Curbing the Attention-Deficit: Influences of Task Demand During On-Road Driving

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Abstract

Previous research has indicated a critical role of task demand in determining driving outcomes amongst individuals with attention-deficit/hyperactivity disorder (ADHD). These findings have predominantly come from laboratory simulations, thus how task demand and arousal interact with attention to determine performance in real traffic situations is still unclear. The present study assessed driving performance amongst medicated and unmedicated ADHD drivers in a real driving task, using different traffic conditions to explore the effects of task demand on ADHD driving. Driver behaviour was recorded as participants navigated an on-road route in their own vehicles involving driving in urban, residential, rural, and highway environments. While unmedicated drivers employed fewer safe driving skills, and committed more inattentive and impatient driving errors, medicated drivers performed similarly to controls, attesting to the efficacy of stimulant medications. Greater task demands associated with manual as opposed to automatic driving; and urban as opposed to rural or highway environments were shown to improve attention and performance, particularly amongst unmedicated ADHD drivers. This is the first study to document such influences of task demand in real traffic. The present findings suggest that intervention strategies that focus on manipulating the level of task demand may be useful in improving driving outcomes amongst this established high-risk driving population.

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is characterised by pervasive functional impairments related to inattention, hyperactivity and impulse control (American Psychiatric Association, 2013). In adulthood, this combination of symptoms has significant consequences for driving. ADHD is associated with repeat driving infringements; most commonly for excess speed, and high rates of illegal driving (Barkley, Guevremont, Anastopoulos, DuPaul, & Shelton, 1993; Woodward, Fergusson, & Horwood, 2000). Drivers with ADHD report more frequent engagement in risky driving behaviours, collisions, and are more likely to be found at fault in these collisions (Fried et al., 2006; Merkel et al., 2013). Furthermore, collisions that involve an ADHD driver are associated with greater harm or injury (Woodward et al., 2000). Drivers with ADHD also make more insurance claims, at a greater overall cost per claimant (Swensen et al., 2004).

Pharmacological treatment currently represents the most effective intervention for drivers with ADHD. Studies suggest medication can lead to improvements in basic driving skills, fewer instances of inattention and impulsivity, and reduced involvement in erratic driving and collisions (Cox et al., 2012; Sobanski et al., 2013). These studies however tend to be exclusively outcome driven, offering comparisons of performance pre- and post-treatment without reflection upon the cognitive functions underlying risk. As a result, attributes of the driving experience that can both maintain and impede sustained attention; an innate feature of ADHD, remain relatively uncharted (Reimer, Mehler, D'Ambrosio, & Fried, 2010).

Sustained attention is critical for coherent cognitive function (Lavie, 2005). Research has shown that an individual's ability to sustain attention is largely jeopardised when demand is low, resulting in impaired vigilance and error prone performance (Thiffault & Bergeron, 1995; Wilde & Stinsson, 1983). In the case of driving, monotonous environments such as rural or highway roads that are repetitive may also encourage cognitive underload, thus impairing attention and performance, and increasing the risk of adverse road safety outcomes (Cox et al., 2006; Thiffault & Bergeron, 1995; Reimer et al., 2010). Given that individuals with ADHD require an elevated threshold of stimulation for sustained attention, compromises to attention and performance associated with low demand, monotonous tasks are accentuated amongst this population (Forster, Robertson, & Jennings, 2014). In a simulated driving study, participants with and without ADHD completed a secondary hands-free phone task introduced during high-demand urban and low-demand highway driving. While ADHD and control group performance was similar under the high demand condition, introduction of a secondary cognitive task was shown to impair ADHD driver performance considerably during low demand driving (Reimer et al., 2010). In a similar study, Biederman et al. (2012) found that ADHD drivers were significantly more likely to collide with a hazard presented in the periphery than were controls during dull, highway driving.

Outside the context of driving, researchers have shown that ADHD attention and performance may be improved by increasing the cognitive demands of a task. For example, in a letter search task, distractor stimuli were found to significantly impair the response times of ADHD participants compared to controls. By increasing the size of the search set however, distractor interference was reduced, resulting in improved response times amongst ADHD participants (Forster et al., 2014). Similarly, moderate auditory white noise has been shown to increase demand in the classroom, impairing control's performance on a cognitive challenge, but improving the performance of ADHD participants compared to a baseline, no-noise condition (Söderlund, Sikström, & Smart, 2007).

To date, just one study has examined an intervention amongst ADHD drivers where a high demand condition is introduced to improve driver attention and performance (Cox et al., 2006). Cox and colleagues (2006) compared the performance of 10 adolescent males with ADHD during simulated driving in both automatic and manual transmission modes. During manual driving, self-reports of improved attention to the driving task, and objective improvements in driving were found compared to automatic driving (Cox et al., 2006). Increased task demand is proposed to underlie the efficacy of this intervention, as effective operation of a manual vehicle requires more frequent attention to the driving process (Cox et al., 2006). Participants must monitor and control their speed and tachometer readings using the clutch, accelerator, brake, and gear stick, thus sustaining attention to the driving task, and evading the distractibility effects experienced during low demand driving.

The objective of the present study was threefold: to assess the driving performance of medicated and unmedicated ADHD drivers in a real driving task; to assess the effect of task demand on ADHD driving by assessing performance across different traffic conditions and vehicle transmissions; and to compare self and observer reported measures of driving performance and behaviour. Although simulator studies have been used to introduce secondary distractor tasks and risk events, and to manipulate demand conditions, the effects of naturally occurring driving events are yet to be explored. Thus, in the present study, participants navigated driving routes incorporating rural, urban, residential, and highway environments in their own automatic or manual transmission vehicles, while measures of attention and performance were collected.

Method

Participants

A total of 44 licenced drivers were recruited to participate in the study. Control group drivers (*n* = 17) without a diagnosis of ADHD or history of taking stimulant medication were recruited through advertisements on community and university notice boards. Drivers formally diagnosed with ADHD drivers were recruited through social media forums, and presentations at ADHD Adult group meetings. Those taking a prescribed stimulant treatment constituted the Medicated ADHD group (*n* = 15), and were instructed to take their medication as normal on the day of assessment. Drivers who had not taken medication for their ADHD in the month prior to and during participation in the study were designated as being in the Unmedicated ADHD group (*n* = 12). Recruitment and testing protocols were approved by the School of Psychology Human Research and Ethics Committee at the University of Waikato.

The 17 Control group drivers (11 female, 6 male, aged 19 to 57) reported 12 to 436 months of licensed driving experience, and drove between 30 and 500 kilometres a week. Control group symptom scores fell within the normal range on the Conners' Adult ADHD Rating Scale (CAARS–S:L; Conners, Erhardt, & Sparrow, 1999). The 15 Medicated ADHD drivers (8 female, 7 male, aged 17 to 67) reported 8 to 452 months of licensed driving experience, and drove 20 to 500 kilometres a week. The Unmedicated ADHD group was made up of 12 (9 male, 3 female) drivers aged between 21 and 65 who reported 17 to 564 months of licensed driving experience, and drove between 10 and 500 kilometres a week. ADHD symptom severity was not found to differ between drivers from the medicated and unmedicated ADHD groups. Both group *t*-score means fell above the 98th percentile for DSM-IV ADHD Symptoms Total, indicative of severe ADHD symptomology. The ADHD groups were made up of a similar proportion of predominantly inattentive, predominantly hyperactive-impulsive, and combined subtype diagnoses. There were no significant group differences in age, driving experience, driving license type, average weekly mileage, or vehicle transmission. There was, however, a significant gender imbalance across the three groups, due to a preponderance of male drivers in the Unmedicated group ($F(2, 41) = 12.96$, $p = .002$).

Driving scenarios

A naturalistic method was employed to collect on-road driving performance data. Participants drove predetermined driving routes in their own car while accompanied by an observer. A total of 10 driving routes were developed, each containing urban, residential, rural and highway conditions to represent different levels of environmental demand. The driving routes were approximately 10 to 15 km in length, and required 25 minutes to complete. At 12 locations throughout each route, participants performed one of five assessed driving tasks: right turn at a roundabout or into a side street, left or right turn at a controlled intersection, or lane change left or right. The driving routes were designed to include each of the tasks at least twice. Video was recorded throughout each drive, capturing the driver's face, hands, speedometer, and the view ahead and to the right of the driver.

Driving performance measures

To score the specific driving tasks, performance was partitioned into eight component measures of driving performance: observation, passenger comfort, following distance, signalling, gap selection, hazard detection, hazard response, and speed, according to New Zealand driver licence testing standards (NZTA, 2012). These eight performance measures were calculated on a scale of 0 to 100. In addition, an overall measure of driving performance was formed from the mean of the eight components. Finally, performance scores for urban, residential, rural, and highway driving were calculated by averaging the component measures taken from those sections of each driving route.

Three error measures were also calculated for each drive: inattentive, impatient, and aggressive errors. An inattentive error described a lapse in driver attention, such as a failure to signal or give way, or delayed recognition of driving hazards. Impatient errors were violations that lacked a malicious or aggressive aim, and included impulsive and impatient on-road behaviours such as speeding, weaving between lanes, and running red lights. Aggressive errors were interpersonally aggressive and hostile in nature, such as cutting off vehicles or excessive tailgating (Lawton, Parker, Manstead, & Stradling, 1997).

Scoring of the performance measures was initially conducted by an in car observer who was not blinded to condition. Two independent, blind-observers later scored the video footage of 5 randomly selected participants from each group as they completed 5 driving tasks. The blind observers were instructed to read carefully over the scoring guide, and to replay the video footage as necessary to score each item. Cronbach's alpha was calculated using this data to determine agreement between observers. There was substantial agreement between the blinded observers and the in car observer, $\alpha = .895$ (95% CI = .841 to .931), $p < .001$.

Procedure

Drivers who expressed an interest in the study were provided an information sheet outlining the research background and procedure. Details related to the use of a video camera during the driving segment of the test were provided, and participants were encouraged to ask questions before reviewing and signing the consent form. Driving was assessed in the participant's own vehicle to minimise errors attributable to unfamiliarity. Drivers were instructed to drive as they normally would whilst directions were provided by the researcher. The first 5-minutes of the driving route served as a preliminary test of the basic driving skills required to safely complete the on-road tasks. All participants successfully passed the preliminary safety check, proceeding on to the assessed part of the drive. Participants received a $20 gift voucher as reimbursement.

Statistical analyses

Group differences in overall driving performance and errors were analysed using one-way ANOVAs. This was followed by Bonferroni-adjusted pairwise comparisons between the three groups. To test the effect of environmental demand, a 3 (Group) X 4 (Environment) MANOVA was used to examine group differences in driving errors across the four types of driving environment; rural, urban, residential, and highway. Because the number of assessment opportunities differed across these environments, overall performance scores were standardised within each of the four driving environments by subtracting the overall mean (across environments) from each score and dividing by the standard deviation. The effect of vehicle transmission type was tested by comparing the performance of participants who drove vehicles with either a manual or automatic transmission. The comparisons were made separately for each group using independent *t*-tests.

Results

Driving performance

Table 1 shows the group means scores for observer-reported measures of on-road driving performance and engagement in driving errors. Compared to the Unmedicated group, Medicated ADHD drivers selected significantly safer gaps in traffic (p = .017), drove at safer speeds (p = .028), and scored more highly on an overall measure of performance (p = .025). Control group drivers also maintained safer speeds than Unmedicated drivers (p = .036) and tended to identify hazards in the driving environment more effectively (p = .070), although responses to identified hazards were often less effective than those of Medicated (p = .034) and Unmedicated ADHD drivers (p = .070).

Table 1. On road driving performance by group

	Control (n = 17)	Medicated (n = 15)	Unmedicated (n = 12)	F(2, 41)	p	η_p^2
Performance						
Observation	91.80 (1.99)	94.26 (1.49)	86.69 (2.81)	3.116	.056	.303
Comfort	82.90 (4.10)	90.91 (1.31)	78.60 (5.23)	2.533	.092	.261
Following distance	92.53 (1.91)	95.44 (2.41)	85.55 (5.60)	2.115	.134	.225
Signalling	92.35 (2.72)	85.49 (3.31)	81.37 (4.14)	2.542	.092	.262
Gap selection	94.34 (1.40)	97.16 (0.98)	87.85 (3.87)	4.326*	.020	.370
Hazard detection	94.32 (2.26)	94.06 (2.33)	86.08 (3.11)	3.166*	.050	.306
Hazard response	78.54 (5.24)	94.35 (2.61)	85.80 (4.57)	3.440*	.042	.322
Speed	86.03 (2.28)	86.91 (2.22)	74.17 (5.16)	4.465*	.018	.376
Overall	88.10 (1.91)	91.84 (1.32)	83.26 (3.19)	3.721*	.033	.332
Errors						
Inattentive	1.47 (0.26)	1.50 (0.29)	2.83 (0.49)	4.797*	.013	.384
Impatient	0.71 (0.27)	0.67 (0.24)	2.92 (0.70)	9.095***	< .001	.519
Aggressive	0.47 (0.26)	0.23 (0.11)	1.42 (0.70)	2.473	.097	.251
Total	2.65 (0.49)	2.40 (0.47)	7.17 (1.41)	10.301***	< .001	.545

Note. Mean (SE). $^*p < 0.05$. $^{**}p < .01$. $^{***}p < .001$. Effect size (η_p^2) = Partial Eta Squared.

Significant effects of group were also revealed for inattentive, impatient, and total driving errors (see Table 1). Unmedicated ADHD drivers engaged in significantly more inattentive (p = .020; p = .028), impatient (p = .001; p = .002), and total driving errors (p = .001; p = .001) than drivers from the Control and Medicated ADHD groups, respectively.

Environmental demand

The effect of driving environment demand (i.e., high demand urban and residential driving, and low demand rural and highway driving) on the rate of driving errors was then explored for each group. A 3 (Group) x 4 (Environment) MANOVA was calculated across the three error measures. This revealed a significant multivariate interaction between group and environment; *Wilk's lambda* = .798, F(18, 458) = 2.122, p = .005. Significant effects of environment on Medicated drivers' inattentive; F(3, 56) = 4.624, p = .006, η_p^2 = .409, and impatient errors; F(3, 56) = 3.795, p = .015, η_p^2 = .371 were shown. For Unmedicated drivers, effects of environment were shown for inattentive; F(3, 44) = 6.363, p = .001, η_p^2 = .516, and aggressive errors; F(3, 44) = 3.139, p = .035, η_p^2 = .369.

As shown in Figure 1, attention to the driving task was best during high demand, urban driving. As environmental demand decreased, drivers experienced increased difficulty attending to the driving task, resulting in more frequent inattentive errors. Significantly higher rates of inattentive errors were observed during highway driving compared to driving on residential (p = .021; p = .027) and urban (p = .006; p = .007) roadway amongst Medicated and Unmedicated drivers, respectively. Rural driving was also associated with more frequent inattentive errors amongst the Unmedicated group compared to residential (p = .044), and urban (p = .013) driving.

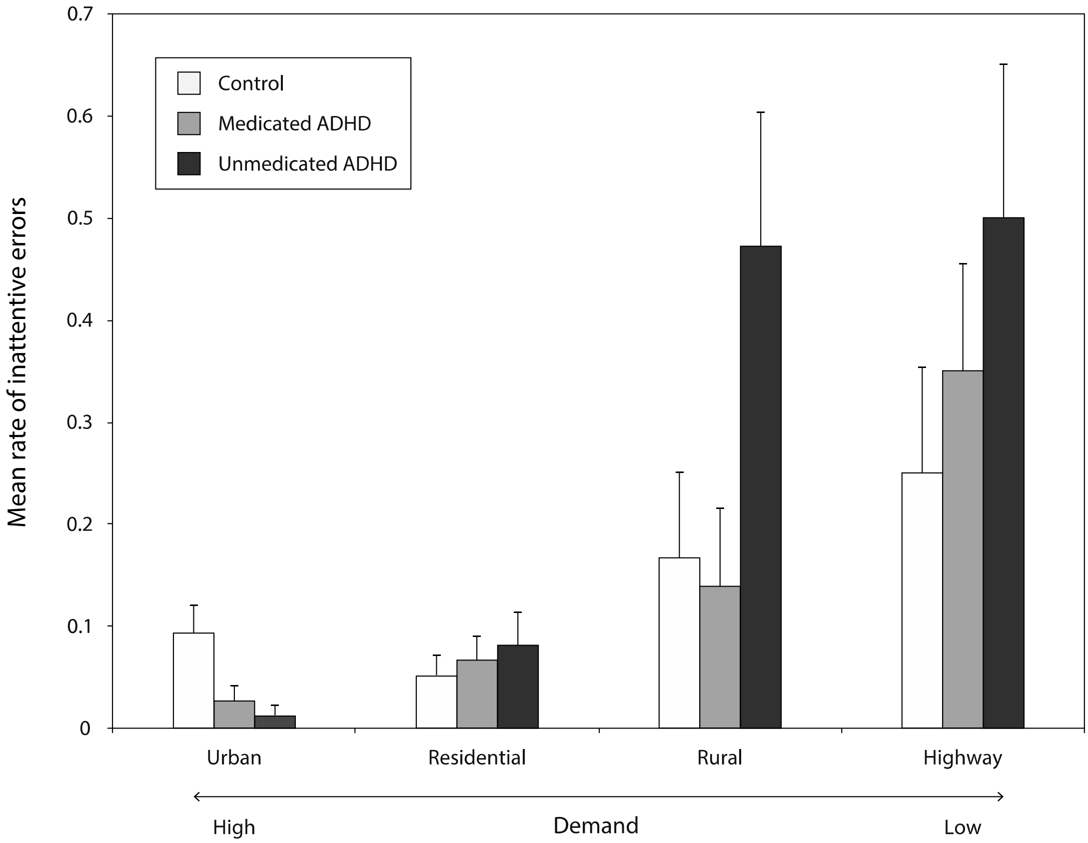

Figure 1. Group mean rate of inattentive errors by driving environment. Error bars show 95% confidence intervals.

Unlike inattentive errors, impatient and aggressive driving errors were observed very rarely during low demand, rural driving for all three driver groups. While Medicated drivers engaged most in impatient errors during highway driving (M = 0.21, SD = 0.33), no impatient errors were observed on rural roadway (M = 0) (p = .014). Unmedicated ADHD drivers tended to commit aggressive errors during urban driving (M = 0.23, SD = 0.39), but not during driving in rural (M = 0) (p = .084) and residential environments (M = 0) (p = .084).

Transmission

The effect of vehicle transmission on performance was explored for each group by comparing the performance of participants who drove an automatic vehicle with that of manual transmission drivers. No significant effect of transmission was revealed amongst the Control group. Manual drivers from both the Medicated and Unmedicated ADHD groups performed on average better than automatic drivers from the same group across all measures of driving performance (see Table 2). Compared to automatic drivers (n = 9), manual drivers (n = 6) from the Medicated ADHD group scored significantly higher on measures of hazard detection and overall performance. Manual driving was also associated with better use of signals and greater levels of passenger comfort, however these differences were not statistically significant. Manual drivers (*n* = 6) amongst the Unmedicated ADHD group maintained significantly safer following distances than automatic drivers (*n* = 6), and tended to perform better on measures of signalling and overall performance.

Table 2. ***Medicated and Unmedicated ADHD group driving performance by vehicle transmission***

	Group	Automatic	Manual	*t*	*p*	Effect size (*r*)
Observation	Medicated	92.68 (2.07)	96.73 (1.10)	-1.50	.158	.383
	Unmedicated	84.79 (4.67)	89.32 (1.77)	-0.91	.392	.313
Comfort	Medicated	87.61 (2.24)	93.23 (1.57)	-1.84	.088	.457
	Unmedicated	75.29 (5.93)	83.22 (9.86)	-0.73	.481	.226
Following Distance	Medicated	94.81 (3.61)	97.13 (2.04)	-0.98	.634	.134
	Unmedicated	75.26 (7.47)	100.00 (0.00)	-3.31*	.016	.724
Signalling	Medicated	80.39 (4.27)	93.17 (3.67)	-2.11	.055	.504
	Unmedicated	76.24 (5.72)	88.54 (4.72)	-1.56	.151	.442
Gap Selection	Medicated	94.82 (1.95)	98.33 (1.07)	-1.37	.195	.416
	Unmedicated	86.27 (5.28)	90.04 (6.17)	-0.46	.653	.145
Hazard Detection	Medicated	87.06 (4.78)	98.62 (1.38)	-2.32*	.044	.469
	Unmedicated	85.47 (3.78)	86.92 (5.80)	-0.22	.831	.069
Hazard Response	Medicated	92.12 (3.29)	95.83 (4.17)	-0.70	.494	.192
	Unmedicated	83.21 (6.83)	89.44 (5.85)	-0.65	.528	.203
Speed	Medicated	86.73 (3.26)	89.35 (2.99)	-0.56	.587	.153
	Unmedicated	69.86 (6.60)	80.20 (8.32)	-0.99	.347	.319
Overall	Medicated	89.53 (1.74)	95.32 (1.02)	-2.50*	.026	.635
	Unmedicated	79.54 (4.40)	88.46 (3.87)	-1.44	.179	.416

Note. Mean (SE). *$p < 0.05$. Medicated ADHD $df = 13$, Unmedicated ADHD $df = 10$.

Discussion

This is the first known study to investigate ADHD driver performance as a function of naturally occurring influences of demand in real traffic. In keeping with the predicted outcomes, the driving of Unmedicated ADHD participants was significantly worse than that of drivers from the Control and Medicated ADHD groups. Unmedicated drivers committed more errors on the road, most commonly as a result of inattention or impatience.

Relative to the Medicated group, Unmedicated ADHD drivers demonstrated poor observation and gap selection skills, and more frequently travelled at speeds in excess of the speed limit. A tendency for poorer performance compared to Controls was also observed. There was one exception to this trend. While Controls tended to identify hazards effectively, responses to those hazards were often less effective than those of ADHD drivers. This finding might be related to previous findings related to ADHD responsiveness to increased task load (Reimer et al., 2010); task demand may also increase in potentially threatening situations, resulting in more effective hazard responses amongst drivers with ADHD.

Significant effects of both driving environment and of vehicle transmission were revealed. Attention to the driving task was best during high demand, urban driving. As environmental demand decreased, however, Unmedicated ADHD drivers experienced increased difficulty attending to the driving task, resulting in more frequent inattentive errors. Supporting the findings of Cox and colleagues (2006), heightened task demands associated with the effective operation of a manual vehicle also encouraged improved performance relative to drivers of automatic vehicles. Several participants even noted their preference for driving vehicles with a manual transmission because it was more engaging, or because their mind would wander less. Manual driving was associated with better hazard detection skills, greater levels of passenger comfort, and more appropriate use of indicators amongst Medicated ADHD drivers, and safer following distances and more appropriate use of indicators amongst Unmedicated ADHD drivers.

The results should be considered in light of several limitations. Difficulty recruiting diagnosed ADHD drivers meant that gender could not be balanced between groups. As a result, the Unmedicated ADHD group consisted predominantly of male drivers (75%). The recruited sample is a direct reflection however of those who volunteered to participate, and is consistent with the gender discrepancy in rates of referral and diagnosis (Biederman, Faraone, Monuteaux, Bober, & Cadogen, 2004; Coles, 2012). Secondly, differences in task demand as a function of driving environment were assumed, but not validated. Finally, as participants completed the driving task in their own vehicle, a repeated measures design where participants drive both a manual and automatic vehicle was not feasible. Comparisons were instead conducted between drivers of automatic vehicles and drivers of manual vehicles to explore the effect of vehicle transmission on performance, thus sample size may limit the reliability of these comparisons.

Despite these considerations, this study has established several important influences of ADHD driver performance seldom explored in research to date. Most significantly, influences of demand within the driving experience were shown to impact attention amongst ADHD drivers. These findings impart that individuals with ADHD are capable of resisting distraction when a primary task is perceived to be sufficiently compelling, and that demand can be manipulated to encourage such outcomes (Forster et al., 2014; Reimer et al., 2010; Söderlund et al., 2007). Practical intervention strategies that are able to effectively engage this finding may present a plausible means of relieving the undermining impacts of distraction on ADHD driver performance, thus improving outcomes amongst this established high risk driving population. Recommending individuals with ADHD choose to drive vehicles with a manual transmission represents such an intervention, particularly for adolescents who are considering purchasing their first vehicle (Cox et al., 2006). Low demand driving environments may result in impairments of alertness and vigilance that encourage collisions, independent of drowsiness, therefore means of alleviating compromised attention during periods of monotony at the wheel should be investigated (Thiffault & Bergeron, 1995).

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