Human Factors and Driving Behaviors Differentiating High Risk and Low Risk Drivers with Attention Deficit Hyperactivity Disorder

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Abstract

Compared to non-clinical individuals, younger drivers with Attention Deficit Hyperactivity Disorder are at a greater risk for traffic accidents. There is a wide range of human factors contributing to driving competence that are impaired in this population, stemming from the core symptoms of inattention, impulsivity and hyperactivity. The goal of the present study was to identify specific driving behaviors that contribute to a greater risk for adverse driving events for ADHD drivers. The present study utilized a DriveCam recording system to monitor driving of 17 young adult ADHD drivers over three months. The seven High Risk ADHD drivers, those with a collision during the observation period, were primarily differentiated from the Low Risk ADHD drivers by inattentive and distracted behaviors.
Human Factors and Driver Behaviors Differentiating High Risk and Low Risk Drivers with Attention Deficit Hyperactivity Disorder

Attention Deficit Hyperactivity Disorder (ADHD) is characterized by deficits in sustained attention, resistance to distraction, voluntary motor inhibition and regulation of activity levels relative to same-aged individuals (American Psychiatric Association, 2001; Barkley, 2006). For those with ADHD, these deficits impact many functional domains, resulting in adverse effects on social relationships, community functioning, and educational and vocational success (Barkley, Fischer, Smallish, & Fletcher, 2004; Mannuzza & Klein, 1999). Originating in early childhood, ADHD is a relatively persistent condition with up to 80% of diagnosed children continuing to meet diagnostic criteria in adolescence (Barkley, Fischer, Edelbrock, & Smallish, 1990; Weiss & Hechtman, 1993) and up to 67% continuing into adulthood (Barkley, Fischer, Smallish, & Fletcher, 2002). Although the core symptoms of inattention, impulsivity and hyperactivity may show improvement into adulthood, many associated problems and impairments persist. These enduring difficulties expand into functional realms requiring greater responsibility, including work performance, sexual relationships, substance dependence or abuse, and driving (Barkley, Fischer, Smallish, & Fletcher, 2004; Mannuzza & Klein, 1999).

In addition to the symptom-based deficits that negatively impact many functional domains for this population, individuals with ADHD also have a greater propensity to engage in risky behaviors compared to their peers. Farmer and Peterson (1995) found that adolescents with ADHD not only anticipated less severe consequences following risky behavior but also reported fewer active methods of preventing injury compared to matched controls. The researchers reasoned that cognitive factors such as a lowered expectation of personal risk in hazardous
situations and a minimized capacity to generate prevention strategies contributed to the increased injury liability found for the ADHD sample.

Furthermore, adolescents and young adults with ADHD are more likely to be involved with deviant peer groups and certain social pressures associated with this negative affiliation, which has been linked to an increase in risk taking for these individuals (Marshal, Molina & Pelham, 2003). Marshal, Molina and Pelham found that deviant peer affiliation mediated the relationship between ADHD and substance use, suggesting that adolescents and young adults with ADHD are more likely than those without ADHD to become involved with deviant peers and, as a result, more likely to use illegal substances. Furthermore, the researchers found that the relationship between deviant peer affiliation and substance use was stronger for those with ADHD: once immersed in a deviant peer group, adolescents and young adults with ADHD are more vulnerable to negative social influences.

Driving is one of the most concerning domains in which the specific symptom-based deficits, the increased tendency towards risky behaviors, and the greater vulnerability to negative social influences may be particularly deleterious for adolescents and young adults with ADHD. Therefore, the present study is primarily concerned with elucidating the specific impairments in safe driving behaviors and the overall increased driving risk for young adults with ADHD.

**ADHD and Driving**

Driving is an activity that contributes substantially to self-sufficiency and independence for adolescents, young adults and adults. It provides a means of engagement in most domains of adaptive functioning, including employment, family care, educational pursuits, social engagements and entertainment. These activities would be greatly impeded if an individual were deprived of this privilege, particularly in most areas of the United States where there is more
dependence on driving compared to some European cultures. However, balanced against the various life activities that driving facilitates is the increased exposure to adverse outcomes that accompanies operating a motor vehicle capable of traveling at high speeds, such as harm to one’s self, to others and to property (Barkley & Cox, 2007).

Younger, less experienced American drivers have the highest injury and fatality rate (National Highway Traffic and Safety Commission, 2005). Outcomes are even worse when considering the driving records of those diagnosed with ADHD (Barkley & Cox, 2007; Jerome, Segal, & Habinski, 2006). There is now evidence from multiple prospective studies involving adolescents with ADHD and comparison non-ADHD controls that young drivers with ADHD are two to four times more likely to have traffic accidents (Barkley, Murphy, & Kwasnik, 1996; Cox, Merkel, Kovatchev, & Seward, 2000) and three times as likely to have injuries resulting from these mishaps (Barkley et al., 1996). Therefore, not only do individuals with ADHD have a greater number of on-road incidents, but the incidents that they have are also more severe and produce more unfavorable outcomes. Successive studies have supported these findings. For example, Barkley, Guevremont, Anastopoulos, DuPaul and Shelton (1993) surveyed parents about a variety of negative driving outcomes their teens may have experienced in the three to five years following license acquisition. These teens and young adults with ADHD were (a) more likely to have illegally driven a vehicle prior to state-mandated eligibility; (b) less likely to be engaging in sound driving habits; (c) six to eight times more likely to have their license revoked; (d) more likely to have received repeated traffic citations, particularly for speeding; and (e) four times as likely to have had an at-fault accident (Barkley et al., 1993).

Although for the general population driving competence and use of safe driving behaviors tends to increase concordantly with age and experience, Cox, Cox and Cox (2011)
found that this is not necessarily the case for ADHD drivers. In their recent study, the researchers found that the increased tendency for those with ADHD to be involved with driving mishaps does not improve with maturation: collision rates for males increased with age, while females were similar to the general population with fewer collisions during middle-age (Cox, Cox & Cox). Therefore, these domain-specific impairments remain an issue for this population in such a manner that cannot be mediated by experience, further highlighting the greater and sustained risk for this population on the road.

Factors Contributing to Driving Risk

The factors that contribute to automobile accidents are generally divided into three categories: human factors, vehicle-related factors and environmental factors (Barkley & Cox, 2007). Human factors are considered to be the most common cause of automobile accidents and are of primary consideration when investigating clinical populations and driving behaviors. Factors of this type include both actions taken by the driver and the overall condition of the driver. Four factors in particular have been consistently highlighted in the literature to be of paramount concern for ADHD drivers on the road: inattention, executive functioning deficits, negative emotionality and overestimation of abilities.

Of these factors, inattention and internal- and external-vehicle distraction have generally been found to be primary contributors to traffic citations and collisions (Lam, 2002; United States General Accounting Office, 2003). Therefore, individuals with a disorder that markedly impairs attention and resistance to distraction, such as ADHD, are already at a greater risk for crashes and other adverse driving outcomes (Rosenbloom & Wultz, 2011).

Inattention and Distraction. Rosenbloom and Wultz (2011) compared risky driving behavior utilizing a comprehensive list of driving violations and faults among 38 adults with and
without ADHD over 30 days. Faults were defined as (a) failures of observation that may be hazardous to others and (b) planned actions that fail to accomplish their intended outcomes (e.g., failing to check rear-view mirror before changing lanes or braking too quickly on a slippery road). Violations were defined as deliberate actions not representative of safe driving practices (e.g., blatant disregard for speed limit). The researchers found a significant difference between ADHD and non-ADHD drivers in faults (i.e. failures in observation) but not in violations (i.e. deliberate maneuvers). These results provided evidence for greater inattention among the drivers with ADHD as they failed to stay attentive for sustained periods of time and therefore executed more failures of observation than the non-ADHD drivers. On the other hand, ADHD drivers were not differentiated from non-ADHD drivers based on deliberate actions, suggesting a basic knowledge of safe and appropriate driving behaviors.

In another study, Reimer, Mehler, D’Ambrosio and Fried (2010) investigated 60 young adult ADHD drivers in high stimulus and low stimulus settings. The results suggest that the interaction of the nature of the driving context and a secondary distraction task significantly influenced how drivers with ADHD allocated attention and, in turn, on the relative impact of driving performance. Drivers with ADHD were generally more inattentive to the driving task compared to matched controls and appeared to be particularly susceptible to distraction during periods of low stimulus driving. Distracted driving in low stimulus settings is especially salient during nocturnal driving in the early mornings or late evenings, when younger drivers are more likely to get into an on-road collision (Williams, 2003).

Executive Functioning Deficits. Executive functioning deficits have also been found to be particularly impairing for ADHD drivers. Biederman et al. (2006) examined 358 adults who were divided into four groups: adults with ADHD, adults without ADHD, ADHD adults with
deficits in executive functioning and non-ADHD adults with deficits in executive functioning. Significant differences were found between the four groups for the number of driving tickets, the number of automobile accidents and the rates of ever being arrested. Pairwise comparisons showed the same pattern for all three variables: both ADHD adults with and without executive functioning had more tickets, accidents and a higher arrest rate than the comparison group. Furthermore, the group of ADHD individuals with deficits of executive functioning had more tickets, accidents and a higher rate of arrest than each of the other groups. Therefore, while ADHD drivers in general were at a greater risk for adverse events on the road, the outcomes for those with additional executive functioning deficits were even worse. These findings emphasize the variation among individuals with ADHD to such an extent that would put some drivers at a greater risk behind the wheel than others.

**Negative Emotionality.** The third human factor of principal concern for ADHD drivers is negative emotionality and dysfunctions in emotion processing, evidenced by poor temper control, overreactions to stresses in life and mood lability (Jensen & Rosen, 2004; Maedgen & Carlson, 2000). In the driving domain, negative emotionality behind the wheel can be particularly injurious as driving is often a stressful and aggravating experience due to the large number of uncontrollable events that are likely to occur. Moreover, in highly populous areas of the country where traffic congestion is notoriously an issue, the risk of road rage and the concordant detrimental actions become even more pertinent. With a sample of 594 ADHD and non-ADHD individuals, Richards, Deffenbacher, Barkley and Rodricks (2006) elucidated the impact of negative emotionality on safe and competent driving behaviors. ADHD participants reported more driving anger and aggressive expressions through the use of their vehicles and less adaptive and constructive expressions than the non-clinical controls. Similarly, young adult
ADHD drivers rated themselves as more angry, risky and unsafe, and they also reported experiencing more losses of concentration and vehicular control than the non-clinical group.

**Overestimation of Abilities.** Another factor that contributes to less competent and less safe driving for ADHD individuals is an inflated self-perception and overestimation of abilities (Hoza et al., 2004). Behind the wheel, this overestimation manifests for ADHD drivers as a failure to recognize their increased risk and a concordant failure to take the necessary precautions while driving. Knouse, Bagwell, Barkley and Murphy (2005) investigated the accuracy of self-appraisals of driving performance in both naturalistic and virtual-reality settings with a sample of 88 ADHD and non-ADHD adults. According to driving histories, ADHD adult drivers had significantly higher rates of collisions, speeding tickets and total driving citations (Knouse et al.). Similarly, safe driving behaviors were reported less frequently for these drivers in naturalistic settings and used less in the virtual-reality setting on a driving simulator (Knouse et al.). However, despite these significantly different and less safe driving ratings for ADHD drivers, self-assessments were similar between the ADHD and community comparison groups, highlighting the over-estimation of driving abilities across both self-reported and objective measures (Knouse et al.). A study from Prevatt et al. (2011) supported these findings with a sample of college students with and without an ADHD diagnosis on self-reported driving behaviors. With regard to driving citations, the researchers found that 46% of participants with ADHD, compared to 31% of the non-ADHD group, gave a global rating of their performance that indicated an over-estimation based on what would be predicted from their specific ratings.

**Childhood and Adolescent Predictive Factors of Future Driving Risk**

A series of longitudinal studies conducted in New Zealand have investigated predictive factors for risky driving and have consequently found that specific ADHD-related symptoms and
deficits in childhood and early adolescence can predict later on-road driving risk. In a longitudinal study that followed clinically-referred hyperactive children and community control children for 13 years, a greater percentage of drivers from the hyperactive group reported less-safe driving practices, more traffic citations and more driving errors from impulsiveness in on-road tests (Fischer, Barkley, Smallish & Fletcher, 2007).

Results from longitudinal studies that recruited community-based rather than clinic-based samples matched these findings. In a large sample study, Woodward, Fergusson and Horwood (2000) found that young drivers who demonstrated more attention deficits at age 13 had a greater risk for collision-related injuries and traffic violations as well as a greater likelihood to have driven without a license; these effects remained significant even after controlling for confounding factors such as comorbidities. Another longitudinal study found comparable results. Nada-Raja et al. (1997) found that attention deficits in early adolescence predicted later increased risk for collisions involving injury, driving without a license and traffic violations; similarly, these effects remained significant even when controlling for conduct problems, driving experience and gender. The findings from these longitudinal studies highlight specific symptoms and impairments in childhood and adolescent years that may be predictive of future on-road risks and adverse outcomes for ADHD drivers.

**Models of Driving Abilities**

To further elucidate the human factors category that contributes to automobile accidents, John Michon developed a three-dimensional hierarchical model of driving abilities that includes three organized and increasing levels of competency: operational, tactical and strategic (Michon, 1979; Barkley, 2004). During driving, higher levels of competency harness lower levels for the achievement of larger goals, such as safely navigating on-road hazards or detours (Michon).
Therefore, according to the model, deficits in lower levels of the hierarchy may have profound effects on higher levels of competency that are required for safe driving; however, deficits at higher levels may have little or no influence on the lower levels.

The first level of Michon’s hierarchical model, operational competency, comprises of elementary mental functions that are inherent to any driving task. Operational competency functions include attention and concentration, reaction time, visual scanning, spatial perception and orientation, visual-motor integration, speed of cognitive processing, motor coordination, and other basic neuropsychological abilities (Michon, 1979; Barkley & Cox, 2007). Tactical competency, the second level, includes behaviors and skills that are associated with driving in traffic or among other automobiles on the road, such as the adjustment of driving speed to road or weather conditions, use of headlights to improve visibility, and decisions about whether to pass other vehicles (Michon; Barkley & Cox). The third and highest level, strategic competency, involves decisions and planning abilities that pertain to the specific context in which the vehicle is being utilized. This level includes the goals for the particular driving session, the current time of day or planned trip sequence/route, and a global evaluation of general risks (e.g. traffic conditions, density and climate) that pertain to the specific drive (Michon; Barkley & Cox). Any disorder that may affect driving skills at any of these three levels can produce direct or indirect adverse effects on driving competence and safety while possibly causing the driver to subject him- or herself or others to harm (Michon; Barkley & Cox).

Drivers with ADHD have consistently been found to have more collisions and moving vehicle violations compared to age- and gender-matched peers (Barkley et al., 1996). Specific to this disorder, individuals with ADHD exhibit motor and cognitive deficits in areas such as visual working memory, response inhibition, sustained attention, freedom from distraction and divided
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and selective attention—functions typical of the first level of Michon’s model, operational competency (Barkley, 2004). Therefore, Barkley (2004) proposed that ADHD’s core symptoms of inattention, impulsivity and hyperactivity directly impact the first level of Michon’s model and thus affect the two subsequent levels, tactical and strategic competency. This proposition was supported by a previous study by Barkley, Murphy and Kwasnik (1996) that found that drivers with ADHD do not have a greater lack of knowledge of traffic regulations compared to non-ADHD drivers, but that they have a more difficult time addressing and sustaining their attention to relevant stimuli on the road, and therefore may display higher levels of driving mistakes. Given the specific impairments on the most basic competency level, drivers with ADHD begin at a disadvantage in the driving domain with a greater risk for mishaps resulting from basic motor and cognitive deficits.

Another model that is employed to make the connection between the individual and the driving domain is the Task-Capability Interface (TCI) model and the task difficulty homeostasis hypothesis developed by Fuller (2000). This model suggests an interaction between the demands of the particular driving task (e.g., speed, hazards, road conditions) and the available capabilities of the driver (e.g., attention, vigilance, fatigue). For example, according to Fuller and the TCI model, loss of control resulting in automobile accidents may arise in poor weather when the driver is not maintaining proper safety margins or not paying enough attention to the road. For the general non-clinical population, drivers are able to maintain control and achieve safe driving outcomes by moderating the interface between task demands and available capabilities. However, within the population of ADHD drivers, the TCI model may explain how these aforementioned impairments inhibit the available capabilities of the ADHD driver to such an extent that is below the demands of the particular driving task.
Present Study

Traditional approaches to collecting and analyzing human factors-related driving data has included methods such as epidemiological studies, surveys, retrospective self-reports, ecological momentary assessment (EMA) and simulator studies. However, an inherent flaw pervading each of these methods is that they are not directly measuring the behaviors of the driver or the exact driving outcomes in a naturalistic manner. Epidemiological studies, while useful in assessing driving data often collected at a national level, lack sufficient detail to be helpful for many analyses and applications. Surveys and retrospective self-report data fall victim to the many biases that are inherent in such designs. EMA studies, which involve repeated sampling of subjects’ current self-reported behaviors or experiences in real-time with handheld technology, unfortunately do not provide an objective view of the driver’s behaviors and general ability. More recently, an empirical approach to driving studies has been through the use of high-fidelity driving simulators to monitor on-road driver behavior and competency. Though a valid method and easily palatable to the public, the experimental process is necessarily contrived and does not always capture the complexities of the driving environment or natural behavior as participants are often more alert and more careful in a virtual reality simulation environment or when an experimenter is present (Dingus et al., 2006).

To overcome many of the issues with these designs, the present study utilized audio and video recording technology that is installed inside each participant’s vehicle to capture objective data through a more naturalistic approach. The use of this technology provides much greater information than has been typically available, even after detailed incident or crash investigations. One advantage to the naturalistic approach is that the video recordings allow direct viewing of all pre-incident and during-incident parameters, including a wide array of driving behaviors.
Given the range of human factors that influence the condition of the driver and his or her overall driving abilities, it is clear that the magnitude of impairment across any of these factors would vary from one ADHD driver to another. Consequently, the competency of ADHD drivers behind the wheel will differ greatly as well. As there is little currently known about the exact driving behaviors that increase collision and citation risk, the present study aims to identify factors that differentiate high risk and low risk young adult drivers with ADHD to highlight those behaviors that put drivers at a greater risk for adverse outcomes on the road. As a preliminary examination into this question, we analyzed in-car driving videos of drivers with ADHD who did or did not have collisions during a specified observation period in order to determine if and how high risk drivers with ADHD differ from low risk drivers with ADHD.

Method

Participants

Seventeen participants completed all aspects of the study. The mean age of participants was 20.82 years (SD=2.4) and their average years of driving was 3.8 years (SD=1.2) with an average miles driven in the past 12 months of 13,967 (SD=523). The majority were males (n=14) and of Caucasian ethnicity (n=13).

The ADHD drivers were divided into High Risk and Low Risk groups. The High Risk ADHD drivers (n=7) were operationally defined as those who had an on-road collision during the three month observation period. Conversely, the Low Risk group (n=10) was comprised of ADHD drivers who did not have an on-road collision during the three month observation period. Collisions were defined and coded as an event in which the participating driver hit another object that resulted in physical damage to the driver’s vehicle. The demographic characteristics for High Risk and Low Risk drivers are shown in Table 1.
The inclusion criteria for ADHD participants were: (1) current diagnosis of ADHD, (2) history of responsiveness to stimulant medication, (3) not currently taking psycho-active medication, (4) having no current diagnosis of substance abuse, bipolar disorder, depression, anxiety or psychosis, (5) having no significant history of skin rashes or other skin conditions, (6) having a valid driver’s license, (7) routinely driving a car more than three times a week, (8) having had more than one driving mishap (collisions and/or citations) in the past two years, and (9) being the primary driver of a single vehicle in which a video recording system could be installed. No participants were excluded for points 5-9.

**Procedure**

Advertisements for this study were placed in local public and college newspapers and fliers were posted in public locations. Participants were offered a free and focused physical exam, ADHD diagnosis testing, and up to $300 for completing the study (with partial payment for partial completion of the study). This resulted in 160 inquiries, of which 41 qualified for participation after an initial telephone screening.

Qualifying potential participants were informed about study procedures, shown a picture of the in-car video monitoring system that was to be installed in their car (See Figure 1; DriveCam.com) and asked to review and sign an IRB-approved consent form. Subsequently, participants were administered the Structured Clinical Interview for the DSM-IV (SCID) by a trained examiner to verify ADHD diagnosis and the presence of any comorbidities, and then participants completed the following psychometrics: Conners’ Adult ADHD Rating Scale (CAARS) (Erhardt et al., 1999) and the Cox Assessment of Risky Driving Scale (CARDS) (Cox & Cox, 2009). Participants then met with a psychiatrist for brief physical, neurological and psychiatric exams; a comprehensive medical history was completed to rule out any health
condition that might be complicated by stimulant treatment. The Barkley Structured Interview for ADHD (Barkley, 2005) was also administered to further confirm an ADHD diagnosis.

Participants’ driving was monitored for six months, three months on medication and three months while taking a placebo. For the purposes of the present study, only video clips from the three months when the drivers were taking the placebo were included in the data analyses. After confirming that the participants satisfied all inclusion criteria, a DriveCam video system was installed in each participant’s vehicle and they were randomly assigned to either No Medication - Medication or Medication - No Medication conditions to randomize the order in which they were to receive the medication.

The DriveCam audio and video recording system consists of two video cameras and an accelerometer mounted unobtrusively behind the rear view mirror. One camera faces out toward the road, capturing the driver’s view, and a second camera faces in toward the car, capturing the driver and any passengers. While the cameras were continually recording, only 10 seconds before and 10 seconds after the accelerometer detected a change in g-force of 0.6 or greater were saved. Thus the system documented erratic driving events when the vehicle suddenly decelerated, accelerated, went over bumps or swerved to the right or left. The DriveCam system did not indicate to the driver when the accelerometer detected an erratic maneuver and when data was being saved.

The 20 second videos were coded by a primary coder blind to diagnosis and condition using a standard coding system (Williams, 2003) refined for use with drivers diagnosed with ADHD (Cox et al., 2008). The primary data coder was instructed on the use of this coding system and practiced on pilot DriveCam data until there was 90% agreement in the coding
results between the primary and a secondary coder. The primary coder coded all videos and these data were used for data analysis.

**Results**

**Data Analysis**

The in-vehicle driving data were analyzed with chi-square tests and t tests. Chi-square was used to compare the frequencies of driving behaviors between the High Risk and Low Risk groups during the three month observation period. For two-group comparisons of means—g-force magnitudes and passenger variables—t tests were used. Furthermore, Cramer’s V was calculated post hoc to determine the strength of associations between the driving behavior variables and risk category, high or low, determined in the chi-square analyses.

**Collisions and Events**

There were eight collisions recorded during the three month observation period when the ADHD drivers were off medication, accounted for by seven drivers (see Table 2). Two of these events were reported to the police and three were reported to the insurance company. The average repair cost per collision was $987.40. The seven drivers who recorded a collision constituted the High Risk group and the 10 drivers who did not have a recorded collision during the three month period constituted the Low Risk group.

There were significantly more erratic driving events, as defined by the accelerometer, for the Low Risk group compared to the High Risk group during the three month observation period (see Table 3). There were 1142 events for the Low Risk drivers and 448 events for the High Risk drivers (mean = 114.2 events/driver vs. 64 events/driver, respectively, p <.0001). Although Low Risk drivers had more events, the nature of these events differed significantly across a range of variables, suggesting more risky driving behaviors for the High Risk ADHD drivers. The mean
strength of both the lateral (p=.003) and forward (p=.002) g-forces during the events were significantly stronger for the High Risk ADHD drivers than for the Low Risk ADHD drivers, suggesting more severe vehicle movements. Furthermore, although the Low Risk drivers had more g-force events during the observation period, the High Risk drivers were more likely to be involved in “near miss” events (p=.001).

Partly based on Rosenboom and Wultz (2011), the g-force events were divided into violations, errors, reactions and passenger variables. Violations were defined as “deliberate departures from behaviors believed to represent safe driving practices” (Rosenbloom & Wultz) and Errors were defined as “failures of observation that may be hazardous to others” (Rosenbloom & Wultz). Given the present sample of ADHD drivers, errors were differentiated separated into primarily inattentive driving errors and primarily hyperactive/impulsive driving errors.

**Violations**

Three variables were representative of the violations subcategory: driver not wearing a seatbelt, speeding and passenger wearing a seatbelt (see Table 4). Surprisingly, the Low Risk ADHD drivers were more likely to be observed engaging in these violations compared to the High Risk drivers. Not only were the Low Risk drivers more likely to be speeding (p<.0001) or not wearing a seatbelt (p<.0001), the passengers in the vehicle at the time of the events were also more likely to not be wearing a seatbelt (p<.0001). Both speeding (V=.233) and not wearing a seatbelt (V=.219) had significant moderate associations to low risk category.

**Errors**

Impulsive/Hyperactive Errors included three variables: reckless driving, having one or both hands off of the steering wheel and hyperactive behaviors (see Table 5). Reckless driving
was operationally defined and coded as intentional on the part of the driver either with or without other vehicles present in the vicinity. Hyperactive behavior was operationally defined and coded as hyperactive movement while driving such as dancing or moving to the music, fidgeting or squirming around for no discernible reason, and weaving in and out of the driving lane due to boredom. There were no significant differences between the High Risk and Low Risk ADHD drivers for the frequency of reckless driving and hyperactive behaviors. However, there were interesting trends for both of these impulsive/hyperactive errors that suggest a greater frequency for both reckless driving and hyperactive behaviors for the High Risk ADHD drivers.

Interestingly, the Low Risk ADHD drivers were significantly more likely to have one or both hands off of the steering wheel at the time of the g-force incident compared to the High Risk drivers (p<.0001; V=.112).

In contrast to the frequencies of impulsive/hyperactive errors, inattentive errors were significant differentiating factors of risk category for the ADHD drivers (see Table 5). Compared to Low Risk ADHD drivers, the High Risk drivers were: (a) more likely to exhibit visual inattention to the roadway, which includes daydreaming, looking out the driver’s side of the car, looking out the passenger’s side of the car, looking in the rearview mirror or looking inside the vehicle (p=.024; V=.104); (b) more likely to be distracted by something external to the vehicle, such as pedestrians, animals, billboards, etc. (p<.0001; V=.111); (c) more likely to be using a cell phone, which includes talking on the phone handheld or hands-free, answering the phone or dialing or texting on the phone (p=.043; V=.078); (d) more likely to be eating or drinking, which includes reaching for or putting away food or drink (p<.0001; V=.102); (e) more likely to be partaking in personal grooming or hygienic activities such as fixing hair, applying makeup, shaving, brushing teeth, fixing nails or putting on or taking of clothing or jewelry (p<.0001;
V=.105); and (f) listening to music, either singing along or not (p=.002; V=.093). Compared to the High Risk drivers, the Low Risk ADHD drivers were significantly more likely to be smoking at the time of the g-force incident (p<.0001; V=.102).

**Reaction**

Following the g-force events, High Risk ADHD drivers were more likely than Low Risk drivers to look at the recording system (p=.008) and have an emotional reaction to the event of either enjoyment or distress (p=.001; V=.097) (see Table 6).

**Passenger**

Regarding passenger influences, High Risk ADHD drivers were more likely to have teen or young adult peer passengers in the vehicle at the time of the g-force events (p<.0001). Similarly, High Risk drivers were also more likely to be engaged in some sort of interaction with the passenger, including conversation, conflict or physical action (p=.020) (see Table 7). The presence of one or more teen or young adult passengers in the vehicle had a significant moderate relationship (V=.148) to high risk category.

**Discussion**

The purpose of the present study was to explicate the specific driving behaviors that contribute to more risky driving and a greater risk for adverse events on the road for drivers with Attention Deficit Hyperactivity Disorder. The unique methods utilized in this study, namely the DriveCam audio and video recording system, provided the opportunity for naturalistic observation of the ADHD drivers during the three month observation period. The driving behaviors coded and witnessed in the video clips of on-road events provided evidence for the significant variability within the population of ADHD drivers concerning risky driving behaviors and risk for adverse events.
In light of these results, it is important to remember that ADHD drivers are in general at a much higher risk for on-road mishaps compared to non-ADHD drivers (Barkley & Cox, 2007). Furthermore, the extent to which ADHD drivers engage in risky driving behaviors behind the wheel is much higher than that for non-clinical drivers (Barkley & Cox). Within the population of ADHD drivers, those identified as High Risk who had a collision over the three month observation period exhibited errors across several domains at a much greater frequency than those who did not have a collision during that same period, the Low Risk group.

Collisions

Investigation and coding of the on-road collisions indicated that there were three collisions where the driver did not detect that the lead car had stopped at an intersection due to use of a cell phone in some manner; two collisions where the driver backed up into an object while either looking down or simply not paying attention to the task; and one event where the driver made a turn into an object while looking around, not at the road or turning direction. Given these narratives, the eight collisions recorded for the ADHD drivers from the seven participants in the High Risk group were primarily recognized as inattentive errors. Therefore, purely based on collision frequency and definition, this highlights the core symptom of inattention as a significant contributor to risky driving and adverse outcomes for ADHD drivers. Furthermore, the driver’s use of a cell phone contributed to an alarming number of these collisions, reflecting back on driver inattention and the general hazards that cell phones are bringing into the driving domain.

Events

The High Risk ADHD drivers differed from the Low Risk drivers on a range of variables necessary for safe and competent driving. Simons-Morton, Zhang, Jackson & Albert (In review)
found elevated g-force event rates to be a significant predictor of the likelihood of future crashes and near crashes in a normative sample. Contradictory to these findings, a greater frequency of erratic driving events was not predictive of risk category for ADHD drivers in the present study: the mean number of events per driver was higher for the Low Risk ADHD drivers compared to the High Risk drivers. Rather, the findings of the present study suggest that it may not be simply the number of g-force events that is predictive of future crash or near crash risk but rather the severity of these events. The mean magnitudes or strengths of both lateral and forward g-forces for the recorded events were significantly greater for the High Risk drivers, corresponding to more severe decelerations and more sudden swerves or turns.

These results highlight the specific impairments associated with ADHD symptoms such that the increased risk for this population is not a result of continued risky behaviors but rather a result of sudden lapses in judgment and safe driving behaviors. Furthermore, these findings also support the higher accident and injury rate for ADHD individuals behind the wheel. The High Risk drivers, who were defined based on accidents/collisions during the observation period, recorded stronger g-forces, corresponding to more sudden or last-minute reactions to events and hazards on the road.

**Hyperactive/Impulsive Errors**

In general, hyperactive/impulsive driving behaviors were not indicative of risk category for the ADHD drivers. The behaviors included in this category of errors included reckless driving, having one or both hand off of the steering wheel, and hyperactive behaviors. Interestingly, the Low Risk ADHD drivers were more likely to have one or both hands off of the steering wheel at the time of the events. There were additional surprising results in the violations subcategory as well: the low risk ADHD drivers were also more likely to be speeding or not
wearing a seatbelt at the time of the g-force events. Despite these findings, these violations and the hyperactive/impulsive errors did not seem to impair driving competency in the ADHD drivers to an extent that would put them at a greater risk for collisions. These results are particularly interesting in light of past research that has highlighted childhood and adolescent hyperactivity as a predictive factor for future collision risk. For example, Fischer, Barkley, Smallish and Fletcher (2007) found in a longitudinal study that a greater percentage of hyperactive children reported less-safe driving practices, more traffic citations and more driving errors from impulsiveness compared to matched control children. Future research should focus on hyperactive/impulsive errors in the driving domain to further examine these driving behaviors and the extent to which these two core ADHD symptoms are expressed behind the wheel.

The DriveCam video and audio recordings also presented some insight into the smoking behaviors of ADHD drivers behind the wheel and the associated impact on driving behavior: Low Risk drivers were significantly more likely to be smoking a cigarette at the time of the g-force events. This finding supports the present literature concerning the effects of nicotine on the core symptoms of ADHD and the “self-medication” rationale that is used to explain the greater cigarette use among persons with ADHD (Gray and Upadhyaya, 2009). Conners et al. (1996) found that nicotine increased self-rated vigor and concentration in adults and adolescents with ADHD and also improved performance on measures of attention and timing accuracy. In lieu of these findings with regards to smoking behaviors in the Low Risk group, smoking may be beneficial for ADHD drivers in terms of increasing driving safety and competence. However, more research needs to be done in order to make any real conclusions on the impact of smoking on ADHD and driving safety, particularly with any possible adverse effects on attention.
**Inattentive/Distracted Errors**

In general, the High Risk ADHD drivers were particularly more likely to display inattentive/distracted driving errors. High Risk ADHD drivers were more likely to be inattentive to the roadway, daydreaming, distracted by something external to the vehicle, using a cell phone, eating or drinking, partaking in hygienic activities, and listening to music. Due to the nature of the collisions and these inattentive/distracted errors that differentiated high risk and low risk ADHD drivers, these results suggest that greater inattention and a higher rate of inattentive errors committed puts ADHD drivers at an increased risk for mishaps on the road. Given that it is necessary to devote a substantial amount of attention in order to navigate roads safely and avoid present or emerging hazards, ADHD drivers and particularly those at a higher risk may be more susceptible to inattention and distraction and therefore more likely to have on road mishaps.

The findings of the present study support past research. In their study, Dingus et al. (2006) found that almost 80 percent of all crashes and about 65 percent of all near-crashes involved the driver looking away from the roadway just prior to the onset of the conflict. This was also found to be the case in the present study as High Risk ADHD drivers committed significantly more inattentive and distracted errors than the Low Risk drivers. Furthermore, Dingus et al. found that inattention, defined as: (a) secondary task distraction; (b) driving-related inattention to the roadway; (c) moderate to extreme drowsiness; and (d) other non-driving-related eye glances, was a contributing factor for about 90 percent of conflicts and minor collisions, particularly with lead-vehicles.

An important inattention-related finding of the present study was the frequency of adverse outcomes that involved the driver’s use of a cell phone: three of the eight collisions involved the driver’s focus on a cell phone, either texting or dialing, and the concordant
inattention to the roadway. This finding supports the current literature on the hazards involved with driver’s cell phone use. Drews, Pasupathi & Strayer (2008) found that the number of errors during a simulated driving scenario was highest when the driver was conversing on a cell phone compared to when they were conversing with a passenger. The researchers reasoned that passenger conversations differ from cell phone conversations in that the traffic and present driving conditions become a topic of conversation only with a passenger, helping the driver and passenger share situational awareness; there is no such shared situation awareness in cell phone conversations. Similarly, Dingus et al. (2006) found that the use of hand-held wireless devices was associated with the highest frequency of secondary task distraction-related events and the highest frequency of crashes and minor collisions.

**Passenger Influence**

The impact and influence of passengers on safe and competent driving behaviors has been cited in several driving safety studies. Simons-Morton, Lemer & Singer (2005) found that teenagers drove faster than the general traffic and allowed shorter headways when exiting from a parking lot in the presence of a young passenger. Gender effects were also found such that both male and female teenage drivers were more likely to engage in risky maneuvers in the presence of male passengers. Similarly, Williams, Ferguson & McCartt (2007) found that passenger presence increased the risk for adverse outcomes on the road for teenage drivers, particularly when the passenger is male. The authors suggest that it is not only the social influence that increased driver risk taking but also passenger-induced distraction.

The results of the present study support these findings. High Risk ADHD drivers were not only more likely to have teen or young adult peer passengers in the vehicle at the time of the g-force events but they were also more likely to be engaged in some sort of interaction with the
passenger. In addition to the possible negative social pressures that may have increased risk and risk taking for the High Risk ADHD drivers, the passengers could have also hindered the driver’s attention, creating an even riskier driving condition for the young adult driver.

**General Discussion**

Though most of the driving behaviors discussed in these analyses ought to be considered as potentially responsible for adverse outcomes or at-fault collisions, they can also negatively impact defensive driving. Particularly with inattentive/distracted driving behaviors, ADHD drivers and especially those at a higher risk may not be aware of or attentive to emerging hazards on the road to such an extent that would allow them to take appropriate evasive actions. As one of the main goals of this study was to determine the specific driving behaviors that put ADHD drivers at a greater risk for adverse outcomes on the road, these results should be considered in light of possible driver training paradigms. Not only should driving-specific interventions target the driving behaviors found to be most responsible for on-road mishaps, they should also emphasize the acquisition of safe driving skills and defensive driving behaviors.

Although risk category could be operationally defined in many different ways, the present study was only concerned with on-road collisions during the three month observation period. In this manner, the High Risk and Low Risk ADHD drivers were behaviorally categorized according to symptom manifestations behind the wheel and related adverse outcomes during those three months. Given the different risk category definitions, future research should further explore different factors that may further define risk category such as the nature of past citations or collision history (How many accidents or tickets? What was the nature of these adverse outcomes?), ADHD symptom severity, or ADHD subtype.
There are inherent shortcomings to the present study given that it was meant to be exploratory in nature to get an initial idea of the differences and behavioral variation within the population of ADHD drivers. First, due to the small sample size and specific inclusion criteria, it would be beneficial to replicate these findings in a larger multi-center study. This would allow for greater variability in ADHD symptom severity and thus more variability in risky driving behaviors. Another shortcoming is that the DriveCam monitoring system only saved the driving clips when the accelerometer picked up a significant g-force change, corresponding to sudden braking, accelerating, swerving or turning. While this technology and the results of this study highlight some of the behaviors contributing to risk category for ADHD drivers, there was still a significant amount of driving and driving behaviors not recorded by the system.

The findings of the present study have significant clinical implications. In determining the proper way to train ADHD drivers to best navigate the difficulties that they face on the road, general or driving-specific behavioral interventions may be designed and implemented that specifically address the shortcomings and difficulties that differentiate the High Risk and Low Risk drivers. Another very valuable implication of the present study is that the results may be generalized to the population of non-clinical drivers to highlight the driving behaviors that may in fact differentiate safe and risky driving in general. As we have seen in the results of the present study, there are a number of driving behaviors that contributed to more risky driving and a greater risk for adverse outcomes on the road. Extending these findings to the normative population of drivers, it could be that these same driving behaviors are indicative or predictive of crash and collision risk for any population.

Driving safety is an important area of research due to the practical and direct impact that it has on general well-being and health. Although driving is a very fundamental ability that
contributes substantially to self-sufficiency among young adults and adults, it can also be very hazardous and impaired in almost every clinical population, such as with the present sample of individuals diagnosed with ADHD. Increased risk in the driving domain and overall driver incompetence not only puts the individual at a greater likelihood for adverse outcomes, such as citations or collisions, it may also bring danger to passengers, pedestrians and others on the road. The results of the present study provide valuable insight into specific driving behaviors that increase risk for young adult ADHD drivers.
References


young adults with attention-deficit/hyperactivity disorder. *Archives of Pediatrics & Adolescent Medicine, 162*(8):793-794.


Figure 1

The DriveCam audio and video monitoring system employed by the present study. This console included an accelerometer and two video monitors, the first directed outside the front windshield towards the road and the second directed inside the vehicle towards the driver and passengers.
Table 1

*Demographic information for participants in each risk category*

<table>
<thead>
<tr>
<th></th>
<th>High Risk (n=7)</th>
<th>Low Risk (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Age (SD; Range)</td>
<td>19.86 (1.95; 17-22)</td>
<td>21.50 (2.55; 18-25)</td>
</tr>
<tr>
<td>% Female</td>
<td>29% (n=2)</td>
<td>10% (n=1)</td>
</tr>
<tr>
<td>% Not In School</td>
<td>14% (n=1)</td>
<td>40% (n=4)</td>
</tr>
<tr>
<td>% Non-Caucasian</td>
<td>43% (n=3)</td>
<td>10% (n=1)</td>
</tr>
</tbody>
</table>
Table 2

*Crash narratives for each of the eight collisions recorded during the three month observation period*

<table>
<thead>
<tr>
<th>Event</th>
<th>Sex</th>
<th>Nature of collision</th>
<th>Driver behavior at collision</th>
<th>ADHD symptom responsible</th>
<th>At fault</th>
<th># Passengers</th>
<th>Impact force</th>
<th>Day Time</th>
<th>Repair cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>Rear ended stopped car</td>
<td>Looking down to ringing cell phone</td>
<td>Inattention</td>
<td>Yes</td>
<td>0</td>
<td>1.61</td>
<td>Thu/13:30</td>
<td>$155</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>Rear ended stopped car</td>
<td>Texting</td>
<td>Inattention</td>
<td>Yes</td>
<td>0</td>
<td>4.41</td>
<td>Thu/19:36</td>
<td>$2,000</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>Rear ended stopped car</td>
<td>Texting</td>
<td>Inattention</td>
<td>Yes</td>
<td>1</td>
<td>7.61</td>
<td>Thu/08:06</td>
<td>$3,500</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>Backed into metal rail</td>
<td>Looking down</td>
<td>Inattention</td>
<td>Yes</td>
<td>0</td>
<td>1.53</td>
<td>Tue/18:30</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>Backed into parked car</td>
<td>N/A</td>
<td>Inattention</td>
<td>Yes</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
<td>$250</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>Over correct and hit guard rail</td>
<td>Looking out left window</td>
<td>Impulsivity</td>
<td>Yes</td>
<td>0</td>
<td>4.27</td>
<td>Tue/08:03</td>
<td>$1,768</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>Turned into something</td>
<td>Looking around</td>
<td>Inattention</td>
<td>Yes</td>
<td>0</td>
<td>0.78</td>
<td>Tue/22:12</td>
<td>$95</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>Hit deer crossing road</td>
<td>Looking straight ahead</td>
<td>Inattention</td>
<td>No</td>
<td>0</td>
<td>0.79</td>
<td>Sun/22:47</td>
<td>$111</td>
</tr>
</tbody>
</table>
Table 3

*Frequencies and statistics for Event variables*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Driving Event</th>
<th>Low Risk (n=10)</th>
<th>High Risk (n=7)</th>
<th>P level</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-Force Events</td>
<td>DriveCam triggered events/driver</td>
<td>114.2 (1142 total)</td>
<td>64 events/driver (448 total)</td>
<td>p&lt;.0001 (\chi^2(1)=302.916)</td>
</tr>
<tr>
<td>G-Force</td>
<td>T-Forward (mean)</td>
<td>-.055 (SD= 1.590)</td>
<td>-.293 (SD=.475)</td>
<td>p=.002 (t(1588)=3.120)</td>
</tr>
<tr>
<td></td>
<td>Sudden deceleration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-Lateral (mean)</td>
<td>.038 (SD=.658)</td>
<td>.144 (SD=.604)</td>
<td>p=.003 (t(1588)=-2.978)</td>
</tr>
<tr>
<td></td>
<td>Sudden lateral turns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Miss</td>
<td>Near miss event</td>
<td>1.9% 22/1142</td>
<td>4.9% 22/448</td>
<td>p=.001 (\chi^2(1)=10.650)</td>
</tr>
</tbody>
</table>
Table 4

*Frequencies and statistics for Violations variables*

<table>
<thead>
<tr>
<th>Driver Behavior</th>
<th>Low Risk (n=10)</th>
<th>High Risk (n=7)</th>
<th>P level (Chi-Square)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No seatbelt – Driver</td>
<td>39.7%</td>
<td>16.4%</td>
<td>p&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>457/1150</td>
<td>72/439</td>
<td>$\chi^2(1)=81.540$</td>
</tr>
<tr>
<td>No seatbelt – Front</td>
<td>36.5%</td>
<td>15.8%</td>
<td>p&lt;.0001</td>
</tr>
<tr>
<td>Passenger</td>
<td>125/342</td>
<td>24/152</td>
<td>$\chi^2(1)=26.583$</td>
</tr>
<tr>
<td>Speeding</td>
<td>21.4%</td>
<td>9.8%</td>
<td>p&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>246/1150</td>
<td>43/439</td>
<td>$\chi^2(1)=31.597$</td>
</tr>
</tbody>
</table>
Table 5

*Frequencies and statistics for Error variables – Impulsive/Hyperactive and Inattentive/Distracted*

<table>
<thead>
<tr>
<th>Driver Behavior</th>
<th>Low Risk (n=10)</th>
<th>High Risk (n=7)</th>
<th>P level (Chi-Square)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impulsive/Hyperactive Errors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reckless Driving</td>
<td>2.3% 26/1148</td>
<td>2.7% 12/439</td>
<td>NS</td>
</tr>
<tr>
<td>One hand or both hands off wheel</td>
<td>61.1% 703/1150</td>
<td>50.3% 221/439</td>
<td>p&lt;.0001 χ²(3)=21.522</td>
</tr>
<tr>
<td>Hyperactive (dancing; squirming; weaving)</td>
<td>8.0% 92/1145</td>
<td>11.4% 50/439</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Inattentive/Distracted Errors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inattentive/Daydreaming</td>
<td>32.2% 369/1145</td>
<td>40.8% 179/439</td>
<td>p=.024 χ²(5)=12.899</td>
</tr>
<tr>
<td>Looking at something outside the vehicle</td>
<td>2.1% 24/1145</td>
<td>6.2% 27/439</td>
<td>p&lt;.0001 χ²(2)=18.317</td>
</tr>
<tr>
<td>Smoking</td>
<td>3.6% 41/1145</td>
<td>0.0% 0/439</td>
<td>p&lt;.0001 χ²(1)=16.137</td>
</tr>
<tr>
<td>Using cell phone (talking on; looking for; texting/dialing)</td>
<td>3.7% 42/1145</td>
<td>4.6% 20/439</td>
<td>p=.043 χ²(4)=9.846</td>
</tr>
<tr>
<td>Eating</td>
<td>2.8% 32/1145</td>
<td>7.1% 31/439</td>
<td>p&lt;.0001 χ²(1)=15.127</td>
</tr>
<tr>
<td>Personal grooming</td>
<td>0.1% 25/1145</td>
<td>5.7% 25/439</td>
<td>p&lt;.0001 χ²(1)=15.562</td>
</tr>
<tr>
<td>Music</td>
<td>74.4% 856/1150</td>
<td>82.7% 363/439</td>
<td>χ²(2)=12.143</td>
</tr>
</tbody>
</table>
Table 6

*Frequencies and statistics for Driver Reaction variables*

<table>
<thead>
<tr>
<th>Driver Reaction</th>
<th>Low Risk (n=10)</th>
<th>High Risk (n=7)</th>
<th>P level (Chi-Square)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looks at camera</td>
<td>15.6% 178/1144</td>
<td>21.2% 93/439</td>
<td>p=.008 χ2(1)=7.075</td>
</tr>
<tr>
<td>Emotional reaction following (enjoyment or distress)</td>
<td>5.9% 68/1145</td>
<td>11.2% 49/439</td>
<td>p=.001 χ2(1)=14.772</td>
</tr>
</tbody>
</table>
### Table 7

*Frequencies and statistics for Passenger variables*

<table>
<thead>
<tr>
<th>Driving Event</th>
<th>Low Risk (n=10)</th>
<th>High Risk (n=7)</th>
<th>P level (Chi-Square)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passenger</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teen/young adult peer or child</td>
<td>20.0% 230/1149</td>
<td>26.7% 117/439</td>
<td>p&lt;.0001 χ²(3)=36.607</td>
</tr>
<tr>
<td><strong>Passenger Influence</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction with passenger (conflict, conversation or physical action)</td>
<td>20.0% 230/1149</td>
<td>26.7% 117/439</td>
<td>p=.020 χ²(4)=11.670</td>
</tr>
</tbody>
</table>