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Assessing inattention and impulsivity in children during the Go/NoGo task

Serena Bezdjian, **Laura A. Baker***, **Dora Isabel Lozano**, and **Adrian Raine**
Department of Psychology, University of Southern California, Los Angeles, California, USA

Abstract

Behavioural performance in the Go/NoGo task was compared with caregiver and teacher reports of inattention and hyperactivity–impulsivity in 1,151 children (*N* = 557 boys; *N* = 594 girls) age 9–10 years old. Errors of commission (NoGo errors) were significantly correlated with symptom counts of hyperactivity–impulsivity, while errors of omission (Go errors) were significantly correlated with symptom counts for inattention in both caregiver and teacher reports. Cross-correlations were also evident, however, such that errors of commission were related to inattention symptoms, and errors of omission were related to hyperactivity–impulsivity. Moreover, hyperactivity–impulsivity and inattention symptoms were highly intercorrelated in both caregiver (*r* = .52) and teacher reports (*r* = .70), while errors of commission and omission were virtually uncorrelated in the Go/NoGo task (*r* = .06). The results highlight the difficulty in disentangling hyperactivity–impulsivity and inattention in questionnaires, and suggest that these constructs may be more clearly distinguished in laboratory measures such as the Go/NoGo task.

The constructs of impulsivity and inattention are key features of self-regulatory ability and are an integral part of development in school-aged children (Kochanska, Murray, & Harlan, 2000; Kopp, 1989). During school years children learn how to focus their attention on teacher-directed activities, interact appropriately with peers and authority figures, and follow spoken and unspoken rules in the classroom. Thus, they acquire the basic building-blocks of later academic success as they learn emergent literacy, math, and language skills (Spira & Fischel, 2005).

Not all children however, master these critical skills. For some children difficulties with impulse control, attentional capacity, and hyperactivity hinder the ability to benefit from the valuable lessons of grade school and later academic experiences (Spira & Fischel, 2005). Children who are deficient in these skills are at an elevated risk for a diverse range of behavioural, social, and academic problems in childhood and adolescence (Calkins, 1994; Campbell, 1995). Furthermore, impulsive and inattentive behaviours are defining features of several disorders associated with aggression (Plutchik & Van Praag, 1989, 1995), conduct and attention deficit problems (August, Realmuto, MacDonald, Nugent, & Crosby, 1996), peer rejection (Hinshaw & Melnick, 1995; Whalen, Henker, & Granger, 1990) and problems in learning and achievement (Hinshaw, 1992). The prevalence and potential long-term consequences of impulsivity and inattention necessitate further exploration and clarification.

Past measures of inattention and hyperactivity–impulsivity have relied on questionnaire, interview, and self-report methods. Self-report questionnaires have been by far the most commonly used technique for measuring impulsivity among young adolescents and adults.

*Correspondence should be addressed to Laura A. Baker, Department of Psychology, University of Southern California, Los Angeles, CA 90089-1061, USA (lbaker@usc.edu).

The number of questionnaires and/or surveys that have been developed to measure impulsivity is extensive (see Barratt & Patton, 1983). Most questionnaires and structured interview measures have low or negligible correlations with one another (Monahan & Steadman, 1994), and have low order and often, insignificant correlations with non-questionnaire measures (of inattention or impulsivity) (Barratt & Patton, 1983). Furthermore, questionnaires might be unsuitable for repeated use, which may also be a disadvantage (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001).

Most studies that have used children's self-reports have primarily relied on surveys and interviews, the results of which could be affected by social desirability, poor reading skills, and a general lack of comprehension, which are likely to occur in children (Lyon, 1995). Furthermore, it may be more difficult to delineate different, complex constructs (such as impulsivity and inattention) using questionnaire and interview measures.

For example, a psychiatric disorder where impulsivity is evident is attention deficit hyperactivity disorder (ADHD). According to the DSM-IV definition of the disorder, attention deficit and hyperactivity can occur together, or independently. The diagnostic criteria related to impulsivity in the definition are 'often blurts answers before questions have been completed', 'often has difficulty in awaiting turns', and 'often interrupts or intrudes on to others'. However, other items defined as inattention such as 'often has difficulty in sustaining attention in tasks or play activities', or 'often does not follow through on instructions or fails to finish schoolwork, chores, or duties in workplace', or hyperactivity items such as 'often leaves seat in classroom or in other situations in which remaining seated is expected' seem to be well related to a broad definition of impulsivity (Evenden, 1999). Thus, the general behaviour pattern may be characterized by common factors or mechanisms in 'impulsivity', 'hyperactivity', and 'inattention', but may also occur independently of one another (Evenden, 1999). Therefore, laboratory measures such as the Go/NoGo may provide successful, alternative methods of investigating complex constructs such as impulsivity (of lack of inhibition) and inattention in children.

The Go/NoGo task, which demonstrates reasonable test–retest reliability (Kindlon, Mezzacappa, & Earls, 1995), requires participants to respond to the presence of a target stimulus (e.g. a single digit or letter) amidst a stream of similar stimuli (e.g. other digits or letters). In the most common version of the Go/NoGo task, participants have to make a motor response (button press) to one stimulus category (Go stimuli) and refrain from responding to the other (NoGo stimuli). Participants are then rapidly presented with both types of stimuli over successive trials and in turn, a dominant response set is established (Fishbein, 2000). This non-invasive paradigm and its requirement for attentional control has made it very attractive for studying disorders such as ADHD (Epstein *et al.*, 2003).

Numerous studies that explore the disinhibitory nature of ADHD have utilized laboratory measures such as the Go/NoGo task (Nigg, 2001). The symptom domains of both impulsivity (which include difficulties in inhibitory control and response) and inattention (which include difficulties in sustaining and focusing attention) are exemplified in a Go/NoGo paradigm. For example, because errors of commission (NoGo errors) are responses that occur when no response is required, they are assumed to reflect impulsivity. Errors of omission (the absence of response to a target) are assumed to reflect symptoms of inattention (Barkley, 1991; Halperin, Wolf, Greenblatt, & Young, 1991). Furthermore, deficient inhibitory control is considered to be the core cognitive symptom of attention deficit disorders in children (Barkley, 1997; Brandeis *et al.*, 1998; Nigg, 2001). Research confirms that disinhibited children respond too quickly and too often when they are required to wait and watch for events as is often seen in impulsive errors (errors of commission) (Corkum & Siegel, 1993). Research has also shown

that males commit more impulsive errors (NoGo errors) than females during continuous performance-type tasks (Newcorn *et al.*, 2001).

Laboratory based measures have considerable utility for investigating symptoms of impulsivity and inattention because they are not as susceptible to informant biases as are questionnaire measures, and may thus provide a less contaminated assessment of impulsivity, inattention, and occasionally hyperactivity symptoms. Laboratory procedures also provide precision and control over manipulating the variables related to the desired behaviour. Furthermore, they provide an operationalization under which the behaviour can be clearly specified (Fishbein, 2000). Relevant laboratory tasks include continuous performance tasks (CPT) and variations, such as the Go/NoGo task. Moreover, studies of children with ADHD found that an increased number of commission errors (i.e. false alarms) were made when compared to control children (Nigg, 2001).

The aim of the present study was to assess impulsivity and inattention in children during a Go/NoGo task and compare the behavioural performance measures of the Go/NoGo task to symptom count ratings of hyperactivity–impulsivity and inattention obtained from the children's caregivers and teachers. The primary goal was to demonstrate that a laboratory task such as the Go/NoGo maybe useful in assessing and delineating complex constructs including hyperactivity–impulsivity and inattention in children. Understanding the relationship between Go/NoGo performance measures and questionnaire measures of hyperactivity–impulsivity and inattention may help shed light on the nature of these two important constructs in children.

Method

Subjects

The participants were recruited from the Los Angeles community, and consisted of 9 and 10-year-old twins (total N = 1,219 children) and their primary caregivers. Twins were recruited from both private and public school districts, as well as advertisements in local newspapers and public buildings. Children's ethnicity was determined by the ethnicity of their two biological parents, as reported by the primary caregiver. The ethnic composition of the twins was as follows: 37.5% Hispanic; 26.6% Caucasian; 14.3% African-American; 4.5% Asian and 16.7% mixed; and 0.3% other ethnicities. This ethnic distribution is comparable to that of the greater Los Angeles area and thus, provides a diverse community sample representative of a large urban area both ethnically and socioeconomically. Moreover, the children participating in the study were fluent English speakers, as demonstrated by a standardized test of English proficiency administered through their schools.

Families identified as having twins were sent letters describing the study in extensive detail. Each letter contained an enclosed preaddressed/prepaid envelope that contained a form for interested families to provide contact information and return to the twin study staff. Basic demographic information was also requested. Interested families were contacted and the study was explained to them in detail. The families who agreed to participate were scheduled for a full day's laboratory visit at USC, during which assessments were made of the twins and their primary caregivers. The twins participated in an extensive interview process, cognitive and neuropsychological testing (including IQ testing and the Go/NoGo task), and psychophysiological assessment.

The caregivers were also asked to participate in an extensive interview process that included questions about parental antisocial behaviour, substance use, as well as detailed information about the twins' behaviours (at home and at school). With parental permission, the twins' teachers were also contacted via mail to fill out questionnaires about the twins' behaviours at school. Participating families were offered group summaries of study results.

Procedure

Participants were brought to the laboratory at USC by an adult caregiver (usually the biological mother) for a full day's visit (approximately 7–8 hours). The session was divided into two 3–4 hour sessions (before and after a 45 minute lunch break). One twin was interviewed about their behaviour and tested on the neurocognitive tasks, while the other participated in the psychophysiological testing. After lunch, the twins would switch. The order of which twin participated in interview/neurocognitive versus psychophysiological testing was randomly determined before the families arrived at the lab. Both twins were administered the tasks for either the interview/neurocognitive or psychophysiological session in the same order. Caregivers were administered self-report questionnaires and interviewed about their habits and behaviour, their marriage, as well as their twins' behaviour with one another and their peers while at home and in school. The families were compensated for their visit to the lab.

Examiners consisted of full- or part-time staff members with a B.A., as well as USC graduate students and upper-class undergraduates. All examiners were rigorously trained (approximately 3–4 weeks) on the psychophysiological and neuropsychological testing procedures and in the administration of the behavioural interviews. Training included inter-examiner reliability checks, videotaped monitoring to ensure strict adherence to standardized testing protocols, and supervised training sessions for all aspects of testing. A more detailed description of the study sample, design, and procedures can be found in Baker, Barton, Lozano, Raine, and Fowler (2006) and Baker, Jacobson, Raine, Lozano, and Bezdjian (2007).

Measures

Assessment of impulsivity and inattention in the twins was made using the Go/NoGo task, while assessments of symptom counts of hyperactivity–impulsivity and inattention were obtained from survey measures administered to caregivers and teachers. The Go/NoGo was administered during the psychophysiology session, while the questionnaires were administered during caregiver interviews and surveys mailed to teachers.

The Go/NoGo task

The Go/NoGo task is a response inhibition task where a motor response must either be executed or inhibited. During this task, participants were required to watch a sequential presentation of letters and respond to a target letter by pressing a button. The presentation began with a 2 × 2 array with four stars (one in each square of the array). A single letter (P or R) was then presented in one of the squares for a duration of 500 milliseconds with an inter-stimulus interval of 1,500 milliseconds. In the first condition (P-Go), participants were asked to press a button in response to the target letter P and withhold their response to the non-target letter R. The ratio of targets to non-targets was 80:20. The first condition consisted of 160 trials. A second, reversal condition (R-Go) was then administered, and paticipants were now asked to make a response to the target letter R and withhold their response to the non-target letter P (the letter that they were initially conditioned to make a motor response to in the first, P-Go condition). The ratio of targets to non-targets stays exactly the same during the reversal (R-Go) condition (ratio of targets to non-targets-80:20). Together, the two conditions consisted of 320 trials total. Prior to the task, the paticipants were administered a brief practice session to ensure the task was fully comprehended. Behavioural performance of the task was assessed by calculating four values in each condition: (1) correct responses to the target (Go) letter (hits); (2) errors of omission (misses) to the Go letter; (3) errors of commission (false alarms) (i.e. responding incorrectly to the NoGo letter); and; (4) correct rejections to the NoGo letter. In addition, reaction time (RT) and RT variability to the Go letter was assessed and calculated for each participant. Go errors are typically considered as an indicator of inattention to the task, while NoGo errors and RT to Go responses are considered as indicators of impulsivity (Barkley, 1991; Halperin *et al.*, 1991).

The Go/NoGo task was presented using stimulus presentation software from the James Long Company. During the Go/NoGo task, the research assistant (RA) would leave the testing room so that each participating child could perform the task without distraction. Participants were monitored through a video-camera at all times. In addition, the testing room was equipped with a microphone, so that the RA would readily hear if the child had a question. The RA would conduct a brief practice run of the task (10–15 trials) to ensure that the children understood the full extent of the task. Each participant performed 10–15 practice trials with the RA coaching the child as needed and practice trials were repeated if necessary. Once the RA was confident that the child fully understood the task, he/she would reiterate the task instructions and leave the room allowing the participant to begin the task. The child would then complete the first condition of the task (160 trials), requiring a response to the more frequent letter P (P-Go condition). The RA would then re-enter the room and recite the instructions for the second reversal condition of the Go/NoGo task (R-Go condition). The instructions to the reversal portion of the task also appeared on the paticipants' computer monitor. The task was run from a remote computer in an adjacent 'control room' operated by the examiner. The duration of the entire Go/NoGo task (P-Go and R-Go conditions) was approximately 8 minutes, including task instructions.

Symptom measures of hyperactivity–impulsivity and inattention

Caregiver interviews: Diagnostic Interview Schedule for Children version IV (DISC-IV) (Shaffer, Fisher, Lucas, & Comer, 2000)—The Diagnostic Interview Schedule for Children is a highly structured interview designed to assess psychiatric disorders (adapted from the DSM-IV) and symptoms in children and adolescents aged 6–17 years. The DISC is designed for administration by well-trained lay interviewers for epidemiological research. The DISC-IV (parent version) was administered to the caregivers during their interview assessment of each twin's behaviour. The caregivers were asked to report on their twins' symptoms of impulsivity, hyperactivity, and inattention at home within the past year.

Teacher surveys—With parental permission, the twins' teachers were also contacted via mail to fill out comprehensive questionnaires about the twins' behaviours at school. These included the 18 items listed as criteria for ADHD in the DSM-III-R, placed into a checklist format (DuPaul *et al.*, 1990). The items were rated on a 4-point Likert scale (never or rarely, sometimes, often, and very often). The teachers returned completed surveys in prepaid self-addressed envelopes, and were sent small gifts as compensation for their time. Since the teacher report items were taken directly from DSM criteria, which included both hyperactivity/impulsivity and inattention symptoms in versions IIIR and IV, comparable scales for these groups of symptoms could be obtained from caregiver and teacher reports. Table 1 presents the 21 items comprising the DISC-IV ADHD symptoms rated by the parents, along with the corresponding items in the teacher questionnaire.

Comparisons among the laboratory and questionnaire measures were made to assess the constructs of inattention and impulsivity derived from both teacher and caregiver reports. The Go/NoGo should serve as a valuable tool in measuring inattention and impulsivity in children since it is not susceptible to informant biases, and thus may generate a less contaminated assessment of these constructs (Marks, Himelstein, Newcorn, & Halperin, 1999).

Data analyses

Several preliminary analyses were conducted on the Go/NoGo data in order to ensure reliable and valid estimates of the response parameters derived from this task. We first examined contiguous trials indicating very low RTs preceded by a missing response. Corrections to some trials were made if children had late responses or very low RTs on the nth trial ($RT_n < 0.12$ seconds), combined with no response on the previous ($n - 1$th) trial (R_{n-1} = no). On such trials,

it was assumed that the child responded on the n – 1th trial, but the response time exceeded the allotted 1-second interval for the trial, thus carrying over to the next trial. The subsequent trial was then considered to be missing. Thus, RT_{n-1} was modified to be 1 + RT_n and R_{n-1} = yes (would equal a yes response). For the remaining trials with a very low RT (<0.12 seconds), the data were recoded as RT_n = missing and R_n = missing. The total number of missing trials was then calculated for each child. If the number of trials missing exceeded 25% of the total 320 trials, those cases were dropped from the data set on account of having too few data points. Outlier participants with excessive numbers of trials missing due to non-response or to response box failures reported by the examiners were also omitted from the data set (N = 13 total participants omitted from data sample). There were 55 additional cases of children who refused to participate in the task. Thus, valid Go/NoGo data were available for 1,151 children.

RTs and RT variability for trials with Go responses, as well as the number of errors during both Go and NoGo trials were calculated. The total number of errors during both Go conditions was calculated by summing the number of misses (omission errors) committed during both the Go and NoGo conditions (P and R, respectively). The average reaction times were computed for each of the Go conditions by summing the total number of hits (correct responses) divided by the total number of times the letter appears on the screen (128). Intra-subject reaction time variability was tabulated by computing the standard deviations for the Go response reaction times across trials (128 in each condition) (Leth-Steensen, Elbaz, & Douglas, 2000). A greater number of NoGo errors and shorter reaction times are typically considered to be indicators of impulsive responding (Baker, 2001; Halperin *et al.*, 1991).

Correlational analyses were employed to examine the relationship between ADHD symptoms (hyperactivity/impulsivity and inattention) with the Go/NoGo task. In particular, four performance measures: Go errors (errors of omission); NoGo errors (errors of commission); Go reaction times; and Go reaction time variability. Correlations between these performance measures and ADHD symptoms were computed separately for each of the two conditions in the Go/NoGo task, as well as for the average across conditions for each of the four performance measures.

Further analyses of the relationship between ADHD and Go/NoGo performance examined changes in behavioural performance within the Go/NoGo task for the three ADHD subtypes [inattention only (ADHD-IA), hyperactive only (ADHD-HI), and combined (ADHD-C)] compared to non-ADHD controls. The ADHD subtype diagnoses were determined by parent ratings from the DISC-IV.

The ADHD groups included 507 male and 576 female normal comparisons; 39 male and 20 female ‘inattention only’; 28 male and 15 female ‘hyperactive only’; and 20 male and 14 female ‘combined’ subtypes. In both the ADHD-HI and ADHD-IA subtypes, males outnumbered the females by nearly a 2:1 ratio, while the ADHD-C group had a male to female ratio of 1.43:1. Conversely, the non-ADHD control group consisted of more females than males with a male to female ratio of 1:1.40. According to caregiver reports, 48 children from our sample were currently diagnosed with ADHD or some form of attention deficit disorder, and 18 children were currently on medication for their symptoms.

Results

Factor analyses on the ADHD symptoms confirmed a two-factor solution for the ADHD items in both teacher surveys using the ADHD checklist and in caregiver interviews using the DISC-IV interview. This result falls in line with previous literature on the factor structure of ADHD symptoms (Hudziak *et al.*, 1998; Marsh & Williams, 2004). The two emerging factors were (1) a hyperactivity/impulsivity factor and (2) an inattention factor (analyses available upon

request). Thus, composite mean scores for hyperactivity/impulsivity and inattention were created separately for caregiver and teacher reports of ADHD and used in all subsequent analyses.

The Pearson correlations for the caregiver and teacher reports of hyperactivity/impulsivity and inattention are provided in Table 2. The relationship between hyperactivity/impulsivity and inattention was significantly and strongly correlated within each rater ($r = .52$, $p < .01$ for caregiver reports and $r = .70$, $p < .01$ for teacher reports). In addition, mean symptoms scores for hyperactivity/impulsivity and inattention were also significantly correlated across raters. Hyperactivity/impulsivity and inattention were moderately and significantly correlated between caregiver and teacher reports ($r < .44$; $p < .01$ for hyperactivity/impulsivity and $r = .48$; $p < .01$ for inattention respectively).

Go/NoGo task

Descriptive statistics for the Go and NoGo errors, as well as RT and RT variability for the P-Go and R-Go conditions are presented in Table 3. Consistent with previous literature (Newcorn *et al*., 2001) there were sex differences for the NoGo errors and Go reaction times for both conditions [$t(1, 149) = 14.07$, $p < .001$ (R-NoGo); $t(1, 149) = 11.33$, $p < .001$ (P-NoGo); $t(1, 149) = -10.36$, $p < 001$ P-Go RT; $t(1, 149) = -11:56$, $p < .01$ (R-Go RT)] with males committing significantly more NoGo errors and displaying significantly faster reaction times. No sex differences were found for the Go errors for either P-Go or R-Go [$t(1, 149) = 1.77$, $p = .08$ (P-Go); $t(1, 149) = 1.30$, $p = .08$ (R-Go)], or for RT variability either for the P-Go or R-Go RT variability [$t(1, 149) = 1.2$, $p = .21$; $t(1, 149) = 0.56$, $p = .58$]. Go errors were slightly skewed (see Table 3), thus square root transformations were computed on these data. After transformation, the skewness for the Go errors decreased from 1.99 to 0.48 (for P-Go) and 1.70 to 0.44 (for R-Go). The square root transformed Go errors were used in subsequent analyses.

Both error types and reaction times were strongly correlated ($p < .01$) across the two conditions of the task ($r = .69$ for Go errors and $r = .74$ for NoGo errors, and $r = .84$ for Go reaction times, and $r = .69$ for RT variability). Due to strong, significant correlations between the two conditions of the task (for both errors and reaction times), the errors were summed across the two conditions to yield combined scores for Go errors, NoGo errors. Similarly, Go reaction times and variability were averaged across the two conditions. These combined scores were used in all subsequent analyses.

Furthermore, there was a significant but weak correlation between the Go errors and the NoGo errors ($r = .06$, $p < .05$) for the first condition, and a negligible and non-significant correlation ($r = -.05$, $p = .12$) for the reversal condition, indicating relative independence of Go and NoGo errors, and a correlation of $r = .06$ ($p < .05$) when the two conditions were combined. To the extent that these respective errors are indicative of inattention and impulsivity, it appears that the Go/NoGo task does in fact measure these two constructs relatively independently.

Consistent with previous studies using laboratory tasks such as the Go/NoGo, correlations among the errors of commission (NoGo errors) and Go reaction times showed a strong inverse relationship ($r = -.70$, $p < .01$). Greater NoGo errors and faster reaction times are typically considered to reflect impulsive responding (Halperin, Wolf, Pascualvaca, Newcorn, & Healey, 1988; Halperin *et al*., 1991). Faster response times were strongly related to increased false alarm (i.e. NoGo) errors, whereas Go errors were weakly related to slower reaction times $r = .19$ ($p < .01$). However, RT variability was strongly related to Go errors $r = .62$ ($p < .01$), but weakly related to NoGo errors $r = .06$ ($p = .05$). Thus, it may not be speed of response *per se* that is indicative of impulsive responding, but speed of response accompanied by a higher number of false alarm errors.

Symptom ratings

The two factors obtained from the caregiver and teacher reports were also significantly correlated. Hyperactivity–impulsivity and inattention were correlated for both caregiver reports ($r = .52$, $p < .01$), and teacher reports ($r = .70$, $p < .01$). The significant and moderate to strong correlations between hyperactivity/impulsivity and inattention indicate a fairly strong relationship between the constructs of hyperactivity–impulsivity and inattention that might be difficult to partial out and distinguish in symptom questionnaires.

Go/NoGo performance and symptom ratings

Correlations between the Go and NoGo errors and the ADHD symptom dimensions are presented in Table 4. Go errors were significantly correlated with both caregiver and teacher reports of inattention and hyperactivity–impulsivity. Similarly, NoGo errors were significantly correlated with both caregiver and teacher reports of inattention and hyperactivity–impulsivity. Furthermore, Go RT variability was also correlated with both inattention and hyperactivity–impulsivity in both caregiver and teacher reports of ADHD. Although highly significant in this large sample of children, these correlations between ADHD symptoms and NoGo performance are notably low in magnitude.

In spite of the strong correlation between Go reaction times and NoGo errors, Go reaction times did not significantly correlate with either of the two caregiver and teacher reports of ADHD symptoms. This could be due to the multidimensional factor of impulsivity, in that a fast response does not necessarily reflect impulsivity. A participant may respond quickly, but may not make errors that are indicative of inattention or impulsivity.

ANOVAs were used to compare mean Go/NoGo performance for the three ADHD groups (hyperactive only, inattentive only, and combined) and normal controls, and revealed some group differences for each of the four performance measures. Moreover, these group differences appeared to vary across sex for Go errors, based on a significant *Sex* × *ADHDGroup* interaction ($F = 4.27$, $df = 3$, $p < .01$). Given this significant interaction [although the *Sex* £ *ADHDGroup* interactions were not significant for NoGo errors ($F = 1.13$, $df = 3$, $p = .34$), Go reaction times ($F = 1.55$, $df = 3, 1, 139$, $p = .20$), or Go reaction time variability ($F = 1.92$, $df = 3$, $p = .12$)], we decided to graphically display the data for all four-performance measures separately by sex (see Figure 1a and 1b).

As shown, our results indicate that there were no significant ADHD group differences for any of the Go/NoGo behavioural performance measures in boys. However, males do seem to be responding faster than females and have significantly shorter reaction times overall (see Table 3). Our results also illustrate that the ADHD combined type females make the most Go errors, have significantly longer reaction times and display more variability in their response times and thus appear to be the most inattentive compared to control or other ADHD females. Overall, there do appear to be sex differences in patterns of response for ADHD groups in the Go/NoGo task, with somewhat different patterns for the ADHD subtypes. In addition, Bonferroni *post hoc* analyses of group differences within each sex revealed significant mean level differences between the ADHD-C group and controls for Go errors, Go reaction times (marginal significance), and Go RT variability in females ($p < .05$) (see Figure 1b). Furthermore, *post hoc* analyses also revealed significant mean level differences between ADHD-C and ADHD-IA for Go errors in females ($p < .05$). There were no mean level group differences for any of the Go/NoGo behavioural performance measures in boys.

Some studies have found associations between IQ and performance on vigilance or CPT (Pascualvaca *et al.*, 1997), therefore differences in IQ were also investigated in this study to ensure that deficits associated with inattention or impulsivity cannot be more parsimoniously

explained by group differences in intelligence. Mean IQs for verbal and performance IQ are reported in Table 5. Additional one-way ANOVAs revealed no difference between ADHD subtypes and controls on either performance or verbal IQ. In addition, correlations between the ADHD-IA and ADHD-HI symptom counts with verbal and performance IQ indicated a significant inverse relationship in the entire sample. Specifically, symptom counts for ADHD-IA were inversely correlated with verbal and performance IQ ($r = -.14$, $p < .01$; $r = -.16$, $p < .01$, respectively). The symptom counts for ADHD-HI were also inversely correlated with verbal and performance IQ ($r = -.10$, $p < .01$; $r = -.12$, $p < .01$, respectively).

Go/NoGo performance was also inversely correlated with verbal and performance IQ. Specifically, Go errors (errors of omission) were significantly correlated with both verbal and performance IQ ($r = -.27$, $p < .01$; $r = -.23$, $p < .01$, respectively).

Go reaction times were also significantly correlated with performance IQ only ($r = -.10$, $p < .01$). Moreover, Go reaction time variability was also correlated with both performance ($r = -.27$, $p < .01$), and verbal IQ ($r = -.23$, $p < .01$).

Discussion

Previous studies examining the constructs of inattention and hyperactivity–impulsivity have been to some extent hindered by inadequate assessment methods, which rely primarily on questionnaire ratings by parents and teachers. This study aimed to gain a better grasp of hyperactivity–impulsivity and inattention in children through the use of a laboratory task, the Go/NoGo.

Performance in the Go/NoGo task (Go errors, NoGo errors, Go reaction times, and variability of Go reaction times) was compared to ADHD symptom ratings of hyperactivity–impulsivity and inattention. Consistent with previous literature, there was a strong inverse relationship between the number of NoGo errors and the Go reaction times ($r = -.70$; $p < .01$), both of which are posited to indicate impulsive responding (Halperin *et al.*, 1991). There was a relatively small relationship, however, between Go and NoGo errors, or between Go errors and Go reaction times, suggesting greater independence between disinhibition (impulsive responding) and inattention within this task.

Exploratory factor analyses suggested a two-factor solution for the ADHD symptoms (hyperactivity/impulsivity and inattention) in these school age children as rated by both their caregivers and teachers. Research has generally supported this two-dimensional symptom structure for ADHD (Hudziak *et al.*, 1998; Marsh & Williams, 2004). Thus, mean scores for the hyperactivity/impulsivity and inattention symptoms were tabulated. Caregiver and teacher ratings of inattention were significantly and moderately correlated, as were caregiver and teacher ratings of hyperactivity–impulsivity. The correlations between multiple raters in the present study are stronger than what has been previously reported in the literature on child behaviour ratings (Achenbach, McConaughy, & Howell, 1987).

In contrast to the negligible relationship between impulsive responding and inattention in the Go/NoGo task, mean scores for hyperactivity–impulsivity and Inattention symptoms created from caregiver and teacher reports in the DISC-IV were significantly and strongly correlated within rater (see Table 2). These moderate-to-strong correlations may suggest common underlying mechanisms for the constructs of inattention and hyperactivity–impulsivity, as defined through symptom counts, highlighting the difficulty of delineating and separating these constructs in questionnaire measures. The lack of independence of these constructs in behavioural rating scales might make their effects difficult to distinguish in external validity studies. Furthermore, it might also be the case that parents who have children with behaviour

problems might be biased, and tend to rate their children more highly on a variety of behaviour scales.

On the contrary, the correlations between the Go errors (purported to measure inattention) and NoGo errors (purported to measure disinhibition/impulsivity) are $r = .06$ for the first condition and $r = -.05$ for the second condition, and $r = .08$ when the conditions are combined, indicate that a laboratory task such as the Go/NoGo might serve as a better alternative in assessing these complex behaviours compared to survey reports. Furthermore, the fact that Go and NoGo errors are relatively independent suggests that the Go/NoGo task maybe a more effective and less bias way of separating these two related processes, perhaps even better than questionnaire measures of these constructs.

In addition, 3–6-month test–retest analyses conducted on the Go/NoGo task indicated that the performance measures within the task were quite stable over time. This is consistent with previous research on the Go/NoGo, which found the task to be both reliable and stable over time (Kindlon *et al.*, 1995). Correlations for the Go/NoGo performance measures ranged from $r = .50$, $p < .01$ (for the Go errors) to $r = .86$, $p < .01$ (for the Go reaction times).

In comparisons of Go/NoGo performance and ADHD symptoms, NoGo errors were correlated with both hyperactive–impulsive and inattentive symptoms from both caregiver and teacher ratings. There were significant correlations between the Go errors and the Inattentive and hyperactive–impulsive symptoms (in both caregiver and teacher reports as well). Thus, perhaps the constructs of inattention and impulsivity are closely intertwined, especially in survey measures. For example, Loeber, Green, Lahey, and Stouthamer-Loeber (1989) has identified discrepancies between parent and teacher ratings, suggesting that certain elements of a disorder may be situationally specific and difficult for informants who do not observe the child in that situation or setting to clearly identify. Furthermore, the significant inter-correlations among the Go/NoGo performance measures and the ADHD symptoms may be due to the fact that impulsivity is not unidimensional, but rather may reflect several different facets.

Tasks that tap into neurocognitive domains such as impulsivity (lack of inhibition), and attention have been useful in distinguishing children with ADHD from controls. Thus we performed additional analyses on the Go/NoGo task, which integrates the domains of inhibition and attention. We examined the behavioural performance of the children during the Go/NoGo task. Our results indicated that: (1) the ADHD combined type females make the most Go errors, have significantly longer reaction times and display more variability in their response times and thus appear to be the most inattentive compared to control or other ADHD females; (2) there were no significant ADHD group differences for any of the Go/NoGo behavioural performance measures in boys; (3) for Go Reaction Times, combined type ADHD females are slowest across the board compared to other females; and (4) there were no significant group differences for NoGo errors in either males or females. However, males seem to be responding faster than females and have significantly shorter reaction times overall (see Table 3), which is consistent with literature (Greenberg & Waldman, 1993;Pascualvaca *et al.*, 1997). Overall, there do appear to be some sex differences in patterns of responding for ADHD groups in the Go/NoGo task, with somewhat different patterns for the ADHD subtypes. Combined-type girls are both slow and make more Go errors, suggesting they have the greatest problems attending to the task. These girls are not, however, more impulsive than other ADHD or control girls according to their NoGo errors.

The ADHD groups did not seem to be characterized in their Go/NoGo performance as might be predicted (i.e. more frequent NoGo errors for those with H/I, and more Go errors for those with IA). Instead a common factor among the subtype groups may be attention (or deficit in attention) since it is also a crucial component of the ADHD-C group. In addition, several studies

have suggested that children with ADHD-C and children with ADHD-IA display similar impairments (Lahey *et al.*, 1998; Willcutt, Pennington, Chhabildas, Friedman, & Alexander, 1999). Our results fall in line with previous literature. Chhabildas, Pennington, and Willcutt (2001) demonstrated that symptoms of inattention were associated with neuropsychological or neurocognitive impairment. However, our results did demonstrate that the ADHD-C group was significantly different from the ADHD-IA group in females for their Go errors (a purported measure of attention). We did not see any significant group differences among any of the groups for any of the performance measures in males. One reason for this might be due to the difficult nature in assessing children's behaviour through reports or interviews. Another reason might be due to the fact that the numbers of participants in the ADHD groups are quite small, and this in turn could limit the power to detect any significant group differences for the different Go/NoGo performance measures.

Since the symptom ratings for the two ADHD dimensions are highly correlated in our sample, it is possible that both inattention and hyperactivity/impulsivity are associated with similar underlying deficits. Thus, because the two dimensions are so highly correlated, one symptom dimension could be associated with underlying neuropsychological impairments while the other dimension may simply be indexing symptoms that are highly correlated with the deficits associated with the first dimension (Chhabildas *et al.*, 2001). As demonstrated by the significant correlation between the two ADHD dimensions, caregivers might find it difficult to decipher the 'hyperactive–impulsive' questions from the 'inattention' questions. Some questionnaire items purported to measure inattention might be mistaken for impulsivity (or impulsive actions) depending on the rater (in this case, caregivers and teachers). For example, items such as, 'often does not follow through on instructions and fails to complete work' also might fall within the broader definition of impulsivity (Evenden, 1999). Since the inattention symptoms correlate highly with the hyperactive/impulsive symptoms, several of the hyperactive/impulsive symptoms may also describe behaviours that arguably reflect deficits in attention (Nigg, 1999, 2001). Perhaps deficits can be more severe for the ADHD-C type because they have elevated levels on both dimensions, so one would expect them to exhibit deficits in all three-performance measures (or exhibits deficits in inhibition, attention, and processing speed).

Correlations among the Go/NoGo performance measures, the ADHD subtype symptom counts, and IQ (verbal and performance) indicated a significant inverse relationship between Go errors and verbal and performance IQ. Thus, the greater the number of Go errors (a purported measure of inattention) the lower the verbal and performance IQ. We also found a weak but nevertheless significant relationship between the ADHD-IA symptom counts and Verbal and Performance IQ. This might further suggest the importance of attention in these measures. As demonstrated by the overall results of this study, the Go/NoGo task appears to be quite a valuable tool in detecting deficits in both attention as well as inhibition, perhaps better than questionnaires or structured interviews that might incorporate certain intrinsic biases. Consistent with literature, no differences were found across the ADHD groups and controls on either verbal or performance IQ (Rubia, Smith, & Taylor, 2007).

As demonstrated by the overall results of this study, the Go/NoGo task appears to be a valuable tool in detecting deficits in both attention as well as inhibition, perhaps better than questionnaires or structured interviews that might incorporate certain intrinsic biases.

The results of the present study were also interesting because unlike previous studies (e.g. Carrillo de la Pena *et al.*, 1993; White *et al.*, 1994), our findings indicated a significant relationship between laboratory measures of impulsivity and inattention and questionnaire measures of these same constructs. Our findings are consistent with a more recent study conducted by Avila *et al.* (2004), and suggest that tasks such as the Go/NoGo task might be

more sensitive than parent or teacher ratings in capturing impulsivity and inattention and related disorders.

Study limitations

The fact that these analyses were based on data obtained in a general population could be considered both a strength and possible limitation. The use of school-based samples and the requirement that families be willing to come to the laboratory for a full assessment battery may have led to an under sampling of the most severely affected impulsive and inattentive children. Moreover, the fact that 18 of the 48 children who had received a diagnosis of ADHD or some form of attention deficit disorder were on medication for their symptoms might also help explain the lack of strong group differences found in this study.

The narrow age range of 9 and 10-year-olds could also be considered both a strength and limitation. However, targeting pre-adolescent children may be beneficial when studying correlates or precursors to antisocial behaviour such as impulsivity. Another limitation might have to do with the fact that the Go/NoGo task is not primarily thought of as a task of assessing attention, however, errors of omission may provide a good marker of inattention. Furthermore, another limitation is the fact that we only used parent-reports of the children's ADHD symptoms to conduct our subgroup analyses.

This may have contributed to the lack of strong findings. Lastly, a major limitation to the study is the fact that there is no 'gold standard' for measuring impulsivity. Since impulsivity is perceived to be a multidimensional construct, it is quite difficult to compare various methods of measurement. However, laboratory measures such as the Go/NoGo might be an optimal and less biased way to isolate and measure this important construct.

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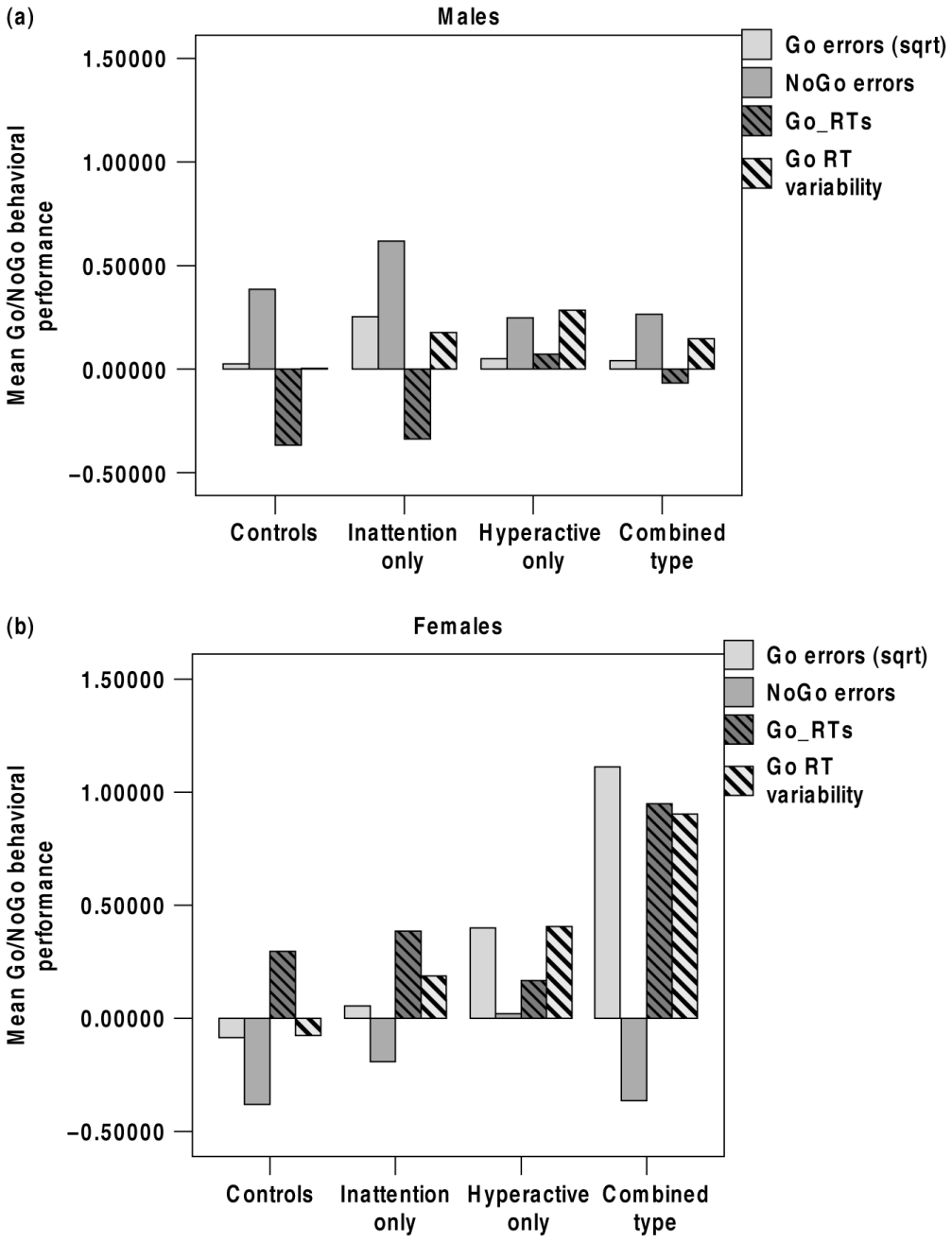

Figure 1.

(a) *Note*: Illustrates ADHD group performance for each Go/NoGo behavioural measure (standardized) in males. (b) *Note*: Illustrates ADHD group performance for each Go/NoGo behavioural measure (standardized) in females.

Table 1

Items from ADHD questionnaire (caregiver and teacher)

Inattention	**Hyperactivity/impulsivity**
Parent (*Caregiver*)	
Had trouble finishing homework	Often climbed on things and ran around (H)
Often lost things in the past year	Often talked a lot more than other children (H)
Forgot what they were supposed to do	Made much more noise while playing (H)
Couldn't keep mind on one thing	Fidgety/restless in past year (H)
Trouble keeping mind on task	Been on the go more than usual (H)
Often disliked doing things that require mental effort	Left seat (in class, movies, etc.) (H)
Often tried to avoid doing things that require mental effort	Often butted in on what others were doing (I)
Often made a lot of mistakes	Often had trouble waiting for turns (I)
Was disorganized in the past year	Often interrupted others (I)
Started activities without finishing them	Blurted out answers before hearing whole question (I)
Often didn't listen when people were speaking	
Teacher	
Does not follow through on instructions or fails to finish	Fidgets with hands and feet (H)
Avoids tasks that require mental effort	Is on the go driven by a motor (H)
Is forgetful in daily activities	Talks excessively (H)
Has difficulty organizing tasks	Has difficulty playing quietly (H)
Fails to give close attention to detail	Runs about or climbs on things (H)
Is easily distracted	Left seat (as in school, movies, etc.) (H)
Does not seem to be listening when spoken to directly	Interrupts or intrudes (I)
Has difficulty sustaining attention	Blurts out answers before questions are completed (I)
Loses things necessary for tasks	Has difficulty waiting for turn (I)

Table 2

Correlations among caregiver and teacher inattention and hyperactivity/impulsivity factors (ADHD questionnaire)

	Caregiver report		Teacher report	
	Inattention	**Hyperactivity/impulsivity**	**Inattention**	**Hyperactivity/impulsivity**
Caregiver report				
Inattention	–	.52**	.48**	.35**
Hyperactivity/impulsivity		–	.35**	.44**
Teacher report				
Inattention			–	.70**
Hyperactivity/impulsivity				–

** Significant at $p < .01$ level.

Table 3

Descriptive statistics for the Go/NoGo task (N = 1, 151)

	Mean	*SD*	Skewness	Kurtosis
Errors				
P-Go				
Males	8.25	9.40	1.91	4.52
Females	7.32	8.43	2.05	5.75
R-Go				
Males	10.66	10.97	1.55	2.35
Females	9.85	10.49	1.80	5.75
R-NoGo				
Males	15.18[a]	6.13	0.03	−0.62
Females	10.32	5.60	0.61	−0.15
P-NoGo				
Males	17.04[a]	5.73	−0.19	−0.57
Females	13.12	5.98	0.32	−0.56
Reaction times				
P-Go				
Males	0.48[a]	0.08	0.23	0.35
Females	0.53	0.07	0.26	−0.06
R-Go				
Males	0.47[a]	0.08	0.22	0.13
Females	0.53	0.08	0.17	−0.14
Reaction time variability				
P-Go RT variability				
Males	0.14	0.03	0.84	1.67
Females	0.14	0.03	0.50	0.50
R-Go RT variability				
Males	0.16	0.04	0.74	1.90
Females	0.16	0.03	0.78	1.69

[a]Indicates a significant sex difference between the means.

Table 4

Correlations between Go/NoGo performance and caregiver and teacher inattention and hyperactivity/impulsivity factors (ADHD)

	Caregiver reports		Teacher reports	
	Inattention	**Hyperactivity/impulsivity**	**Inattention**	**Hyperactivity/impulsivity**
Go errors (sqrt)	.22**	.12**	.21**	.17**
NoGo errors	.12**	.06*	.20**	.14**
Go RTs	.02	.02	−.01	−.02
Go RT variability	.18**	.13**	.25**	.16**

* Significant at $p < .05$ level,

** Significant at $p < .01$ level.

Table 5

Description of the sample and ADHD groups

	ADHD-IA (*N* = 59)	**ADHD-HI (*N* = 43)**	**ADHD-C (*N* = 34**	**Controls (*N* = 1, 083)**
Gender (M:F)	1.95:1	1.86:1	1.43:1	1:1.40
Inattention symptoms[a]	4.29	2.28	4.50	1.17
Hyperactive/impulsivity symptoms[a]	1.73	4.13	4.03	0.94
Verbal IQ	97.63	101.95	100.12	101.80
Performance IQ	97.64	97.21	95.85	100.91

[a]Symptom counts are based on caregiver reports on the DISC-IV (based on DSM-IV criteria).