

## Effect of Stimulant Medication on Driving Performance of Young Adults with Attention-Deficit Hyperactivity Disorder: A Preliminary Double-Blind Placebo Controlled Trial

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This study was funded by a grant from the University of Virginia Health Sciences Center.



### Abstract

Driving performance of adult males with attention-deficit hyperactivity disorder (ADHD) was compared with matched controls in a double-blind (Ritalin vs. placebo) cross-over design, using a high-fidelity driving simulator. Seven ADHD and six non-ADHD drivers (mean age 22) were screened to rule out comorbidity and assess for ADHD, and then admitted to the General Clinical Research Center to control diet and sleep before testing. At 0800 and 1530, subjects consumed either a placebo or Ritalin pill in a counter-balanced manner, and at 0930 and 1700, subjects drove the simulator. After both drives, subjects rated their driving performance. Compared with non-ADHD subjects, ADHD subjects had more career driving accidents ( $p < .04$ ) and motor vehicle violations ( $p = .059$ ), drove worse on the simulator under placebo condition ( $p < .05$ ), demonstrated significant improvement under the Ritalin condition ( $p < .05$ ), rated themselves as driving poorer during the placebo condition ( $p = .05$ ), and tended to perceive their driving to be better during the Ritalin condition ( $p = .07$ ). This would suggest that individuals with ADHD should have the therapeutic benefit of a stimulant medication when operating a vehicle.

Adolescents and young adults with attention-deficit hyperactivity disorder (ADHD) have poorer motor vehicle driving performance than their peers. Follow-up investigations of driving records showed that individuals with ADHD were more likely to be involved in crashes than matched controls ([Weiss et al., 1979](#)). [Barkley et al. \(1993\)](#) demonstrated in a survey study that young adults with ADHD more often drove illegally before obtaining a license, had poorer driving habits as rated by their parents, more often had suspended or revoked licenses, had more traffic citations (usually speeding), and had almost four times as many auto accidents when compared with matched controls. Similar results were also found in another follow-up analysis by [Barkley et al. \(1996\)](#). However, [Nada-Raja et al. \(1997\)](#) conducting a community survey of young drivers (ages 15 to 18), reported ADHD without the comorbidity of conduct disorder was associated with increased accidents only for female subjects. Given the various neuropsychological deficits that have been demonstrated in ADHD ([Barkley, 1990](#); [Barkley et al., 1996](#)), it is understandable that people with ADHD would have more difficulty driving, but the exact mechanism through which this occurs has not been demonstrated. Nor has it been shown that treatment of ADHD with stimulant medication improves driving performance.

[Barkley et al. \(1996\)](#) used a computerized driving simulator to delineate the specific mechanisms behind the poor driving

records of those with ADHD. In their study, 25 young adults with ADHD, who were off medication for at least 24 hours before testing, were compared with 23 matched controls without ADHD, on six driving parameters: steering control, reaction time, field responding, adjusting to change, self-control, and consistency, while driving three increasingly complex driving trials. On the least complex driving trial, ADHD subjects had significantly more crashes and scrapes ( $p < .01$ ) than the controls, but not on the more complex driving trials. They did not, however, significantly differ from the controls on any of the specific driving performance measures, except steering control ( $p < .02$ ), but they did receive nonpassing scores on more of the driving parameters compared with the non-ADHD subjects ( $p < .04$ ). In addition, by measuring driving knowledge, they demonstrated that the driving difficulties experienced by those with ADHD were more likely to be the result of driving performance, specifically motor control problems, than driving knowledge. They suggest that stimulant medication may improve the motor performance of those with ADHD but did not demonstrate this.

Stimulants are the mainstay of the treatment of ADHD. They have been shown to diminish the symptomatic behaviors of ADHD, including "motoric overactivity, impulsivity, and inattentiveness" as well as "associated behaviors including on-task behavior, academic performance, and social function" (Spencer et al., 1996). In adults with ADHD, stimulants have also been shown to improve occupational and marital functioning (Wender et al., 1985). Methylphenidate (Ritalin) has been studied in adults more than any other stimulant, and despite the limited number of studies compared with use in children, it has been shown, in general, to be effective (Bhandary et al., 1997; Spencer et al., 1996; Wilens et al., 1995). However, its efficacy in terms of driving performance has never been studied.

The present study was designed to corroborate poorer driving performance in those with ADHD, utilizing a more sophisticated driving simulator, as well as to determine driving performance after the use of a neurostimulant, specifically Ritalin. This study investigated the driving performance of 7 ADHD and 6 matched control male subjects, age 19 to 25, with a double-blind, placebo-controlled, crossover, counter-balanced design. This study addressed three specific questions: a) do young male adults with ADHD have poorer driving performance as measured on a computerized driving simulator when compared to matched controls, b) does ADHD driving performance improve with the use of Ritalin, and c) are ADHD subjects aware of their relative driving performance?

## Methods

### Subjects

Seven ADHD male subjects and six non-ADHD male subjects were recruited from the local community through television and computer bulletin board notices, as well as direct physician referrals. Inclusion criteria were either ADHD or not, with no other current comorbidity, as assessed by the Structured Clinical Interview for Diagnosis (SCID). ADHD subjects had to have previously taken Ritalin but could not be taking any medication for their condition within the past 6 months. Table 1 depicts relevant demographic data. Comparing ADHD with non-ADHD subjects, mean  $\pm$  standard deviation age was  $22.1 \pm 2.3$  and  $21.8 \pm 3$ .

Table 1

### Procedure

Patients met with a researcher and were asked to sign an Institutional Review Board-approved informed consent form. To confirm the DSM-IV criteria for ADHD and to rule out such criteria in the case of non-ADHD subjects, participants were interviewed using Barkley's structured interview for ADHD and the DSM-III-R criteria (Barkley, 1990). They were also screened for major psychiatric illness and Tourette's disease by using the SCID and active (past 12 months) substance abuse by using the Michigan Alcoholism Screening Test and a urine drug screen. All ADHD subjects had current and childhood symptoms, consistent with the DSM-III-R criteria.

Subjects were instructed not to have alcohol or other drug intake (except for essential medication) for 1 week before admission to the General Clinical Research Center (GCRC) at the University of Virginia. Subjects were admitted to the

GCRC between 1800 and 1900 to control for diet and sleep conditions. That evening, the drug-of-abuse urine screen was collected. Subjects were introduced to the driving simulator and drove the practice course for a minimum of 15 minutes, until they felt comfortable with its operations. Subjects went to bed by 2300.

The next morning subjects woke at 0700 and had breakfast at 0800. The placebo/Ritalin pills were given at 0800. The subject, the research nurse administering the medication, and the research assistant administering the driving simulation test were kept blind to the Ritalin/placebo condition. Ten milligrams of Ritalin was chosen as the oral dose because it was felt to be a minimally adequate dose for those with ADHD, although not placing undue risk upon those subjects without ADHD. The placebo condition involved a similarly shaped pill containing vitamin C. Ritalin and vitamin C were administered in a counter-balanced manner. Subjects then drove one of two equivalent driving scenarios, for approximately 30 minutes, starting at 0930. The scenarios were chosen to simulate routine, fairly monotonous driving, given the concept that those with ADHD perform better on certain more demanding or stimulating tasks. After completing the 30-minute drive, subjects were asked to rate "Overall, how well do you think you drove?" on a 5-point scale (1 = poor, 5 = well). At 1200, subjects ate lunch, at 1530 they had a snack, and the alternative Ritalin/placebo medication and the test sequence was repeated using the alternative driving scenario. The two driving times, 0930 and 1700, were chosen to correspond with times of peak motor vehicle crashes ([National Highway Traffic Safety Administration, 1993](#)). After data collection, subjects were paid \$100 and the session concluded.

### Driving Simulator

To objectively assess driving in a controlled environment, the Atari Research Driving Simulator was employed. It is a realistic, interactive, fixed-platform simulator that generates accurate and sensitive driving performance data (see [Figure 1](#)). The current three-screen version of the simulator has been used to differentiate: a) visually compromised drivers from controls ([Szylk et al., 1991, 1992, 1993a](#)); b) Alzheimer's disease outpatients from age-matched controls ([Cox et al., 1998](#)); c) middle-aged and senior male subjects both when sober and intoxicated ([Quillian et al., 1999](#)); and d) old from very old drivers ([Cox et al., 1997](#); Cox et al. [Cited Here...](#)). Additionally, performance on this simulator has correlated with age-sensitive cognitive-motor testing and actual on-road driving performance ([Guerrier et al., 1995, in press](#)). Finally, performance on this simulator has predicted occurrence of future accidents among senior drivers ([Cox et al., 1999](#)).



Fig. 1

The simulator has three 25-inch computer screens that "wrap around" the driver, providing a 160° visual field, along with a programmed rear-view mirror depicting rear traffic. The driving environment is realistic, incorporating a typical-sized steering wheel, gas and brake pedals, seat, and seat belt. Driving performance feedback is provided to the subject *visually* through the three screens that updated at a rate of 60 times/second, *auditorially* through quadraphonic speakers delivering engine, tire, and road noises, and *kinesthetically* through the steering wheel and pedal pressure.

There are two equivalent driving courses, with similar driving demands, designed to simulate driving demands of a typical grade-2 U.S. highway (Virginia Department of Transportation). The 16-mile courses take approximately 30 minutes to complete when following the posted speed limits. The simulator records data eight times a second, quantifying steering, braking, and crash variables. These variables were converted to z-scores for individual subjects and then summed across the variables to create the Impaired Driving score. Thus, an Impaired Driving score of 0 would be average and +1 would be one standard deviation worse than the mean. See [Cox et al. \(1998\)](#) for further details on the driving simulator and its operations.

### Data Analyses

Demographics were compared using nonpaired *t*-tests. A two (ADHD vs. control) × 2 (Ritalin vs. vitamin C) repeated measures ANOVA was used to assess Driving Impairment scores. Subjective ratings of driving performance were analyzed using a Mann-Whitney test. All *p*-values were two-tailed probabilities, except where otherwise noted. SPSS Pc was used for all data analyses.

## Results

Compared with control subjects, ADHD subjects reported having more accidents (2.7 vs. .8, *p* = .018) and more citations (2.6 vs. 1.5, *p* = .06, one-tailed probabilities) in their driving careers.

As [Figure 2](#) illustrates, there was a significant interaction effect between ADHD and non-ADHD subjects and placebo-Ritalin conditions ( $F = 10.06, p < .01$ ). ADHD subjects had an elevated Impaired Driving score while on placebo, which was significantly different from non-ADHD subjects on placebo ( $t = 2.4, p = .038$ ). The Impaired Driving score was significantly improved on Ritalin for ADHD subjects ( $t = 1.68, p = .05$ ) only. There was no difference between ADHD and non-ADHD subjects while on Ritalin.

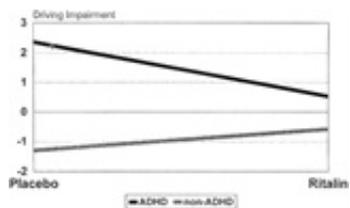


Fig. 2

Under placebo conditions, as illustrated in [Figure 3](#), ADHD subjects rated their driving performance lower (mean = 3.0) than non-ADHD (mean = 3.9) subjects (*p* = .05). There was a marginal significance for ADHD subjects to appraise their driving as being better (mean = 3.5) and non-ADHD as worse (mean = 3.6) on Ritalin (*p* = .07).

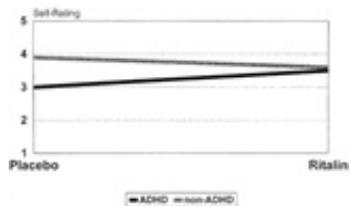


Fig. 3

## Discussion

Despite the small sample size, significant differences were demonstrated in driving performance between young adult males with and without ADHD, on placebo. These driving differences were supported by the report of past motor vehicle violations and crashes, and patients' self-appraisals of how well they drove on the simulator. These results are also consistent with neuropsychological findings indicating ADHD adults have significant deficits in executive control type functioning ([Gansler et al., 1998](#)). Also consistent with [Gansler et al. \(1998\)](#), data appearing in [Table 1](#) suggest that different subtypes of ADHD may have different cognitive-motor deficits. That is the hyperactive/impulsive plus inattentive subtype appears to perform worse on the simulator than the inattentive subtype.

Of possibly greater importance is the observation that Ritalin improved ADHD driving performance significantly, to the non-ADHD level. This objective positive medication effect was confirmed by subjects' self-appraisal. Further, it is of interest to note in [Table 1](#) that all of the individual ADHD subjects demonstrated better driving (lower Impaired Driving scores) on Ritalin, whereas only one non-ADHD subject demonstrated a similar improvement. This is the first study demonstrating the objective benefit of a stimulant medication on driving performance.

These results must be interpreted with some caution, given limitations of the study. First, the sample size was quite small, making generalization of the findings premature. Given the limited sample size, there was not enough power to analyze specific driving parameters that ADHD impaired or that Ritalin enhanced. The restricted age sample also limits generalization of these findings. It may be that less experienced drivers, who must rely on immediate information processing and decision making, may have both greater impairments and benefits from stimulant medication, whereas

more experienced drivers may show less impairment and less benefit from medication. Despite the fact that objective and subjective effects were documented, both for ADHD and Ritalin, the study may have benefited from a more thorough evaluation of ADHD and comorbid conditions. This may have included dual evaluators with demonstrated interrater reliability and standardized interviews of parents.

A major limitation with Ritalin and driving is its short half-life. If a driver takes the medication twice a day, at breakfast and lunch, then there would be no medication in the blood stream at one of the high accident times, the 5:00 to 6:00 p.m. rush-hour. If the patient takes their Ritalin at breakfast, lunch, and dinner, then it would not be available during the times of highest motor vehicle fatalities/miles driven, 1:00 to 3:00 a.m. Consequently, although Ritalin may improve driving, its typical use may not match with times of greatest driving risk. If longer-acting medications are equally beneficial in terms of driving improvement, then they might be considered the medication of choice for active drivers.

Another barrier to the effective use of stimulant medications is the typical resistance to routine medication use by this age group. Although not substantial ( $p = .07$ ), the current data suggests that ADHD patients are aware of their improved driving performance while on medication. For patients who are aware of such benefits, this may be a substantial motivator for its routine use.

Given that this was a small sample, employing a single dosage of a single short-acting medication, further research is needed. With a larger sample, specific driving parameters associated with high-risk driving might be identified. Different medications and different dosages may be differentially beneficial. Such information may have significant implications for driving legislation.

## References

Barkley RA (1990) *Attention-deficit hyperactivity disorder*. New York, Guilford.

Barkley RA, Guevremont DC, Anastopoulos AD, DuPaul GJ, Shelton TL (1993) Driving-related risks and outcomes of attention deficit hyperactivity disorder in adolescents and young adults: A 3- to 5-year follow-up survey. *Pediatrics* 92:212-218.

Barkley RA, Murphy KR, Kwasnik D (1996) Motor vehicle driving competencies and risks in teens and young adults with attention deficit hyperactivity disorder. *Pediatrics* 98:1089-1095.

Bhandary AN, Fernandez F, Gregory RJ, Tucker P, Masand P (1997) Pharmacotherapy in adults with ADHD. *Psychiatr Ann* 27:545-555.

Cox DJ, Kovatchev BP, Kiernan B, Quillian W, Guerrier J, George C (1997) Evaluation of older driver's performance employing driving simulator. In A Kemeny (Ed), *DSC 97 Driving Simulation, Conference ETNA, Teknea*. Paris.

Cox DJ, Quillian WC, Thorndike FP, Kovatchev BP, Hanna G (1998) Evaluating driving performance of outpatients with Alzheimer's disease. *J Am Board Family Prac* 11:264-271.

Cox DJ, Taylor P, Kovatchev B (1999) Driving simulation performance predicts future accidents among senior drivers. *J Am Geriatr Soc* 47:381-382.

Gansler DA, Fucetola R, Kregel M, Stetson S, Zimering R, Makary C (1998) Are there cognitive subtypes in adult attention deficit/hyperactivity disorder? *J Nerv Ment Dis* 186:776-781.

Guerrier JH, Cox DJ (in press) The validity of a low cost driving simulator in assessing driving performance. *Hum Factors*.

Guerrier JH, Manivannan P, Pacheco A, Wilkie FL (1995) The relationship of age and cognitive characteristics of drivers to performance of driving tasks on an interactive driving simulator. *Proc Hum Factors Ergonom Soc* 172-176.

National Highway Traffic Safety Administration (1993) *Traffic safety facts 1993*. Washington, DC: U.S. Department of Transportation.

Nada-Raja S, Langley JD, McGee R, Williams SM, Begg DJ, Reeder AI (1997) Inattentive and hyperactive behaviors, driving offenses in adolescence. *J Am Acad Child Adolesc Psychiatry* 36:515-522.

Quillian WC, Cox DJ, Kovatchev BP, Phillips C (1999) The effects of age and alcohol intoxication on simulated driving performance, awareness, and self-restraint. *Age Aging* 28:59-66.

Spencer T, Biederman J, Wilens T, Harding M, O'Donnell D, Griffin S (1996) Pharmacotherapy of attention-deficit hyperactivity disorder across the life cycle. *J Am Acad Child Adolesc Psychiatry* 35:409-432.

Szylk JP, Alexander KR, Severing K, Fishman GA (1992) Assessment of driving performance in patients with retinitis pigmentosa. *Arch Ophthalmol* 110:1709-1713.

Szylk JP, Brigell M, Seiple W (1993a) Effects of age and hemianoptic visual field loss on driving. *Optometry Vision Sci* 70:1031-1037.

Szylk JP, Fishman GA, Severing K, Alexander KR, Viana M (1993b) Evaluation of driving performance in patients with juvenile macular dystrophies. *Arch Ophthalmol* 111:207-212.

Szylk JP, Severing K, Fishman GA (1991) *Peripheral visual field loss and driving performance*. Washington, DC: AAA Foundation for Traffic Safety Research Reports.

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

Wender PH, F Reimherr, D Wood, M Ward (1985) A controlled study of methylphenidate in the treatment of attention deficit disorder, residual type, in adults. *Am J Psychiatry* 142:547-552.

Wilens TE, J Biederman, TJ Spencer, J Prince (1995) Pharmacotherapy of adult attention deficit/hyperactivity disorder: A review. *J Clin Psychopharmacol* 15:270-279.

<sup>2</sup> Cox DJ, Kiernan BP, Kovatchev BP, Guerrier J, Gulliano A, George C. Specific driving impairments with progressive age. Unpublished manuscript. [Cited Here...](#)

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