different pattern from that of the ADHD-C/H group. The contrasting patterns between the two tasks in the ADHD-I group is consistent with findings that patients with only patients with right-hemisphere lesions show clear evidence of neglect across different tasks of spatial attention. Therefore, if ADHD-I is, in fact, not related to right-hemisphere dysfunction, the perceptual biases of this group are likely to vary across different lateralization tasks.

Drawing Task

The lateralization drawing task has not been utilized prior to the current study. Based on prior lateralization research, a priori hypotheses suggested that the control group would show a non-significant bias toward the left of center, the ADHD-I group would show a significant bias to the left of center, and the ADHD-C/H group would also show a significant, but opposite, bias to the right of center. The expected pattern was observed for both the control and ADHD-C/H groups, but contrary to prediction, the

ADHD-I group showed evidence of an opposite pattern, paralleling that of the ADHD-C/H group.

One possible explanation is that the drawing task utilizes different brain regions/processes than the other two tasks that rely heavily on perception of existing images. Research on the perception of art implicates the prefrontal cortex, an area also commonly implicated in ADHD (Zeki, 2001). However, little research has been done on the brain regions involved in the production of art. In a meta-analysis conducted by Dietrich and Kanso (2010), they concluded that the current literature does not support specific correlations between particular brain regions and the production of art. In fact, they posit that creativity is most likely the result of a complex neural network (Dietrich and Kanso). Although this avenue of research is tentative at best, it does suggest that that the lateralization drawing task may draw on neurocognitive resources, unrelated to specific right-hemisphere dysfunction, in which the two subtypes of ADHD share a deficit. Finding no relationship between the drawing task and the other measures of lateralization supports the hypothesis that the drawing task is measuring a unique cognitive process.

Current Subtype Classification

The observed differences between the two groups suggest the current two ADHD subtypes may, in fact, represent completely different disorders. Although the two classifications obviously share some features, the symptoms of ADHD can be caused by a number of different disorders and biological mechanisms (Monastra, 2008), indicating that the shared features between the two subtypes may not share the same causes. The patterns of perceptual biases in ADHD-C/H clearly point to deficits in the right hemisphere, supporting the more general belief that ADHD results from right hemisphere dysfunction. However, ADHD-I does not seem to be related to these same deficits, commonly displaying deficit patterns that are inconsistent with specific right hemisphere dysfunction and, possibly, that the Inattentive subtype is a similar but distinct disorder.

The American Psychiatric Association (2010) has proposed three options for revision of the current diagnostic criteria and subtype classification for ADHD. One option, consistent with the above conclusions, recommends creating a new diagnosis of "Attention-Deficit Disorder" that includes the current criteria for the ADHD-Predominantly Inattentive subtype without the presence of any hyperactive or impulsive symptoms. This change, should it be adopted, is supported by neuropsychological studies including the current study that suggest different patterns of neurological deficits between the ADHD-Inattentive type and the other two current subtypes.

Limitations

The current study had a number of limitations. The primary limitation of the current study is its small sample size, particularly in the two ADHD subgroups. Keeping this in mind, it is difficult to draw conclusions based on the current findings. Second, although the choice to group the ADHD-Combined type and ADHD-Hyperactive/Impulsive types together was based on behavioral and neurochemical evidence suggesting that the two subtypes share common deficits, these subtypes have not been tested separately to determine whether or not they share the same perceptual biases.

Third, although our original intention was to use all three ADHD scales in the analyses, the relatively low correlations between the scales made conclusions based on such analyses difficult to interpret. The Wender Utah Rating Scale has been widely used in research to retrospectively assess the presence of ADHD in childhood, but research by Suhr, Zimak, Buelow, and Fox (2009) casts doubt on its ability to discriminate between behaviors found to be consistent with ADHD and a diagnosis of ADHD. They found that using the standard cutoff score of 46 resulted in the correct identification of only 17% of participants with an existing diagnosis of ADHD and a false-positive rate of 2% for controls (4% for males and 1% for females) and 16% for participants with an unrelated psychological condition, for which the current study did not screen. As a result, the likelihood that the WURS over-diagnosed the presence of ADHD in the current sample is high, limiting its usefulness in the current study. Research on the Adult ADHD Self-Report Scale has shown the first 6 questions to be the most clearly associated with a diagnosis of ADHD. Although the scale has been used to more widely assess the presence of specific categories of symptoms (Adler et al., 2006), this method has not been widely utilized and proved to be not sensitive enough for use in the current study.

The fourth limitation is specific to the lateralization drawing task. We did not control for the order in which the participants drew the three objects or when they were drawn in relation to any additional, irrelevant decorations. Since the presence of each object affects the space available for all subsequent objects, both of these omissions may have had substantial effects on the participants' overall compositions and the resulting bias scores.

The usefulness of the cancellation task as a measure of lateralization was limited because the task was untimed. Although participants were instructed to work as quickly as possible, they were under no pressure to complete the task in a specified period of time. When given a time limit insufficient to fully complete the task, participants must make choices about how and where they search. We suspect that participants would show increased evidence of the expected biases when required to complete the task within a given time limit.

Lastly, despite efforts to exclude participants with uncorrectable vision problems and comorbid learning disorders, both of these items relied solely on self-report. Several participants indicated that they had uncorrectable vision problems in the initial survey, but later, when asked for clarification via email, indicated that they made an error during the survey and actually had normal or corrected-to-normal vision. This inconsistency was only observed in those who answered with a false positive because those who answered negatively – on either the vision or learning disorder question – were not contacted with follow-up questions. Both learning disabilities (Klimkeit & Bradshaw, 2006) and abnormal vision have been associated with anomalies in spatial perception. Thus, without directly testing for visual disturbances and learning disabilities, we cannot be sure that our sample did not include confounding effects of these unintended variables.

Implications

The presence of perceptual asymmetries in young adults is of particular interest because this age group tends to rely heavily on attention in a number of tasks – college courses, driving, sports – and may be more likely to engage in behaviors thought to interfere with attention including alcohol use (Wester, Verster, Volkerts, Böcker, & Kenemans, 2010), substance use (Kalapatapu , 2011; Thoma et al., 2011), and sleep deprivation (Chee, 2011; McCoy & Strecker, 2011; Zerouali, 2010). As a result, it is important to understand the unique patterns of attentional biases in young adults with ADHD who, in combination with these other risk factors, may be at the highest risk for complications of inattention – classroom difficulties, motor vehicle accidents, sports injuries, and the like. Further research is needed on the specific biases and underlying mechanisms within this population.

Conclusion

The current study provides support for the existing literature on ADHD that suggests the subtypes have important neuropsychological differences and may, in fact, be neurologically distinct disorders. Further research is needed to determine exactly how these two disorders differ and to develop treatments for each. In research with stroke patients exhibiting hemi-spatial neglect, Harvey and Milner (1999) found that patients line bisections improved over time even if the spatial neglect itself, as measured by the Landmark test, remained unchanged. The authors posited that over time, the patients may have learned through the results of testing and through everyday tasks that their perceptions were incorrect and likely developed strategies for dealing with the abnormal spatial perception. A similar directed tactic aimed at the specific hemispheric deficits implied in the two subtypes of ADHD may help these individuals to learn to compensate for deficits in spatial perception. Research into the effects of perceptual asymmetries on day-to-day tasks will be important in developing targeted behavioral treatments.

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Table 1

Mean scores (standard deviation in parantheses) for all groups on the Edinburgh Handedness Inventory (EHI), the Wender Utah Rating Scale (WURS), the Adult ADHD Self-Report Scale (ASRS; including subscales for inattentive symptoms, hyperactive symptoms, total symptoms, and diagnostic screening), and the Conners Adult ADHD Rating Scales Self-Report: Screening Version (CAARS S:SV; including subscales for inattentive symptoms, hyperactive symptoms, total symptoms, and ADHD index)

			ASRS				CAARS			
Group	EHI	WURS	Inattentive	Hyperactive	Total Symptoms	ADHD Screening	Inattentive	Hyperactive	Total Symptoms	ADHD Index
ADHD-I (*N* = 12)*	74.96 (17.59)	55.71 (17.68)	24.57 (4.86)	11.14 (6.20)	15.71 (3.99)	35.71 (6.82)	69.43 (4.43)	53.86 (5.27)	63.43 (3.99)	62.14 (6.98)
ADHD-C/H (*N* = 7)*	72.75 (19.72)	53.58 (14.69	24.58 (8.19)	19.75 (9.95)	17.58 (5.70)	44.33 (16.05)	66.83 (12.19)	69.00 (7.07)	71.50 (9.64)	63.33 (9.69)
Controls (*N* = 57)*	78.48 (14.21)	42.14 (16.96)	7.68 (6.32)	5.46 (4.43)	5.53 (4.99)	13.14 (8.43)	44.79 (10.53)	42.61 (11.12)	43.47 (10.55)	43.89 (10.58)
Total (*N* = 76)*	77.25 (15.41)	45.20 (17.33)	11.91 (9.79)	8.24 (7.75)	8.37 (7.03)	20.14 (15.75)	50.54 (14.39)	47.82 (14.06)	49.74 (14.87)	48.64 (13.03)
ADHD-I (*N* = 5)**	80.94 (17.53)	54.20 (21.06)	26.00 (5.15)	11.40 (6.03)	17.20 (3.49)	37.40 (6.03)	70.60 (4.83)	55.20 (3.56)	64.60 (3.44)	63.80 (6.98)
ADHD-C/H (*N* = 4)**	72.50 (27.54)	53.75 (21.28)	30.00 (8.04)	24.25 (12.58)	20.00 (6.68)	54.25 (18.72)	69.50 (8.19)	70.75 (9.91)	73.50 (8.89)	65.25 (9.32)
Controls (*N* = 36)**	76.56 (14.47)	44.00 (14.55)	8.28 (6.02)	5.14 (4.30)	5.78 (4.58)	13.42 (7.63)	47.17 (4.90)	44.06 (7.93)	44.54 (5.78)	45.47 (6.25)
Total (*N* = 45)**	76.69 (15.81)	46.00 (16.00)	12.18 (9.94)	7.53 (7.79)	8.31 (6.89)	19.71 (15.81)	51.76 (10.58)	47.67 (11.11)	50.07 (11.16)	49.27 (10.02)

*Data presented includes the ADHD subtype groups and total means for the whole sample.

** Data presented include the ADHD subtype groups and total means for participants who returned for the second part of the study.

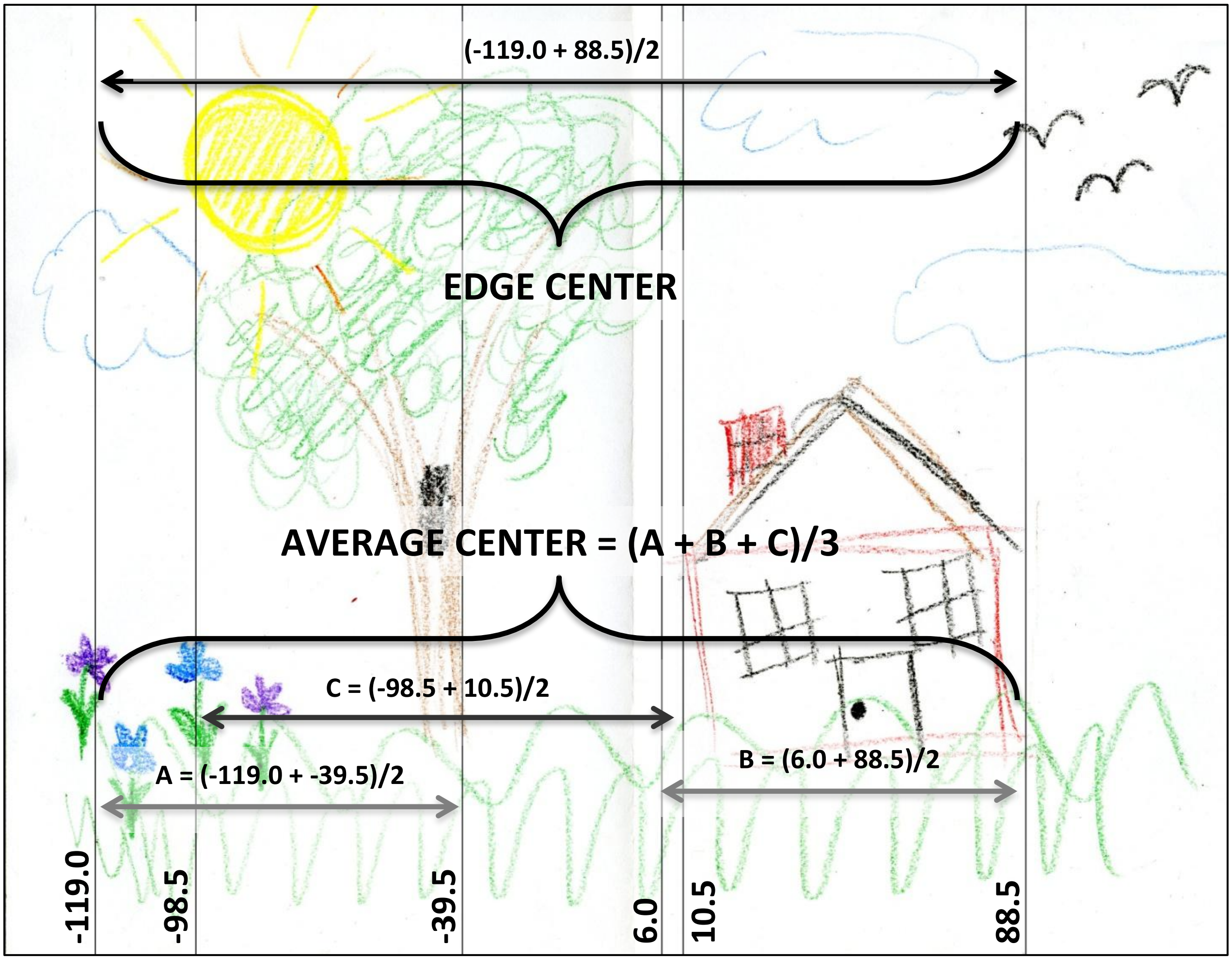

Figure 1. Two methods of data analysis for the lateralization drawing task. The Average Center score is calculated as the average of the mid-point of the three relevant objects: tree, sun, and house. The Edge Center score is calculated as the mid-point of the farthest left and farthest right points of the relevant objects.

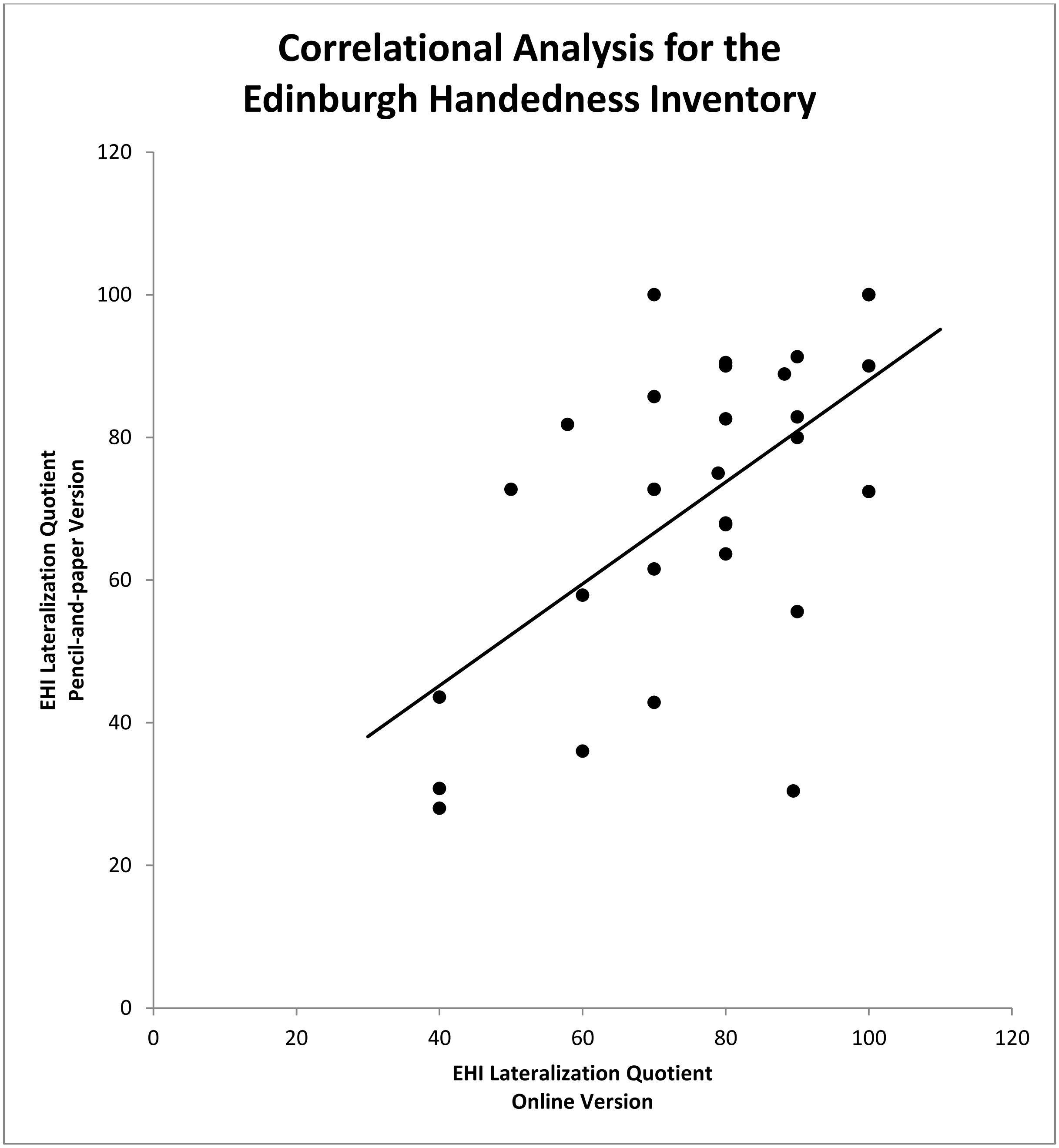

Figure 2. Pearson Correlation for the online and paper-and-pencil versions of the EHI. The laterality quotients for the two versions of the Edinburgh Handedness Inventory are compared.

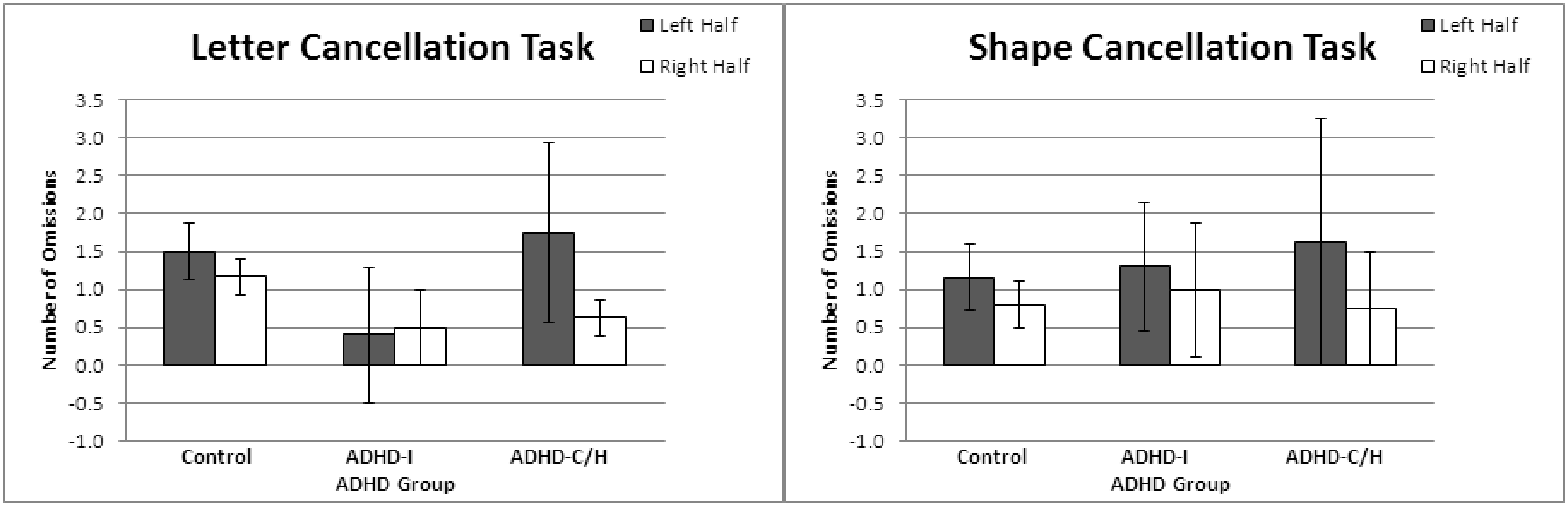

Figure 3. Mean number of omissions for the left and right sides of the cancellation arrays for participants with ADHD-Combined/Hyperactive, ADHD-Inattentive, and controls. Error bars show ±1 SE of the mean. [1,2]Significance at $p < .05$.

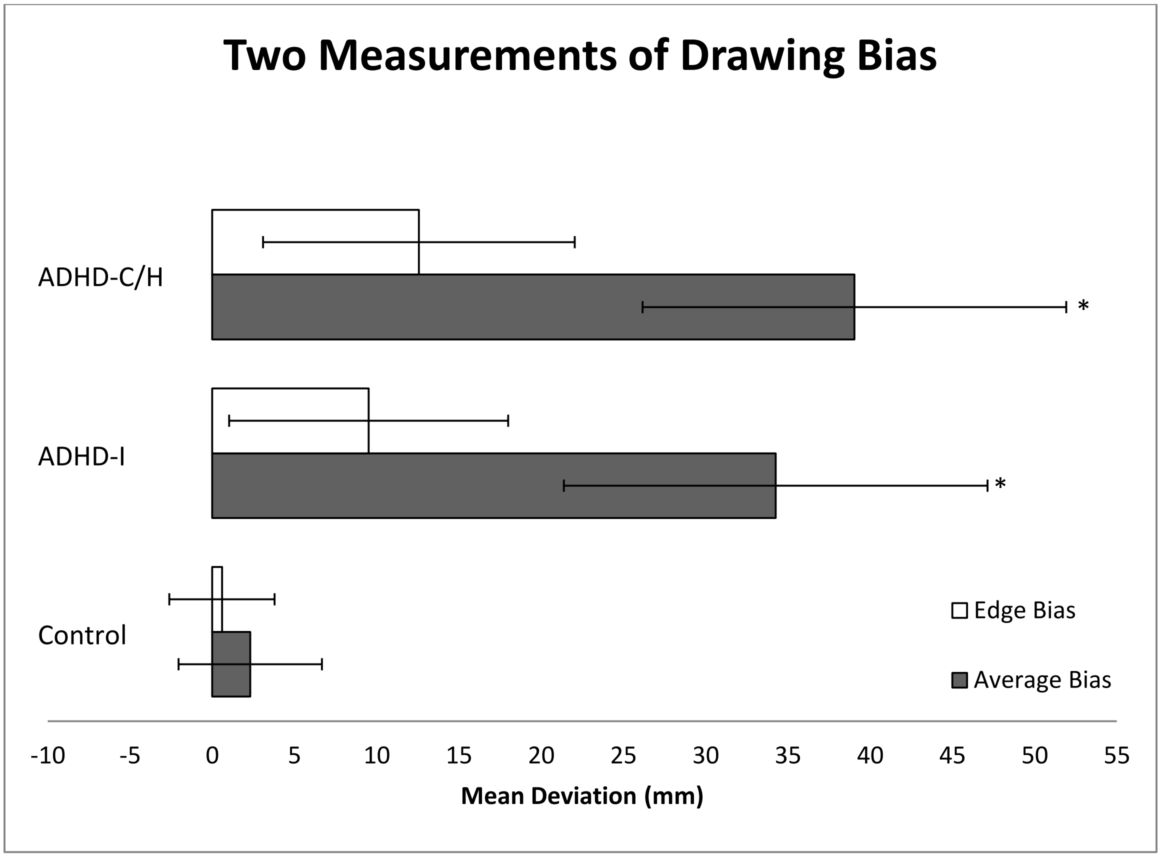

Figure 4. Mean deviations from the true center (mm) measured as the average center of the three objects of interest (Average Bias) and the overall center using the most extreme left and right measurements (Edge Bias). Positive numbers indicate a bias to the right of center and negative numbers indicate a bias to the left of center. Error bars show ±1 SE of the mean. *Significance at $p < .01$.

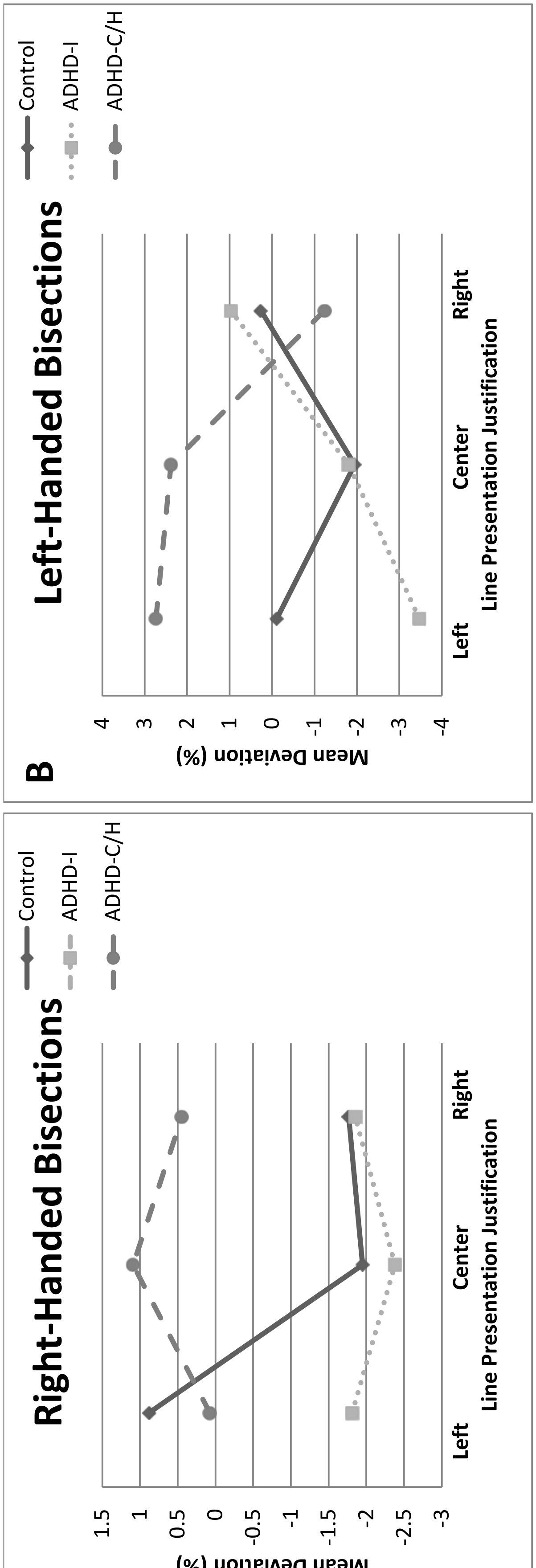

Figure 5. Mean deviations from the true center (%) for (A) right-handed and (B) left-handed bisections of adults with ADHD-Combined/Hyperactive, ADHD-Inattentive, and controls on the visual line bisection task. Negative numbers indicate a bias to the left and positive numbers indicate a bias to the right.

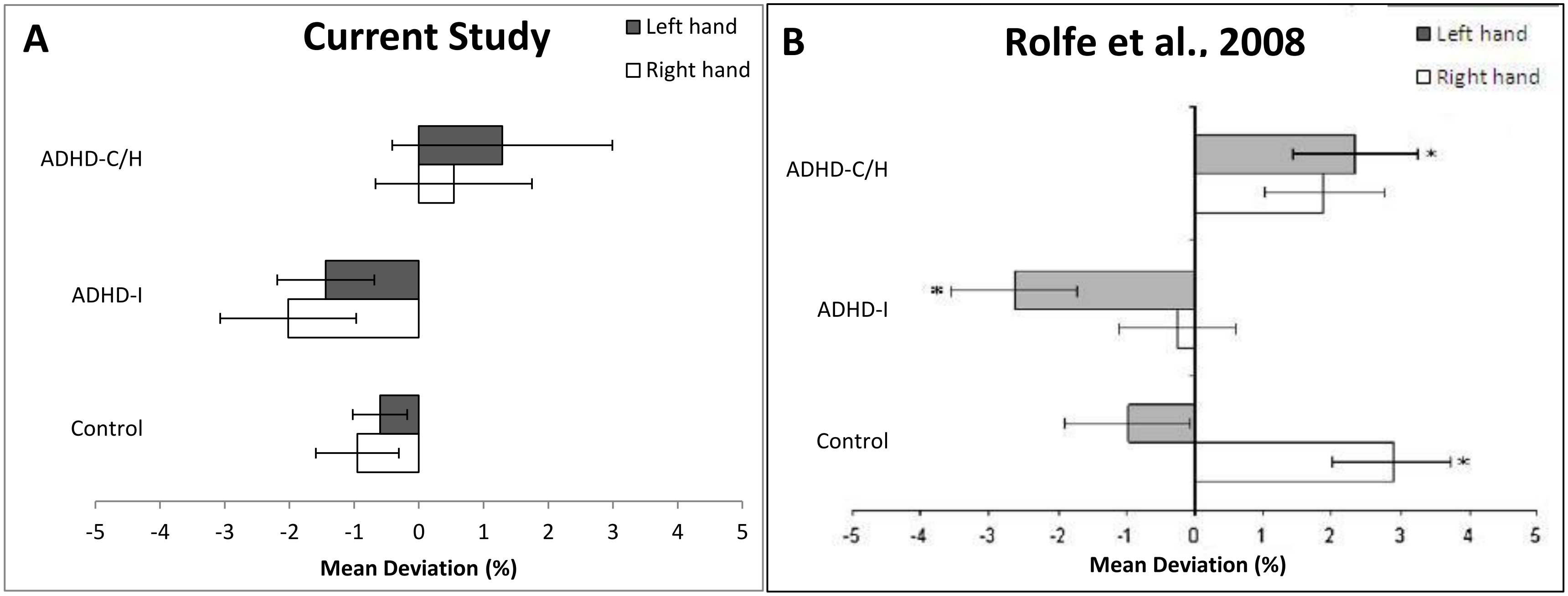

Figure 6. Mean deviations from the true center (%) for (A) adults and (B) children with ADHD-Combined/Hyperactive, ADHD-Inattentive, and controls on the visual line bisection task. Negative numbers indicate a bias to the left and positive numbers indicate a bias to the right. Error bars show ±1 SE of the mean. *Significance at $p < .05$.

Appendix A

Edinburgh Handedness Inventory

Have you ever had any tendency to left-handedness?

YES NO

INSTRUCTIONS: Please indicate your preferences in the use of hands in the following activities by putting + in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put + +. If in any case you are really indifferent put + in both columns.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand-preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

		R	L
1	Writing		
2	Drawing		
3	Throwing		
4	Scissors		
5	Comb		
6	Toothbrush		
7	Knife (without fork)		
8	Spoon		
9	Hammer		
10	Screwdriver		
11	Tennis Racket		
12	Knife (with fork)		
13	Cricket or baseball bat (lower hand)		
14	Golf Club (lower hand)		
15	Broom (upper hand)		
16	Rake (upper hand)		
17	Striking match (match)		
18	Opening box (lid)		
19	Dealing cards (card being dealt)		
20	Threading needle (needle or thread according to which is moved)		
40	Which foot do you prefer to kick with?		
41	Which eye do you use when using only one?		

Appendix B

Wender Utah Rating Scale (modified)

INSTRUCTIONS: For each of the following statements, check the box which best describes you as a CHILD.

As a child I was (or had):	Not at all or very slightly	Mildly	Moderately	Quite a bit	Very much
1. Concentration problems, easily distracted					
2. Anxious, worrying					
3. Nervous, fidgety					
4. Inattentive, daydreaming					
5. Hot- or short-tempered, low boiling point					
6. Temper outbursts, tantrums					
7. Trouble with stick-to-it-tiveness, not following through, failing to finish things started					
8. Stubborn, strong-willed					
9. Sad or blue, depressed, unhappy					
10. Disobedient with parents, rebellious, sassy					
11. Low opinion of myself					
12. Irritable					
13. Moody, ups and downs					
14. Angry					
15. Acting without thinking, impulsive					
16. Tendency to be immature					
17. Guilty feelings, regretful					
18. Losing control of myself					
19. Tendency to be or act irrational					
20. Unpopular with other children, didn't keep friends for very long, didn't get along with other children					
21. Trouble seeing things from someone else's point of view					
22. Trouble with authorities, trouble with school, visits to principal's office					
23. Overall a poor student, slow learner					
24. Trouble with mathematics or numbers					
25. Not achieving up to potential					

Appendix C

Adult ADHD Self-Report Scale (ASRS-v 1.1) Symptom Checklist

INSTRUCTIONS: Please answer the questions below, rating yourself on each of the criteria shown using the scale on the right side of the page. As you answer each question, place an 'X' in 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?					
7. How often do you make careless mistakes when you have to work on a boring or difficult project?					
8. How often do you have difficulty keeping your attention when you are doing boring or repetitive work?					
9. How often do you have difficulty concentrating on what people say to you, even when they are speaking directly to you?					
10. How often do you misplace or have difficulty finding things at home or at work?					
11. How often are you distracted by activity or noise around you?					
12. How often do you leave your seat in meetings or other situations in which you are expected to remain seated?					
13. How often do you feel restless or fidgety?					
14. How often do you have difficulty unwinding and relaxing when you have time to					

	Never	Rarely	Sometimes	Often	Very Often
15. How often do you find yourself talking too much when you are in social situations?					
16. When you're in a conversation, how often do you find yourself finishing the sentences of the people you are talking to, before they can finish them themselves?					
17. How often do you have difficulty waiting your turn in situations when turn-taking is required?					
18. How often do you interrupt others when they are busy?					

Appendix D

Demographic Questionnaire

INSTRUCTIONS: Please answer the following questions by circling one of the provided options or filling in the blank.

What is your age in years? ___________

What is your gender?

MALE FEMALE

What is your race/ethnicity?

BLACK/AFRICAN-AMERICAN

ASIAN/PACIFIC-ISLANDER

AMERICAN INDIAN/ALASKA-NATIVE

HISPANIC/LATINO

WHITE/CAUCASIAN

Do you have normal vision or corrected to normal vision (with contacts or glasses)?

YES NO

Have you ever been diagnosed with a learning disability?

YES NO

If you answered "yes" in question 5, what is or was your diagnosis?

____

Have you ever broken or had surgery on either arm?

YES NO

Is either arm currently injured?

YES NO

Have you used any alcohol, drugs, or medications not prescribed to you in the last 24 hours?

YES NO

Appendix E

ADHD Medication List

Have you taken any of the following medications in the past 24 hours? If so, please inform the experimenter immediately.

Medication	Alternative Names
Adderall	Adderall XR
Dextroamphetamine	Dexedrine, Dexidrine Spansule, Dextrostat
Vyvanse	Lisdexamfetamine
Focalin	Dexmethylphenidate, Focalin XR
Ritalin	Methylin, Methylphenidate, Metadate ER, Methylin ER, Metadate CD, Concerta, Daytrana Patch, Ritalin LA, Ritalin SR
Strattera	Atomoxetine
Intuniv	Guanfacine, Clonidine, Catapres, Tenex
Bupropion	Wellbutrin, Wellbutrin SR, Wellbutrin XL)
Imipramine	Antideprin, Deprimin, Deprinol, Depsol, Depsonil, Dynaprin, Eupramin, Imipramil, Irmin, Janimine, Melipramin, Surplix, Tofranil
Nortryptiline	Pamelor, Aventyl
Desipramine	Nopramin, Pertofrane
Provigil	Modafanil
Risperdal	Risperidone

Taken from WebMD (ADHD medication chart, 2009).