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Driving in young adults with attention deficit hyperactivity disorder: Knowledge, performance, adverse outcomes, and the role of executive functioning

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Abstract

Past studies find that attention deficit hyperactivity disorder (ADHD) creates a higher risk for adverse driving outcomes. This study comprehensively evaluated driving in adults with ADHD by comparing 105 young adults with the disorder (age 17–28) to 64 community control (CC) adults on five domains of driving ability and a battery of executive function tasks. The ADHD group self-reported significantly more traffic citations, particularly for speeding, vehicular crashes, and license suspensions than the CC group, with most of these differences corroborated in the official DMV records. Cognitively, the ADHD group was less attentive and made more errors during a visual reaction task under rule-reversed conditions than the CC group. The ADHD group also obtained lower scores on a test of driving rules and decision-making but not on a simple driving simulator. Both self- and other-ratings showed the CC group employed safer routine driving habits than the ADHD group. Relationships between the cognitive and driving measures and the adverse outcomes were limited or absent, calling into question their use in screening ADHD adults for driving risks. Several executive functions also were significantly yet modestly related to accident frequency and total traffic violations after controlling for severity of ADHD. These results are consistent with earlier studies showing significant driving problems are associated with ADHD. This study found that these driving difficulties were not a function of comorbid oppositional defiant disorder, depression, anxiety, or frequency of alcohol or illegal drug use. Findings to date argue for the development of interventions to reduce driving risks among adults with ADHD. (*JINS*, 2002, *8*, 655–672.)

Keywords: Attention deficit hyperactivity disorder, Driving, Executive functions, Young adults

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) has been conceptualized as a developmental disability involving impaired sustained attention, poor resistance to distraction, deficient response inhibition, and/or hyperactivity relative to same-aged peers (American Psychiatric Association, 1994; Barkley, 1998). Early longitudinal investigations of hyperactive children followed to adulthood found that they were more likely to be involved in traffic accidents as drivers than their normal peers (Weiss et al., 1979; Weiss & Hechtman, 1993). Given this finding, a subsequent 3- to 5-year follow-up driving survey was conducted with ADHD adolescents and a community control group (Barkley et al., 1993). That study found that teens with ADHD were (1) more likely to have driven an automobile illegally prior to the time they became eligible as licensed drivers; (2) less likely to be employing sound driving habits in their current driving performance, as reported by their parents; (3) more likely to have had their licenses suspended or revoked; (4) more likely to have received repeated traffic citations, most notably for speeding; and (5) nearly 4 times more likely to have had an accident while they were the driver of a vehicle.

Subsequent studies involving somewhat older samples have revealed much the same pattern of negative driving outcomes in the driving history of adults with ADHD (Barkley et al., 1996; Murphy & Barkley, 1996a). Most of these

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studies were limited by their exclusive reliance on participants' self-reports of driving history. Barkley et al. (1996), however, corroborated some of their self-reported findings in the official records from the state Department of Motor Vehicles (DMV). These findings of significant driving problems are not limited to studies using clinic-referred samples but have been noted in an epidemiological study of adolescents in New Zealand (Nada-Raja et al., 1997). Despite the consistency of results across these studies, the sample sizes have been relatively small and may have restricted the statistical power needed to detect other driving risks that may be of a smaller magnitude than those found to date. Also, only one study has attempted to corroborate the results of self-report against official driving records. Consequently, the present study evaluated considerably larger samples of both young adults with ADHD and control adults and utilized both self-reports of adverse outcomes as well as official driving records.

Unfortunately, previous studies did not attempt to examine the basis for this increased frequency of adverse driving outcomes in ADHD teens and adults. Left unanswered is the question of just how ADHD interferes with the operation of a motor vehicle so as to predispose these drivers to greater citations, vehicular crashes, and license suspensions or revocations than the general population of drivers. The present study sought to replicate these earlier findings and extend them by evaluating multiple levels of driving abilities in ADHD and control adults. Similar to Michon (1979), we conceptualized driving as involving a multifactorial model selecting measures that assessed each component. These included basic neuropsychological abilities that are prerequisites to operating a vehicle (Level I: *basic cognitive*), such as sustained attention (vigilance), risk-taking or inhibition, visual discrimination, reaction time, and rule following. Operational abilities (Level II) involve the tactical management of the vehicle relative to the roadway, hazards, and other drivers, assessed here using a driving simulator. Strategic (Level III) driving ability includes driving knowledge and decision-making while operating the motor vehicle in the midst of other drivers and was evaluated here using a videotape test of driving knowledge and rapid-decision making in high-risk driving scenarios. Actual driving behavior and use of safe driving practices (Level IV) was evaluated by behavior ratings provided by participants and other people who knew the participant's driving well. Adverse driving outcomes (Level V) were examined through both self-report of driving offenses and accidents as well as through official DMV driving records.

Many of the measures chosen here to assess driving and related cognitive abilities were originally developed for evaluating brain-injured or elderly populations, for which there is evidence of their validity (see "Dependent Measures," below). No previous research exists, however, on the validity of these measures for predicting driving outcomes in those having ADHD. The present study therefore examined the degree to which these measures were associated with each other and with adverse driving outcomes.

Apart from those components of driving noted above, other mechanisms may be involved in predisposing adults with ADHD to greater driving risks. ADHD is reliably associated with diminished executive functioning (EF), particularly on measures of response inhibition, interference control, and working memory (Barkley, 1997). It is conceivable that such deficits contribute to the driving problems among young adults with ADHD. No prior studies of driving in adults with ADHD have examined the role of EF in relation to driving performance and negative outcomes. Deficits in EF have already been reported in the sample of ADHD adults employed here (Murphy et al., 2001). The present study therefore evaluated the degree to which measures of EF were associated with safe driving habits and self-reported and DMV recorded adverse driving outcomes (crashes and traffic violations).

Previous research on ADHD has often found that groups of clinic-referred ADHD participants have lower levels of measured intelligence than the control groups (Barkley, 1997, 1998). It is possible that these group differences in intelligence may explain some of the difficulties in the driving performance of the ADHD group instead of or in addition to those attributable directly to ADHD. Determining this contribution of IQ level to driving performance in ADHD is a complicated issue. Studies of community-derived samples find a significant negative relationship between degree of ADHD symptoms and IQ (Hinshaw et al., 1987; McGee et al., 1984), suggesting that the group differences in IQ found in studies of clinical samples may not be merely an artifact of recruitment bias. ADHD seems to have an inherent negative relationship with IQ, perhaps in part through its impact on executive functioning which itself is related to IQ. Statistically controlling IQ level in data analyses, as in analysis of covariance, may not be appropriate, however, in view of this relationship of IQ to ADHD as it risks removing effects on the dependent variables that are due to ADHD. Instead, the present study examined this issue by employing level of intelligence as a separate factor in the analyses of those measures with which IQ was significantly correlated.

Other disorders often co-occur with ADHD in adults, such as anxiety, depression, oppositional defiant disorder, conduct disorder, and greater alcohol and drug use (Barkley, 1998; Murphy & Barkley, 1996a). Such comorbidity makes it unclear whether previous findings on driving and ADHD are a consequence of ADHD or of these comorbid disorders. The present study therefore conducted extensive *post-hoc* analyses to examine the potential contribution these comorbid conditions may have made to the results. To summarize, the specific aims of the present study were as follows:

- Replicate the findings of earlier studies concerning the various adverse outcomes in the driving histories of young people with ADHD employing the largest samples studied to date and rigorous clinical diagnostic criteria. In keeping with prior studies, we hypothesized that the ADHD group would have significantly greater general citations, and especially speeding tickets, accidents, and license suspensions than the control group.

- Examine the impact of ADHD on multiple levels of driving ability including basic cognitive functioning, performance on a driving simulator, knowledge and rapid decision-making, and self and other ratings of actual driving behavior. No hypotheses were asserted here given that many of these measures, except the latter ratings, have not been well studied.
- Determine the extent to which these results may be a function of reduced level of intelligence often associated with ADHD in clinical samples. We hypothesized that while level of IQ may affect performance on lab measures of driving, the adverse driving outcomes previously associated with ADHD would not be a function of low IQ.
- Evaluate the potential impact of comorbid ODD, anxiety, and depression on the driving problems that may be found for the ADHD group. We hypothesized that these disorders would not make a significant contribution to any driving problems or adverse outcomes associated with ADHD.
- Assess the degree to which level of alcohol and illegal substance use may have contributed to the driving difficulties evident in the ADHD group. We had no hypotheses regarding the contribution of these variables to the measures collected here.
- Determine the degree to which these various driving measures are related to each other and the extent to which they are predictive of safe driving behavior and adverse driving outcomes. No hypotheses were asserted here in view of the absence of any prior information on these issues in clinical samples having ADHD.
- And finally, examine the extent to which EF tasks predicted safe driving behavior and risk for adverse driving outcomes.

METHODS

Research Participants

Two groups of young adults ages 17 to 28 years were compared: (1) a group having ADHD ($N = 105$); and (2) a normal control group ($N = 64$). All participants met the following entry criteria into the study: (1) chronological age between 17 years and 28 years; (2) composite IQ greater than 80 on the Kaufman Brief Intelligence Test (KBIT; Kaufman & Kaufman, 1983); (3) corrected or uncorrected visual acuity of no worse than 20/30 based on a brief screening using a Snelling chart; (4) a valid state driver's license; and (5) no evidence of deafness, blindness, severe language delay, cerebral palsy, epilepsy, autism, or psychosis as established through clinical diagnostic interview.

Participants in the ADHD group were recruited from consecutive referrals to clinics specializing in child and adult ADHD at a northeastern medical school. They had to receive a clinical diagnosis of ADHD established not only by meeting the DSM–IV diagnostic criteria (American Psychiatric Association, 1994) but also the judgment of an expert clinician. Detailed information on the recruiting procedures and selection criteria employed for the ADHD group can be found in the paper by Murphy et al. (2001). Using this multi-stage and multi-source approach, 55% of the 105 ADHD participants were diagnosed as Combined Type, 34% as Predominantly Inattentive Type, 2% as Predominantly Hyperactive–Impulsive Type, and 9% as ADHD Not Otherwise Specified (Residual Type). Forty-one percent had previously been diagnosed by a medical or mental health professional as having ADHD at some time in their life.

Twenty-one members of the ADHD group were currently taking psychiatric medication. Most were taking stimulant medications ($N = 17$). These were requested to cease their medication at least 24 hr prior to testing and to inform their physician of this requirement. The 4 participants taking antidepressant medication were tested after 2 weeks of being off of their medication, again with requests to inform their physicians that they were doing so.[1] As for their history of treatment with psychiatric medications, 80% had taken stimulants previously (M duration = 40 months, $SD = 39$), 37% had taken antidepressants (M duration = 9.5 months; $SD = 11.1$), 9% had taken anti-anxiety medications (M duration = 4.3 months, $SD = 5.2$), 2% had taken antihypertensives (M duration = 3 months; $SD = 0$), and 6% had been on anti-psychotic medications (M duration = 29.3 months; $SD = 37.2$).

Participants in the Community Control group were recruited through advertisements placed in the regional newspaper. They were required to have: (1) no history of a major psychiatric disorder based on a diagnostic interview with the participant; (2) less than 6 symptoms of ADHD rated as occurring *pretty much* or *very much* on the ADHD Rating Scale used to assess current functioning, as discussed below; and (3) no history of receiving mental health treatment services for major psychiatric disorders. This project was reviewed and approved by the university's Institutional Review Board.

Procedures

On the day of their initial evaluation, all participants (and parents, whenever possible) were interviewed by a licensed clinical psychologist. Each participant then received an extensive battery of measures administered by an MA level psychological assistant. This assistant was not blind to the group membership. These measures included structured clin-

[1]The currently medicated and unmedicated ADHD participants were compared on all of the dependent measures and none reached significance ($p < .01$), and so the two groups are collapsed here into a single ADHD group for all further analyses.

ical interviews concerning various areas of adaptive functioning, neuropsychological tests, and the tests of motor vehicle driving knowledge, skills, and performance discussed below. The results of the EF measures are reported elsewhere (Murphy et al., 2001) as are those pertaining to sense of time (Barkley et al., 2001). However, factor scores derived from the EF battery are evaluated here as predictors of driving risks (see Results below). All of the measures were given in the same sequence for all subjects. Participants were paid a stipend of $100 for their participation.

Screening Measures

Kaufman Brief Intelligence Test (KBIT; Kaufman & Kaufman, 1983)

This contains verbal (vocabulary) and nonverbal subtests (matrix reasoning). The total composite score was employed here.

Structured Clinical Interview of Disruptive Behavior Disorders

An interview was created for this project that consisted of the criteria from the DSM–IV for ADHD, ODD, and conduct disorder (CD). Symptoms of ADHD were reviewed twice, once for current functioning (past 6 months) and a second time for childhood between 5 and 12 years of age. Symptoms of ODD and CD were reviewed only for current functioning.

ADHD Rating Scale for Adults (Barkley & Murphy, 1998)

This scale contains the 18 items from the diagnostic criteria for ADHD in the DSM–IV. Each item is rated on a scale from zero to 3, representing *not at all* or *rarely*, *sometimes*, *often*, and *very often*, respectively. Participants completed two versions of this scale, one being for current symptoms and the other for recall of childhood symptoms between ages 5 to 12 years. Norms for both scales are available for the region in which this study took place (Murphy & Barkley, 1996b). The scores represented the number of items answered as *often* or *very often*.

The Symptom Checklist 90–Revised (Derogatis, 1986)

This is a widely used scale evaluating nine dimensions of adult psychopathology (e.g., anxiety, paranoid ideation, interpersonal hostility, depression, etc.). The Depression and Anxiety scores were employed in this study to evaluate the extent of comorbidity for these disorders in the ADHD group.

Dependent Measures

Driving history interview

Participants were interviewed about their driving experience as well as their history of various adverse driving outcomes including citations for various traffic infractions (e.g., speeding, reckless driving, driving while intoxicated, parking violations, etc.), accidents, and license suspensions or revocations. This interview also included questions about the dollar damage estimates associated with each of the first four crashes as well as a range of factors (e.g., speeding, inattention, alcohol use, etc.) that may have contributed to the crash.

Official DMV driving record

From this record, the following events were recorded: (1) total number of traffic citations for all offenses on the record; (2) number of speeding citations; (3) number of license suspensions or revocations, (4) number of citations for reckless driving; (5) number of citations for driving while intoxicated, and (6) and number of crashes.

Basic cognitive abilities

To assess this domain, two tasks were used.

Conners Continuous Performance Test (Conners, 1994). This is a standardized computer-administered continuous performance test that evaluates inattention (vigilance), reaction time, and impulsive responding. Single letters ($N = 360$) are shown on a display screen for 250 milliseconds each. The 360 trials are presented in 18 blocks of 20 trials each. The 18 blocks are presented at three different rates: 1, 2, and 4 s. These interstimulus intervals (ISIs) are block randomized across the 18 blocks. In other words, the task involves six consecutive time blocks with each time block containing all three ISIs. The task lasts about 14 min. The task used a response format that is the reverse of most CPTs. The participant presses the computer space bar in response to every signal (any letter except *X*) shown but then must inhibit their responding when the target signal (*X*) appears. Ten percent of the trials in each block involve targets with the remainder being foils or nontarget signals. Norms are available for this CPT from the publisher (Multi-Health Systems). Two dependent measures were employed here, *Beta*, and *D*-prime. *Beta* refers to the odds ratio derived from dividing the standardized score from the *Y*-axis for the signal probability by the standardized height of the Y-axis for the noise (foils) probability. Higher *Beta* scores reflect a more inhibited response style in which the person makes relatively few false alarms but at the expense of fewer correct hits. *D*-prime represents the distance between the signal distribution and noise distribution in standard score units. Larger values reflect greater amounts of vigilance or accuracy (signal detection relative to noise; Epstein et al., 1997). CPTs like the present one have been used extensively in research on ADHD children and adults, frequently finding them to make more errors of omission (inattention) and commission (impulsiveness) (see Barkley, 1997; Corkum & Siegel, 1993, for reviews). The Conners CPT is relatively new and does not yet have published information available on its reliability. Its validity has been demonstrated in studies showing that children and adults with ADHD perform this task more poorly than do control samples (Barkley et al., 1996; Conners, 1994).

Cognitive Behavioral Driving Inventory (CBDI; Engum & Lambert, 1990). The CBDI was developed to assess basic cognitive abilities in brain-injured patients as part of their rehabilitation planning (Engum et al., 1989). The battery includes a brake reaction time measure, a vision test, two subtests from the Wechsler Adult Intelligence Test (picture completion and digit symbol), and the Trails A and B tests. But the majority of the battery is derived from four computerized tasks derived from Bracy's Cognitive Rehabilitation Programs (Bracy, 1990; Lambert & Engum, 1992). The present study employed just these four computerized tasks to evaluate visual discrimination and reaction time, rule-following, and visual scanning in left and right visual fields.

1. *Visual Reaction Differential Response (VRDR)*: The subject sits before a computer screen that is bisected by a line down the middle of the screen. A small yellow square appears on the screen, positioned randomly with a variable intertrial interval. The subject responds by pushing a joystick toward the side of the screen in which the square is presented. There were 40 trials given from which three scores were calculated, these being overall reaction time, reaction time variability, and errors. The task is believed to assess visual attention and reaction time.
2. *Visual Reaction Differential Response Reversed*: The task is very similar to the VRDR above except that the examinee is now instructed to push the joystick to the opposite side of where the square appears. Forty trials were given and the same scores as on the VRDR task were derived. The task evaluates attention, reaction time, resistance to cognitive interference, rule adherence, and rapid decision-making.
3. *Visual Discrimination Differential Response II*: This task is somewhat similar to the VRDR above. This time, however, three large squares are presented instead of one. These squares vary in color randomly. When either of the outside squares matches the center one in color, the participant must move the joystick to the side that corresponds to the match. Three sets of 20 trials are given. Results are scored as the percent correct and number of false positive errors. The task evaluates visual discrimination and rapid decision-making.
4. *Visual Scanning III*: Two columns of alphabetical characters are displayed in random order, one on each side of the screen. Starting at the left side of the screen, a character group is highlighted by the computer. The examinee must find the character group on the right that matches the group on the left and move the highlighter to it using the up/down arrow keys and then pressing the space bar to enter the answer. The participant must then do the opposite, obtaining the target from the right side of the screen and matching it with the column of characters on the left side. This alternating procedure continues until 20 trials are completed. Scores are the number correct for each side and the mean time to respond to each side. The task is purported to evaluate attentional shifting and complex decision-making.

Evidence for the reliability of these four tests comes from their relatively high internal consistency (item to total correlations ranging from .32 to .83 with most *r*s in the .65 to .75 range) and their high association with a psychologist's pass/fail decision concerning driving ability based on the entire battery ($r = .85$; Engum & Lambert, 1990). Test–retest reliability is not available on these tests. The validity of the tests has been demonstrated through their discrimination of brain injured patients who subsequently passed or failed a behind-the-wheel road-test by a driving instructor ($r = .80, p < .001$; Engum & Lambert, 1990; Engum et al., 1988). Patients passing the road test performed significantly better on all subtests of this battery than did those failing the test. All patients, regardless of road-test status, performed significantly worse than normal control subjects on all of these measures except for VRDR errors, which was marginally significant ($p < .054$), and VDDR errors ($p = .10$).

Driving performance

The Elemental Driving Simulator (EDS; Gianutsos, 1994) is a computer software program employing a personal computer, monitor, and a driving console. The console houses a steering wheel with directional signal stem. On the floor of the console are pedals for accelerating and braking. Participants practice on the simulator until they indicate that they are ready to undertake the driving test. In the test, they must drive a simulated vehicle through a two-dimensional roadway in three different driving courses. Testing time is approximately 20 min. The driving courses (essentially maze corridors), become progressively more difficult in the variation in the roadway and in the requirements of the participant to respond to objects appearing to the left and right side of the road. For instance, in the second course, participants must turn the turn signal to the same direction as the side of the road where a face appeared. In the third course, the signaling rule is reversed and they must signal to the opposite side of where the face appeared. The measure is described in more detail in earlier papers (Barkley et al., 1996; Gianutsos, 1994). This task was administered twice, separated by a period of 7 to 10 days. The following seven scores were obtained on both occasions and then averaged across the two trials to obtain the scores reported here (standard scores):

A. *Steering Control*: The moment-to-moment unsteadiness in the lateral position of the vehicle on the roadway as measured by mean deviations from the center line and the standard deviation calculated across these mean deviations.

B. *Response Time*: The reaction time of the participant to the target signals appearing on the screen measured in hundredths of seconds.

C. *Field Responding*: The differences in the median reaction time to the target signals appearing to the right and left of the screen in the second and third driving courses.

D. *Adjusting to Change*: The median reaction time to the targets during the third, most difficult course.

E. *Consistency*: The consistency of the participant's responding to the targets across the second and third driving courses as reflected in the difference between the mean and median reaction times across the two courses.

F. *Self-Control*: The percentage of errors in responding to the targets in the third driving course expressed as a percentage of the 20 targets presented, with each error having a value of 5%.

G. *Self-Appraisal*: Before beginning each trial, participants were given an opportunity to rate their own abilities in each of the above areas. These ratings were then averaged across the areas and converted to a standard score ($M = 100$, $SD = 15$) in comparison to norms collected by the test developer.

Previous information on the test-retest reliability of this simulator could not be located. Given that two different testing sessions were conducted in the present study, however, test–retest reliability over a 7- to 10-day period could be examined. Pearson correlations were computed between the first and second testing session for the above scores, with the results being: .79 for Steering Control ($p < .001$), .74 for Response Time ($p < .001$), .24 for Field Responding ($p = .004$), .78 for Adjusting to Change ($p < .001$), .09 for Consistency ($p = .27$), .34 for Self-Control ($p < .001$), and .65 for Self-Appraisal ($p < .001$). Thus, four of the seven scores appear to have acceptable test–retest reliability ($r > .60$) while three scores do not.

Validity for the simulator has been established through studies by the developer showing that elderly drivers perform significantly worse than a normal driving sample and that drivers from a physical rehabilitation program who failed a road test performed significantly worse than those who passed the test (Gianutsos, 1994). Using an earlier version of the EDS, we also demonstrated significantly poorer performance in a sample of young adults with ADHD relative to a control group (Barkley et al., 1996).

Driving knowledge and rapid decision-making

The *Driver Performance Analysis System* (DPAS; Weaver, 1990) is a 1-hr videotape task that presents 192 actual driving scenarios from the viewpoint of the driver inside a car. It forces the examinee to respond to multiple-choice answers with a decision within 10 s following the video display and reading of the answers to the participant. The test has four parts, administered in succession: Part I (Driver and Traffic Knowledge) evaluated knowledge concerning general traffic laws and rules of the road. Part II (Traffic Perceptual Skills) assessed perceptual abilities in hazardous situations/conditions. Part III (Recognizing and Controlling Traffic Risk) evaluated decision-making during high-risk traffic situations that involve yielding, vehicle positioning, speed control, passing, and environmental risks (such as weather conditions). Finally, Part IV (Driver and Traffic Procedures) focused on observing traffic situations, communicating intentions to other drivers, speed adjustment for conditions, vehicle positioning, and judgments about timing and spacing of the vehicle relative to other vehicles. Completed answer sheets were sent to the test developer for scoring. Scores essentially represented the percent correct for each part of the test.

No information on the reliability of this test could be located. The validity of the test is based on an analysis of the performance and driving records of 2,000 randomly selected experienced truck and bus drivers who drove at least 40,000 miles per year. Drivers obtaining below average scores on this test were found to have higher accident rates than those obtaining average or higher scores (Weaver, 1990).

The *Driving Behavior Rating Scale* (see Barkley et al., 1996) was collected from participants and their parents. It contained 20 items that assess the participant's safe driving habits in a number of areas related to safe driving practices. For instance, items dealt with checking and waiting for oncoming traffic before proceeding into a traffic intersection, using directional signals, checking mirrors before driving or backing up, etc. Each item is rated on a 3-point Likert scale as to how often they employed these habits while driving (corresponding to *not at all*, *sometimes*, and *often*, respectively). Higher scores reflect better driving behavior and use of sound driving habits. Information on the test-retest reliability of the scale is unavailable. Evidence for validity comes from several sources. Prior studies found ADHD teens and young adults to be rated significantly lower than control groups on the scale. Self-reports from the scale significantly correlated with adverse driving outcomes as reported by the teens (Barkley et al., 1993, 1996). And, self-reports were significantly correlated with the ratings of others about the participant's driving using this same scale (Barkley et al., 1996; also, $r = .46$, $p < .001$, in the present study).

Factor scores from the EF tasks

A battery of EF tasks was administered to these participants, the detailed descriptions of which are reported elsewhere (Murphy et al., 2001). For the present study, these tasks were submitted to a principal components factor analysis with varimax rotation in which missing values were replaced by mean scores. Four factors emerged having Eigenvalues greater than 1.00. Factor I, labeled *Inattention*, accounted for 27% of the variance and consisted of the Conners CPT hit reaction time standard error (loading .850), variability of standard error (.862), and omission errors (.691) as well as the WAIS–III digit Symbol subtest (−.585). Factor II, labeled *Inhibition*, explained 16% of the variance and consisted of the CPT hit reaction time (.846) and commission errors (−.761). Factor III, termed *Interference Control*, accounted for 13% of the variance and comprised the Stroop Word–Color Test (Part III Interference) scores of percentile correct (.565) and number incorrect (−.558), and the total score for the WAIS–III Digit Span subtest (.544). Finally, Factor IV, labeled *Working Memory*, explained 11% of the variance and included the total words generated to the F-A-S verbal fluency subtest of the Controlled Oral Word Association Test (.588), the total number of diverse ideas generated on the Object Uses Task (.508), and the longest correctly completed musical sequence on the Simon game (.480). Factor scores were generated from the factor loadings and used as measures in the regression analyses below.

RESULTS

Initial Subject Characteristics

The sex composition of each group was not significantly different ($\chi^2 = 0.84$, $p =$ n.s.), with 75.2% of the ADHD group and 68.8% of the CC group being male. Initial information on the groups is presented in Table 1. The groups did not differ significantly in their age or in their socioeconomic status as determined from the Hollingshead Two-Factor Index of Social Position (Hollingshead, 1975). They also did not differ in the percent graduating from high school ($\chi^2 = 1.56$, $p =$ n.s.), with 81.9% of the ADHD group and 89.1% of the CC group graduating. The ADHD group, however, had significantly fewer years of education and had a lower IQ score than the CC group.

Consistent with the selection criteria, the ADHD group also rated themselves as having significantly more current and childhood symptoms of ADHD than the CC group on the ADHD Rating Scale (see Table 1). The ADHD group also displayed more current symptoms of oppositional defiant disorder (ODD) than did the CC group. The groups therefore differed significantly in the proportion meeting DSM-IV diagnostic criteria for ODD ($\chi^2 = 16.23$, $p < .001$), with 21.9% of the ADHD group having ODD while none of the CC group had this disorder. Despite differing significantly in their frequency of CD symptoms, the two groups did not differ in the proportion meeting diagnostic criteria for CD ($\chi^2 = 3.14$, $p =$ n.s.), with 4.8% of the ADHD group having CD and none of the CC group doing so. Levels of both anxiety and depression symptoms as assessed by the SCL–90–R were significantly higher in the ADHD group than CC group.

In terms of driving experience, the groups did not differ in the time since obtaining their drivers' license nor in the average number of miles they reported driving each week (Table 1). As for frequency of substance use, the ADHD group reported consuming significantly more alcoholic drinks per week, having gotten drunk significantly more often in the previous three months, and having used illegal drugs more often in the past 3 months than had the CC group (Table 1).

Table 1. Initial demographic and selection information by group

	ADHD group		Control group			
Characteristic	*M*	*SD*	*M*	*SD*	*t*	*p* <
Age (in years)	21.1	2.7	21.2	2.4	−0.38	—
Educational attainment (in years)	13.1	1.9	14.3	1.9	4.08	.001
Hollingshead Social Index	17.3	14.3	18.9	17.9	0.63	—
KBIT IQ Score	104.4	9.8	110.7	7.9	4.32	.001
# Current ADHD symptoms	11.5	2.9	0.5	1.1	33.72	.001
# Childhood ADHD symptoms	12.3	3.3	0.8	1.5	29.92	.001
# Current ODD symptoms	1.8	2.0	0.1	0.4	8.26	.001
# Current CD symptoms	0.5	1.1	0.0	0.1	4.34	.001
Depression *T* score (SCL–90–R)	67.9	11.0	48.3	9.2	11.86	.001
Anxiety *T* score (SCL–90–R)	61.1	11.5	48.1	5.1	10.08	.001
Time licensed to drive (Mos.)	53.7	30.7	58.4	27.9	0.99	—
Average miles driven/week	221.1	188.6	212.5	194.4	0.28	—
Frequency of alcoholic drinks consumed per week	8.8	16.1	5.2	6.7	1.98	.049
Number of times gotten drunk in past 3 months	7.5	13.9	4.0	6.2	2.22	.028
Frequency of illegal drug use in past 3 months	18.9	41.3	5.5	12.0	109.41	.009

Note. ADHD = Attention Deficit Hyperactivity Disorder; ODD = Oppositional Defiant Disorder; CD = Conduct Disorder; *SD* = standard deviation; *t* = results of the *t* test (where Levine's Test for Equality of Variances was statistically significant at .05 level, the *t* test for unequal variances is reported); *p* = probability value for the *t* test if significant (<.05); KBIT = Kaufman Brief Intelligence Test; SCL–90–R = Symptom Checklist–90–Revised.

Preliminary Examination of ADHD Subtypes

Analyses were initially conducted to determine if the subtypes of ADHD differed significantly on any measures. For these analyses, the Predominantly Hyperactive–Impulsive (HI) and Combined Types were collapsed into a single group (n = 60), given that all were characterized by poor inhibition. They were compared against those having the Predominantly Inattentive Type (n = 36). The few subjects diagnosed with ADHD NOS (n = 9) were not used in this analysis. Where possible, multivariate analyses of variance (MANOVA) were employed. Significance was set at $p <$ .05 for the MANOVA F-test and $p <$ .01 for the univariate ANOVAs. The MANOVA on the 14 basic cognitive measures was not significant (F = 1.29, df = 14/58, p = .23) nor were any of the univariate ANOVAs. The MANOVA using all 13 driving measures also was not significant (F = 0.84, df = 13/64, p = .60) nor were any of the univariate ANOVAs. The MANOVA on the four measures taken from the DMV record was not significant (F = 2.28, df = 4/91, p = .07) nor were any of the univariate ANOVAs. Separate analyses of variance (ANOVA) were then conducted on the six measures derived from the self-reported driving histories. Since sample sizes varied markedly across these measures given the conditional nature of some of the questions (e.g., at fault if in any accident), MANOVA was not used. None of the analyses reached significance ($p <$ .01). And so to maximize statistical power for the analysis of group differences between the ADHD and control group, all ADHD subtypes were collapsed into a single ADHD group for all of the analyses to be reported below.

Preliminary Examination of Sex Differences

The potential influence of sex on the results was then explored using 2 (Group) × 2 (Sex) designs in the analyses. Main effects for group are not discussed here as they are the subject of the major subsequent analyses reported below. Of interest here was any main effect for sex or interaction of Sex × Group. The MANOVA on the basic cognitive measures was not significant for either the main effect of sex (F = 0.90, df = 14/126, p = .55) or the interaction of Group × Sex (F = 0.95, df = 14/126, p = .98). Likewise, the MANOVA on the battery of driving measures was also not significant either for the main effect of sex (F = 1.25, df = 13/130, p = .25) or for the interaction term of Group × Sex (F = 0.95, df = 13/130, p = .93). The MANOVA for the analysis of the DMV measures was also not significant for either the main effect of sex (F = 1.58, df = 4/161, p = .20) or its interaction with group (F = 0.98, df = 4/161, p = .41). Nor was the main effect for sex or its interaction with group found to be significant on any of the six ANOVAs from the self-reported driving history. So once again groups were collapsed across sex in the analyses to be reported below.

Data Analytic Plan

As noted above, the two groups differed significantly in level of intelligence. To determine if analysis of covariance could be employed to control for IQ score in the evaluation of group differences on the dependent measures, a Pearson correlation was computed between IQ score and degree of ADHD symptoms in the entire sample. The result was significant ($r = -.25$, p = .001). This is consistent with prior studies of ADHD in both clinical and epidemiological samples, as noted earlier, and violates an assumption necessary for analysis of covariance. Therefore, to examine the impact of IQ score on the measures, the following alternative approach was taken. For each family of dimensional measures discussed below, correlations were computed initially between IQ score and those measures. If found to be significant, IQ level was used as a separate factor in the analyses of those measures. To do so, each group was subdivided into those having above average IQ or better (IQ ≥ 110) or those having average IQ or lower (IQ ≤ 109). The process resulted in 29 CC members (45%) and 74 ADHD members being assigned to the average IQ group and 35 CC and 31 ADHD members being assigned to the above average IQ group. Because of the large number of measures to be analyzed (n = 36), family-wise Bonferroni corrections were employed such that the number of measures derived from a particular test was divided into .05 to determine the threshold for significance for those measures. This correction was also applied to the Chi-square analyses used for evaluating categorical outcomes in the driving history and DMV records.

Frequency of Adverse Driving Outcomes

Six self-reported adverse outcomes occurred with sufficient frequency to permit statistical analyses of their scores. None of these six were significantly correlated with level of intelligence, and so IQ level was ignored for these analyses. Statistical significance was set at $p <$ .009 for these analyses (.05/6 = .0083). Given the *a priori* hypothesis that the ADHD group would demonstrate significantly more of these adverse outcomes than the CC group, one-tailed tests were employed. The results appear in Table 2. In comparison to the CC group, the ADHD group had significantly greater (1) total traffic citations, (2) license suspensions or revocations, (3) vehicular crashes, (4) crashes in which they were at fault, and (5) speeding tickets. To examine the severity of their accidents, the estimate of the costs associated with their first accident (in dollars) was obtained from participants. Such costs were significantly greater for the young adults with ADHD than for the CC group.

Four measures were obtained from the official DMV record, and so $p \leq$ .013 was used to determine significance. None of these measures were significantly correlated with IQ score. The results for these measures also appear in Table 2. The ADHD group had significantly more (1) total traffic citations, (2) license suspensions and revocations,

Table 2. Group means and standard deviations for the frequency scores from the driving history interview and official driving record

	ADHD group			Control group				
Measure	*N*	*M*	*SD*	*N*	*M*	*SD*	*t*	*p* <
Self-reported history:								
Total tickets for traffic violations	88	11.7	20.6	44	4.8	3.2	3.07	.001
License suspensions or revocations	105	0.5	1.26	64	0.1	.21	3.57	.001
Vehicular crashes as driver	105	1.9	2.4	64	1.2	1.1	2.55	.006
If so, at faults in vehicular crashes	75	1.3	1.2	43	0.9	0.8	2.43	.008
Damage caused in 1st crash ($)	76	4221.2	8051.8	43	1665.6	2229.6	2.60	.005
Speeding ticket	88	3.9	5.2	44	2.4	1.5	2.55	.006
Official DMV records:								
Tickets for traffic violations	105	5.1	8.4	63	2.1	2.4	3.45	.001
License suspensions or revocations	105	1.1	2.2	63	0.3	0.7	3.34	.001
Vehicular crashes as driver	105	0.6	0.9	63	0.4	0.8	1.33	—
Speeding ticket	105	1.6	2.0	63	1.0	1.2	2.46	.007

Note. ADHD = Attention deficit hyperactivity disorder; all results reported are for *t* tests. *T* = results for the *t* test ; *p* = one-tailed statistical probability for the *t* test (where Levene's Test for Equality of Variances was statistically significant at .05 level, the *t* test for unequal variances is reported); *SD* = standard deviation; DMV = Department of Motor Vehicles.

and (3) speeding tickets than the CC group. Frequency of vehicular crashes did not distinguish the groups, as it had in the self-reported driving history.

Percentage Experiencing Adverse Driving Outcomes

Another, more clinically informative means of evaluating adverse outcomes is to examine them categorically for the proportion of each group experiencing such adversities. Most members of both the ADHD and CC groups had received speeding tickets (95%) and been involved in vehicular crashes (72 *vs*. 67%, respectively). And so categorical outcomes were created that reflected unusually excessive occurrences of adverse events. This was defined as the extent to which these events had occurred to a degree that was two or more standard deviations above the mean for the CC group. Chi-square analyses with Fisher's Exact Test (one-tailed) therefore were used to evaluate differences between groups in the proportion self-reporting these excessive driving outcomes as well as those same negative outcomes obtained from the DMV driving records. These results are displayed in Table 3. Statistical significance was set at $p <$ .008 for the seven categorical outcomes from the self-reported driving history and $p < .01$ for the five outcomes derived from the DMV records.

As this table indicates, significantly more ADHD than CC participants self-reported that they (1) had driven illegally before they had been licensed to drive, (2) had been ticketed for at least 12 or more driving offenses, (3) had received at least 5 or more speeding tickets; (4) had their license suspended or revoked during their driving careers, and (5) had been involved in three or more vehicular crashes.

The results from the official DMV records are also displayed in Table 3. Results showed that more of the ADHD than CC group had received at least one traffic citation.

Factors Contributing to Motor Vehicle Crashes

Participants were interviewed about possible factors they believe may have contributed to the crashes as drivers. Though interviewed about up to five such crashes, sufficient sample sizes were available for analysis on only the first two crashes. The results are shown in Table 4. The ADHD and CC groups did not differ in the percentage that endorsed each of these possible contributing factors for either the first crash they experienced ($\chi^2 = 5.44$, $df = 7$, $p =$ .61), or the second one ($\chi^2 = 6.51$, $df = 7$, $p = .48$). Noteworthy is that both groups believed their inattention to be the most common contributor to either their first or second crashes, endorsing this factor nearly twice as often as any other.

Basic Cognitive Abilities

Conners CPT

Preliminary analyses found that IQ was correlated significantly with both scores from the CPT, and so IQ was used as a separate factor in these analyses. The results for these measures are shown in Table 5. Significance was set at $p <$ .025 (.05/2) for this task. The univariate ANOVAs indicated that the ADHD group obtained a significantly lower *D*-prime score, indicating reduced attentiveness to the task, than the CC group. A main effect for IQ level was found on the Beta score in which the *above average* IQ group ob-

Table 3. Negative driving outcomes (categorical answers) from the driving history interview and the official DMV driving record

	ADHD group		Control group			
Measure	*N*	% Yes	*N*	% Yes	χ^2	*p*
Self-reported history						
Drove illegally before licensed to do so	105	63.8	64	40.6	8.64	.003
Twelve or more traffic citations	105	20.0	64	3.1	9.63	.001
Five or more speeding citations	105	20.0	64	3.1	9.63	.001
License suspended or revoked	105	21.9	64	4.7	9.05	.002
Three or more vehicular crashes	105	25.7	64	9.4	6.76	.007
Three or more at fault vehicular crashes	105	7.6	64	3.1	1.44	—
$6000 or more damage in first crash	76	19.7	43	7.0	3.48	—
Official DMV record						
Ever ticketed for traffic violations	105	80.0	64	59.4	8.45	.003
Seven or more traffic tickets	105	20.0	64	6.3	5.96	—
Four or more speeding tickets	105	11.4	64	3.1	3.61	—
License suspended or revoked	105	35.2	64	20.3	4.25	—
Two or more vehicular crashes	105	17.1	64	12.5	0.66	—

Note. ADHD = attention deficit hyperactivity disorder. *N* = total sample size per group used in the analysis; % Yes = percentage of each group responding affirmatively; χ^2 = results of the chi-square; *p* = probability value for the chi-square test (one-sided Fisher's Exact Test) if significant; DMV = Department of Motor Vehicles.

tained lower scores (less inhibition) than the *average* IQ group. No interaction of Group × IQ level was significant on either score.

Visual Reaction Differential Response Task (VRDR)

The results for the four CBDI tasks are displayed in Table 5. IQ score was significantly correlated with the VRDR scores, resulting in its use as a separate factor in their analysis. Significance for these three measures was set at $p \leq .017$ $(.05/3 = .017)$. The main effect for group was not significant on any measure. The main effect for IQ level was significant for the average time taken to perform the trials. The above average IQ group was significantly faster than the average IQ group. No other main effects for IQ level were significant nor were any interactions of Group × IQ level.

Visual Reaction Differential Response–Reversed Task (VRDR–R)

Again, IQ score was significantly correlated with these measures. Significance was again $p \leq .017$. Results indicated that the ADHD group made significantly more errors than did the CC group. No other main effects for group reached significance. The above average IQ group once again performed the task significantly faster than the average IQ group, but no other main effects for IQ level were found. None of the interactions of Group × IQ Level achieved significance.

Table 4. Factors contributing to first two motor vehicle crashes by group

	First vehicular crash			Second vehicular crash		
Contributing factor	ADHD %	Control %	Total %	ADHD %	Control %	Total %
Alcohol/drug use	6.5	2.3	5.0	5.6	0.0	3.8
Road conditions	19.7	18.6	19.3	13.2	28.0	17.9
Mechanical failure	2.6	0.0	1.7	1.9	0.0	1.3
Speeding	14.5	20.9	16.8	9.4	8.0	9.0
Emotional state at the time	1.3	0.0	0.8	1.9	0.0	1.3
Inattention	35.5	46.5	39.5	41.5	52.0	44.9
Other factors	19.7	11.6	16.8	26.4	12.0	21.8

Note. ADHD = attention deficit hyperactivity disorder. Sample sizes for first crash were ADHD = 76 and control = 43, and for second crash were ADHD = 53, control = 25.

Table 5. Group means, standard deviations, and statistical test results for the basic cognitive tasks by group and by IQ level (when significantly correlated with the measure)

		ADHD group		Control group			
Measures	IQ level	*M*	*SD*	*M*	*SD*	*F*	*p*
CPT D-prime score	Ave.	2.8	1.2	3.3	1.1	G = 5.74	.018
	Above	3.1	0.9	3.5	0.8	IQ = 1.81	—
						G × IQ = 0.25	—
CPT Beta score	Ave.	0.13	0.18	0.09	0.19	G = 1.63	—
	Above	0.06	0.13	0.03	0.04	IQ = 7.28	.008
						G × IQ = 0.03	—
VRDR average time (hundredths)	Ave.	46.0	10.1	43.6	5.0	G = 3.17	—
	Above	42.7	6.6	40.2	4.9	IQ = 6.16	.014
						G × IQ = 0.01	—
VRDR variability (hundredths)	Ave.	3.3	6.1	1.3	9.4	G = 2.30	—
	Above	2.1	3.6	1.7	3.1	IQ = 0.25	—
						G × IQ = 1.09	—
VRDR errors	Ave.	0.6	0.9	0.2	0.6	G = 0.70	—
	Above	0.5	0.8	0.7	0.8	IQ = 2.00	—
						G × IQ = 2.67	—
VRDR–R average time (hundredths)	Ave.	51.6	13.1	49.6	8.3	G = 2.62	—
	Above	48.2	9.3	44.2	1.6	IQ = 5.60	.017
						G × IQ = 0.27	—
VRDR–R variability (hundredths)	Ave.	2.4	3.0	1.5	1.6	G = 3.44	—
	Above	1.5	1.4	1.0	7.6	IQ = 3.50	—
						G × IQ = 0.32	—
VRDR–R errors	Ave.	0.9	1.2	0.5	0.7	G = 8.08	.005
	Above	1.2	1.6	0.5	0.8	IQ = 0.65	—
						G × IQ = 1.13	—
VDDR percent correct		97.1	2.7	97.9	2.2	G = 4.00	—
VDDR errors		1.7	1.9	1.2	1.4	G = 3.99	—
VS correct–left field	Ave.	19.4	0.9	19.7	0.5	G = 0.61	—
	Above	19.7	0.5	19.7	0.5	IQ = 1.86	—
						G × IQ = 2.37	—
VS time–left field	Ave.	5.0	1.0	4.4	0.6	G = 2.51	—
	Above	4.1	0.6	4.2	0.8	IQ = 14.76	.001
						G × IQ = 4.37	—
VS correct–right field	Ave.	19.6	0.7	19.7	0.5	G = 10.18	.002
	Above	19.1	1.2	19.8	0.5	IQ = 2.02	—
						G × IQ = 4.37	—
VS time–right field	Ave.	4.4	1.0	4.1	0.8	G = 2.41	—
	Above	3.7	0.7	3.6	0.8	IQ = 15.67	.001
						G × IQ = 0.80	—

Note. ADHD = attention deficit hyperactivity disorder; *SD* = standard deviation; Ave. = average or below IQ; Above = above average or better IQ; *F* = results for the *F*-test; G = main effect for group; IQ = main effect for IQ; G × IQ = interaction term; *p* = statistical probability for the *F*-test; CPT = Continuous Performance Test; VRDR = Visual Reaction Differential Response Task; VRDR–R = VRDR Reversed Task; VDDR = Visual Discrimination Differential Response Task; VS = Visual Scanning Task. Sample sizes were ADHD average IQ = 61; ADHD above average IQ = 24; control average IQ = 28; control above average IQ = 35.

Visual Discrimination Differential Response Task (VDDR)

Two measures were derived from this task and so p was set at $\leq .025$. Neither of these scores correlated significantly with IQ and so they were analyzed using one-way ANOVAs. None reached significance.

Visual Scanning Task (VS)

This task yielded four measures, setting p at $\leq .013$. The scores were significantly correlated with IQ score resulting in IQ being used in their analysis. The ADHD group obtained fewer correct trials in the right visual field than did the CC group. No other main effects for group were significant. Two main effects for IQ level achieved significance. The *above average* IQ group was significantly faster in responding to trials in both the left and right visual fields than was the *average* IQ group. No other main effects for IQ level were significant nor were any interaction terms.

Driving Performance Measures

IQ score significantly correlated with the measures derived from this videotape exam, and so IQ level was used as a separate factor in the analyses of these scores. Significance was set at $p \leq .013$ for these comparisons. The results for these four measures appear in Table 6. The ADHD group achieved a significantly lower score than did the CC group on the Total Knowledge score. No other main effects for group were significant. Three of the four main effects for IQ level were significant, indicating that the *above average* IQ group scored significantly better on the Total Knowledge, Traffic Risk, and Driving Procedures portions of this examination than did the Average IQ group. None of the interactions of Group × IQ Level achieved significance.

Table 6. Group means and standard deviations for the measures from the driving knowledge and performance tasks and the ratings of driving behavior

		ADHD group		Control group			
Measures	IQ Level	*M*	*SD*	*M*	*SD*	*F*	*p*
DPAS Driving Knowledge (% correct)	Ave.	72.2	10.4	78.6	6.3	G = 7.35	.007
	Above	78.8	8.5	80.4	7.3	IQ = 8.12	.005
						G × IQ = 2.65	—
DPAS Perceptual Skills (% correct)	Ave.	53.5	9.4	53.9	7.3	G = 0.01	—
	Above	56.3	11.0	56.0	8.8	IQ = 2.56	—
						G × IQ = 0.07	—
DPAS Traffic Risk (% correct)	Ave.	50.1	10.8	51.9	9.5	G = 1.78	—
	Above	54.1	5.9	56.4	8.4	IQ = 7.46	.007
						G × IQ = 0.02	—
DPAS Driving Procedures (% correct)	Ave.	61.8	10.8	62.7	9.6	G = 1.28	—
	Above	67.0	11.6	69.8	7.6	IQ = 13.08	.001
						G × IQ = 0.33	—
EDS Steering Control	Ave.	94.7	17.4	103.2	12.7	G = 3.29	—
	Above	105.8	17.2	107.1	14.0	IQ = 7.78	.006
						G × IQ = 1.78	—
EDS Response Time	Ave.	86.6	26.4	88.4	19.6	G = 0.31	—
	Above	94.9	21.2	97.4	17.4	IQ = 5.03	—
						G × IQ = 0.01	—
EDS Field Responding	Ave.	90.3	19.2	99.3	11.7	G = 1.92	—
	Above	101.2	12.7	99.6	11.5	IQ = 4.63	—
						G × IQ = 4.02	—
EDS Adjusts to Change	Ave.	95.2	19.8	99.1	15.2	G = 0.93	—
	Above	103.6	10.1	105.1	13.3	IQ = 6.70	—
						G × IQ = 0.17	—
EDS Self-Control	Ave.	104.2	11.9	107.0	12.3	G = 1.17	—
	Above	104.5	9.7	105.7	9.0	IQ = 0.08	—
						G × IQ = 0.19	—
EDS Consistency	Ave.	89.2	21.6	93.3	20.2	G = 2.46	—
	Above	93.8	14.3	99.6	12.1	IQ = 3.01	—
						G × IQ = 0.07	—
EDS Self-Assessment	Ave.	104.1	7.0	106.6	6.3	G = 7.17	.008
	Above	103.1	6.3	106.3	7.0	IQ = 0.35	—
						G × IQ = 0.13	—
Driving Behavior (self-ratings)		50.5	5.6	55.2	3.7	G = 34.77	.001
Driving Behavior (other ratings)		48.7	6.7	53.0	5.3	G = 18.06	.001

Note. ADHD = attention deficit hyperactivity disorder; *SD* = standard deviation; Ave. = average or below IQ; Above = above average or better IQ; *F* = results for the of *F*-test; G = main effect for group; IQ = main effect for IQ; G × IQ = interaction term; *p* = statistical probability for the *F*-test; DPAS = Driver Performance Analysis System (videotape exam); EDS = Elemental Driving System (simulator); sample sizes for the DPAS and EDS were ADHD average IQ = 73; ADHD above average IQ = 31; control average IQ = 28; control above average IQ = 35. Sample sizes for the Driving Behavior (Self-Ratings) were ADHD average IQ = 74; ADHD above average IQ = 31; control average IQ = 29; control above average IQ = 34. Sample sizes for the Driving Behavior (Other Ratings) were ADHD average IQ = 67; ADHD above average IQ = 29; control average IQ = 29; control above average IQ = 34.

Correlations were significant between IQ and the scores from the driving simulator (EDS). IQ level once again was used as a separate factor in the analyses. The results appear in Table 6. Significance was set at $p < .008$ ($.05/7 = .0072$). Only one main effect for group reached this level of significance and that was on the self-appraisal of driving abilities. The ADHD group rated themselves lower in their likely simulator driving performance than did the CC group. Only one main effect for IQ level was significant, indicating that the *above average* group was better coordinated than the *average* group on the Steering Control measure. No interaction terms of Group × IQ level were significant.

The Driving Behavior Rating Scale scores did not correlate significantly with IQ and so IQ level was not used as a separate factor in those analyses. The results of the one-way (groups) ANOVAs appear in Table 6 as well (significance was $p < .025$). The ADHD group was rated themselves as using less sound driving behavior during actual motor vehicle operations than was the CC group. The same was true on those ratings by others.

Impact of Comorbidity on Driving Measures and Adverse Outcomes

As noted above, the ADHD group had a significantly greater percentage of participants having comorbid ODD than did the control group. This was not the case for comorbid CD. The ADHD group also had significantly higher ratings of depression, anxiety, and alcohol and drug use than did the CC group. It was therefore necessary to examine if these comorbid conditions may account for some or all of the group differences found to be significant for the ADHD group. Just as with IQ above, analysis of covariance is inappropriate to address this issue when there exists a significant relationship between the covariate and the independent variable (e.g., ADHD) since doing so will remove some of the variance in the dependent measures that is due to the independent variable of interest (Miller & Chapman, 2001). This was the case for the relationship of ADHD to ODD, depression, and anxiety in these participants (rs = .75, .68, and .60, respectively, $p < .001$) but not for alcohol or drug use ($r = .06$ for both). An alternative approach used here for dealing with ODD, depression, and anxiety is a cohort control strategy in which subgroups of the ADHD sample are formed on the presence or absence of each of the comorbid conditions and then compared on the dependent measures.

The first set of analyses explored the contribution of comorbid ODD to the results. The ADHD group was subdivided on the basis of those having four or more symptoms of ODD as required in the DSM–IV diagnostic criteria for this disorder. As noted earlier, 21.9% were classified as ODD ($n = 23$) and 78.1% were not ($n = 82$). These two subgroups were then compared on the 36 dependent measures (Tables 2, 4, & 5) using ANOVA. In view of the large number of analyses, significance was set at $p < .01$. None reached significance.

To examine the extent to which comorbid depression may have affected the results for the ADHD group, this group was subdivided into those who did ($n = 61$) and did not ($n = 44$) exceed a T score of 65 on the SCL–90–R Depression scale. This threshold was chosen as it represents +1.5 *SD* above the mean for the normative group on this scale (93rd percentile). These subgroups were then compared on all of the measures using univariate ANOVAs with statistical significance once again set at $p < .01$. None reached significance.

Comorbid anxiety was examined in the same fashion. ADHD subgroups were formed on the basis of those who did ($n = 44$) and did not ($n = 61$) have T scores above the threshold of 65 on the Anxiety scale from the SCL–90–R. Comparisons found that none of the 36 measures were significant ($p < .01$).

As noted above, alcohol and drug use were not correlated with severity of ADHD and so might be used as covariates in a re-analysis for the contribution of comorbidity to those measures on which group differences had been significant in the earlier analyses. To determine if this needed to be done, correlations were computed between the three drug use variables (frequency of the average weekly alcohol consumption, number of times the person had gotten drunk, and frequency of drug use in the past 3 months) and all of the dimensional measures on which significant group differences had been found. Drug and alcohol use were not significantly correlated ($p < .05$) with any of the adverse outcomes from the DMV record or from self-reported driving history. Nor were they significantly correlated with the CPT scores, basic cognitive tests results, or the knowledge score from the driving test (DPAS). There was, however, a significant correlation between frequency of drunkenness in the past three months and self-rated driving behavior ($r = -.21$, $p = .008$). Group differences on this measure were therefore re-analyzed using analysis of covariance. The group difference remained significant ($F = 31.86$, $df = 1/157$, $p < .001$). These analyses suggest that greater frequency of alcohol and illegal drug use in the ADHD group did not account for their driving difficulties.

Relationship of Driving Measures to Adverse Driving Outcomes

The next aim of the study was to determine the relationships among the cognitive and driving measures and their ability to predict (concurrently) the risks of these participants for adverse driving outcomes. To reduce the numerous measures to their underlying dimensions, principle components factor analysis with Varimax rotation with Kaiser normalization was conducted on all of the cognitive and laboratory driving tests (except EDS self-appraisal) using all participants. Eight factors were extracted having Eigenvalues above 1.00, accounting for 67.6% of the variance. These are shown in Table 7 along with the factor loadings for the measures. The numbers in italic type reflect the factor on which each measure had its highest loading. The

Table 7. Rotated components matrix from the factor analysis of cognitive and driving measures

	Component and Percent Variance							
Measure	Reaction Time	Driving Knowledge	Driving Performance	Visual Discrimination	Rule Following	Attention Shifting	Perceptual Skills	Inhibition/ Attentiveness
CPT Risk Taking (Beta)	.061	.016	−.092	.082	−.059	−.065	−.011	−*.793*
CPT Attentiveness	.095	.214	.117	.078	−.247	.049	−.100	*.657*
VRDR Reaction Time (RT)	*.807*	−.171	−.253	−.029	−.168	.058	.108	−.015
VRDR RT Variability	.384	−.212	−.178	−.095	−.176	.071	*.530*	−.184
VRDR Total Errors	−.198	−.054	−.084	−.012	*.755*	−.149	−.090	−.140
VRDR Reversed RT	*.876*	−.128	−.264	−.016	.043	−.052	−.064	.045
VRDR Rev. RT Variability	*.842*	−.024	−.201	.090	.074	−.095	−.051	−.022
VRDR Rev. Total Errors	.328	−.109	.107	−.019	*.696*	.215	.098	−.112
VDDR Percent Correct	.023	.032	.030	−*.976*	−.030	.022	−.035	.072
VDDR Total Errors	−.011	.023	.044	*.980*	.044	.053	.034	−.019
Visual Scan Correct–Left	−.089	.110	−.020	−.056	−.011	*.777*	.103	.151
Visual Scan Time–Left	.235	−*.646*	−.273	.039	.056	−.233	.348	.215
Visual Scan Correct–Right	.076	.071	−.122	−.047	.023	.517	−*.533*	.035
Visual Scan Time–Right	.292	−*.622*	−.292	.067	.051	−.211	.294	.168
DPAS Driving Knowledge	−.122	*.661*	.161	.014	−.050	−.015	−.089	.082
DPAS Perceptual Skills	−.152	.382	.105	.130	.093	.189	*.687*	−.017
DPAS Traffic Risk	.079	*.704*	.081	.065	−.013	−.143	.183	.067
DPAS Driving Procedures	−.089	*.780*	−.030	−.062	−.027	.097	.217	.214
EDS Steering Control	−.099	.204	*.540*	.089	−.218	.264	−.068	−.018
EDS Response Time	−.216	.145	*.792*	.095	.113	−.157	−.051	.078
EDS Field Responding	−.092	.015	*.733*	−.082	−.076	−.043	.053	.054
EDS Adjust to Change	−.280	.140	*.765*	.105	.045	−.097	−.021	.057
EDS Self-Control	.107	−.044	−.026	−.170	−*.496*	.484	.013	−.080
EDS Consistency	−.240	.149	*.500*	−.196	.159	.145	.163	.185

Note. CPT = Continuous Performance Test; VRDR = Visual Reaction Differential Response Task; VRDR–R = VRDR Reversed Task; VDDR = Visual Discrimination Differential Response Task; VS = Visual Scanning Task; DPAS = Driver Performance Analysis System (videotape exam); EDS = Elemental Driving System (simulator); Rev. = reversed. Factor loading shown in italic typeface indicates component on which this measure had its highest loading. Variance accounted for by each factor: Reaction Time (11.9%), Driving Knowledge (11.5%), Driving Performance (11.5%), Visual Discrimination (8.6%), Rule Following (6.4%), Attention Shifting (6.2%), Perceptual Skills (5.9%), and Inhibition/Attentiveness (5.6%).

factors seem to largely reflect method variance, or the different tasks used here, with some exceptions. Five of the factors may represent the basic cognitive abilities of Reaction Time, Visual Discrimination, Rule Following, Attention Shifting, and Inhibition. One factor reflects Driving Perceptual Skills, another represents Driving Knowledge and Rapid Decision Making, and the final one represents Simulator Performance.

Factor scores for these eight factors were then entered into multiple regression equations using stepwise analysis (F to enter of $p \leq .05$) to predict the two ratings of safe driving habits (self and others) and total citations and total crashes as reflected in self reports and in official DMV records. The participants' self-ratings of safe driving habits were predicted by Driving Knowledge/Rapid Decision-Making (R *square* = .027, F *change* = 4.66, $df = 1/166$, $p = .032$) and Visual Discrimination (R *square change* = .024, F *change* = .412, $df = 1/165$, $p = .044$). Even then, these factors were only weakly associated with the outcome, explaining just 5.1% of the variance in the ratings. No factors predicted the ratings of safe driving habits provided by others, the number of self reported crashes, or the number of self-reported total citations. Only the factor of Driving Performance (simulator) significantly predicted self-reported license suspensions (R *square* = .028, $F = 4.87$, $df = 1/167$, $p = .029$), this relationship also being quite weak.

Results were only slightly better for predicting outcomes in the DMV records. Again, Driving Knowledge predicted the number of crashes (R *square* = .044, $F = 7.62$, $df = 1/166$, $p = .006$), albeit modestly so. No factors predicted total DMV citations, while only Visual Discrimination predicted DMV license suspensions (R *square* = .043, $F = 7.49$, $df = 1/166$, $p = .007$), albeit weakly.

EF Factors as Mediators of Adverse Driving Outcomes

The four factors derived from the EF battery (see "Dependent Measures," above) were then examined for their contribution to the same adverse outcomes used above for the driving measures. Additionally, this contribution was also examined after controlling for initial level of ADHD symptoms to see if EF contributed unique variance to the outcome measure beyond its association with ADHD. Then the order of entry was reversed (EF first, ADHD second) to evaluate whether EF mediated the relationship of ADHD to the outcome. First, the four EF factor scores were all entered at Block 1 using stepwise regression analysis in the initial examination of self-rated driving behavior. Only the Working Memory factor was significant (*R square* = .026, F = 4.40, *df* = 1/166, p = .037). This analysis was then repeated entering the total ADHD symptom score at Block 1 and the EF factor scores at Block 2 to determine if the Working Memory factor made a significant contribution beyond ADHD severity. In this case it did not, with only ADHD severity being significantly related to self-rated driving behavior (*R square* = .227, F = 48.74, *df* = 1/166, p < .001). The analysis was repeated again with the independent variables entered in the reverse order (Working Memory first) to determine if the Working Memory factor mediated the contribution of ADHD severity. It did not, as ADHD severity remained a substantial contributor to this outcome (*R square change* = .235, F = 45.16, *df* = 1/165, p < .001). The same analytic approach was taken for predicting the driving behavior ratings provided by others. Neither the EF factors nor ADHD severity significantly contributed to this outcome.

Next, the contribution of EF factors to the total self-reported accidents were evaluated, the results of which found the Inhibition factor to be significant (*R square* = .028, F = 4.74, *df* = 1/167, p = .031). Once again, entering ADHD severity first into the equation resulted in the EF factor becoming nonsignificant while the ADHD score was significantly associated with this outcome (*R square* = .024, F = 4.11, *df* = 1/167, p = .044). Examining the variables in the reverse order found that ADHD severity was no longer significant beyond that contribution made by Inhibition. This implied that Inhibition might be the mediator of this particular association of ADHD with accidents. Total accidents recorded on the DMV record was evaluated next. Here again the Inhibition factor was initially found to be significantly related to this outcome (*R square* = .048, F = 8.44, *df* = 1/166, p = .004). In this case, however, the Inhibition factor remained significant even after forcing ADHD severity into the equation at Block 1 (*R square* = .048, F = 8.44, df = 1/166, p = .004). ADHD severity was not significantly related to this particular adverse outcome regardless of its order of entry, again suggesting that it is this EF that may mediate any association of ADHD to accident frequency.

Self-reported total traffic violations were then examined. In the initial analysis, the factor of Interference Control was significantly associated with this outcome (*R square* = .04, F = 5.38, *df* = 1/130, p = 022). When entered first, ADHD severity made a significant contribution (*R square* = .056, F = 7.67, *df* = 1/130, p = .006) but Interference Control continued to make a significant contribution beyond level of ADHD (*R square change* = .05, *F change* = 7.15, *df* = 1/129, p = .008). Reversing the order of entry showed that ADHD severity continued its significant contribution after controlling for level of Interference Control (*R square change* = .066, *F change* = 9.46, *df* = 1/129, p = .003). Lastly, the total number of traffic violations recorded in the DMV record was examined using this analytic approach. No EF factor score made a significant contribution to this particular adverse driving outcome nor did ADHD severity.

DISCUSSION

The present study conducted the most comprehensive multi-level, multi-method evaluation to date of driving performance and outcomes in young adults having ADHD. In doing so, this study replicated the results of several earlier, smaller studies that documented a higher frequency of various adverse driving outcomes in ADHD teens and young adults. Previous studies of ADHD teens and young adults (Barkley et al., 1993, 1996; Nada-Raja et al., 1997) found that participants with ADHD experienced more adverse driving outcomes, such as accidents, speeding citations, and license suspensions, than control groups with equivalent driving experience. This was documented primarily through self-reported outcomes (Barkley et al., 1993, 1996) and, to a lesser extent, in their official DMV records (Barkley et al., 1996). In keeping with these past findings, the present study found that ADHD young adults experienced more adverse driving outcomes than CC adults both in the participants' own self-reported histories and in their official DMV records. Young adults with ADHD received more than twice the number of driving citations, particularly for speeding, than the control group and had more license suspensions/ revocations in their relatively short driving careers to date. Moreover, the ADHD group reported being involved in more vehicular crashes as the driver, being at fault in more such crashes, and having more severe crashes as reflected in dollar damage than did the CC group. With the exception of vehicular crashes, group differences on several of these adverse outcomes were further corroborated in the official DMV records. Such driving risks may begin even earlier in adolescence in the ADHD than in the control group. As we found in a previous smaller study of teens (Barkley et al., 1993), significantly more of the ADHD group reported having driven a motor vehicle illegally as teenagers prior to being licensed to drive than did the control group. These findings clearly highlight the high risk that those with ADHD have in their daily driving activities.

Moreover, the present study extended earlier research by examining multiple levels of basic cognitive ability and driving performance beyond just assessing adverse outcomes from driving histories. Here, as well, the ADHD group manifested some limitations in basic cognitive functions related to driving. On the CPT, the ADHD group was substantially less attentive during the task than the control group. They were not, however, more impulsive on that task. The ADHD group also performed comparable to the control group on basic visual discrimination and reaction time tasks, suggesting no perceptual impairments that might affect driving. In contrast, the ADHD group made significantly more errors when the instructions for this task were reversed, implying difficulties in rule-governed behavior under such circumstances. And they achieved significantly fewer correct responses in a visual scanning task, particularly when items were presented to the right visual field. Why this should be the case is unclear and is deserving of replication in future studies. The difficulties with attentiveness and rule following evident here have been found in previous studies of cognitive functioning in ADHD children (Barkley, 1997; Corkum & Siegel, 1993). They extend those deficits to the young adult age group of this disorder and may provide some hint as to one reason for the greater frequency of accidents in the ADHD group. Driver inattentiveness was given by both ADHD and control participants here as the single most frequent reason for their first two vehicular crashes.

Four areas of knowledge were assessed here. In three of these, the ADHD group did not differ from the control group, suggesting equivalent knowledge in perceptual skills, traffic risk situations, and driving procedures. In contrast, general driving knowledge (driving laws and rules of the road) was significantly lower in the ADHD than the CC group. This is the first study to document that drivers having ADHD may be at a disadvantage in some areas of driving knowledge than are non-ADHD drivers. It is not clear whether this represents a deficit in driving knowledge or in the rapid application of that knowledge during decision-making.

Efforts were made here to evaluate the tactical or operational driving performance of participants through the use of a computer-based driving simulation program previously used for screening elderly and head-injured adults. Our previous study of a smaller sample of young adults (Barkley et al., 1996) found the ADHD group to have more steering incoordination, more scrapes, and more crashes of the simulated vehicle while driving through the three different courses. The present study was unable to replicate these results. This occurred despite testing participants twice on the simulator to enhance the sensitivity of the measure to any potential impairment in the ADHD group. It is possible that young adults with ADHD simply have no difficulties with the tactical operation of a motor vehicle in terms of negotiating driving courses. Or, it may be that the previous results were due more to group differences in IQ, than to ADHD, given that the effect of IQ level on simulator performance in that study was not examined. It is also possible that an inexpensive, computer-based simulator such as the one used here is simply not sensitive enough to any subtle difficulties that young adults with ADHD may have in operating a motor vehicle. The results here may suggest that simple driving simulators are inadequate for evaluating the driving risks of young adults with ADHD while more modern, virtual reality driving simulation systems may be required to detect group differences.

This study made special efforts to examine what other factors than ADHD may have contributed to these group differences. Sex of the participants and ADHD subtype appeared to make no contribution. Nor did the initial group differences in IQ. Although several of the lab measures of basic cognitive abilities and driving knowledge and performance showed significant main effects for IQ level in this study, in no instance was there a significant interaction of Group $\times$ IQ level. Comorbid ODD, depression, and anxiety, as well as frequency of alcohol, drunkenness, and drug use also did not account for the group differences reported here. It is still possible that these comorbid conditions may contribute small effects to the measures collected here that went undetected given the relatively modest sample sizes available for each comparison. Nevertheless, these results give some confidence to the conclusion that the group differences evident here are largely, if not wholly, the result of ADHD.

One aim of this study was to examine the utility of the lab measures of cognitive ability and driving to predict actual safe driving habits and various adverse outcomes. Visual discrimination ability was associated with self-ratings of safe driving habits and with total DMV license suspensions, but not with any other adverse outcomes. Driving knowledge and rapid decision-making was associated with safe driving habits and the total DMV recorded vehicular crashes. Driving simulator performance was only associated with self-reported total license suspensions and not with any other ratings or adverse outcomes. Despite such evidence of validity for these components of the driving battery, the strength of these relationships was meager in all cases accounting for just 2 to 5% of the variance in the outcome measures. This is quite disappointing from the standpoint of the clinical utility of these measures. It implies that such tests may not be well suited to the assessment of driving risks in the groups studied here. Perhaps this is because these groups manifest rather mild, few, and subtle basic cognitive impairments as opposed to the more obvious and substantial cognitive and driving deficits evident in brain-injured or elderly populations, for whom these measures were originally intended for use in rehabilitation planning. If the prediction of driving risks in an ADHD population is the goal, then the severity of ADHD symptoms alone may be the most powerful evidence available. The addition of a comprehensive driving assessment comprised of the measures used here would add very little additional predictive power.

Similar results were noted for the EF factors derived from the EF battery. Working memory was related to self-rated driving behavior, suggesting that this EF domain may contribute modestly to unsafe driving habits. But this contribution did not remain after controlling for that made by ADHD symptom severity. Response Inhibition was also modestly associated with both self-reported and DMV recorded vehicular crashes and remained so, at least for DMV recorded crashes, after controlling for ADHD severity. And the EF domain of Interference Control was associated to a small degree with self-reported total traffic violations and remained so after controlling for severity of ADHD. Such findings imply that some forms of EF (Inhibition and Interference Control) contribute to driving behavior and risk for negative outcomes beyond ADHD severity. In fact, results here suggest that the EF domain of Inhibition may actually be the mediator of the link between ADHD severity and accident frequency (self-reported). Even so, relationships of the EF factors to driving outcomes was quite modest (typically below 5%) suggesting that their inclusion in driving evaluations of adults with ADHD would add little to the predictive validity of the examination.

The limited utility of EF tasks in predicting driving risks may well stem from the short sampling time frame for these tasks and hence their limited ecological validity. Such tasks typically take only 15 to 30 min each and do not correlate well with behavioral ratings of executive functioning in the natural setting among patients with prefrontal lobe injuries (Burgess et al., 1998). Perhaps those EF behavioral ratings might prove more useful in driving evaluations for ADHD adults than did the tasks used here, sampling as they do a considerably longer time frame and behavior in more natural settings.

Of course, there are several limitations that deserve consideration in interpreting these findings, not the least of which was the lack of blindness of the examiner to the group membership of the participants. However, since most of the tests were computer administered and scored (CBDI and EDS), self-administered by the participants (DPAS, behavior ratings) or others (ratings by parents), scored by the test developers (EDS, DPAS), or derived from official DMV records, this lack of experimenter blindness would seem to have played little role in explaining most of the group differences found here. That these results were also quite consistent with earlier studies employing similar measures (self-reports, ratings, DMV measures) lends further confidence to there being *bona fide* outcomes associated with ADHD.

The participants studied here were quite young (*M* age 21 years) placing many in or near the age of greatest driving risks in the general population (16–19 years). That, indeed, was the intention of the study—to evaluate those age groups at highest risk for driving difficulties. It is possible that the problems with driving performance and knowledge identified here in those with ADHD may not be so evident in older, more experienced ADHD drivers. To partly address the issue, we conducted *post-hoc* analyses subdividing each group by those under or over 21 years of age, resulting in relatively equal sized subgroups within each diagnostic group. No significant main effects for age or interaction of age with diagnostic group were found on any of the lab measures of driving knowledge and performance or basic cognitive abilities, or on the behavior ratings ($p <$ .01). If age serves to moderate the results, it would need to be of a substantially greater period of years than that separating these two subgroups to be of any benefit. In contrast to these measures, the opportunity for experiencing adverse driving outcomes increases with age (duration of driving opportunity). It is possible therefore that even larger group differences in driving histories for these adverse outcomes may emerge in older samples of both groups. Supporting this view, further *post-hoc* analyses were done here comparing the two age groups on the adverse driving outcomes and found that age was a factor for license suspensions, speeding tickets, and total traffic citations, both self-reported and in the DMV records. Older drivers reported having experienced significantly more such events than younger drivers. The number of accidents was not significantly different but was marginally so ($p < .05$), suggesting that with time this outcome also may come to distinguish older from younger drivers. In no instance did age significantly interact with group, however.

The totality of results to date on driving risks in ADHD young adults argues for the need to initiate intervention aimed at the reduction or elimination of these adverse driving outcomes and basic driving deficiencies in those with ADHD. Among the possible extant interventions, the use of stimulant medication for the management of these driving problems would seem to hold the greatest promise. This argument is predicated not only on past studies showing that stimulants can improve performance on similar types of basic cognitive tasks like those used here (Rapport & Kelly, 1993) but that, unlike behavioral therapy, medication can be used even when the individual is engaged in solitary driving.

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REFERENCES

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Barkley, R.A. (1997). *ADHD and the nature of self-control*. New York: Guilford.

Barkley, R.A. (1998). *Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment (2nd ed.)*. New York: Guilford.

Barkley, R.A., Guevremont, D.G., Anastopoulos, A.D., DuPaul, G.J., & Shelton, T.L. (1993). Driving-related risks and outcomes of attention deficit hyperactivity disorder in adolescents and young adults: A 3–5 year follow-up survey. *Pediatrics*, *92*, 212–218.

Barkley, R.A. & Murphy, K.R. (1998). *Attention deficit hyperactivity disorder: A clinical workbook*. New York: Guilford.

Barkley, R.A., Murphy, K.R., & Bush, T. (2001). Time perception and reproduction in young adults with attention deficit hyperactivity disorder (ADHD). *Neuropsychology*, *15*, 351–360.

Barkley, R.A., Murphy, K.R., & Kwasnik, D. (1996). Motor vehicle driving competencies and risks in teens and young adults with attention deficit hyperactivity disorder. *Pediatrics*, *98*, 1089–1095.

Bracy, O.L. (1990). *Cognitive rehabilitation programs for head-injured, learning-disabled, and stroke patients (Foundations II)*. Indianapolis, IN: Psychological Software Services, Inc.

Conners, C.K. (1994). *The Conners Continuous Performance Test*. North Tonawanda, NY: Multi-Health Systems, Inc.

Corkum, P.V. & Siegel, L.S. (1993). Is the continuous performance task a valuable research tool for use with children with attention-deficit-hyperactivity disorder? *Journal of Child Psychology and Psychiatry*, *34*, 1217–1239.

Derogatis, L. (1984). *The Symptom Checklist–90–Revised*. Minneapolis, MN: National Computer Scoring (NCS).

Engum, E.S. & Lambert, E.W. (1990). *Manual for the Cognitive Behavioral Driver's Inventory* (Version 2.0). Indianapolis, IN: Psychological Software Services, Inc.

Engum, E.S., Lambert, E.W., Scott, K., Pendergrass, T., & Womac, J. (1989). Criterion-related validity of the Cognitive Behavioral Driver's Index. *Cognitive Rehabilitation*, *7*, 22–31.

Epstein, J.N., Goldberg, N.A., Conners, C.K., & March, J.S. (1997). The effects of anxiety on continuous performance test functioning in an ADHD clinic sample. *Journal of Attention Disorders*, *2*, 45–52.

Gianutsos, R. (1994). Driving advisement with the Elemental Driving Simulator (EDS): When less suffices. *Behavioral Research Methods Instruments and Computers*, *26*, 183–186.

Hinshaw, S.P., Morrison, D.C., Carte, E.T., & Cornsweet, C. (1987). Factorial dimensions of the Revised Behavior Problem Checklist: Replication and validation within a kindergarten sample. *Journal of Abnormal Child Psychology*, *15*, 309–327.

Hollingshead, A.B. (1975). *Four Factor Index of Social Status*. New Haven, CT: Yale University Sociology Department.

Kaufman, A.S. & Kaufman, N.L. (1983). *Kaufman Brief Intelligence Test*. Circle Pines, MN: American Guidance Service.

Lambert, E.W. & Engum, E.S. (1992). Construct validity of the Cognitive Behavioral Driver's Inventory: Age, diagnosis, and driving ability. *Journal of Cognitive Rehabilitation*, *May/June*, 32–43.

Michon, J.A. (1979). Dealing with danger: Summary of a Workshop in the Traffic Safety Research Center, State University, Groningen, The Netherlands, cited in van Zomeren, A., Brouwer, W., & Minderhoud, J. (Eds.), Acquired brain damage and driving: A review. *Archives of Physical Medicine and Rehabilitation*, *68*, 697–705.

Miller, G.A. & Chapman, J.P. (2001). Misunderstanding analysis of covariance. *Journal of Abnormal Psychology*, *110*, 40–48.

Murphy, K.R. & Barkley, R.A. (1996a). Adults with ADHD: Comorbidity and adaptive functioning. *Comprehensive Psychiatry*, *37*, 393–401.

Murphy, K.R. & Barkley, R.A. (1996b). Prevalence of ADHD and ODD symptoms in a community sample of adult licensed drivers. *Journal of Attention Disorders*, *1*, 147–161.

Murphy, K.R., Barkley, R.A., & Bush, T. (2001). Executive functioning and olfactory identification in young adults with attention deficit hyperactivity disorder. *Neuropsychology*, *15*, 211–220.

Nada-Raja, S., Langley, J.D., McGee, R., Williams, S.M., Begg, D.J., & Reeder, A.I. Inattentive and hyperactive behaviors and driving offenses in adolescence. *Journal of the American Academy of Child and Adolescent Psychiatry*, *36*, 515–522.

Rapport, M. & Kelly, K.L. (1993). Psychostimulant effects on learning and cognitive function. In J.L. Matson (Ed.), *Handbook of hyperactive children* (pp. 97–135). Boston: Allyn & Bacon.

Weaver, J. (1990). *The Driver Performance Analysis System*. Clearwater, FL: Advanced Driving Skills Institute.

Weiss, G. & Hechtman, L.T. (1993). *Hyperactive children grown up*. New York: Guilford.

Weiss, G., Hechtman, L., Perlman, T., Hopkins, J., & Wener, A. (1979). Hyperactives as young adults: A controlled prospective ten-year follow-up of 75 children. *Archives of General Psychiatry*, *36*, 675–681.