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Driving Under the Influence of ADHD: Research and Policy Implications

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Although ADHD is most often thought of as a disorder that affects children, it is becoming increasingly obvious that the disorder also strongly affects the lives of adults, impairing their ability to function across many domains. Adults with ADHD often encounter difficulty at work, within personal and social relationships, and in many seemingly simple, and often taken for granted, everyday tasks. One such task is that of driving an automobile. While most adults manage to drive safely and carefully without having to devote a great deal of cognitive effort, the same is not necessarily true for adults with ADHD. The cognitive deficits present in those with the disorder set the stage for potentially seriously impaired driving performance, and for this reason it is imperative that researchers, clinicians, and individuals with the disorder (and those close to them) learn as much as possible about the dangers and ways in which they can be prevented. Here, we wish to summarize research findings from an article we recently published in the journal *Experimental and Clinical Psychopharmacology* and highlight several policy implications (Weafer, Camarillo, Fillmore, Milich, & Marczinski, 2008).

As most people familiar with the disorder are well aware, ADHD in adults is characterized by deficits in inhibitory and attentional mechanisms. Individuals with ADHD experience difficulty with impulse control and behavior regulation, as well as with sustaining attention for prolonged periods of time (Barkley, 1997; Tannock, 1998). Adults with ADHD also display impaired executive functioning, which is the ability to regulate behavior in accordance with current context as well as planning for future events (Nigg et al., 2005). Each of these deficits can have severe implications for driving safety. In order to safely operate a motor vehicle, one must be acutely aware of one's surroundings at all times. This requires extreme and prolonged vigilance. Further, drivers must also maintain constant focus on the task at hand (i.e., driving), while ignoring the myriad distracters that are inevitably encountered (i.e., from other stimuli in the environment). Finally, drivers must remain calm and plan for future maneuvers (e.g., switching lanes, making turns), and refrain from making split–second decisions that other driv-

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ers are not expecting. The heightened impulsivity and impaired executive functioning and behavioral control observed in individuals with ADHD could make all of these tasks difficult and could potentially contribute to driving impairment.

Much epidemiological research examining driving outcomes in individuals with ADHD has in fact reported elevated risks and problems within this population. Survey research has shown that teenagers with ADHD were more likely to engage in illegal driving procedures (e.g., speeding) and receive traffic citations and license suspensions/revocations, and were nearly four times more likely to have had an accident than those in comparison groups (Barkley, Guevremont, Anastopoulos, DuPaul, & Shelton, 1993). More recent studies have reported similar results among older adult drivers with ADHD. Adults with ADHD were more likely than controls to have been involved in accidents, receive traffic citations for speeding, and have their licenses suspended or revoked (Barkley, Murphy, DuPaul, & Bush, 2002; Fried et al., 2006). Further, Barkley (2006a) reported results from one of the largest investigations to date of driving outcomes in individuals with ADHD in a previous issue of this publication (Results of the entire study are available in the new book by Barkley, Murphy, and Fischer, 2008). In this study, the investigators compared adverse driving–related events in adults with ADHD to both a community control sample and a clinical control sample (not diagnosed as having ADHD). Consistent with previous research, the drivers with ADHD were more likely to have had their licenses suspended or revoked, to have driven without a valid driver's license, to have crashed while driving, to have been at fault in a crash, and to have been cited for speeding and reckless driving than were community controls. Further, the drivers with ADHD were also more likely to have had their licenses suspended or revoked and to have been given a speeding ticket than were the clinical controls. In terms of frequency of adverse events, adults with ADHD were also found to have had more license suspensions/revocations, more crashes, more speeding citations, and were held to be at fault in more crashes than either the community or clinical control adults.

The disturbing risks for driving impairment suggested by this epidemiological evidence led researchers to look for direct experimental evidence of impaired driving skills in individuals with ADHD. Driving simulation studies provide a controlled environment in which to conduct objective assessments of driving performance in individuals with ADHD and controls. To date, only a handful of these studies have been conducted. One study found that unmedicated adults with ADHD displayed poorer steering control in a driving simulation and incurred more scrapes and crashes to the vehicle compared with a control group (Barkley, Murphy, & Kwasnik, 1996). However, these results were not replicated by the same group of researchers in a later study, which the authors suggested might have been due to the lack of sensitivity of the specific computer–based driving simulator (Barkley et al., 2002).

QUANTIFYING DRIVER DEFICITS

Taken together, the current epidemiological and experimental evidence suggests that individuals with ADHD do display some degree of driving impairment (see Barkley & Cox, 2007, and Jerome, Segal, & Habinski, 2006, for comprehensive reviews). However, it is difficult to speak about just how impaired these drivers are relative to the rest of the drivers on the road. Similarly, simulation studies do not specifically address the relevance of the degree of impairment in terms of how it might confer actual risk for traffic–related injury outside the lab. In order to better address this question, we conducted a study using driving performance of legally intoxicated drivers as a benchmark for comparison. This has been used as a "gold standard" for assessing impairing effects of other potential driving hazards, such as cell phone use and fatigue (Arnedt, Wilde, Munt, &

MacLean, 2001; Strayer, Drews, & Crouch, 2006). Driving at or above the point of legal intoxication (.08% blood alcohol concentration, BAC) is prohibited throughout most of the United States. This is due largely to laboratory research of simulated driving and epidemiological studies of automobile accidents that have shown a substantially elevated accident risk at this BAC (Holloway, 1995; Linnoila, Stapleton, Lister, Guthrie, & Eckardt, 1986). Thus, this comparison has considerable relevance for traffic safety by virtue of its association with decreased driving abilities that pose significant risks to the drivers and society in general. Similarly, a great deal of epidemiological and laboratory research has also shown an elevated risk for citations and accidents in drivers with ADHD. In fact, the cognitive impairments observed in individuals with ADHD (e.g., impaired attention, information processing, and inhibitory control) are quite similar to those observed in intoxicated individuals (Fillmore & Vogel–Sprott, 1999). Moreover, these are the very impairments that are cited for the decreased driving ability of intoxicated individuals (Linnoila et al., 1986; Moskowitz & Robinson, 1987). Taken together, this evidence suggests a very serious risk for drivers with ADHD, which might even be comparable to that of legally intoxicated drivers.

To test this hypothesis, we conducted a study in which simulated driving performance of individuals with ADHD (medication free) was compared to that of both sober and intoxicated healthy controls (Weafer et al., 2008). The simulated drive was approximately 20 minutes long and consisted of a winding road and occasional hills presented in a rural wooded area with a few buildings. Other vehicles were occasionally presented on the road, but no braking or passing by the participant was required. Participants were instructed to maintain a constant speed of 55 mph throughout the drive. After becoming familiar with the drive, individuals with ADHD completed one test drive. The healthy controls came into the lab for two test sessions on two different days. They performed the drive while sober in one test session and while intoxicated (at a mean BAC of .08%) in the other (order was counterbalanced). The groups were then compared in terms of within–lane deviation (LPSD), the average rate at which they turned the steering wheel (STR), and speed variability (SPSD).

We first compared the sober driving performance of controls to their intoxicated driving performance. As expected, alcohol impaired performance on all three measures. Lane position deviation, speed of steering, and speed variation all increased when participants performed the task while intoxicated, compared to their sober performance. We then analyzed sober driving in controls relative to individuals with ADHD. We found that the individuals with ADHD had significantly greater LPSD and STR scores. Thus, these drivers were swerving more within their lanes, as well as using faster, jerkier movements to control the steering wheel than were sober controls. The groups did not differ in the degree to which their speed varied throughout the task. Our next step was to compare driving performance in the individuals with ADHD to that of the intoxicated controls. Here, we found no differences in driving performance on any measures. Thus, the individuals with ADHD displayed driving impairment consistent with that observed in controls at the legal level of intoxication.

After finding that sober individuals with ADHD exhibited a profile of driving impairment similar to that of intoxicated controls, we then wondered how driving performance in this group would be affected by alcohol. To answer this question, we administered two active doses of alcohol and a placebo to a group of adults with ADHD (again, medication–free) and a group of healthy controls. The higher dose of alcohol was the same dose administered to the controls in the previous experiment, and produced a mean peak BAC of .08% (legal level of intoxication in the U.S.). The lower dose produced a mean peak BAC of .05% and was utilized to test the hypothesis that driving performance in individuals with ADHD might be impaired at doses below the legal limit.

In this study the same drive was administered and the same three measures were examined to assess driving performance as in the original study. Lane position deviation was increased in response to alcohol in both groups, and the individuals with ADHD swerved significantly more than controls in all dose conditions. Similarly, individuals with ADHD again controlled the steering wheel with faster, jerkier movements than did controls in all dose conditions. In terms of speed variation, individuals with ADHD had more difficulty maintaining a constant speed than the controls in all dose conditions. Further, only the ADHD group had more difficulty maintaining a constant speed in response to alcohol relative to placebo.

Another important aspect of this second study concerned self–reported ratings of intoxication and ability to drive. Both groups provided these ratings in response to both doses of alcohol and placebo. The groups did not differ in ratings of intoxication in response to placebo or the lower dose of alcohol; however, the individuals with ADHD rated themselves as significantly *less* intoxicated than did the controls in response to the higher dose. Further, those with ADHD rated themselves as more able to drive than did controls in all dose conditions. This is consistent with the positive illusory bias often observed in children with ADHD (Diener & Milich, 1997). This bias refers to the overly positive view that these children have of their own abilities, given the actual cognitive deficits they possess. Although children with ADHD are clearly impaired in many aspects relative to their peers, they still judge their abilities as being at the same level as that of other children. In our study, we

found that the adults with ADHD made the same erroneous judgments concerning their ability to drive. In fact, these individuals did not just rate their ability to drive as comparable to controls, they actually rated themselves as *more* able to drive than did controls, which is clearly not the case. Moreover, those with ADHD also rated themselves as significantly *less* intoxicated in response to the high dose of alcohol. These findings replicate and extend the earlier research by Knouse and colleagues (Knouse, Bagwell, Barkley, & Murphy, 2005) that also found ADHD drivers to show a positive illusory bias and so underestimate the extent of their actual driving deficits and more impaired driving history. This unfounded belief in superior driving ability, coupled with an inaccurately low estimation of intoxication level, could result in extremely hazardous situations. To the degree that these self–efficacy beliefs influence actual driving behavior, the adults with ADHD are at heightened risk for making potentially dangerous decisions about their ability to drive in a safe and responsible fashion.

RESEARCH ON REDUCING THE RISKS

Given the risk factors associated with driving for individuals with ADHD, it is important to consider the possible protective factors that could improve driving performance in these individuals. One potential protective factor against impairment for drivers with ADHD is treatment with medication. ADHD medications have been shown to significantly improve many of the cognitive deficits observed in ADHD, and it is certainly possible that these improvements would carry over into driving performance. To date, only a handful of studies have examined the effects of medication on simulated driving performance in individuals with ADHD (Barkley, Anderson, & Kruesi, 2007; Barkley, Murphy, O'Connell, & Connor, 2005; Cox, Merkel, Kovatchev, & Seward, 2000; see Barkley & Cox, 2007, for a review), and these studies have reported that ADHD medications do have a beneficial effect on driving performance in individuals with ADHD.

Another potential protective factor could be the level of stimulation of a particular driving task. Higher stimulation levels could serve to increase arousal and combat boredom, thus increasing attention to the task of driving. Cox and colleagues (2006) conducted a study to get at this hypothesis by comparing simulated driving performance in adolescent males with ADHD using a manual transmission and an automatic transmission. They found that driving performance was significantly improved and safer in the manual transmission mode, and this was attributed to the increased amount of attention required to shift gears and manipulate the clutch. This might have guarded against lapses in attention, or it might have served to quickly refocus attention to the driving task at hand when it began to wander.

Another means of testing this stimulation hypothesis would be to directly compare simulated driving performance on a low versus high stimulation drive. Our laboratory is currently conducting just such a study. For the low stimulation drive, we are administering the 20–minute drive on a slightly winding country road with very few other cars or buildings and no traffic signs or signals to observe or follow (described above). For the high stimulation drive, we are administering a shorter drive (around 8 minutes) through a city environment. This drive includes many buildings, signs, and other vehicles, as well as traffic signs and signals. Participants perform both drives under alcohol and placebo. Based on past studies and pilot data, we hypothesize that individuals with ADHD will exhibit a deficit in driving performance compared to controls on the low stimulation drive, and they may demonstrate an additive impairment in response to alcohol on this drive. We expect the attentional deficits inherent in ADHD to surface during this drive, leading to driver inattention and, as a result, impaired driving. However, the high stimulation drive may successfully sustain the attention of the individuals with ADHD, resulting in a potential lack of impairment observed in this group compared to controls.

Although the simulated driving procedure has provided a good means to examine driving behavior in individuals with ADHD, it is important to consider the limitations of this methodology when interpreting the results of the types of studies described above. The most obvious flaw, of course, is the fact that simulators do not provide a direct measure of real–life driving performance. They are used in an artificial laboratory environment, as opposed to an actual road with vehicles operated by human beings. The driver's view is limited to what is presented on computer monitors, and the gears, pedals, and steering wheel, while very life–like, still do not recreate the experience of driving an actual car. This is important in terms of the ecological validity of the task and in terms of driver motivation. It is likely that the motivation level of the driver is lower in a simulation than in a real–life driving experience, primarily because there is no actual personal safety or health risk involved in performing the simulated task. On the contrary, driving in the real world involves an inherent element of risk and danger that is experienced to some degree by all drivers, resulting in increased vigilance and caution while driving. Another shortcoming of driving simulators is their propensity to cause motion sickness and nausea (Barkley et al., 2005). Carsickness is not extremely common in drivers in the real world, and attempting to drive while experiencing these symptoms could potentially impair performance. For these reasons, driving simulators are sometimes criticized as underestimating the quality of driver performance, and this is true for both individuals with ADHD and controls.

At the same time, the simulation procedure can also be argued to overestimate driver performance, particularly in drivers with ADHD. The simulated driving scenario is generally free of the many distracters typically encountered in real–life driving situations—such as

noisy passengers, cell–phone conversations, or music on the radio—that make driving more dangerous. These additional elements of real–life driving situations require the ability to divide attention and ignore distraction, likely resulting in a much more challenging situation for drivers, especially for those with ADHD, given their attentional deficits. This may seem counterintuitive, especially given our hypothesis (described above) that a greater degree of stimulation associated with a drive might serve to increase attention toward, and therefore performance on, the driving task. However, external distracters may differ from the task–relevant stimuli (e.g., traffic signals) included in the high–stimulation driving simulation procedure. It could be that the task–relevant stimuli serve to orient attention towards the driving task, whereas external stimuli distract attention from driving.

Additional aspects of the simulation procedure might lead to overestimation of driver performance. For instance, the demand characteristics likely influence participant motivation to do their best and perform as well as possible in the lab. Further, the novelty of the simulated driving procedure itself could serve to increase vigilance and lead to increased driver performance.

IMPLICATIONS AND POTENTIAL RISK MANAGEMENT STRATEGIES

Despite the inherent limitations posed by driving simulation research, the evidence to date concerning driving impairment in individuals with ADHD raises many concerns about the risks posed to the drivers themselves, as well as to society in general. Clearly, these risks cannot be ignored, and attention must be drawn to the problem as well as the implementation of possible solutions. Perhaps the single most effective way for individuals with ADHD to increase their driving performance is to be on medication while driving. ADHD medication has been shown to increase vigilance, reduce impulsivity, and improve behavioral control, all of which contribute greatly to driving ability. Further, the few laboratory simulation studies available have demonstrated the effectiveness of medication on driving performance in individuals with ADHD. However, medication alone cannot remove all driving risks. One problem with most ADHD medications is that their effects would generally have worn off by nighttime and that driving would therefore still be dangerous at that time, even in medicated individuals. This is especially concerning since most young adults (ADHD or not) do a great deal of driving at night.

A second major issue with the medication solution is simple medication adherence. Many adults with ADHD report inconsistent compliance with their medication regimen at best, and, at worst, a complete refusal to take any medication, citing unpleasant side effects or a desire not to have to rely on medication. Of those who do report taking medication, some only take it when necessary (i.e., for work or school), and they often do not take it during the summer or on weekends. Again, these are prime driving times, especially for young adults. This issue could be addressed through mandated medication adherence for drivers with ADHD, as is done for individuals with other medical disorders, such as epilepsy. However, this is a problematic issue concerning personal rights and liberties, as well as one that would be extremely difficult to enforce. There is no quick and easy test (similar to a breathalyzer) for drug metabolites of ADHD medications, short of actually bringing the driver in to a hospital or police station and performing a blood or urine test. This would be extremely invasive, and the test would have to be done any time a police officer even suspected that a driver with ADHD was unmedicated. Further, the decision to take or not take medication is considered by many to be a personal issue, and it is not clear whether medication adherence should be a legal issue. However, the right to make this decision is sometimes removed when there is a safety threat to other individuals. For instance, as mentioned above, individuals diagnosed with epilepsy must provide proof from their doctors that they are receiving treatment and have been symptom-free for a designated period of time before they are able to receive a driver's license. Similarly, if an individual with ADHD wishes to have the privilege of driving, it may be necessary for the safety of the individual and other drivers to mandate that medication must be taken in order for him/her to get behind the wheel.

It has also been suggested that individuals with ADHD might benefit from a graduated licensing procedure (Barkley, 2004). This could involve longer and more intensive training periods, stressing the importance of driving safety and the risks and dangers involved in careless, inattentive driving habits. The length of time required for driving with only a learner's permit could be increased in young drivers with ADHD in order to allow them more time to practice proper driving habits. Further, it might be necessary to prohibit young drivers with ADHD from driving with multiple passengers in the car for a specified period after receiving their licenses. Groups of young passengers (especially teenagers) are likely to be loud and boisterous, which can be extremely distracting for a driver. Further, new drivers may feel the desire to "show off" in front of their friends by engaging in risky driving behavior, such as driving too fast and disregarding some traffic signals. In addition, the use of cell phones may need to be prohibited for these individuals (and, arguably, all other drivers) while they are behind the wheel. All of this would serve to decrease distractions and focus attention on driving.

Another major issue that needs to be addressed in terms of driving risks in individuals with ADHD is that of driv-

ing under the influence of alcohol or drugs. Research has shown that individuals with ADHD are more likely to use alcohol or illicit substances than are controls, and that these individuals are at a heightened risk for substance abuse problems (Barkley, 2006b; Barkley et al., 2008; Flory, Milich, Lynam, Leukefeld, & Clayton, 2003; Molina, Smith, & Pelham, 1999). Given their well–documented impairments in behavioral control, as well as their impaired ability to judge their level of intoxication, those with ADHD might also be more likely to engage in impulsive, risky behaviors while intoxicated, including driving an automobile. Thus, the risks associated with intoxicated driving are especially critical for drivers with ADHD.

As discussed above, we have demonstrated significantly worse driving performance in adults with ADHD relative to controls under both a moderate and high dose of alcohol in our lab (Weafer et al., 2008). In fact, on some driving measures, those with ADHD displayed significant impairment relative to placebo in response to the moderate dose of alcohol, which produced mean BACs around .05% (well under the legal limit of intoxication). This raises the issue of whether the legal limit set for drivers in the United States is suitable for drivers with ADHD. Due to the additive decrement of performance observed in response to alcohol in addition to their already impaired driving ability, this limit of intoxication may need to be adjusted for those with this disorder. Similar to the zero tolerance law for minors behind the wheel, a law that prohibits driving in individuals with ADHD who have any alcohol in their system whatsoever may need to be considered.

Another possibility would be to increase education for individuals with ADHD concerning the risks involved in driving under the influence, especially for those with pre–existing deficits in attention and impulse control. Tutorials explaining the mechanisms through which alcohol impairs driving ability, aimed specifically at how this disruption is multiplied in those with ADHD, might help some with this disorder better understand why it is so important not to take the risk of driving in this condition. Epidemiological information detailing the increased risk of accidents in drivers with ADHD, intoxicated drivers, and intoxicated drivers with ADHD might also serve to instill an appreciation of the serious dangers associated with these conditions. As Knouse and colleagues (2007) previously noted, given the research cited above showing a positive illusory bias in adults with ADHD concerning their driving ability, they may be unlikely to attend such programs, believing themselves instead to be as good at driving as those without ADHD.

In addition to education, some type of incentive program might prove beneficial in improving driving performance in individuals with ADHD. For instance, "traffic school" could be mandated for new drivers with ADHD. The curriculum could center on information similar to that described in the preceding paragraph. Regular (e.g., monthly) attendance could be required for these classes, along with various other possible requirements. Driving performance would be monitored in attendees, including any citations, accidents, and so forth. Any negative driving–related occurrences would result in various consequences, including increased driving restrictions. The absence of any such occurrences for given periods of time would result in fewer restrictions and increased privileges. Such a policy would result in continuous education that would reinforce the importance of driving safety, as well as provide extrinsic motivation to follow traffic laws and to drive as carefully as possible.

Clearly, some of the recommendations offered here may be considered extreme. However, the potential safety hazards and driving risks associated with having individuals with ADHD behind the wheel demand attention. These risks come with many social, health–related, and ethical implications. Is it fair to restrict the driving privileges of those with this disorder? Is it fair to mandate extra training or education for these individuals or to force them to take unwanted medication? Is it fair to the rest of society to allow unrestricted driving by individuals who might be significantly impaired? Additionally, will findings related to driving impairment with ADHD unfairly raise insurance rates for these individuals? Obviously, much more research is necessary before any decisions can be made or new policies implemented. It is imperative that increasing numbers of researchers and policy makers recognize the severities of this issue and combine their efforts towards developing means to decrease the risks involved.

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