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Processing Speed Weakness in Children and Adolescents with Non-Hyperactive but Inattentive ADHD (ADD)

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Abstract

DSM-IV-TR defines ADHD-Predominantly Inattentive as allowing up to five symptoms of hyperactivity/impulsivity, while theories of the inattentive type usually assume a group that is hypoactive and characterized by processing speed and cognitive interference deficits. In a community-recruited sample of 572 children and adolescents, a pure inattentive subtype of ADHD (ADD) was defined as those who met DSM-IV-TR criteria for ADHD-PI but had two or fewer hyperactive/impulsive symptoms. Processing and output speeds of those with ADD were compared to those identified with DSM-IV-TR ADHD combined type and non-ADHD controls. These results were then contrasted with those found when DSM-IV-TR defined ADHD-PI was compared with ADHD-C and controls. Processing and output speed were assessed with the Trailmaking A and B and the Stroop Naming Tests. Cognitive interference control was assessed with the interference score from the Stroop Task. Slower cognitive interference speed was found in the ADD vs. ADHD-C and controls comparisons, but not the ADHD-PI versus ADHD-C and controls comparisons. On output speed measures, ADD exhibited the slowest performance, significantly different from controls and the effect size for the set-shifting speed contrast (Trailmaking B) contrast was double that of the ADHD-PI vs. control comparison. ADHD-Inattentive type as defined by the DSM-IV-TR is a heterogeneous condition with a meaningful proportion of those affected exhibiting virtually no hyperactive/impulsive symptoms. This subgroup may represent a distinct inattentive condition characterized by poor cognitive interference control and slow processing or output speed.

Keywords

attention-deficit/hyperactivity disorder; inattentive subtype; processing speed; Stroop color/word test; ADD

DSM-IV-TR (American Psychiatric Association, 2000) specifies three subtypes of Attention Deficit Hyperactivity Disorder (ADHD): Predominantly Inattentive (ADHD-PI), Predominantly Hyperactive/Impulsive (ADHD-HI), and Combined (ADHD-C). The possibility of some type of non-hyperactive, inattentive condition that is etiologically and

nosologically distinct from ADHD-C type has been hypothesized, both in the past (Goodyear & Hynd, 1992; Hynd, et al., 1992), and more recently (Barkley, 2001; Diamond, 2005; Milich, Balentine, & Lynam, 2001). Yet efforts to validate this distinction using DSM-IV-TR criteria for ADHD-PI have been inconclusive, suggesting either that such a subtype does not exist, or is not effectively captured by the existing criteria. In the current paper, we attempt to externally validate a “pure inattentive” subgroup of children with ADHD using measures of processing speed and interference control.

In DSM-III, the term Attention Deficit Disorder without Hyperactivity (ADD/VO) was used to refer to children who were inattentive and impulsive but not hyperactive (American Psychiatric Association, 1980). More recently, Diamond (2005) resurrected the term ADD and suggested it as an appropriate taxon for those impaired by inattention but lacking DSM-IV symptoms of hyperactivity/impulsivity. In this paper, following Diamond (2005), we use the term “ADD” to refer to children who are inattentive but low on a combined hyperactive/impulsive dimension, so as to distinguish them from ADHD-PI as defined in DSM-IV-TR. ADD, as used in the present study, is not intended to conform to DSM-III criteria for ADD/VO. Most notably, impulsivity is not assumed to be associated with this proposed inattentive type as it was in ADD/VO.

It is likely that if ADD is a valid entity, it is not captured efficiently by the DSM-IV-TR ADHD-PI designation. Family history meta-analytic data suggested that there is heterogeneity within ADHD-PI. Relatives of children with ADHD-PI had both ADHD-PI and ADHD-C, whereas children with ADHD-C had only elevated ADHD-C in their relatives. This suggests that some of the ADHD-PI cases are subthreshold ADHD in relation to family history (see Stawicki, Nigg, & von Eye, 2006). Isolating a subgroup with a distinct disorder therefore may require identifying them within the ADHD-PI group. On the other hand, because ADHD-C, by definition, features more total symptoms than ADHD-PI, non-significant differences or worse cognitive performance for ADHD-C as compared to ADHD-PI may merely suggest that ADHD-PI is a milder version of ADHD-C. Such a “severity hypothesis” tends to provide a parsimonious explanation of most (though not all) of the external validation data on the DSM-IV-TR ADHD types (Faraone, et al., 1998; Geurts, et al., 2005; Hinshaw, et al., 2002; Hinshaw, et al., 2007; Huang-Pollock, et al., 2005; Klorman, et al., 1999; Solanto, et al., 2007).

If such an “ADD” group exists, and if the DSM-IV-TR does not adequately capture it, what alternative operational definitions should be considered? The most common proposal is to restrict an ADD group to children with few or no hyperactive/impulsive symptoms (Derefinko, et al., 2008; Fillmore, Milich, & Lorch, 2009; McBurnett, et al., 2001; Milich, et al., 2001). Where does one make that cut point? The best recent empirical evidence for the cut point comes from studies using latent class analysis (Volk, et al., 2009) that have identified a class of children with six or more symptoms of inattention but two or fewer symptoms of hyperactivity/impulsivity. That cut point fits with a theoretical suggestion by Milich, et al. (2001) and it has been replicated (Rasmussen, et al., 2002), shown to be heritable (Rasmussen, et al., (2004), and shown to be associated with academic performance problems (Todd, et al, 2002). These latent class analyses provided empirical support for one of the underlying assumptions of the present report, i.e., there is meaningful heterogeneity within the ADHD-PI subtype.

Turning to the hypothesized external validation of such a pure inattentive ADHD subtype, the most explicit theoretical statement of neurocognitive aspects of ADD since the publication of DSM-IV-TR was offered by Diamond (2005). She distinguished between “truly inattentive” ADHD (p. 807, aka. ADD) and subthreshold combined type, arguing that the “truly inattentive” type is an instance of childhood-onset “dysexecutive syndrome” marked by primary deficits in working memory and related deficits in processing speed. A substantial literature has noted that ADHD is associated with slower speed of processing overall (Shanahan, et al., 2006).

Importantly, individuals with ADHD-PI exhibit slower processing speed than those with ADHD-C (Calhoun & Mayes, 2005; Chhabildas, Pennington, & Willcutt, 2001; Nigg, 2001; Nigg, et al., 2002; Solanto et al., 2007; Wodka, et al., 2008) and these differences are not due to common comorbidities associated with ADHD (Mayes, et al., 2009). A second assumption underlying the present investigation is that the heterogeneity created by allowing up to five hyperactive/impulsive symptoms in DSM-IV-TR ADHD-PI obscures the impairments of inattention that are not associated with hyperactivity and impulsivity (Milich, et al., 2001; McBurnett, et al., 2001).

The processing speed hypothesis presents challenges in that there is not yet a consensus on the definition of processing speed as a construct (Shanahan, et al., 2006). A variety of speeded tasks purport to measure processing speed but all such tasks are unlikely to measure similar cognitive processes. Simple operations like recognition and retrieval, output or response speed, and complex operations like cognitive interference control (engaging cognitive processes to manage behavioral output) all fall under or are directly influenced by some form of processing or output speed. Further, from a stages-of-processing viewpoint, speed of scanning, speed of processing, and speed of output might be dissociable. We did not attempt such a full decomposition here, but instead focused on widely used clinical measures that neuropsychologists might relate to operational speed in processing or output.

However, we did seek to distinguish two conceptually important types of tasks. One was speed of response; the other was speed under conditions of interference. Control of cognitive interference is more likely to require mental resources and thus may be a more direct test of Diamond's dysexecutive hypothesis. It involves the ability to inhibit a habitual cognition or response that competes with recognition of a competing stimulus related to a less habitual response. Hynd and colleagues (1991) seemed to imply that interference control might be affected in ADD.

Perhaps the most widely cited neuropsychological measure in this domain is the Stroop Color/Word Test, which is a complex task that clearly entails managing interference (MacLeod, 1991). One meta-analysis of Stroop interference effects found poorer interference control, as measured by non-computerized versions of the Stroop Color/Word Test, for ADHD-PI than for ADHD-C (Van Mourik, Oosterlaan, & Sergeant, 2005). That finding initially suggests that interference control may be a problem specific to ADD, as compared to ADHD-C.

However, some variations of the Stroop test may be relatively less effective in eliciting interference control processes (Kane & Engle, 2003; Kerns, et al., 2004; MacLeod & MacDonald, 2000) and may reflect more of the processing speed dimension of this task. In two readily available, widely used, non-computerized versions of the Stroop (Golden and D-KEFS), all items presented in the color/word condition are incongruent (i.e., all word names are incongruent with the color of the ink in which they are printed) (Delis, Kaplan, & Kramer, 2001; Golden, 1978). Detailed computation and neuroimaging analysis of this task suggests that the consistency of task demands when all color/word items are incongruent may reduce the role of executive function and emphasize the role of speed (Kane & Engle, 2003; Kerns, et al., 2004).

In light of this evidence suggesting an important role for processing speed in the Stroop interference score we considered the Stroop a particularly interesting clinical measure for looking at ADD versus ADHD-C. While we maintain the convention of using the term interference control for the Stroop effect, we are explicitly focused on its role as an index of complex cognitive processing speed. In contrast, the Stroop color naming and word naming conditions tap verbal output speed that is thought to be reflective of effortful semantic processing (Bedard, Ickowicz, & Tannock, 2002; Tannock, Martinussen, & Frijters, 2000).

We therefore investigated ADHD versus ADD differences in the interference versus naming conditions. This type of comparison has not been previously reported to our knowledge. Additional measures are included so that the processing speed domain, broadly conceptualized, is sampled with measures of perceptual/motor output speed and set-shifting speed in addition to Stroop indices of interference control and verbal output speed.

Thus, the present study evaluated an operational definition of a non-hyperactive ADHD inattentive group (ADD) with widely used assessments of processing speed and cognitive interference control in a large and well characterized sample. . The essential strategy employed was to validate the merits of the alternative subtyping strategy by directly assessing the degree to which the ADD group is distinct from ADHD-C and controls and to compare the level of dissociation with that found in comparing DSM-IV-TR defined ADHD-PI with ADHD-C and controls. It was expected that processing speed would be slowest for the alternatively defined ADD group, followed by ADHD-C, and then non-ADHD controls and that there would not be significant processing speed differences between DSM-IV-TR ADHD-PI and ADHD-C due to the presence of significant hyperactivity and impulsivity (three to five symptoms) in DSM-IV-TR ADHD-PI. Larger effect sizes were predicted for the comparisons using the alternative subtyping strategy (ADD) than for the DSM-IV-TR ADHD-PI strategy. All four types of processing speed assessed (interference control, verbal output speed, perceptual/motor speed, and set-shifting speed) were expected to follow the hypothesized trend.

METHOD

Participants

Overview—Participants were 572 children (241 girls) with a mean age of 11.69 years ($SD=3$; range = 6–17). Fifteen percent identified themselves as ethnic minorities. After the classification procedure described below, 145 had DSM-IV-TR defined ADHD (72 ADHD-PI, 66 ADHD-C, and 7 ADHD-HI). Children came from 493 families. 411 families had one child in the study; 76 families had two children in the study; one family had three children in the study.

Recruitment and identification—A broad-based community recruitment strategy enriched for the presence of ADHD was used, with mass mailings to parents in local school districts, public advertisements, and fliers in local clinics. Families passed through a standard multi-gate screening process to establish initial diagnostic groupings according to DSM-IV-TR criteria. At Stage 1, all families were screened by phone to rule out youth prescribed long-acting psychotropic medication (e.g. antidepressants), neurological impairments, seizure history, head injury with loss of consciousness, other major medical conditions, or a prior diagnosis of mental retardation or autistic disorder, as reported by the parent. At Stage 2, standardized ratings were obtained (Child Behavior Checklist [Achenbach, 1991], Conners Rating Scales [Conners, 1997], ADHD Rating Scale [DuPaul, et al., 1998]) from parents and teachers and a structured diagnostic interview was completed with a parent (either the DISC-IV [Schaffer, 2000; $n=181$] or the KSADS-E [Puig-Antich & Ryan, 1986]). Pooling the data across families that received the KSAD and the DISC was justified based on demonstration of acceptable to high agreement between the two methods (in 430 youth in this sample whose parents completed both) for total number of symptoms (inattention, $ICC=.88$, hyperactivity, $ICC=.86$) and presence of 6 or more symptoms of ADHD ($kappa=.79$). In addition, acceptable agreement between the two methods was found for presence of impairment ($kappa=.64$), and presence of ADHD, defined as 6 or more symptoms plus cross-situational impairment ($kappa=.79$). Following review of diagnostic information and placement into ADHD subtypes, participants were further assessed with the neurocognitive measures used in the present study.

ADHD classification and extraction of the ADD subtype—An ADHD symptom was counted as present if the mother rated the item as a “2” or “3” on the 0 to 3 scale on the ADHD Rating Scale (DuPaul, et al., 1998). Children and youth were diagnosed with an ADHD subtype if, in addition to meeting DSM-IV symptom thresholds on the parent ADHD Rating Scale, impairment and duration criteria were established via clinical interview, and total symptom scores six or more total symptoms were reported on the teacher-completed ADHD Rating Scale (approximately corresponding to the 80th percentile point established in normative studies; [DuPaul, et al., 1997]). Children and youth were assigned to the non-ADHD control condition if, in addition to having fewer than six inattention and six hyperactive/impulsive symptoms, they also had fewer than six total symptoms on the teacher-completed ADHD rating scale.

The DSM-IV-TR inattentive subtype was created using established DSM-IV-TR criteria (hereafter designated as the “Standard DSM-IV-TR approach”) requiring the presence of six or more inattention symptoms and fewer than six hyperactive/impulsive symptoms in addition to the aforementioned criteria. From this group, a non-hyperactive inattentive subgroup was extracted (hereafter designated as ADD). The ADD group had six or more inattention symptoms but two or fewer hyperactive/impulsive symptoms, as recommended by Milich et al. (2001) and Volk et al. (2009).

Comorbid diagnoses—The DISC-IV or KSADS-E interview was used for establishing the presence of child and adolescent Oppositional Defiant Disorder, Conduct Disorder, anxiety disorders, and depressive disorders using DSM-IV-TR criteria. IQ was estimated with a short form of the Wechsler Intelligence Scale for Children-3rd edition (WISC-III [The Psychological Corporation, 1991]). The Vocabulary, Similarities, Picture Completion, and Block Design subtests were administered (Sattler, 2001). Reading problems were diagnosed if the word reading test score from the Wechsler Individual Achievement Test-2nd edition (WIAT-II [The Psychological Corporation, 2001]) was one standard deviation below the normative mean for the test. This decision is consistent with the consensus that poor readers whose reading scores are discrepant from IQ scores do not differ meaningfully from poor readers whose reading scores are not discrepant from IQ scores and that reading problems are reliably identified by basic word reading tests (Fletcher, et al., 2005).

Processing speed measures

Perceptual/motor output speed—To index slowed output speed in the perceptual-motor domain, children completed the *Trailmaking Test Part A* (Trails A) (Strauss, Sherman, & Spreen, 2006). An array of numbers is presented, and respondents are to draw a line between numbers in sequential order. Trails A is a perceptual-motor task involving visual search and automatic sequencing, comparable to other processing speed measures known to be associated with developmental changes in working memory (Fry & Hale, 1996; Kail, 2007).

Set-shifting speed—The *Trailmaking Test Part B* (Trails B) (Strauss, Sherman, & Spreen, 2006) was used as a measure of set shifting speed. It is thought to test the speed of the aspect of working memory that allows individuals to efficiently shift attention across task demands. An array of letters and numbers is presented and respondents are to correctly sequence numbers and letters in order by alternating between letters and numbers. To isolate set-shifting from more basic visual search, sequencing, and output speed tapped by Trails A, the Trails B score reported herein is adjusted for Trails A time (by regressing out Trails A time and saving the residual).

Verbal output speed—To index output speed in the speech/language domain, children and youth completed the color and word naming conditions of the *Stroop Color-Word Test* (*Stroop*): word naming, color naming. Color and word naming were averaged (after being

standardized) due to their high correlation ($r = .81$; $p < .001$) and related conceptual function for our purpose.

Interference control—To index the speed of interference control processes, participants completed the *Stroop* interference (color-word) condition. Color and word naming speed were removed from color-word naming speed by regression. This statistical strategy addresses the recommendation that a ratio score, computed by dividing the color naming speed by the speed of naming the color/word pairs, should be used to avoid psychometric problems associated with alternative methods of scoring the Stroop effect (Lansbergen, Kenemans, & van Engeland, 2007). In the present sample, the correlation between the Stroop residual score and the ratio score is .85 ($p < .001$). The ratio score does not control for the effect of basic word naming speed (Lansbergen, et al., 2007). In the present study the correlation between the Stroop residual score and the ratio score corrected for word naming speed is .97 ($p < .001$), indicating that the regression method used effectively addresses the recommendations for isolating the Stroop effect. (Efforts to construct a single latent variable for these speed measures using confirmatory factor analysis were not successful, suggesting that they capture significantly different dimensions of processing speed.)

During the first several years of the study, the Golden (1978) version was administered ($n = 365$). For this task the participant is to name as many colors as possible in 45 seconds, and number correct is the outcome measure. Scoring was reversed so that a high score would reflect slow processing. Later participants ($n = 207$) were administered the Delis-Kaplan et al (2001) Executive Functioning System (DKEFS) version of the Stroop. For this version, participants completed a fixed list of color/word pairs and time to completion is the outcome measure, so again, a high score reflects slower processing. Both versions use blocked trials. Scores for each type of Stroop test were standardized within task type; again a high z score indicates slower processing. All subsequent analyses were checked by covarying the type of Stroop test used. In addition, each analysis was performed separately for the subset of the sample that used each of the Stroop variations. No significant differences from the overall findings reported below were related to the version of the Stroop used.

Data Analytic Strategies

Three percent of all data points were missing. Correlation of missingness with study variables yielded no more associations than would be expected by chance. Therefore, missing data were imputed using the expectation-maximization algorithm (EM). Age was covaried in all analyses since age effects are found for both the dependent measures and the ADHD Rating Scales (DuPaul, et al., 1998). Due to controversy regarding the appropriateness of statistical control of IQ (Barkley, 2005; Dennis, et al., 2009), results are reported with and without its covariation. We also checked that results were not explained by co-occurring reading disability or internalizing disorder (Hinshaw, 2001), or any variable not randomly distributed across ADHD groups.

RESULTS

Sample Characteristics

Sample characteristics relative to group assignments for the modified DSM-IV-TR subtyping approach (ADD) are shown in Table 1. The clinical profiles shown are consistent with expectations and suggest valid subtype groupings. The ADD group did not differ from ADHD-C or controls on any demographic characteristics but did have lower reading scores than controls. With regard to comorbid psychiatric problems the ADD group had fewer externalizing problems than the ADHD-C group, as expected. The ADHD-C group differed from controls on age, income, sex, IQ, reading scores, and reading problems. Subsequent

analyses were performed with and without these variables covaried as a check on their possible influence on the basic findings reported.

Extraction of the ADD group from the DSM-IV-TR defined ADHD-PI subtype identified 40 individuals who met the present study's criteria for the ADD subtype as presented in Table 1. The DSM-IV-TR defined subtype also included 32 individuals who met DSM-IV-TR criteria for ADHD-PI but had three to five symptoms of hyperactivity/impulsivity and were thus excluded from primary analyses of this study. However, for the sake of characterizing the sample more completely a separate analysis of demographic characteristics associated with the full ADHD-PI subtype ($n=72$) and the 32 participants excluded by the process of restricting the ADHD-PI subtype was performed. This analysis revealed no significant demographic differences between full ADHD-PI, ADD, and the excluded subset of ADHD-PI. In contrasting the full ADHD-PI group with the ADHD-C and control group, significant differences were found in mean age (controls = 12.48 years vs. ADHD-PI = 11.16 [$p=.02$]) and sex (controls = 52% female; ADHD-PI = 34% female [$p=.001$]). The only significant contrast involving the excluded subset of ADHD-PI was the comparison with controls on age (excluded subset mean age = 10.32; $p=.001$). Otherwise, demographic comparisons involving full ADHD-PI, the excluded subset of ADHD-PI, ADHD-C, and controls mirror the findings presented in Table 1.

Main Subgroup Analyses

ADD (Modified approach)—The first MANCOVA compared the following three groups: (a) ADD (≤ 2 hyperactive/impulsive symptoms), (b) ADHD-C and (c) non-ADHD controls. The dependent variables were perceptual/motor processing speed (Trails A), set-shifting speed (Trails B), verbal output speed (Stroop naming), and interference control (Stroop interference). Age was covaried in all analyses. The MANCOVA yielded a significant effect of group ($F [4,375] = 12.22, p < .001$). Follow-up univariate analyses revealed significant omnibus one-way ANOVAs for all four processing speed measures (See Table 2).

As hypothesized, on Stroop interference control, ADD was slower than ADHD-C and slower than controls (Cohen's $d = .43$ and $.44$, respectively [both $p < .05$]). The ADD and ADHD-C groups were slower than controls on verbal output speed, but did not differ from each other. The ADD group was slower than controls on perceptual/motor processing speed and set shifting speed, but no other pairwise comparison was significant for those measures. These results were all essentially unchanged with sex, income, IQ, reading score, or comorbidity covaried.

DSM-IV-TR approach—The second analysis compared groups as defined in DSM-IV-TR. The ADHD-PI group was compared to the same DSM-IV-TR ADHD-C and no-ADHD control groups as in the prior analysis. The analytic strategy was identical to that used for the first MANCOVA.... The overall MANCOVA for this second analysis showed a significant group effect ($F [4,407] = 14.10, p < .001$). Follow-up univariate analyses revealed significant omnibus one-way ANOVAs for verbal output speed (Stroop naming), perceptual/motor processing speed (Trails A), and set shifting speed (Trails B), but not interference control (See Table 3). On the remaining measures the results were the same as the prior analysis: The ADHD-PI and ADHD-C groups never differed, although the ADHD-PI group was always slower than controls and both groups were slower than controls on verbal output speed (Stroop naming) (see Table 3). There were no substantive changes in results with sex, income, IQ, reading ability, or comorbidity covaried. Thus, unlike the modified approach (ADD), the DSM-IV classification strategy demonstrated no statistically significant processing speed differences between ADHD-PI and ADHD-C. In addition and as hypothesized, the effect size for the contrast between ADHD-PI and controls on set-shifting speed (Trails B) was approximately half the effect size for the contrast between ADD and controls.

DISCUSSION

The DSM-IV-TR-defined ADHD-PI subtype identifies a heterogeneous group of children, possibly obscuring a non-hyperactive ADHD condition which we here label as “ADD” for simplicity. While this thesis has been asserted several times by theorists, the practical examination of a proposed cut point to parse this heterogeneity, while building on the DSM-IV-TR diagnostic system, has been underexplored. In the present study, two alternatives to identifying a mainly inattentive group were examined: the DSM-IV-TR ADHD-PI definition and an ADD subgroup, defined as two or fewer hyperactive-impulsive symptoms. External validation of these subgroups was then attempted via examination of processing speed and interference control deficits across groups. Group differences and effect sizes were examined to determine whether the ADD approach was superior to the DSM-IV-TR ADHD-PI approach in distinguishing an inattentive subtype from ADHD-C and controls.

As expected and consistent with prior studies, the DSM-IV-TR approach did not show speed differences between ADHD-PI and ADHD-C, although the PI group, but not the ADHD-C group, performed more slowly than controls on perceptual/motor sequencing (Trails A) and set-shifting (Trails B). The nature of processing deficits due to “pure inattention” was clarified through the use of an alternative definition of ADHD-PI, with two or fewer hyperactive-impulsive symptoms. The ADD group, on the other hand, did have slower interference control processing than ADHD-C group, while otherwise looking rather like the ADHD-PI group (although qualitatively slower across the board).

As currently defined, the DSM-IV-TR ADHD-PI diagnostic criteria include a significant number of individuals with three to five hyperactive/impulsive symptoms (44% of those meeting DSM-IV-TR ADHD-PI criteria in the present sample), who may represent a subthreshold variant of the combined type. This group’s presence in comparisons of ADHD-C versus ADHD-PI is likely to obscure the neuropsychological problems uniquely associated with significant symptoms of inattention in the relative absence of hyperactivity.

Processing speed deficits were identified in a subset extracted from DSM-IV-TR defined ADHD-PI which does not have hyperactivity (two or fewer symptoms). In a pattern in which this group was slowest overall, it was differentiated from non-ADHD controls on all four processing speed measures assessed. ADHD-C differed from controls only on the verbal output speed, as indexed by the Stroop naming condition. The ADD group differed from ADHD-C on one out of four hypothesized measures, and on the measure that arguably required the most cognitive processing (Stroop interference). If replicated, this finding would support the possibility of an etiologically distinct group at the low-activity end of the inattentive group (Milich et al., 2001; Diamond, 2005). This group has additional cognitive problems that are “worse” than those of ADHD-C, such that the groups do not merely fall on a spectrum of severity in which ADHD-C is always the most severe. Importantly, in the present sample, processing speed impairment was not accounted for or confounded with IQ, reading disability, or comorbid internalizing or externalizing disorders. The results provide partial support for theoretical prediction of the existence of a “truly inattentive” ADHD subtype with two or fewer DSM-IV-TR symptoms of hyperactivity, characterized by deficits in processing speed and working memory (Diamond, 2005).

The finding of slower Stroop interference control in ADD versus ADHD-C is generally consistent with recent reports of sluggish and inhibited performance in ADHD-PI versus ADHD-C in studies in which the inattentive subtype is created by limiting the number of HI symptoms to a lower number than that allowed by DSM-IV-TR criteria. It also replicates the meta-analytic finding of slower interference control in ADHD-PI than ADHD-C (van Mourik, et al., 2005). Derefinko and colleagues (2008) reported that an ADHD-PI group that was limited

to three or fewer hyperactive/impulsive symptoms differed from DSM-IV-TR defined ADHD-C by slower and more variable reaction times and failure to benefit from cues on the cued reaction time task and more omission errors on the go/no go task. Fillmore, et al. (2009) used the same subtyping strategy as Derefinko, et al. and found that ADHD-PI showed better reflexively controlled inhibition than ADHD-C. Fillmore, et al. (2009) suggested that distractibility to external stimuli may be less central in ADHD-PI than in ADHD-C and hypothesized that sluggish and inhibited cognitive style may account for attentional impairments in ADHD-PI. These findings support the contention that the attention problems of a non-hyperactive subset of ADHD-PI differ from the attention problems found in ADHD-C. These studies did not report analyses that would clarify whether or not such differences would have been found using the standard DSM-IV-TR subtyping approach. Carr, Henderson, and Nigg (in press) used an inattentive group of adolescents defined by two or fewer hyperactive/impulsive symptoms. Examining an attentional blink paradigm, they found a clearer picture of attentional selection deficits using this ADD group than when a DSM-IV-TR ADHD-PI group was used. This suggests the effects reported here are not confined only to the common clinical measures used but can also be shown on more refined cognitive measures. When viewed with the present results, these studies provide initial support for the hypothesis that inattentive symptoms in the absence of hyperactivity and impulsivity function differently than the inattentive symptoms of those who are hyperactive and impulsive.

By either classification approach used in the present study, ADHD-PI performed significantly slower than controls on perceptual/motor output speed and set/shifting speed. ADHD-C did not differ from controls on these measures. The effect size for set-shifting speed in the ADHD-PI versus controls contrast was doubled when those with subthreshold ADHD-C (ADHD-PI with three to five HI symptoms) were eliminated from the ADHD PI group. Neither perceptual motor processing speed nor verbal output speed effect sizes were appreciably altered by elimination of subthreshold ADHD-C cases from the ADHD-PI group. Thus, set shifting speed and the speed associated with Stroop interference control are cognitive processes that may be particularly germane to ADD.

The present study relied on simple but widely used clinical measures falling under the umbrella of the processing speed construct. Small to moderate effect sizes were found for the ADD versus ADHD-C comparison. More sophisticated reaction time and working memory measures might reveal stronger effects (Diamond, 2005). The effect sizes for comparisons between ADD and ADHD-C and controls were of a magnitude sufficient to be expected to lead to performance deficits on academic tasks (Gathercole, et al., 2004; Prifitera, Weiss, & Saklofske, 1998), but academic performance was not thoroughly measured in the present study. The perceptual/motor speed problems (Trails A) associated with both inattentive subtypes assessed in the present study may have important links to Developmental Coordination and Written Expression Disorders that could help clarify the nature of the comorbidity of these disorders with inattentive variants of ADHD (Mayes, Calhoun, & Crowell, 2000). Finally, more work is needed to determine whether cognitive findings help to account for variation in long term stability of children with ADD, which is limited as with other ADHD types (Todd et al. 2008).

In all, the current study provides supporting evidence that a non-hyperactive group of ADHD youngsters may exist, validated by slower cognitive processing and interference control. To the extent that this slow processing places constraints on working memory capacity, important effects on academic performance in these children are likely. However, identification of this group requires alternative diagnostic criteria to those used in DSM-IV-TR.

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Table 1

Descriptive Statistics and Significant Contrasts for ADHD Subtypes

	ADD <i>n</i> =40	ADHD-C <i>n</i> =66	Control <i>n</i> =276	<i>p</i> *	Significant Contrasts
Mean family income (in thousands) (SD)	70.23(37.89)	49.86(29.23)	74.54(69.35)	.027	<i>c</i>
Mean age(SD)	11.81(3.8)	10.53(2.40)	12.48(3.03)	<.001	<i>c</i>
% female* (N)	31.70(13)	22.4(15)	52.5(145)	.023	<i>c</i>
% ethnic minority(N)	7.3(3)	14.9(10)	14.9(41)	.539	
IQ mean (SD)	104.08(13.95)	101.37(11.78)	109.43(14.12)	<.001	<i>c</i>
Reading mean SS (SD)	99.85 (13.30)	100.30(14.61)	104.32(10.90)	.015	<i>b,c</i>
% Low reading(N) (<i>ss</i> < 85)	10.0(4)	15.2(10)	4.4(12)	.024	<i>c</i>
# Total ADHD symptoms(SD)					
parent	8.54 (1.38)	15.60(1.78)	1.27(2.24)	<.001	<i>a,b,c</i>
teacher	9.32(2.62)	11.36(3.14)	.47(1.11)	<.001	<i>a,b,c</i>
# Inattention symptoms(SD)					
parent	7.59(1.00)	8.05(1.15)	.83(1.54)	<.001	<i>b,c</i>
teacher	6.95(1.96)	6.76 (2.00)	.15(.50)	<.001	<i>b,c</i>
# Hyperactive/impulsive symptoms(SD)					
parent	.95(.80)	7.55(1.14)	.45(1.00)	<.001	<i>a,c</i>
teacher	2.63(2.69)	5.10(2.76)	.15(.50)	<.001	<i>a,c</i>
Impairment (<i>z</i>) (SD)	.48(.54)	.65 (.71)	-.51(.97)	<.001	<i>b,c</i>
% with oppositional and/ or conduct disorder (N)	26.8(11)	70.1(47)	12.5(34)	<.001	<i>a,c</i>
% with one or more anxiety disorders(N)	22.0(9)	32.8(22)	21.6(59)	.293	
% with one or more mood disorders(N)	0.0(0)	7.5(5)	2.6(7)	.178	

ADD Inattentive Type: ≥ 6 inattention symptoms and ≤ 2 hyperactive/impulsive symptomsADHD-C: ≥ 6 inattention symptoms and ≥ 6 hyperactive/impulsive symptomsControl: < 6 inattention symptoms and < 6 hyperactive/impulsive symptoms

* Significance of omnibus F test or Chi Square. Italicized letters denote post hoc comparisons significant at $p \leq .05$ with Bonferroni correction for multiple contrasts. Contrasts: *a*-(ADD vs. ADHD-C); *b*-(ADD vs. control); *c*-(ADHD-C vs. control).

Table 2

Adjusted Mean z Scores, Standard Error Estimates, Significant Contrasts, and Effect Sizes for the **Modified (ADD)** Sub-typing Approach

	ADD n=40	ADHD-C n=66	Control n=276	3-group p*	Significant Contrasts (effect size)
Stroop interference	.193(.09)	-.085(.07)	-.044(.03)	.032	<i>a</i> (.43) <i>b</i> (.44)
Stroop naming	.174(.11)	.208(.09)	-.260(.04)	.001	<i>b</i> (.62), <i>c</i> (.65)
Trails A time	.363(.15)	.104(.12)	-.116(.06)	.007	<i>b</i> (.39)
Trails B time	.484(.16)	.203(.12)	-.104(.06)	.001	<i>b</i> (.75)

ADD Inattentive Type: ≥ 6 inattention symptoms and ≤ 2 hyperactive/impulsive symptoms

ADHD-C: ≥ 6 inattention symptoms and ≥ 6 hyperactive/impulsive symptoms

Control: < 6 inattention symptoms and < 6 hyperactive/impulsive symptoms

* *P* values refer to significance of the omnibus *F* test for diagnostic group by neuropsychological measure. Age is covaried. Italicized letters denote post hoc comparisons significant at $p \leq .05$ with Bonferroni correction for multiple contrasts. Contrasts: *a*-(**ADD** vs. **ADHD-C**); *b*-(**ADD** vs. **control**); *c*-(**ADHD-C** vs. **control**). Effect size = Cohen's *d*.

Adjusted Mean z Scores, Standard Error Estimates, Significant Contrasts, and Effect Sizes for the **Standard DSM-IV-TR** Sub-typing Approach

Table 3

	ADHD-PI <i>n</i> =72	ADHD-C <i>n</i> =66	Control <i>n</i> =276	3- <i>group</i> <i>p</i> *	Significant Contrasts (effect size)
Stroop interference	.124(.07)	-.077(.07)	-.041(.04)	ns	
Stroop naming	.229 (.08)	.238(.08)	-.233(.04)	<.001	<i>b</i> (.78), <i>c</i> (.69)
Trails A time	.312(.12)	.107(.12)	-.121(.06)	.003	<i>b</i> (.45)
Trails B time	.287(.12)	.209(.12)	-.101(.06)	.004	<i>b</i> (.35)

ADHD-PI Inattentive Type: ≥ 6 inattention symptoms and < 6 hyperactive/ impulsive symptoms

ADHD-C: ≥ 6 inattention symptoms and ≥ 6 hyperactive/impulsive symptoms

Control: < 6 inattention symptoms and < 6 hyperactive/impulsive symptoms

* *P* values refer to significance of the omnibus *F* test for diagnostic group by neuropsychological measure. Age is covaried. Italicized letters denote post hoc comparisons significant at $p \leq .05$ with Bonferroni correction for multiple contrasts. Contrasts: *a*-(**ADHD-PI** vs. **ADHD-C**); *b*-(**ADHD-PI** vs. control); *c*-(**ADHD-C** vs. control). Effect size = Cohen's *d*.