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Acute Effects of Methylphenidate on Impulsivity and Attentional Behavior among Adolescents Comorbid for ADHD and Conduct Disorder

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Introduction

Stimulant medications, such as methylphenidate, are a recommended initial psychopharmacological approach to treatment of adolescents with Attention Deficit Hyperactivity Disorder (ADHD; Pliszka and AACAP workgroup, 2007). Numerous studies have documented improvement in symptoms of ADHD at school and home following methylphenidate treatment (MTA, 1999, 2004; Pelham, Bender, Caddell, Booth, & Moorer, 1985; Prasad et al., 2013; Schachar, Taylor, Wieselberg, Thorley, & Rutter, 1987) and effects are more robust during adolescence than childhood (for review see Spencer et al., 1996). Not only are ADHD symptoms improved, but there is also evidence of methylphenidate-induced performance gains on neuropsychological measures of reaction time, attention, memory, response inhibition, and general executive function (e.g., Bedard, Ickowicz, Logan, & Hogg-Johnson, 2003; Hood, Baird, Rankin, & Isaacs, 2005; Tucha et al., 2006; for review see Coghill et al., 2014). A variety of factors influence the effects of stimulant medications on neuropsychological performance, and the current study explores two of these issues: diagnostic comorbidity and the specificity of effects across distinct aspects of performance.

One primary consideration in evaluating methylphenidate effects on neuropsychological performance is the influence of comorbidities beyond ADHD alone. One of the most common comorbidities with ADHD is Conduct Disorder (CD), which involves a pattern of aggressive and antisocial behaviors (APA, 2013). Although symptoms of both disorders are generally responsive to stimulant medication (Jensen et al., 2001), ADHD with CD typically has poorer clinical outcomes than either condition alone (Jensen et al., 2001; Sibley et al.,

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2011). While comorbidity with CD may emerge during childhood, CD symptoms are typically most severe during adolescence (APA, 2013). Comorbidity with ADHD during adolescence may reflect co-occurrence CD symptoms that first emerged either in childhood or adolescence, which reflect distinct subtypes of CD (APA, 2013). From a neuropsychological perspective, ADHD results in difficulties with “cool” executive functions measured by sustained ability to selectively respond to target stimuli on continuous performance tasks (e.g., Conners CPT; Conners, 1995) and inhibition of responses on stop signal tasks (e.g., Logan, 1994). In contrast, CD presents with difficulties with “hot” executive functions of reward processing in reversal tasks that change stimulus response contingencies (for review see Rubia, 2011). This *hot* and *cold* conceptualization is a parsimonious account for neuropsychological performance and brain imaging outcomes of comorbid CD and ADHD youth.

Apart from this neuropsychology perspective, a separate literature measures and interprets similar processes of inhibition and reward from a behavioral perspective, focusing on impulsivity. From this perspective, comorbidity of ADHD with CD is thought to occur through a shared underlying syndrome of impulsivity (Colledge & Blair, 2001; Mathias et al., 2007; Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001) and methylphenidates effects on ADHD and CD symptoms may result from reductions in impulsivity (Klein et al., 1997). The current behavioral approach uses continuous performance and stop-signal measures similar to those used in the neuropsychological approach, but that have been modified to be more sensitive to the impulsive aspects of performance than the attentional components (Hamilton et al., 2015a). Reward measures are also conceptualized differently in the behavioral approach, with focus on choice for more immediate but smaller rewards over larger-later rewards (Hamilton et al., 2015b). Given previous criticisms of methylphenidate studies that they are not broad enough in their measurement to test the specificity of findings (Nigg, 2005), there is merit in testing this medication in the context of a behavioral model that accounts for a broader spectrum of impulsive behavior.

This study aimed to test the specificity of the acute effects of methylphenidate on behavioral performance and within the context of a behavioral model of impulsivity among adolescents comorbid for ADHD and CD. Impulsivity is a multi-faceted process and different forms of assessment yield divergent information about impulsivity (de Wit, 2009; Lane, Cherek, Rhoades, Pietras, & Tcheremissine, 2003; Reynolds, Ortengren, Richards, & de Wit, 2006; Winstanley, Eagle, & Robbins, 2006). The *Behavioral Model of Impulsivity* (Dougherty, Marsh, Mathias, & Swann, 2005a; Dougherty et al., 2009), provides a conceptual framework for interpreting three processes of impulsive behavior: (1) *Response Initiation* – an action oriented expression of behavior prior to the completion of information processing; (2) *Response Inhibition* – a failure to inhibit an already initiated response; and (3) *Consequence Sensitivity* – a preference for rewards that are available sooner, even if they are smaller in magnitude than those available latter. Tests of the components of this behavioral impulsivity model has been used to study chronic illicit drug use (e.g., Dougherty et al., 2013; Fields, Collins, Leraas, & Reynolds, 2009; Vassileva et al., 2014) as well as acute drug effects (e.g., Dougherty, Marsh-Richard, Hatzis, Nouvion, & Mathias, 2008; McCarthy, Niculete, Treloar, Morris, & Bartholow, 2012; Potter & Newhouse, 2008; Reed, Levin, & Evans, 2012). This same approach may be useful for evaluating methylphenidate treatment effects on

performance as well. The hypothesis was that methylphenidate would acutely reduce impulsivity and increase attentional behavior relative to the placebo condition. Additionally, we were interested in testing the relative magnitude of acute effects of methylphenidate on the three components of impulsivity described by this model and in the context of general performance accuracy reflecting attentional processing.

Methods

Participants

Thirty-one boys and girls participated in this study of methylphenidate effects on impulsive and other behavioral performance. Participants were identified from respondents to advertisements that described symptoms of both Attention Deficit Hyperactivity Disorder (ADHD) and Conduct Disorder (CD). After an initial telephone screening, adolescents and a parent/guardian were invited on site for further screening evaluation if they reported some history of CD and ADHD symptoms. Upon arrival both the parent and adolescent took part in an informed consent/assent procedure describing the research and permission to publish its findings. After both the parent and adolescent provided written confirmation of consent/assent to participate in the study. During this screening, adolescents were assessed for: psychiatric diagnoses and history of treatment (using the Kiddie and Young Adult Schizophrenia and Affective Disorders Schedule, Present State and Lifetime; K-SADS; Kaufman et al., 1997), intelligence (Wechsler Abbreviated Intelligence Scale, WASI; Psychological Corporation, 1999), and history of substance use (Drug History Questionnaire; Dougherty et al., 2013 and the Modified Substance Use Disorders Module of the Structured Clinical Interview for DSM-IV Disorders; Martin, Kaczynski, Maisto, Buckstein, & Moss, 1995). A physical health examination was also performed that included an electrocardiogram, breath alcohol (AlcoTest® 7110 MKIII C device; Draeger Safety Inc., Durango, CO), and urine-drug test (Panel/Dip Drugs of Abuse Testing Device; Redwood Biotech, Santa Rosa, CA). Female participants' urine was also tested to confirm that they were not pregnant. Parents/guardians were interviewed separately about the adolescents' psychiatric history using the K-SADS.

Outcomes of the screening and assessments were evaluated by the treatment team, which included a board-certified child and adolescent psychiatrist (author RLO), to evaluate eligibility. Inclusion criteria were: adolescents ages 13–17 years, and meeting DSM-IV-TR criteria for CD and ADHD, who were not currently or recently (past 60 days) receiving treatment. Potential participants were excluded for: failure to meet full CD and ADHD criteria ($n = 14$), having DSM-IV-TR disorder other than CD and ADHD ($n = 5$), regular illicit drug use ($n = 14$), abnormal electrocardiogram ($n = 8$), low intelligence (< 70 WASI IQ; $n = 4$), and failure to follow-up after initial screening ($n = 5$). The final retained sample was composed of 31 boys and girls.

Procedure

After enrollment adolescents participated in a 5-week study involving baseline assessment, medication treatment, and impulsivity testing. During the first weekly visit, participants experienced a baseline assessment to quantify their unmedicated behavioral performance

(measures described below) and further characterize their clinical histories along with a personality assessment of trait impulsivity (Barratt Impulsiveness Scale, BIS-11; Patton, Stanford, & Barratt, 1995; Stanford et al., 2009). Then participants experienced a medication titration week, experiencing increasing doses of the long acting form of methylphenidate (Ritalin-LA®; Novartis Pharmaceuticals Corporation; East Hanover, NJ) following recommended safety guidelines (Greenhill et al., 2002; Novartis, 2004) and to verify dose tolerability up to 40mg of the methylphenidate. After evaluating safety, participants experienced three consecutive weeks of methylphenidate treatment that involved a 6 day course of placebo, 20mg, or 40mg of the methylphenidate. The research pharmacy kept the double-blinded (both participant and research team blinded), randomized dose-order; the blind was broken after study completion. On the 7th day of each week, participants returned to the laboratory to take that week's methylphenidate dose on site at approximately 9:30 am. After a 1-hr absorption period, they completed a battery of behavioral impulsivity measures (task order was counterbalanced by participant, not by visit). Participants were paid \$40 for the safety/titration visit, \$75 for each weekly testing visit and a \$50 bonus for study completion. At the conclusion of the study, participants were provided a report describing their clinical response and referred for ongoing care. This study and its procedures were reviewed and approved by the human subject's ethics board of our local institution. Data collection was conducted in the United States of America.

Behavioral Measures

Following the *Behavioral Model of Impulsivity* (Dougherty et al., 2005a; Dougherty et al., 2009) three computerized measures of behavioral impulsivity were assessed at each weekly visit, including measures of response initiation, response inhibition, and consequence sensitivity.

Immediate Memory Task (IMT)—The IMT measures response initiation impulsivity by assessing erroneous responding to stimuli prior to the completion of information processing (Dougherty, Marsh, & Mathias, 2002). In this task, participants were instructed to respond to target cues (consecutive matching 5-digit numbers) and avoid responding to non-targets. Some of the non-target stimuli were very similar to the target, matching on 4 of the 5 digits. Erroneous responding to the similar non-targets (Commission Errors) is a measure of response initiation impulsivity, while correct responding to targets (Correct Detections) is a measure of sustained attention (Dougherty et al., 2002). Finally, the proportion of Commission Errors to Correct Detections (the Ratio) is commonly reported as the relative level of these two processes. Using this ratio process is an analytic method that has been used to address conditions when participants adopt a conservative response strategy, responding to few stimuli, in order to avoid the commission errors (Tannock, Schachar, Carr, Chajczyk, & Logan, 1989).

GoStop Impulsivity Paradigm (GoStop)—The GoStop (Dougherty, Mathias, Marsh, & Jagar, 2005b) is a measure of response inhibition assessing the failure to withhold an already initiated response. In this computerized task, the participants were instructed to respond to targeted “go” (black consecutive matching numbers), but withhold responding to “stop” cues (consecutive matching number that turns from black to red font) that are rapidly displayed

on a computer monitor (50, 150, 250, 350 msec after onset). Responding to “go” cues (NoStop) is a measure of sustained attention, while responding to the “stop” cues at the 150 msec interval are interpreted as a measure of response inhibition impulsivity (Dougherty et al., 2005b). Finally, like the IMT, a ratio score is used to account for response strategy, specifically the proportion of NoStop and 150msec responding (the Ratio; Dougherty et al., 2008).

Two Choice Impulsivity Paradigm (TCIP)—The TCIP is a measure of consequence sensitivity and requires 50 discrete-choices between smaller-more-immediate rewards and larger-more-delayed rewards (Dougherty et al., 2005b). In this computerized task, participants made choices between circles associated with a 5 cent reward that could be earned after a delay of 5 seconds and squares associated with a 15 cent reward after a 15 second delay. Both the percentage of the 50 responses for the smaller-more-immediate rewards (Proportion Short) and the successive number of larger-more-delayed reward choices (Consecutive Long) are interpreted as consequence sensitivity impulsivity, although from different perspectives. The Proportion Short score is an overall session measure of relative preference, while the Consecutive Long score represents only the longest run of choices representing maximal delay tolerance (Dougherty et al., 2005b).

Data Analyses

Prior to comparisons of behavior, basic frequency counts and averages were computed for demographic and general clinical characteristics. All analyses were conducted using IBM SPSS Statistics version 21 (IBM Corp. Armonk, NY).

The hypothesis was that methylphenidate would reduce impulsivity and increase attentional behavior relative to the placebo condition. Acute performance effects of methylphenidate were analyzed to test for: (1) statistically significant dose effects; (2) response rates (proportion of sample with improved performance); and (3) magnitude of response (percent change). A series of repeated measures analyses of variance (ANOVA) were conducted separately for each of the primary measures from the IMT, GoStop, and TCIP comparing performance after placebo, 20mg and 40mg doses of methylphenidate. In instances, where there was a significant main effect of Dose ($p < .05$), follow-up comparisons were conducted with using the Benjamini and Hochberg (1995) procedure for correcting for multiple comparisons. Two individuals had missing data, one failed to complete the behavioral tasks during the 20mg condition and another individual failed to perform these tasks during the 40mg condition.

Next, response rates and magnitude of response peak performance (i.e., the more extreme of the two scores after the 20mg or 40mg methylphenidate conditions) were tested as the two within-subjects factors. For example, for IMT Commission Errors the lower of the two scores (representing the least impulsivity) from the 20mg and 40mg conditions were used as the measure of peak performance change for this measure. The rationale for analyses of peak performance measurement is that some participants would be expected to experience optimal response with the 20mg dose and others with the 40mg dose (Pliszka and AACAP workgroup, 2007), and we were interested in testing the maximal effect. Percent change

from placebo to peak performance was calculated to quantify the magnitude of change between these conditions. Additionally, since not all participants would be expected to respond to the medication (Tannock, Schachar, & Logan, 1995), reliable change index scores were calculated (i.e., difference between placebo and peak performance divided by the standard error). Participants with reliable improvements in performance (i.e., reliable change index greater than 1.96; Johnston, Coghill, Matthews, & Steele, 2014) were coded as responders.

Finally, comparisons of placebo with methylphenidate effects on performance were repeated, exploring clinical characteristics as between-subject factors. These analyses paralleled the approach of the first set of repeated measures ANOVA, with the addition of CD Onset Type, CD Severity, and ADHD type separately as the between-subjects factors.

Results

Demographic and Clinical Characteristics

The sample of $N = 31$ youth who participated were predominately composed of boys, of white race, Hispanic ethnicity, aged 14 years of age (median), and in the low-average intelligence range (see Table 1). The sample was nearly evenly split between the Childhood- and Adolescent-CD Onset types with CD most commonly occurring at the Moderate Severity specifier. In terms of ADHD, only a single participant had the Predominantly Hyperactive-Impulsive Type, the remaining cases were split evenly ($n = 15$ each) between Predominantly Inattentive and Combined Types. Self-reported impulsive personality traits were high; they were over a SD greater than the normative mean for the instrument (i.e., norm $M = 62.3$, $SD = 10.3$; Stanford et al., 2011). Prior to initiation of the medication phase of the study, baseline assessments were conducted on measures of performance (Table 1). There was no evidence of floor effects for measures of impulsivity or ceiling effects for attentional measures, meaning that there was room for performance change following placebo and methylphenidate conditions. Of the three measures of impulsivity, variance was high on the TCIP.

Methylphenidate Performance Comparisons

Immediate Memory Task—Significant differences in performance were observed and these effects varied by type of IMT performance (Table 2, IMT section). Following the active dose of medication, there were significant increases in Correct Detections reflecting an improvement attentional processing. IMT Correct Detections were significantly higher in the 40mg condition than either placebo ($F_{1,29} = 10.80$, $p = .003$) or 20mg ($F_{1,28} = 8.85$, $p = .012$) dose conditions. IMT Commission Errors also showed an increase in response initiation impulsivity with medication doses, performance was more impulsive in the 40mg dose than the 20mg dose ($F_{1,28} = 5.63$, $p = .025$), but not placebo ($F_{1,29} = 3.32$, $p = .158$). There were no significant dose effect changes for the IMT Ratio score.

In examining response rates, 19 adolescents (61.2% of the sample) experienced an increase in IMT Correct Detections, while only 12 (38.7%) experienced a decrease in IMT Commission Errors, and 11 (35.5%) experienced a decrease in IMT Ratio performance.

Finally, the magnitude of the change from placebo to Peak Change performance across the full sample are shown in Figure 1 (left panel), with IMT Correct Detections showing the largest effect of Dose (i.e., 17% increase in attentional performance).

GoStop Impulsivity Paradigm—There were no statistically significant dose effects on GoStop (only a trend for higher attentional NoStop performance with methylphenidate; Table 2, GoStop section). Response rates were: 22 adolescents (70.9% of the sample) experienced increases in NoStop responding, while 20 (64.5%) experienced a decrease in 150msec responding, and 15 (48.4%) had decreases in the GoStop Ratio. The magnitude of changes was largest for the NoStop responses (Figure 1, middle panel).

Two Choice Impulsivity Paradigm—Finally, there were no statistically significant dose effects for either Proportion Short responses (i.e., less preference for immediate reinforcement) or Consecutive Long responses (i.e., greater tolerance for successive non-impulsive choices; Table 2, TCIP section). Of the three different behavioral measures, response rates were lowest on the TCIP; only 10 (32.2% of the sample) showed decreases in Proportion Short responses and 11 (35.5% of the sample) showed an increases in Consecutive Long responses following methylphenidate. While the magnitude of changes from placebo to methylphenidate conditions was larger for Consecutive Long responses than Proportion Short, there was large variability in responding on this task (Figure 1, right panel).

Methylphenidate Effects on Behavior as a Function of Clinical Characteristics

Comparisons were made to examine the relationship of clinical characteristics and Dose effects on performance. There were no significant effects of Group or Group by Dose effects in IMT, GoStop, or TCIP performance for any of the following clinical grouping variables: CD Onset Type, CD Severity, or ADHD type.

Discussion

This study tested the acute effects of methylphenidate on three components of the impulsivity, as well as attention among adolescents comorbid for ADHD and CD. The most robust change following methylphenidate was increase in attentional performance. In terms of impulsivity, there was a significant dose effect of worsening response initiation impulsivity. In terms of rates of responding, only a minority of cases showed improvement in response initiation and reward choice impulsivity. Overall response rates in this comorbid ADHD/CD sample were variable and mean changes were small. Response was not related to clinical subtypes within ADHD or CD diagnoses.

Adolescence is the developmental context within which this study was conducted. Compared to childhood, adolescence would be expected to be a developmental period of increased severity of psychiatric symptoms of CD (APA, 2013), declining psychiatric symptoms of ADHD (particularly impulsivity and hyperactivity; Biederman, Mick, & Faraone, 2000), decreasing neuropsychological performance differences between comorbid ADHD (with disruptive behavior disorder) and control groups (Günther, Jolles, Herpertz-Dahlmann, & Konrad, 2009), and increased robustness of stimulant medications effects on

psychiatric symptoms of ADHD (Spencer et al., 1996). The changing developmental course of psychiatric symptoms, medication efficacy, and performance differences may have influenced the pattern results observed herein. The following description provides further interpretation from the perspective of past literature on each type of impulsivity.

Current Findings in the Context of the Previous Measurement Approaches

Continuous Performance Tests—Since at least the 1970's (Werry & Aman, 1975), continuous performance tests have been used to study behavioral changes following methylphenidate treatment. Typically the test parameters have involved less complex stimuli with longer latency response windows than used in the current study. This longer response window presents more opportunity for lapses in sustained attention, while at the same time puts less demand on making rapid responses. This results in a greater demand characteristics on the attentional rather than impulsivity parameters of these other tasks. These previous studies have found that the magnitude of methylphenidate improvements in performance is about twice the size for correct responding as it is for reducing commission errors (effects sizes of 1.6 versus 0.8 respectively in meta-analyses from Losier, McGrath, & Klein, 1996).

Another feature of these previous task parameters is that they can yield floor effects that are not appropriate for statistical comparison (Trommer, Hoepfner, & Zecker, 1991) and potentially resulting in Type I error (Hamilton et al., 2015a). The current study used a task and parameters resulting in performance that was not restricted by floor or ceiling effects and had sufficient range for movement following methylphenidate treatment. The parameters were also further modified, with more complex commission error stimuli and faster presentation, which would be expected to make it more sensitive to detecting impulsivity rather than attentional differences of the typical continuous performance task. Despite the methods and procedures designed to maximize sensitivity for impulse performance, our expectations were not confirmed, the largest change following methylphenidate continued to be around the attentional measures of correct detections rather than the impulsive measure of commission errors.

Stop Signal Tasks—Our outcomes with methylphenidate-enhanced response inhibition on stop signal task performance were not as robust as previous research with other types of stop signal tasks. Much previous research focuses on the Logan (1994) procedure, testing either change in the latency to inhibit responding (i.e., stop signal reaction time; SSRT) or the proportion of success in inhibiting responding at different onsets of stop signal presentation (Inhibition Slope). The current study used the GoStop Impulsivity Paradigm that has several methodological modifications to the standard procedure. First, the impulsivity variable is defined as the rate of failure to inhibit responses on particular trials (150msec) as a ratio of the number of those types of trials. This omits analyses of stop trials that are included as control conditions (i.e., 50msec and 350msec stop signals) that normally would be included in the Inhibition Slope analyses of other measures. Second, the current task uses a fixed presentation rate of stop signals, which allows for interpretation of accuracy rather than speed of inhibition. This makes comparison to performance accuracy on the continuous performance test more direct. Third, another modification in the current method is both go and stop signals are presented in the visual modality, which can facilitate the

interpretation of outcomes resulting from competing go and stop responses (i.e., within context of the of the race model; Dougherty et al., 2005b). Other common stop signal tasks use auditory stimuli as a stop signal, which require the additional step of integration of visual and auditory inputs for comparison stop and go processes. Previous work has demonstrated that methylphenidate accelerates the inhibition function in hyperactive youth and inhibition is an important component to theories of ADHD (Barkley, 2003). But the current study did not find this necessarily improves accuracy of performance (i.e. reducing response inhibition failures).

Reward Choice Task—While many of the studies on reward process and methylphenidate effects examine reward manipulations on neuropsychological tasks (often in a brain imaging context; e.g., Rubia et al., 2009), this study used the behavioral choice approach involving selection between smaller-rewards after shorter-delays versus larger rewards delivered at longer delays. This behavioral reward choice impulsivity is a popular approach for other psychopharmacology studies, especially substance use studies (Hamilton et al., 2015b). This current study involved participants actually experiencing delays before receiving reinforcement, rather than the hypothetical procedures like delay discounting. Comparisons of the “hypothetical” and “experiential” task manipulations tends to find them equivalent with reward to appraisal of the reward (Johnson & Bickel, 2002), but it less is understood about the processing of the delay period. Findings are mixed regarding stimulant medication on hypothetical versus experiential tasks, with some studies only finding stimulant effect with the experiential type (Shiels et al., 2009). This mixed pattern of performance change may also explain the current findings, where large effects were observed but in a lower proportion of patients than with the response initiation and inhibition measures. Reward aspects of impulsivity are suggested to be more influenced by learning from one’s environment than genetics (Kuntsi et al., 2006), therefore there may have been some influence of life experience that was not captured in the current study that was systematically affecting methylphenidate response.

Limitations

There are several limitations to consider when interpreting outcomes from the current study. First, the selection of measures focused exclusively on the behavioral approach, there are important differences (described above) in interpreting these outcomes relative to traditional neuropsychological performance. Second, this study only focused on measurement after 7 days experience with each dose of methylphenidate; previous studies have raised the question of behavioral performance differing between acute and chronic conditions medication effects (Rhodes, Coghill, & Matthews, 2006). Third, negative findings may reflect lack of power; the sample size was small although larger than 80% of the studies reviewed for effects of methylphenidate on cognitive function in ADHD (Coghill et al., 2014). Finally, the sample was exclusively a comorbid group (CD with ADHD), who tend to have poorer clinical response to treatment than ADHD alone (Jensen et al., 2001; Sibley et al., 2011) and therefore may have diminished behavioral effect as well.

Conclusions

This study tested the effects of methylphenidate on impulsive and attentional performance among adolescents comorbid for ADHD and CD. These tests were conducted and interpreted within the context of a behavioral theory of impulsivity. Contrary to expectation, methylphenidate-induced change in attentional performance was of greater magnitude and was observed in a larger proportion of the sample than changes on measures of impulsivity.

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Figure 1.

Average Percent Change in Performance following Methylphenidate for Immediate Memory Task (IMT), GoStop Impulsivity Paradigm (GoStop), and Two Choice Impulsivity Paradigm (TCIP).

Table 1

Demographic and Clinical Characteristics

Characteristics	N	%
Gender,		
Boys	24	77
Girls	7	23
Race		
White	20	64
Black	8	26
> 1 race	3	10
Ethnicity, Hispanic	18	58
ADHD Type		
Inattentive	15	48
Hyperactive	1	4
Combined	15	48
Childhood Onset CD	15	48
CD Severity		
Mild	7	23
Moderate	18	58
Severe	6	19
	M	SD
Age, years	14.13	1.41
Intelligence, WASI	87.52	9.96
Impulsive Personality, BIS-11	76.09	9.06
Baseline Performance	M	SD
Immediate Memory Task		
Commission Errors	39.68	10.74
Correct Detections	69.60	15.49
Ratio	59.05	17.53
GoStop Impulsivity Paradigm		
150msec responses	38.39	16.60
NoStop responses	79.88	9.91
Ratio	48.13	21.58
Two Choice Impulsivity Paradigm		
Proportion Short	36.29	21.60
Consecutive Long	12.39	9.93

Note. CD Severity specifier and Onset type based on DSM-IV-TR criteria. BIS-11 - Barratt Impulsiveness Scale; WASI - Wechsler Abbreviated Intelligence Scale

Table 2

Comparisons of Performance after Placebo, 20mg, and 40mg Methylphenidate

Behavioral Variable	Methylphenidate						F	df	p
	Placebo		20MG		40MG				
	M	SD	M	SD	M	SD			
IMT									
Correct Detections	73.99	20.67	74.78	19.42	80.90	18.19	5.627	2,56	.006
Commission Errors	39.46	16.15	38.54	13.36	44.79	18.97	3.356	2,56	.042
Ratio	55.21	22.43	52.58	15.43	52.05	16.80	0.793	2,56	.457
GoStop									
NoStops	63.58	19.72	70.00	20.18	70.99	20.51	3.045	2,56	.056
150msec	29.66	20.91	33.79	21.74	28.44	22.60	1.301	2,56	.280
Ratio	45.56	31.56	47.55	29.19	42.06	31.99	0.575	2,56	.566
TCIP									
Proportion Short	26.45	28.94	26.31	31.72	23.10	26.54	0.249	2,56	.781
Consecutive Long	23.65	20.40	27.37	21.00	26.62	19.58	0.610	2,56	.547

Note. IMT – Immediate Memory Task; GoStop – GoStop Impulsivity Paradigm; TCIP – Two Choice Impulsivity Paradigm. $p < .05$ statistically significant difference in omnibus test of methylphenidate dose.