Driving with Attention-Deficit/ Hyperactivity Disorder:

Influences of Demand and Arousal in Real Traffic

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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 are derived predominantly from laboratory simulations. The objective of the present study therefore was to investigate the relationship between factors influencing demand and arousal in real traffic, and the performance of drivers medicated (n = 15) and unmedicated for ADHD (n = 12), compared to a control group (n = 17). Self-reported data relating to risky driving behaviours and driving history, and symptoms of ADHD in adulthood were collected. To determine the influence of demand on driving performance and errors, participants navigated a route incorporating rural, urban, residential, and highway environments. Relative to controls, unmedicated ADHD drivers employed fewer safe driving skills ($p < .05$), committed more inattentive ($p < .05$), and impatient driving errors ($p < .01$), and reported engaging in more frequent aggressive violations ($p < .05$). ADHD was associated with higher rates of crashes ($p < .01$) and multiple crashes ($p = .05$). Attesting to the efficacy of stimulant treatment, medicated ADHD driver performance in the present study was comparable to, if not better than controls. While unmedicated drivers undervalued the risk related to driving behaviours predictive of poor outcomes, medicated ADHD drivers largely overestimated the severity of their risky driving ($p < .01$). Demand was found to significantly impact the performance of unmedicated ADHD drivers particularly. Attention was best during high demand, urban driving. As environmental demand declined, more frequent attentional lapses occasioned increased impairment to performance ($p < .01$). Relative to drivers of automatic vehicles, high demand manual driving was linked with better hazard detection ($p < .05$) and overall performance ($p < .05$) amongst medicated drivers, and safer following distances amongst unmedicated ADHD drivers ($p < .05$). Apparently distinct driving styles were also revealed between ADHD subtypes. This is the first study to

document the impact of factors influencing task demand on ADHD driver performance in real traffic. Further exploration of the present findings could prove fundamental for future strategies of behavioural intervention.

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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, a critical presentation of dysfunction can be observed behind the wheel (Jerome, Segal, & Habinski, 2006). Adverse road safety outcomes were first broadly linked to a group of young hyperactive drivers in a longitudinal study by Weiss in 1979 (Weiss, Hechtman, Perlman, Hopkins, & Wener, 1979). It was Russell Barkley's 1993 paper however that cast issues of ADHD and road safety to the fore, proposing a risk of collision nearly fourfold that of drivers without ADHD (Barkley, Guevremont, Anastopoulos, DuPaul, & Shelton, 1993). Researchers have since pursued one of two broad lines of enquiry; further establishing the risk relationship, and more recently, exploring the alleviating effects of medication on impaired driving.

During adolescence, ADHD is associated with high rates of illegal driving prior to and post suspension of license, reception of repeated driving infringements; most commonly for excess speed, and reduced employment of safe driving practices (Barkley et al., 1993; Fischer, Barkley, Smallish, & Fletcher, 2007; Narad et al., 2013; Woodward, Fergusson, & Horwood, 2000). Drivers with ADHD are involved in more collisions, and are more likely to be found at fault in these collisions (Merkel et al., 2013). Furthermore, collisions that involve an ADHD driver are associated with outcomes of greater harm or injury than those involving drivers without ADHD (Woodward et al., 2000). ADHD drivers also make more insurance claims, at a greater overall cost per claimant (Swensen et al., 2004). They report more frequent engagement in risky behaviours predictive of poor outcomes on the road, demonstrate scepticism with regard to consequence, hold optimistic expectations of risk taking behaviours, and are disinclined to pursue measures of injury prevention (Farmer & Peterson, 1995; Fried et al., 2006; Knouse, Bagwell, Barkley, & Murphy, 2005; Merkel et al., 2013).

Pharmacological treatment measures currently represent the most effective intervention option for drivers with ADHD, and are underpinned by a vast and robust research base. Research conducted in real traffic suggests that medication leads to improvements in basic driving skills (Sobanski et al., 2013), fewer instances of inattention and impulsivity (Cox, Humphrey, Merkel, Penberthy, & Kovatchev, 2004a; Sobanski et al., 2013), and reduced involvement in erratic driving events and collisions (Cox et al., 2012). These studies tend to be exclusively outcome driven however, offering definitive comparisons of performance pre- and post-intervention without reflection upon the functions underlying risk. As a result, important attributes of the driving experience that can both nurture and impede sustained attention; an innate feature of ADHD, remain relatively uncharted (Reimer, Mehler, D'Ambrosio, & Fried, 2010).

Sustained attention in the presence of distraction is critical for coherent cognitive function (Lavie, 2005). This can, however, present an incredible challenge for individuals with ADHD, particularly during periods of low arousal (Forster, Robertson, & Jennings, 2014). As a task requiring sustained attention, driving is therefore also susceptible to the influences of distractibility and arousal associated with ADHD. The past decade has seen emergence of behavioural research and intervention strategies that point to the critical role of demand in determining attention and performance amongst individuals with ADHD (Cox et al., 2006b; Forster et al., 2014; Reimer, D'Ambrosio, Coughlin, Fried, & Biederman, 2007; Reimer et al., 2010).

The following review will summarise several influences of performance amongst the ADHD driving population. Studies of both pharmacological and behavioural strategies of intervention are discussed. Factors that serve to further jeopardise driving outcomes, such as comorbid conditions, overestimation of driving ability, and aggression are then described. Finally, the possibility that differential symptom presentations might engender a distinction of diagnostic subtype driving styles amongst the ADHD groups is considered.

Pharmacological Intervention

Various stimulant and non-stimulant treatments have been demonstrated to improve performance amongst the ADHD driving population (see Table A1 for an overview of the studies and their outcomes). The stimulant methylphenidate (MPH) currently represents the most commonly prescribed medication in New Zealand, and is recommended as a first line intervention for individuals with ADHD (see Table 1; PHARMAC, 2014). MPH is available in a range of dosages and release forms. While immediate release forms require multiple administrations across the day, sustained release MPH is ingested just once daily (PHARMAC, 2014). Researchers describe differential efficacy based on MPH release form.

Table 1

Pharmacotherapy of ADHD and its use in New Zealand

Medication	Drug name	Form	Use in New Zealand	Duration
Mixed Amphetamine Salts (MAS-XR)	Adderall	Dexamphetamine, Levoamphetamine extended release	Not available	8 – 12 hours
Dexamfetamine (DEX)	PSM/ Dexedrine	Dexamphetamine sulphate short acting	Fully subsidised	4 – 6 hours
Methylphenidate (MPH)	Rubifen IR [a]	Methylphenidate Hydrochloride immediate-release	Fully subsidised	3 – 4 hours
	Rubifen SR	Methylphenidate Hydrochloride sustained-release	Fully subsidised	4 – 8 hours
	Ritalin IR [a]	Methylphenidate Hydrochloride immediate-release	PHARMAC funding ceased Now Rubifen SR	3 – 4 hours
	Ritalin SR	Methylphenidate Hydrochloride intermediate acting	Fully subsidised	4 – 8 hours
	Ritalin LA	Methylphenidate Hydrochloride modified, intermediate-release	Fully subsidised	8 – 10 hours
Methylphenidate (MPH) Extended-release	Concerta XR	Methylphenidate Hydrochloride osmotic-controlled release	Fully subsidised	10 – 12 hours
Methylphenidate Transdermal (MTS) patch	Daytrana patch	Methylphenidate Hydrochloride transdermal-release system	Not available	10 – 12 hours
Lisdexamfetamine (LDX)	Vyvanse	Lisdexamfetamine	Not available	10 – 12 hours
Atomoxetine (ATX)	Strattera [b]	Atomoxetine	Second line treatment	24 hours

Note. [a] Considered bioequivalent. [b] Non-stimulant.

MPH Immediate-Release (MPH-IR).

Several researchers have explored the effect of MPH-IR on ADHD driver performance (Barkley, Murphy, O'Connell, & Connor, 2005; Cox, Merkel, Kovatchev, & Seward, 2000; Verster et al., 2008). Cox and colleagues (2000) assessed the simulated driving performance of drivers with and without ADHD after administration of a single 10 mg dose of MPH-IR compared to placebo. While performance was considerably poorer compared to controls during the placebo condition, ADHD drivers performed as well as controls during treatment with MPH-IR. Objective performance ratings were corroborated by self-reports of safer driving skills (Cox et al., 2000).

Verster et al. (2008) used a camera system to examine the effects of MPH-IR on driving in real traffic. Participants drove a test vehicle across a fixed, 100 km highway route (Verster et al., 2008). Although driving was described by participants as improved and less effortful during treatment with MPH-IR, only a minimal improvement in lane deviation was obtained (Verster et al., 2008). In another study, Barkley investigated the effects of high (20 mg) and low (10 mg) doses of MPH-IR on simulated driving performance compared to placebo (Barkley et al., 2005). Participants performed best when treated with the higher dose of MPH-IR.

MPH Osmotic-controlled Release Oral System (MPH-OROS).

In a study of treatment with MPH-OROS, ADHD drivers navigated a 25 km route in real traffic whilst accompanied by a blind observer (Cox et al., 2004a). MPH-OROS was found to significantly improve observer-reported engagement in inattentive errors compared to a no-drug condition. In another study, Cox et al. (2006a) compared the effects of the stimulants MPH-OROS and mixed amphetamine salts (MAS-XR) on simulated driving performance compared to placebo. MPH-OROS was associated with significantly improved performance compared with placebo and MAS-XR, resulting in reduced lateral lane deviation, less speeding, speed variability, and unnecessary braking (Cox et al., 2006a).

MPH Transdermal System (MPH-MTS).

Just one study of MPH-MTS was identified (Cox et al., 2012). Cox and colleagues (2012) used a DriveCam in-car video monitoring system to measure the performance of 17 participants with ADHD over 6 months of routine driving. The DriveCam system stored footage recorded 10 s before and after accelerometer detected change in g-force events, capturing erratic events such as abrupt braking, rapid acceleration, impact, and swerving (Cox et al., 2012). Three months of data was collected at baseline, and three months during treatment with a 10 to 30 mg MPH-MTS patch applied once daily. No collision events were recorded during MPH-MTS treatment, compared to a total of 8 during no-drug driving ($p < .005$). Drug compliance presented a considerable issue however, with participants only using MTS about half the time (Cox et al., 2012).

Lisdexamfetamine (LDX).

Two studies have explored the effect of LDX on driving, both of which are based on the same sample of 61 outpatients (Biederman et al. 2012a, 2012b). Participants drove a 43 mile (69 km) simulated route incorporating a range of environments at baseline, and after 6 weeks of treatment with either LDX or placebo (Biederman et al. 2012a, 2012b). Five surprise events required drivers quickly act to avoid collision. Dual task conditions were introduced during high stimulus, urban, and low stimulus highway driving. Treatment with LDX improved reaction times to surprise events, and reduced collisions compared to placebo. Collisions mostly occurred during the final period of low-stimulus driving, suggesting increased vulnerability to distraction when environmental demand is low. In a second study, Biederman et al. (2012b) assessed the impact of LDX treatment on self-reported risky driving behaviours using an adaptation of the Manchester Driving Behaviour Questionnaire (DBQ). Participants treated with LDX reported engaging in fewer errors ($p = 0.02$), lapses ($p = 0.02$), and total risky driving behaviours ($p = 0.01$) compared to placebo (Biederman et al., 2012b).

Mixed Amphetamine Salts (MAS-XR).

Kay, Michaels, & Pakull (2009) examined simulated driving performance amongst 19 young adults with ADHD during treatment with MAS-XR 50 mg/day and ATX 80 mg/day compared to placebo. MAS-XR significantly reduced collisions, lateral lane deviation, and reaction times compared to placebo (Kay et al., 2009). Improvements were sustained up to 12 hours post ingestion. It was reported that 75% of participants experienced adverse side effects of treatment (Kay et al.). In another study, a previously sampled group of drivers (Cox et al., 2006a, 2008) was employed to explore gender variability in stimulant effectiveness and tolerability (Mikami et al., 2009). It was found that both genders experienced equivalent treatment efficacy, tolerability, and side effects of MAS-XR (Mikami et al., 2009).

Atomoxetine (ATX).

Research to date presents inconclusive outcomes relating to treatment with the non-stimulant ATX. Kay et al. (2009) reported no significant improvements in driving simulator safety scores 2, 7, or 12 hours post ingestion compared to placebo. In a similar study of ATX treatment, participants described subjective improvements in ADHD symptoms and simulated driving performance, however observer ratings did not significantly improve compared to placebo (Barkley, Anderson, & Kruesi, 2007). Both studies assessed participants after 3 or 4 weeks of treatment (Barkley et al., 2007; Kay et al., 2009), however, ATX may take as long as 12 weeks to reach full efficacy (Sobanski et al., 2013). In a recent, sponsored trial of ATX, a larger sample of participants received 12 weeks of treatment with ATX before on road assessment. An accompanying observer scored driver performance as participants navigated a fixed, 45-minute, urban route in rush hour traffic. Observer-reports of attention to the driving task and employment of safe driving skills were best amongst drivers treated with ATX compared to a group of waiting-list, ADHD controls (Sobanski et al., 2013).

Delivery profiles.

Four studies have explored the delivery profiles of drug treatment (Cox et al., 2000; Cox, Merkel, Penberthy, Kovatchev, & Hankin, 2004b, Cox et al., 2006a; Kay et al., 2009). In these studies, the participants drove an assessed route up to four times in one day following ingestion of a drug treatment. Performance was then compared across time to establish a treatment delivery profile. One study compared the effect of immediate and extended release MPH on ADHD driver performance at night (Cox et al., 2004b). While improvements with MPH-OROS demonstrated no indication of deterioration, MPH-IR was associated with more inappropriate braking on the open road, failure to yield at stop signs, and erratic speed control.

Cox and colleagues (2006a) assessed performance at 17:00, 20:00, and 23:00 during treatment with MPH-OROS, MAS-XR, or placebo (Cox et al., 2006a). Improvements in driving performance with MPH-OROS were sustained as late as 23:00. An all male subsample of the same study was able to demonstrate the sustained efficacy of both MAS-XR and MPH-OROS on simulated driving performance as late as 1:00 am (Cox et al., 2008). No decay of simulated driving performance was evident up to 17 hours after ingestion. In real traffic however, an in-car observer noted more frequent inattentive errors with MAS-XR compared to placebo (p =0.04), suggestive of a possible rebound effect on the road (Cox et al., 2008).

Behavioural Intervention

At present, there exist scarce options for ADHD drivers who choose not to take medication. Development of strategies for effective behavioural intervention will appeal to many. Rather than concealing the functions that underlie risk, behavioural strategies are predicated upon the understanding of such functions, and are more likely to encourage long-term employment of safer driving habits and behaviours, and awareness of ADHD related deficits and vulnerabilities. Further, such intervention does not rely on whether a driver takes their medication, or the timing of administration, but can also be used adjunctively with medication to reduce risks at night time, during drug holidays, or between administrations (Gobbo & Louza, 2014).

An overview of researched strategies of behavioural intervention is provided in Table A2. Targeted interventions such as hazard perception training have been shown to improve certain driving skill sets (Poulsen, Horswill, Wetton, Hill, & Lim, 2010). To truly rival the factors that elevate risk on the road however, behavioural strategies must foremost address the imposing symptoms of distractibility that compromise outcomes amongst individuals with ADHD (Lavie, 2005).

Recent research points to a critical role of task demand in determining an individual's ability to focus attention (Reimer et al., 2010). Sustaining attention in the presence of competing distractor stimuli requires greater effort and cortical activation than that required of individuals without ADHD (Forster et al., 2014). As a result, individuals with ADHD experience twice the distractor interference experienced by those without ADHD (Forster et al., 2014). Mediating the ability of a particular individual with ADHD to sustain attention however is the level and load of the primary task (Lavie, 2005). When task demands compel optimal levels of arousal, distractor interference is minimal. Environments that are low in demand, or lacking stimulation however, lead to involuntary processing of distractor stimuli, thus impairing attention and performance (Forster et al., 2014; Loo et al., 2009). Several studies have investigated performance under low and high demand conditions (Laberge, Ward, Manser, Karatekin, & Yonas, 2005; Reimer et al., 2007; Reimer et al., 2010).

Dual task conditions.

In a study by Reimer and colleagues (2010), participants completed measurable secondary distractor tasks introduced during periods of low and high stimulus driving to determine the influence of demand on distractibility. Financial incentives required participants balance rewards earned for secondary task performance against rewards lost for poor driving (Reimer et al., 2010). ADHD driver performance suffered considerably when presented with a secondary cognitive task during low stimulus driving, resulting in greater distances travelled in excess of the speed limit, and increased speed variability compared to a control group (Reimer et al., 2010). Improved performance on the secondary challenge, a continuous performance task (CPT), suggests poor regulation of attention between the primary driving and secondary distractor task. Under high stimulus driving conditions however, driving performance was analogous between driver groups, indicating that ADHD drivers were able to effectively regulate the attentional demands of the secondary task. This points to the significance and utility of driving environment in both understanding and predicting ADHD driver distraction and performance (Reimer et al., 2010). Under less demanding driving conditions, poor task regulation may predispose ADHD drivers to invest more attention toward a distraction in the driving environment, thus compromising their driving performance (Reimer et al., 2010).

Cognitive distraction.

Other studies have investigated distractibility during periods of low and high demand, without introduction of an overt secondary task or distraction. Biederman et al. (2012a) explored the effect of environmental demand on simulator based impaired driving amongst individuals with and without ADHD. Participants completed a 45 minute simulated route incorporating periods of high demand urban driving, and low demand, monotonous rural and highway driving. Hazardous events presented throughout the drive required quick evasive action in order to avoid a collision. During a second monotonous period, ADHD drivers were significantly more likely to collide with a hazard presented in the periphery than were controls, suggesting impaired ability to sustain attention when environmental demand is low (Biederman et al., 2012a).

A laboratory study of non-ADHD drivers varied weather conditions to manipulate demand (He, Becic, Lee, & McCarley, 2011). Participants drove a straight, dull rural road designed to encourage mind wandering

(He, Becic, Lee, & McCarley, 2011). To determine the effect of task demand on the frequency of mind wandering, the route was completed during fine weather, and heavy wind conditions (He et al., 2011). Whilst heavy winds resulted in greater attention to the driving task, participants reported more frequent mind wandering during the fine weather condition (He et al.).

Transmission.

An array of conditions have been utilised in research to manipulate demand (Biederman et al., 2012a; He et al., 2011; Reimer et al., 2010). Just one study, however, has established an intervention condition that engages the ability to improve performance during high demand driving (Cox et al., 2006b). In a pilot study of the impact of vehicle transmission on driving performance, 10 adolescents with ADHD drove a simulated route in both automatic and manual transmission modes (Cox et al., 2006b). An impaired driving score compiling measures of steering and speed control, and braking reactions was calculated. Drivers self-reported attending best to the driving task during manual driving (Cox et al., 2006b). Impaired driving scores were also found to improve compared to automatic driving. Increased task demand is proposed to underlie the efficacy of this intervention, as effective operation of a manual transmission vehicle requires more frequent attention to the driving process (Cox et al., 2006b). 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 effect experienced in low demand tasks and environments. Recommending individuals with ADHD choose to drive vehicles with a manual transmission represents a simple and encouraging behavioural intervention for adolescents with ADHD, particularly those who are considering purchasing their first vehicle (Cox et al., 2006b).

Amongst ADHD drivers, performance appears to be best during periods of increased demand and arousal. When demand is high, vulnerability to distraction is reduced, and drivers are able to sustain attention to the driving task (Biederman et al., 2012b; Cox et al., 2006b; Reimer et al., 2010).

Non-driving studies.

Several non-driving studies have also introduced a high demand intervention condition to improve performance amongst individuals with ADHD. Söderlund utilised moderate auditory white noise to increase environmental demand, observing improved performance on a cognitive challenge amongst ADHD participants compared to a no noise condition (Söderlund, Sikström, & Smart, 2007). In contrast, control group performance was impaired under the noise condition compared to no noise.

Forster et al. (2014) examined the influence of perceptual load (demand) on the distractibility of adults with ADHD compared to a control group. Participants were to identify target stimulus in a letter search display, and ignore colourful distractor images presented in the periphery. The size of the search set was increased to manipulate demand (Forster et al.). At baseline, the presence of distractor stimuli significantly impaired the response times of adults with ADHD compared to controls (Forster et al.). By increasing the search set size, hence increasing task demand; distractor interference was significantly reduced (Forster et al.).

Such research imparts that individuals with ADHD are capable of effectively resisting distraction when a primary task is perceived to be sufficiently compelling (Forster et al., 2014; Reimer et al., 2010; Söderlund et al., 2007). However, conditions lacking in demand are likely to encourage increased distractibility from the primary task, and less optimal performance outcomes.

Further Influences of Performance

As well as vulnerability to distraction during low demand conditions, further factors serve to influence the performance of drivers with ADHD. ADHD is associated with a high prevalence of comorbid conditions, overestimation of ability; and aggressive driving tendecies, all of which are known to increase the likelihood of adverse outcomes on the road (Knouse et al., 2005; Nada-Raja et al., 1997).

Comorbid conditions.

Comorbidity is a common clinical feature of ADHD, and can confound estimates of risk associated with the condition on the road (Fried et al., 2006; Jerome et al., 2006; Murphy & Barkley, 1996; Nada-Raja et al., 1997; Spencer, Biederman & Mick, 2007; Vaa, 2014). Common comorbidities such as Oppositional Defiant Disorder (ODD), Conduct Disorder (CD), alcohol and substance abuse are established predictors of poor driving outcomes (Jerome et al., 2006). Comorbid conduct problems are associated with both risky and alcohol-impaired driving amongst adolescents and young adults with and without ADHD (Thompson, Molina, Pelham, & Gnagy, 2007). In a New Zealand longitudinal study of inattentive and hyperactive behaviours and driving during adolescence, high rates of driving infringements correlated most strongly with either ODD or CD amongst males (Nada-Raja et al., 1997). Impaired driving measures were also found to interact significantly with a comorbid diagnosis of either ODD or CD in a study by Barkley and colleagues (1993), however the researchers were unable to calculate the relative contributions of these conditions. In a meta-analysis of the relative risk of accidents associated with ADHD in road traffic, Vaa (2014) estimated risk to be 1.86 (1.27; 2.75) amongst ADHD-drivers when the prevalence of comorbid ODD or CD was high, compared to 1.31 (0.96; 1.81) in a sample of ADHD-drivers with no comorbidity.

Overestimation of competence.

Individuals with ADHD have been shown to hold elevated perceptions of self-competence compared to individuals without ADHD (Owens, Goldfine, Evangelista, Hoza, & Kaiser, 2007). Such positive illusory bias serves to further encourage poor outcomes in multiple domains (Bruce, Ungar, & Waschbusch, 2009; Hoza, Waschbusch, Pelham, Molina, & Milich, 2000). Knouse et al. (2005) compared self-appraisals of simulated driving performance amongst individuals with and without ADHD. Despite employing fewer safe driving behaviours, ADHD participants rated their own performance similarly to controls (Knouse et al., 2005). Overestimation of ability amongst individuals with ADHD has also been associated with reduced admission of consequence, more positive expectations of risk taking behaviours, and little inclination to pursue measures of injury prevention (Farmer & Peterson, 1995; Knouse et al., 2005).

Driver aggression.

Oliver and colleagues investigated the influence of aggression on driving performance amongst young adults scoring high and low on a measure of ADHD symptomology (Oliver, Nigg, Cassavaugh, & Backs, 2012). Measures of heart and respiration rate, simulated driving performance, and self-reported driving anger were obtained (Oliver et al., 2012). Participants drove a simulated route at baseline, and again in heavy traffic, with introduced trigger events and a time incentive to simulate frustrating driving conditions (Oliver et al.). During frustrating driving, a high ADHD symptom score was significantly associated with failure to stop at red lights, involvement in collisions, and multiple collisions. This suggests that high symptom ADHD drivers are more impaired by the experience of frustration than low symptom drivers, resulting in maladaptive and impulsive risk-taking behaviours (Oliver et al.).

Subgroups of high ADHD symptom drivers were established based on involvement in multiple vehicular collisions. Greater experience and expression of anger was strongly related to the experience of multiple collisions amongst this group (Oliver et al.). Further, high ADHD symptom drivers who had not been involved in multiple collisions reported less frustration at baseline than both low symptom drivers, and ADHD drivers involved in multiple collisions. This also suggests that a more calm and unperturbed disposition may serve as a protective factor, reducing the risk of poor outcomes amongst ADHD drivers (Oliver et al.).

Diagnostic subtype.

It has been indicated that characteristics such as aggression are differentially associated with the various symptom presentations of ADHD (Derefinko et al., 2008; Dowson & Blackwell, 2010). Three subtypes of ADHD are recognised in the fourth and fifth editions of the Diagnostic and Statistical Manual for Mental Disorders (DSM-IV, DSM-5; American Psychiatric Association, 1994, 2013). Individuals diagnosed with ADHD, Predominantly Inattentive Type (ADHD-PI) present symptoms of inattention only. Those diagnosed with ADHD, Predominantly Hyperactive-Impulsive Type (ADHD-HI) present symptoms of hyperactivity and impulsivity only, and finally, those diagnosed with ADHD, Combined Type (ADHD-CT) present clinical symptoms of both inattention and hyperactivity-impulsivity (American Psychiatric Association, 2013).

Symptoms of hyperactivity (ADHD-HI, CT) are associated with more externalised, conduct related problems, whereas ADHD-PI individuals are more likely to present with comorbid internalising disorders (Derefinko et al., 2008). Rather than the quick, impulsive response style associated with hyperactive-impulsive symptoms (ADHD-HI, CT), individuals with ADHD-PI demonstrate a slow and variable response style, and more severe impairments of sustained attention across multiple contexts. Although subtype differences related to driving style have seldom been explored, it would be reasonable to anticipate that the presentation of symptoms of inattention as opposed to hyperactivity or impulsivity might predispose subtypes to differential driving impairments (Barkley, Murphy, DuPaul, & Bush, 2002; Dahlen, Martin, Ragan, & Kuhlman, 2005).

Summary

Individuals with ADHD are at an increased risk for poor outcomes on the road. Amplifying factors such as comorbid conditions, aggression, and overestimation of competence appear to further elevate risk (Knouse et al., 2005; Oliver et al., 2012; Vaa, 2014). Pharmacological treatment measures have been demonstrated to reduce such risk both in simulator and real traffic settings (see Table A1 for a review). While the efficacy of drug treatment might be considered rationale for the current dominance of pharmacological research, it is likely too that the affluence of pharmaceutical company funding has curbed research ventures outside of the pharmacological sphere (Gobbo & Louza, 2014). A large number of pharmacological studies receive industry funding, with seven of the reviewed trials funded completely by the pharmaceutical company manufacturing the drug (Cox et al., 2004a, 2004b, 2006a, 2012; Kay et al., 2009; Biederman et al., 2012a, 2012b).

While drug treatment effectively conceals the influences of risk and resilience that operate within the driving experience, there is much to be learned from the exploration of such factors. Findings related to the influence of task demand on sustained attention not only suggest that individuals with ADHD are capable of effectively resisting distraction when a primary task is perceived to be sufficiently compelling, but more importantly, they demonstrate the capacity to manipulate demand in order to encourage such outcomes (Forster et al., 2014; Reimer et al., 2010).

The Present Study

The objective of this study is to assess the relationship between driving performance and cognitive factors related to sustained attention in real traffic. Previous research has suggested a crucial role of task demand in determining driving outcomes for the ADHD driving population. This research has predominantly come from laboratory simulations, thus how various elements of the driving experience interact with attention to determine performance in real traffic situations has not yet been established (Reimer et al., 2010).

The present study compared the driving performance of individuals medicated for ADHD, unmedicated ADHD drivers, and non-ADHD controls. Although simulator studies have typically introduced secondary distractor tasks and risk events to manipulate driver arousal, the impact of different types and levels of arousal was explored using naturally occurring driving events. This approach afforded greater realism while avoiding ethical and safety issues that would have resulted from presentation of secondary challenges in real traffic. Participants navigated a driving route incorporating rural, urban, residential, and highway environments in their own cars to reduce novelty effects. To examine potential group differences related to positive illusory bias, self-reported measures of risky driving behaviour and driving history were also obtained and contrasted with observer reports.

Given the established link between ADHD and risk on the road, it was hypothesised firstly that driving impairments would present most amongst ADHD drivers relative to controls. As the capacity to improve driving performance with drug treatment is now well established, it was also expected that medicated ADHD drivers would perform better than those from the unmedicated ADHD group. In addition, overestimation of ability amongst the unmedicated ADHD group was expected to result in differences in the congruence of self and observer-reported measures of risky driving behaviours and driving history between groups.

Cognitive factors influencing task demand, such as vehicle transmission, and driving environment were expected to impact driving performance amongst drivers with ADHD particularly, resulting in improved attention and performance when environmental demand was high; such as during driving in high stimulus urban environments, and increased vulnerability to distraction and impaired performance when demand was low; such as dull periods of rural or highway driving.

High levels of driving related aggression was expected to be associated with poorer driving outcomes, and although largely unexplored, differences related to driving style as a function of diagnostic type were anticipated to present amongst the ADHD groups, with more errors attributable to inattention, but few impatient or aggressive errors amongst Predominantly Inattentive drivers in relation to Hyperactive-Impulsive and Combined type drivers.

Method

Participants

Three driver groups were recruited from across the North Island of New Zealand for this between-groups study; a group medicated for ADHD, an unmedicated ADHD group, and a non-ADHD control group. Poster advertisements (see Appendix B) were placed on healthcare noticeboards, circulated via mailing lists, and presented at ADHD Adult group meetings to recruit the experimental groups. Control group participants were recruited through advertisements on community and university notice boards. All participants were required to hold a current restricted or full New Zealand drivers license and have access to a registered and warranted motor vehicle.

The control group was made up of 17 drivers (11 female, 6 male) without a diagnosis of ADHD or history of taking stimulant medication. These participants were aged between 19 and 57, held either a restricted (n = 2) or full (n = 15) NZ drivers license, and reported between 12 and 436 months of licensed driving experience. Thirteen participants drove a vehicle with an automatic transmission vehicle and 4 drove a manual vehicle. Control group participants drove between 30 and 500 kilometres in an average week.

Drivers in both ADHD groups had been formally diagnosed with ADHD prior to their involvement in the study. Seven male and 8 female medicated ADHD drivers aged 17 to 67 were recruited for the medicated ADHD group, and instructed to take their medication as normal on the day of assessment. Prescribed medications included Concerta® (n = 5), Ritalin SR® or LA® (n = 9), and Rubifen SR® (n = 1). Six of the participants in this group drove a manual transmission vehicle, and 9 an automatic, driving between 20 and 1000 kilometres in an average week. Participants reported between 8 and 452 months of licensed driving experience. Two participants held a restricted and 13 a full NZ drivers license at the time of their participation in the study.

ADHD diagnosed drivers who had not taken medication in the month prior to and during assessment were allocated to the unmedicated ADHD group. Nine males and 3 females aged 21 to 65 comprised the unmedicated group, reporting between 17 and 564 months of licensed driving experience. All held a full NZ drivers license, and drove between 10 and 500 kilometres in an average week. Six drove a vehicle with a manual transmission, and 6 drove an automatic vehicle. Ten participants reported having been prescribed one or more treatment for ADHD in the past, including Dexamfetamine (n = 2), Concerta® (n = 2), Ritalin IR® (n = 2), Ritalin SR® (n = 3), Rubifen SR® (n = 2), and Strattera® (n = 2).

To control the potentially confounding effects of comorbid diagnoses, participants were asked to note any diagnosed health conditions. None of the participating drivers had received a diagnosis of oppositional defiant disorder (ODD) or conduct disorder (CD). Recruitment and testing protocols were approved by the University of Waikato School of Psychology Human Research and Ethics Committee.

Driving Performance Measures

Driving routes.

A naturalistic method was employed to collect on-road driving performance data. A total of 10 driving routes were established. These were located in Hamilton, Tauranga, and at 8 locations across the wider Auckland region including Orewa, Rothesay Bay, Ponsonby, Epsom, Ellerslie, Henderson, Botany Downs, and Pakuranga (see Appendix C for driving routes). Each route was specifically designed to incorporate driving in rural, urban, suburban, and highway environments.

Rural driving was defined as driving through areas used for agriculture, forestry, or reserves; or land outside towns and cities, where the level of roadside development is minimum (NZTA, 2003). Highway environments represent all state highway, motorway, and expressway where the speed limit is between 80 and 100 km/h (NZTA, 2003). In many cases these roads had upwards of 2x2 lanes. Residential environments were those developed and used primarily for housing. Urban driving occurs in traffic areas close to or within a town or city, where land appears fully built-up (NZTA, 2003). In such areas a speed limit of 50km/h is indicated as drivers "can expect to encounter vehicles that are turning, slowing, stopping or parking, pedestrians, cycles and heavy vehicles" (NZTA, 2003). All routes therefore required at some point the participant to drive speeds ranging at minimum from 50-80 km/h. Several driving routes included road works where drivers were to drop to 30 km/h, and others highway driving where the speed limit was 100 km/h. At assessment locations throughout each driving route, drivers were required to perform one of 5 specific driving tasks (for task diagrams, see Appendix D):

1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right

Where practicable, the driving routes were designed to ensure each task was performed at 2 locations across the drive.

Scoring the specific driving tasks.

To score the specific driving tasks, performance was partitioned into measures of observation, comfort, following distance, signalling, gap selection, hazard detection, hazard response, and speed (NZTA, 2012). Each measure was compiled of items describing driving behaviours required to safely perform the driving task. Participants received 1 point for successfully carrying out the described safe driving behaviour. Failure to complete that behaviour resulted in a score of 0, and behaviour performed to a half standard, a 0.5. Operationally defined behaviours for each task were established to ensure consistency across participants (see Appendix E).

At each of the specified driving tasks, a mean score for each measure, and an overall performance score were calculated. The driving observer also noted whether the roadway was rural, urban, residential, or highway to enable comparison of performance scores by driving environment.

Classification of errors.

A score of zero on a specific driving task was indicative of an error; a failure to meet standards for the safe performance of a task. Errors were classed as inattentive, impatient, or aggressive. The score for each of these errors was dependent on the risk involved. If an event or behaviour resulted in minimal increased risk of an accident, it was allocated a score of 0.5. If another road user was forced to evasively act, or if the behaviour or event increased the risk of an accident, causing distress or discomfort, it was allocated a score of 1. These scores were tallied, providing error scores attributable to inattention, impatience, and aggression.

Definitions of the three types of driving errors were consistent with those of the relevant scales of the Manchester Driver Behaviour Questionnaire (DBQ) (Reason, Manstead, Stradling, Baxter, & Campbell, 1990). Inattentive errors reflected lapses, impatient or impulsive errors reflected violations, and aggressive errors, reflected items on the aggressive violations scale of the DBQ (Lawton, Parker, Manstead, & Stradling, 1997; Reason et al., 1990). While impatient and aggressive driving errors; much like violations and aggressive violations, arise with motivation, inattentive driving errors are defined by an absence of wilful intent.

An inattentive error occurred when a lapse in driver attention resulted in failure to safely perform a driving behaviour. Lapses involved minor failures of attention or memory, and occurred when a driver became distracted by an overt secondary task such as using a cell phone or adjusting the dials of a radio, or in the context of inattention or daydreaming, signalled by a gaze fixated in or outside the car, toward pedestrians, animals, or billboards etc. (Reason et al., 1990). Distraction from the forward roadway may manifest errors such as failure to signal, give way at a stop sign, or as delayed recognition of and response to hazards in the driving environment.

Impatient errors include deliberate violations of safe driving behaviours. They involve reckless driving acts that lack a malicious or aggressive aim. Activities such as speeding, and weaving in and out of lanes due to boredom might indicate impatient driving errors (Reason et al., 1990). Aggressive behaviours however are defined by their interpersonally aggressive and typically hostile nature (Lawton et al., 1997). Frustration at other road users can lead to anger, and selfish or competitive aggressive behaviours designed to achieve personal driving goals. Such behaviours might include cutting off other drivers, running red lights, failing to yield, or tailgating (Reason et al.).

Inter Rater Reliability

Scoring was initially conducted by an in car observer who was not blinded to condition. Two independent observers who were blinded to condition, later scored the video footage of 5 randomly selected participants from each group as they completed 5 driving tasks. The blind observers were provided an operationally defined scoring guide (see Appendix E), video footage for the 15 participants, and the times at which participants performed each of the tasks. They were instructed to read carefully over the scoring guide, and to replay the video footage as many times as necessary to score all of the items. No further instruction was given. 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), $p < .001$.

Self-Report Measures

Self-reported data relating to engagement in risky driving behaviours and driving history, symptoms and behaviours of ADHD in adulthood, and absent-mindedness in daily living were collected.

Manchester Driver Behaviour Questionnaire (DBQ).

Developed as an inventory of driving behaviours associated with adverse outcomes on the road, the DBQ (Reason et al., 1990) is now one of the most extensively employed self-report measures of risky driving behaviour (Lajunen, Parker & Summala, 2004). A four-factor model was utilised in the present study yielding a total score, and four scale scores capturing errors, lapses of attention and memory, violations, and aggressive violations. Errors describe unsafe behaviours that are definitively unplanned (Reason et al., 1990). Aggressive violations are distinguishable by their directed aggressive and hostile nature, and might include repeated honking of a horn, or the heated pursuit of another motorist (Lawton et al., 1997). Violations however are intentional digressions from safe driving practice that do not have an aggressive aim; such as exceeding the speed limit or failing to stop at a red light (Lawton et al., 1997). The DBQ was presented to participants in a single-page format with additional questions regarding licensure, average weekly mileage, history of infringements and motor vehicle collisions. Participants indicated on a six-point Likert-type scale how regularly each of the 28 items describing unsafe driving behaviours had happened to them in the past year. A higher score indicates more frequent engagement in the relevant risky driving behaviour. The DBQ has demonstrated moderate to high levels of internal consistency (.65 to .79) and test-retest reliability (r = .65 to .75) at 6-month follow up (Harrison, 2011).

Conners' Adult ADHD Rating Scale.

Designed for use amongst an adult population, the Conners' Adult ADHD Rating Scales (CAARS) assess archetypal problem behaviours associated with ADHD in adulthood (Conners, Erhardt, & Sparrow, 1999). Participants completed the long, self-reported version of the CAARS (CAARS–S:L), comprising 66 items scored on a Likert-type scale ranging from 0 (Not at all, never) to 3 (Very much, frequently). Four scales describing problems of inattention and memory, hyperactivity, impulsivity, and self-concept, 3 DSM-IV (American Psychological Association, 1994) ADHD symptom subscales, a total ADHD symptom scale, and an inconsistency index were obtained and used for data analysis (Conners et al., 1999). Higher scores indicate higher symptom severity. Test-retest reliability scores for the clinical scales of the CAARS–S: L range from r = .88 to r = .91 at one month follow up, indicating strong short-term stability (Conners et al.). Internal consistency varies between .49 and .91, depending on the scale, gender, and age group of the standardised sample.

Cognitive Failures Questionnaire.

Tendency to commit failures of memory, perception, and motor function was measured using the Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, FitzGerald, & Parkes, 1982). Participants were instructed to indicate how frequently they had experienced each of the 25 minor mistakes in the past 6 months on a 5-point Likert-type scale (Broadbent et al., 1982). CFQ total scores were calculated. Higher scores indicate more frequent failures of cognition. The psychometric properties of the CFQ have proven moderately robust, supporting its utility in research and moderate stability over time (Bridger, Johnsen & Brasher, 2013). Internal consistency is high, ranging from .85 to .89, and overall test-retest reliability ranging from r = .71 and r = .82 at 2 year follow-up (Bridger et al., 2013; Broadbent et al.).

Procedure

All participants underwent the same testing procedure. Potential participants who expressed an interest in the study from the noticeboards or emails were provided a Research Information Sheet (see Appendix F) outlining the purpose and background of the research. Participants chose a meeting time, and whether they preferred to meet at a café, another public area, or in their own homes. Participants from the Hamilton area were also invited to meet at an office on campus at the University of Waikato. On the day of testing, participants were first briefed on the background and procedure of the research. Details related to the use of a video camera during the driving segment of the test were provided. Participants were encouraged to ask questions before reviewing and signing both copies of the Research Consent Form (see Appendix G). They were then provided several self-report questionnaires relating to risky driving behaviours and driving history, tendency to commit cognitive failures, and ADHD symptomology.

The driving element of the study was assessed in the participant's own vehicle to minimise the potential or any errors attributable to unfamiliarity. The researcher first ensured a current registration and warrant of fitness was displayed before mounting an in-car camera and being seated in the passenger's seat. The in-car camera recorded video footage throughout the on road assessment (see Figure 1).

Figure 1. Field of view captured by the in car video camera system.

Participants were instructed to drive as they normally would whilst directions were provided by the researcher. Each direction was clearly stated with sufficient time for preparatory behaviours such as head checks and signalling. Participants first navigated a 5-minute safety route serving as a preliminary test of the basic driving skills required to safely complete the on-road task. Drivers who passed the safety check continued to navigate the assessed route as instructed. Those unable to demonstrate such skills however were to return to the start point, concluding the assessed component of the session. All participants successfully passed the preliminary driving safety check, and were able to proceed onto the assessed part of the drive. Performance was scored initially during the drive by the accompanying observer. On completion of the on-road task, all participants were given a $20 MTA voucher (for fuel and other goods) as a thank you, and to reimburse fuel costs.

Statistical Analysis

Raw data were first inspected for outliers using the boxplot function. The data of one control participant was excluded from the analyses, as scores across a number of self and observer reported measures were found to fall more than 3 SD outside the mean for the control group. No further outliers were identified. The first section of the results presents group demographic and clinical characteristics; compared using Pearson's chi-square for categorical variables, and one-way analysis of variance (ANOVA) for scale variables.

Group differences in driving performance and driving errors, history of infringements and crashes, and engagement in risky driving behaviours were investigated using one-way ANOVA. Post hoc testing was conducted using Tukey's HSD, or the Games-Howell procedure when the homogeneity of variance assumption was violated. A logistic regression was conducted to evaluate the effect of group on lifetime involvement in multiple crashes.

Several measures were standardised for comparison by subtracting the overall mean and dividing by the standard deviation. Bivariate correlations were calculated between standardised self- and observer reported measures, and discrepancies compared using one-way ANOVA. To compare the effect of environmental demand and arousal across the groups, standardised measures of performance within each driving environment were compared using one-way ANOVA. Composite measures of impaired performance were also calculated by subtracting each participant's inattentive, impatient, and aggressive error score within each environment from their overall performance in that environment. A 3X4 MANOVA was then used to examine group differences across the four driving environments. Multivariate effects of group and environment were calculated using Wilks' statistic.

Within-group influences of on road performance were investigated using independent *t*-tests for vehicle transmission, and separate one-way ANOVAs for diagnostic type. To explore the effect of aggression on performance outcomes, group bivariate correlations were calculated.

Results

The present study aimed firstly to explore differences between medicated ADHD, unmedicated ADHD, and control group drivers across self and observer reported measures of driving performance and behaviour. The congruency of self and observer-report was investigated. Group differences in specific measures of on road performance are then described. Finally, the influences of environmental demand, aggression, and diagnostic subtype on driving outcomes are explored.

Group Characteristics

Group demographic and driving characteristics are presented in Table 2. Gender composition was found to be unequal between groups, with the control group composed of only 35% males, compared to 47% of the medicated ADHD group, and 75% of the unmedicated ADHD group; $\chi^2_{(2)} = 12.96$, $p = .002$. No further differences in baseline demographic or driving characteristics were found.

Table 2

Group demographic and driving characteristics

	Age	Licensed driving experience	Average weekly mileage	Gender	License type		Transmission	
				Male	Restricted	Full	Automatic	Manual
Control	30.24 (3.31)	146.41(36.36)	210.00 (34.89)	6 (35%)	2 (12%)	15 (88%)	13 (72%)	4 (28%)
Medicated ADHD	38.73 (3.52)	197.07 (43.99)	206.00 (68.04)	7 (47%)	2 (13%)	13 (87%)	9 (60%)	6 (40%)
Unmedicated ADHD	38.67 (3.83)	206.67 (51.76)	223.33 (41.31)	9 (75%)	0 (0%)	12 (100%)	6 (50%)	6 (50%)
Total	35.43 (2.09)	180.11 (24.67)	212.27 (28.44)	22 (49%)	4 (9%)	40 (91%)	28 (59%)	16 (41%)

Note. Mean (SE) or *n* (%)

Group differences in absent-mindedness in daily living (CFQ), ADHD symptomology (CAARS), and diagnosed health conditions are presented in Table 3. A significant effect of group was shown for absent-mindedness in daily living, as measured by CFQ total score. Post hoc analysis revealed that both medicated ($p < .001$) and unmedicated ($p < .001$) ADHD group CFQ scores were significantly higher than those of control participants.

Mean ADHD symptom scores fell within the normal percentile range across all subscales of the CAARS for the control group. Both medicated and unmedicated ADHD group *t*-score means were indicative of severe ADHD symptomology, falling above the 98th percentile for DSM-IV ADHD Symptoms Total. Both ADHD groups reported significantly higher symptom scores than controls across all subscales of the CAARS ($p < .05$). No differences were found between mean Subscale scores reported by the medicated and unmedicated ADHD groups. The two ADHD groups were made up of a similar proportion of predominantly inattentive, predominantly hyperactive-impulsive, and combined subtypes. Diagnostic subtype was supported by symptom scores above the 98th percentile on the relevant subscales of the CAARS.

Table 3

Group clinical characteristics

	Control ($n = 17$)	Medicated ADHD ($n = 15$)	Unmedicated ADHD ($n = 12$)	F (2, 41)	p	η_p^2
CFQ	37.12 (3.42)	67.10 (3.51)	62.75 (4.18)	26.62***	< .001	.737
CAARS-S: L						
Inattention/ Memory	50.82 (2.41)	73.60 (2.47)	71.83 (3.35)	26.63***	< .001	.737
Hyperactivity/ Restlessness	46.41 (1.61)	59.00 (4.20)	64.83 (2.95)	10.33***	< .001	.550
Impulsivity/ Emotional Lability	47.76 (1.92)	65.60 (5.00)	64.58 (3.57)	8.89**	< .01	.518
Problems with Self Concept	48.94 (2.55)	63.00 (4.59)	57.42 (3.77)	4.87*	<.050	.391
DSM-IV Inattentive	52.64 (2.46)	75.87 (4.94)	79.67 (2.99)	18.39***	< .001	.669
DSM-IV Hyperactive-Impulsive	44.29 (2.48)	65.00 (4.86)	74.33 (3.51)	17.49***	< .001	.659
DSM-IV ADHD Symptoms Total	48.53 (2.49)	75.80 (3.82)	81.67 ((2.30)	35.07**	< .001	.796
ADHD Index	47.88 (2.02)	68.53 (3.94)	69.67 (3.37)	16.91***	< .001	.652
Comorbid conditions						
Total	6 (35.29%)	7 (46.67%)	9 (75.00%)	2.357	NS	.241
Depression	1 (5.88%)	6 (40.00%)	8 (66.67%)	7.691**	.001	.483
Anxiety	1 (5.88%)	1 (6.67%)	5 (41.67%)	7.027**	.002	.464
		Medicated ADHD ($n = 15$)	Unmedicated ADHD ($n = 12$)	t(25)	p	
Diagnostic type						
Inattentive		8 (53.3%)	4 (33.3%)	1.51	NS	
Hyperactive-Impulsive		2 (13.3%)	4 (33.3%)	6.18	NS	
Combined		5 (33.3%)	4 (33.3%)	0.00	NS	

Note. Mean (SE) or n(%)

$^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.

A total of 22 (50%) participants reported having been diagnosed with and/or treated for a health condition other than ADHD. The prevalence of mental health conditions was found to differ significantly between groups. A higher prevalence of depression compared to controls (p = .001), and of anxiety compared to controls (p = .005), and medicated ADHD participants (p = .007) was reported by the unmedicated ADHD group. Medicated ADHD drivers were also more likely to have been diagnosed with depression than were controls (p = .046).

Overall Driving Performance

Table 4 presents group differences in overall driving performance and observer reported engagement in errors attributable to inattention, impatience, and aggression. Significant main effects of group were obtained for overall driving performance, engagement in inattentive, impatient, and total driving errors. Post hoc analysis revealed no significant differences in overall driving performance or engagement in driving errors between medicated ADHD and control group drivers.

Table 4

Overall driving performance and error scores by group

	Control (n = 17)	Medicated ADHD (n = 15)	Unmedicated ADHD (n = 12)	$F(2, 41)$	p	η_p^2
Overall performance	88.10 (1.91)	91.84 (1.32)	83.26 (3.19)	3.721*	.033	.332
Inattentive errors	1.47 (0.26)	1.50 (0.29)	2.83 (0.49)	4.797*	.013	.384
Impatient errors	0.71 (0.27)	0.67 (0.24)	2.92 (0.70)	9.095***	< .001	.519
Aggressive errors	0.47 (0.26)	0.23 (0.11)	1.42 (0.70)	2.473	.097	.251
Total errors	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.

Overall driving performance was significantly worse amongst unmedicated compared to medicated ADHD drivers (p = .025). Unmedicated ADHD drivers engaged in significantly more inattentive (p = .028), impatient (p = .002), and total driving errors (p = .001) compared to medicated ADHD drivers. A trend for more aggressive errors was also revealed (p = .097). Compared to controls, unmedicated ADHD drivers committed significantly more errors attributable to inattention (p = .020), and impatience (p = .001), as well as more total driving errors (p = .001).

Self-Report Measures

Driving history.

Self-reported driving infringement data from the past year, and lifetime involvement in crashes and at fault crashes were obtained. Just one unmedicated ADHD participant reported receiving a driving infringement (8.4%), compared to 7 control (41.2%) and 6 medicated ADHD (40.0%) drivers. Group differences in self-reported infringement history were not found to be significant.

Self-reported involvement in crashes was found to differ significantly between groups; $F(2, 39) = 7.021$, $p = .002$, $\eta_p^2 = .549$. Compared to controls (M = 0.69, SE = 0.15), both medicated (p = .007) and unmedicated ADHD (p = .008) drivers were more likely to have been involved in a crash. No differences in self-reported crash involvement were found between the medicated (M = 2.50, SE = 0.95) and unmedicated (M = 2.33, SE = 0.62) ADHD groups. Compared to controls (M = 0.38, SE = 0.13), medicated (M = 0.79, SE = 0.30) and unmedicated ADHD (M = 1.25, SE = 0.48) drivers also reported involvement in more crashes in which they were found at fault, however these differences did not reach statistical significance.

Lifetime involvement in multiple crashes was then investigated. Just 5.8% of control group drivers reported having been involved in multiple crashes, compared to 20.0% of medicated, and 16.7% of unmedicated ADHD participants. A logistic regression of the effects of group, age, and licensed driving experience was conducted (see Table 5). The model explained 39.7% of the variance in reported involvement in multiple crashes, and correctly classified 70.5% of cases. Compared to controls, medicated ADHD drivers were 15.19 times more likely; and unmedicated ADHD drivers 18.96 times more likely, to report involvement in multiple collisions. Age and driving experience did not significantly influence the likelihood of being involved in multiple collisions.

Table 5

Logistic regression of the effects of group, age, and driving experience on involvement in multiple crashes

					95% CI		
Step 1	B (SE)	Wald	df	*p*	Lower	Odds Ratio	Upper
Group		6.42	2	.040			
Medicated ADHD (1)	2.72 (1.18)	5.35*	1	.021	1.52	15.19	152.22
Unmedicated ADHD (2)	2.94 (1.20)	5.97*	1	.015	1.79	18.96	200.81
Age	0.59 (0.43)	1.86	1	.173	0.77	1.80	4.18
Experience	-0.00 (0.00)	0.69	1	.406	0.99	1.00	1.00
Constant	-3.04 (1.15)	6.94**	1	.008		0.05	

Note. CI = confidence interval.

R^2 = .290 (Cox & Snell), .397 (Nagelkerke).

$^*p < 0.05$. $^{**}p < 0.01$.

Risky driving behaviour.

Table 6 presents group differences in self-reported engagement in risky driving behaviours. DBQ total score, and four scale scores describing driver lapses, errors, violations, and aggressive violations were obtained. Scales scores represent an average of the relevant items. Item 15 was omitted amongst participants who drove a vehicle with an automatic transmission, as it describes a driving error relevant only for manual drivers. A significant effect of group was obtained for driving errors, lapses, aggressive violations, and DBQ Total score. Post hoc analysis revealed no significant differences between the medicated and unmedicated ADHD groups. Compared to the control group, medicated ADHD drivers reported engaging in significantly more errors (*p* = .001), lapses (*p* = .013), aggressive violations (*p* = .048), and DBQ Total risky driving behaviours (*p* = .009). Compared to controls, unmedicated ADHD drivers also reported engaging in significantly more aggressive violations (*p* = .039), and total risky driving behaviours (*p* = .025).

Table 6

Self-reported engagement in risky driving behaviours by group

	Control (n = 17)	Medicated ADHD (n = 15)	Unmedicated ADHD (n = 12)	$F(2, 41)$	p	η_p^2
Errors	1.15 (0.14)	2.29 (0.26)	1.83 (0.22)	8.02**	.001	.496
Lapses	0.55 (0.06)	1.08 (0.16)	0.92 (0.16)	4.71*	.015	.384
Violations	1.51 (0.19)	1.82 (0.33)	2.13 (0.24)	1.33	.276	.123
Aggressive Violations	0.86 (0.11)	1.64 (0.29)	1.72 (0.29)	4.28*	.021	.364
DBQ Total Score	27.06 (2.52)	45.93 (5.40)	44.50 (5.21)	5.97**	.005	.433

Note. Mean (SE).

*p < 0.05. **p <0.01.

Accuracy of Self-Report

The relationship between self- and observer-reported measures describing inattentive, impatient, and aggressive driving behaviours were investigated. Scores were first standardised by subtracting the overall mean and dividing by the standard deviation. Error and lapse scale scores were contrasted with observer-reported inattentive errors. Violation scale scores were contrasted with observer-reported impatient errors, and scores on the aggressive violations scale were contrasted with observer-reported impatient and aggressive errors.

Group bivariate correlations between self- and observer-reports were calculated. Self-reported errors were found to correlate significantly with observer-reported inattentive errors amongst control (r = .48, p = .050), and medicated ADHD (r = .67, p = .007) drivers. Self-reported violations (r = .64, p = .010) and aggressive violations (r = 76, p = .001) correlated significantly with observer reported impatient errors amongst the medicated ADHD group. Observed impatient errors were also found to correlate with unmedicated ADHD group self-reports of engagement in violations (r = .61, p = .037), and aggressive violations (r = .66, p = .021). Self- and observer reported impatient and aggressive driving behaviours were not found to correlate amongst control group drivers.

Figure 2 depicts the relationship between standardised self-and observer-report measures by group. Despite underreporting of aggressive driving behaviours, self- and observer-reports appeared to be most congruent amongst the control group. While unmedicated ADHD drivers largely underreported their engagement in inattentive and impatient driving behaviours, medicated ADHD drivers consistently overestimated their engagement in inattentive, impatient, and aggressive driving behaviours compared to that observed on the road.

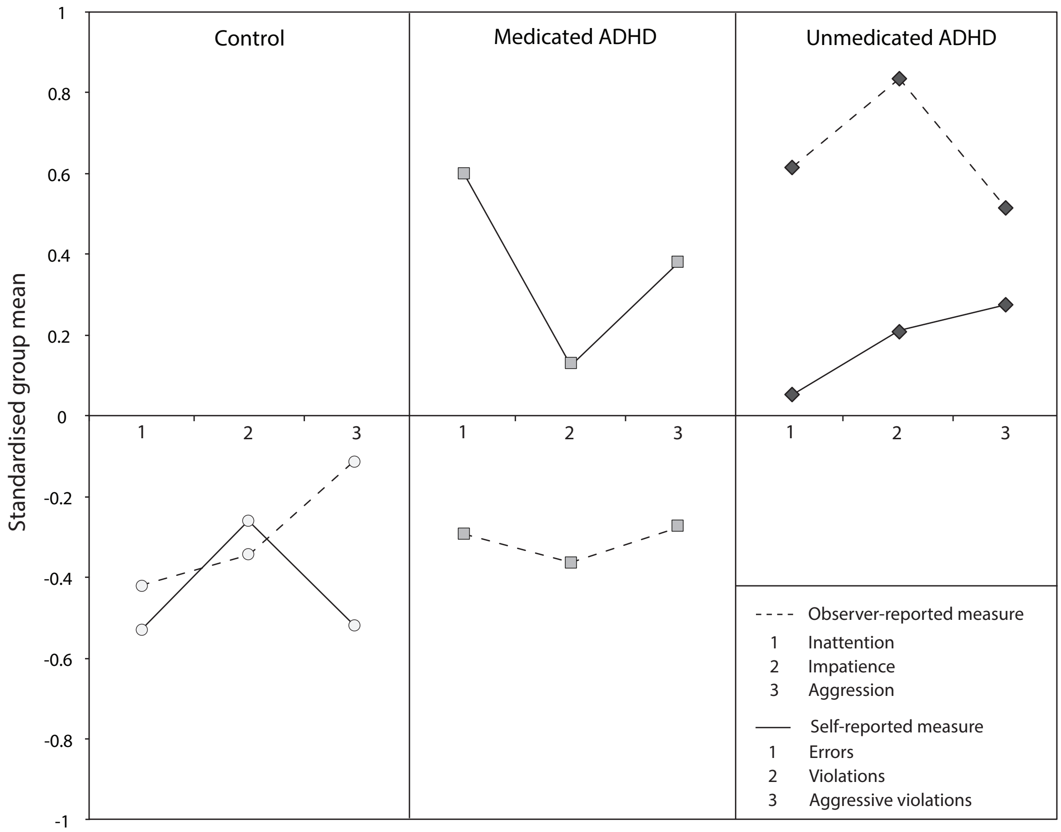

Figure 2. Self- and observer-reported engagement in inattentive, impatient, and aggressive driving behaviours by group.

To establish the significance of these group differences, discrepancy scores were calculated by subtracting self- from observer-reported measures (see Table 7). Negative values therefore indicate underreporting of risky driving compared to that observed on the road. Values close to zero indicate consensus of self-and observer reports, and positive values indicate over-reporting of risky driving compared to that observed on the road.

Significant differences in the congruency of self- and observer-reports were revealed across measures. Medicated ADHD drivers over reported their engagement in inattentive driving behaviours relative to control (*p* = .003) and unmedicated ADHD drivers (*p* < .001). The congruency of self- and observer reported impatient behaviours differed significantly between the ADHD driver groups (*p* = .014). While medicated ADHD drivers largely over reported engagement in impatient behaviours, underreporting was revealed amongst the unmedicated group relative to that observed on the road. Medicated ADHD drivers also over reported their engagement in aggressive driving compared to controls (*p* = .007). Congruence was highest amongst unmedicated ADHD drivers for aggressive driving.

Table 7

Discrepancy between self- and observer reported measures of risky driving behaviour by group

Observer	Self-report	Control (n = 17)	Medicated ADHD (n = 15)	Unmedicated ADHD (n = 12)	$F(2, 41)$	p	η_p^2
Inattention	Errors	-0.27 (0.19)	0.92 (0.20)	-0.84 0.40)	11.747***	< .001	.582
Impatience	Violations	0.12 (0.22)	0.42 (0.28)	-0.75 (0.29)	4.610*	.016	.383
Aggression	Aggressive Violations	-0.47 (0.20)	0.62 (0.30)	-0.11 (0.53)	3.556*	.038	.329

Note. Mean (SE).

*p < 0.05. **p <0.01. ***p <0.001.

Driving Skills

Group differences in specific measures of on road driving skills are presented in Table 8. Significant main effects of group were obtained for gap selection, hazard detection, hazard response, and speed. Post hoc analysis revealed that the medicated ADHD group demonstrated better observation skills (*p* = .047), selected safer gaps in traffic (*p* = .017), and drove at safer speeds (*p* = .028) compared to unmedicated ADHD drivers. Control group drivers maintained significantly safer speeds than unmedicated ADHD drivers (*p* = .036). A non-significant trend for more appropriate use of indicators was also revealed amongst controls compared to unmedicated ADHD drivers (p = .083).

Table 8

On road driving skills by group

	Control (n = 17)	Medicated ADHD (n = 15)	Unmedicated ADHD (n = 12)	$F(2, 41)$	p	η_p^2
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

Note. Mean (SE)

*$p < 0.05$.

While controls tended to identify hazards in the driving environment more effectively than unmedicated ADHD drivers (p = .070), responses to those hazards were more likely to be less effective. Similarly, while medicated ADHD and control group drivers demonstrated similar hazard detection skills, medicated ADHD drivers likely to respond more effectively than controls (p = .034). No further differences between the medicated ADHD and control groups were revealed.

Demand

Transmission.

To establish the effect of vehicle transmission on sustained attention and performance, independent *t*-tests were conducted for each group with transmission as the independent variable. No significant effect was revealed amongst the control group. Figure 3 compares the mean performance of automatic and manual drivers amongst the medicated and unmedicated ADHD groups.

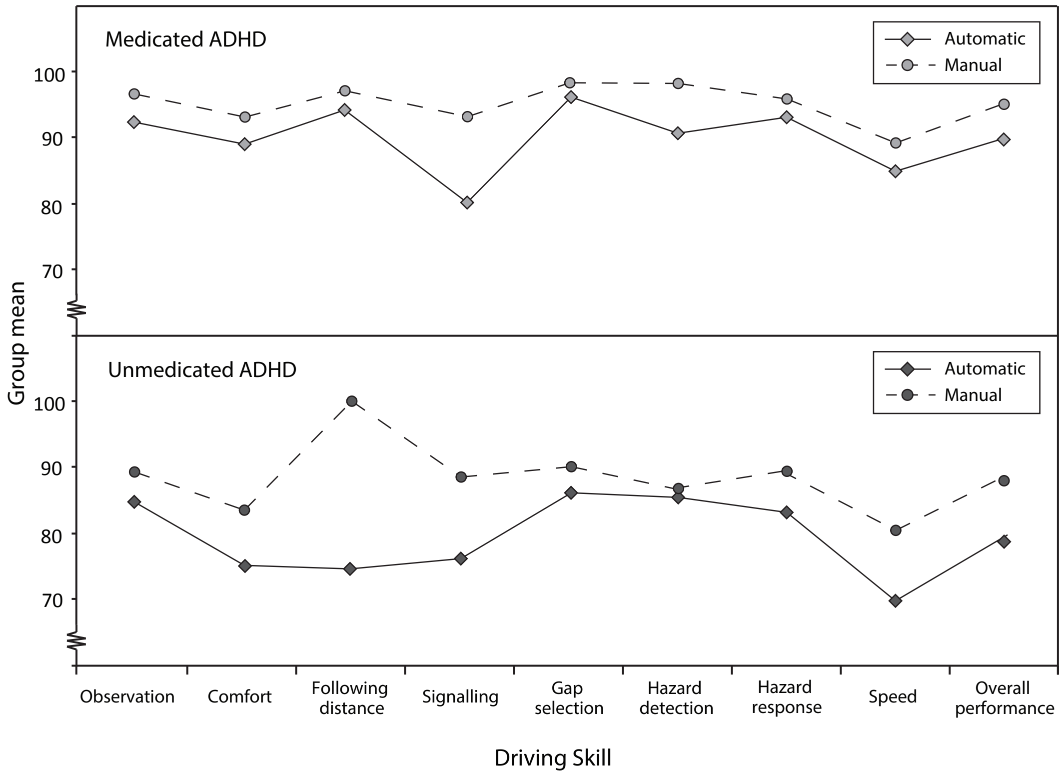

Figure 3. Medicated and unmedicated ADHD group driving skills by vehicle transmission.

Manual drivers from both the medicated and unmedicated ADHD groups performed better across measures than those who drove an automatic vehicle. Compared to automatic drivers (n = 9), manual drivers (n = 6) amongst the medicated ADHD group scored significantly higher on measures of hazard detection; $t(13) = -2.232$, $p = .045$, $r = .541$, and overall performance; $t(13) = -2.503$, $p = .026$, $r = .570$. Manual driving was also associated with better use of signals ($r = .504$), and greater levels of passenger comfort ($r = .457$), however these differences were not statistically significant. Amongst the unmedicated ADHD group, manual drivers (n = 6) maintained significantly safer following distances than automatic drivers (n = 6); $t(10) = -3.315$, $p = .016$, $r = .724$. They also tended to perform better than automatic drivers on measures of signalling ($r = .442$), and overall performance ($r = .416$). These differences did not reach statistical significance.

Environment.

To investigate the impact of environmental demand on performance, each route involved driving in rural, residential, urban, and highway driving environments. Demand was low during driving in rural and highway environments, and highest during urban driving. Overall performance scores within each of the four driving environments were calculated for all participants. The resulting rural, residential, urban, and highway performance scores were then standardised by subtracting the overall performance mean (across groups and environments), and dividing by the standard deviation. Figure 4 presents standardised group performance means within each driving environment.

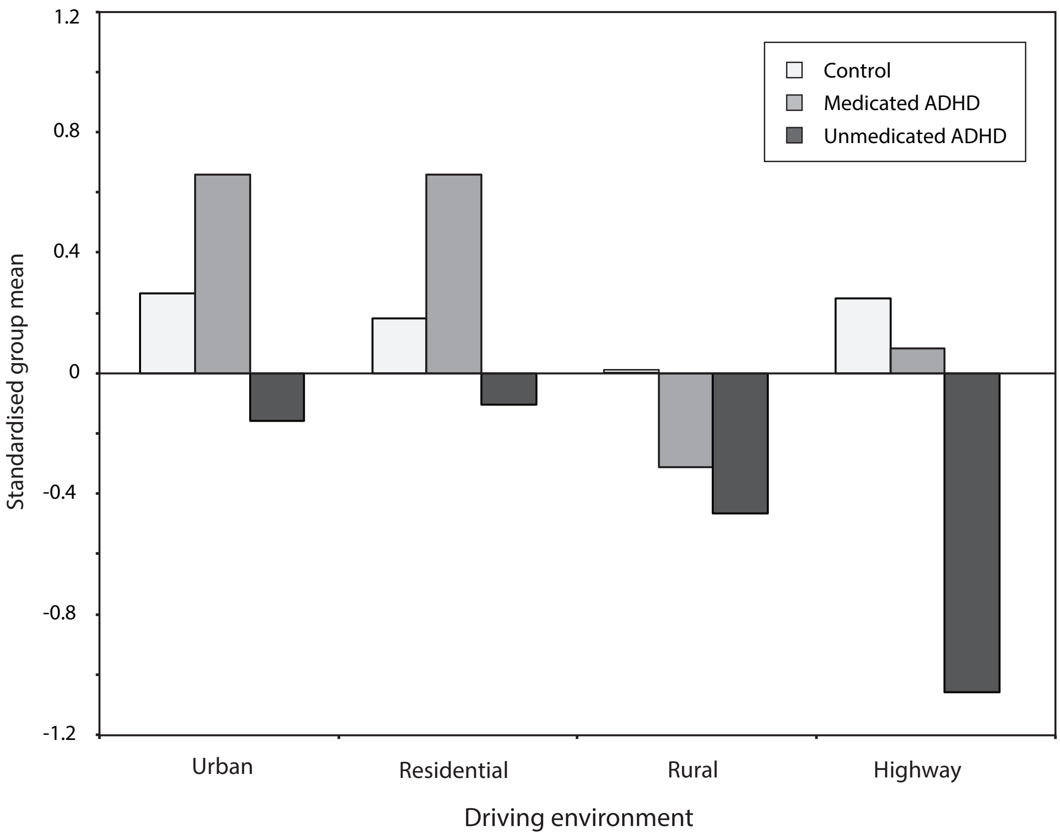

Figure 4. Standardised group mean overall performance scores by driving environment.

While performance apparently declines as demand decreases amongst the medicated and unmedicated ADHD groups, separate one-way ANOVAs indicated the effect of environment on overall performance was not statistically significant.

Whether environmental demand would significantly impact inattentive, impatient, and aggressive driving errors was then explored. Observer-reported engagement in inattentive, impatient, and aggressive errors during rural, residential, urban, and highway driving were calculated. Error rates within each driving environment were then subtracted from the unstandardized measure of performance within the relevant driving environment. Thus, rural driving errors were subtracted from the unstandardized measure of rural driving performance, and so on. Lower scores indicate increased impairment to performance as a result of the relevant driving error. Impaired performance scores as a result of inattentive, impatient, and aggressive driving within each environment are presented in Figure 5.

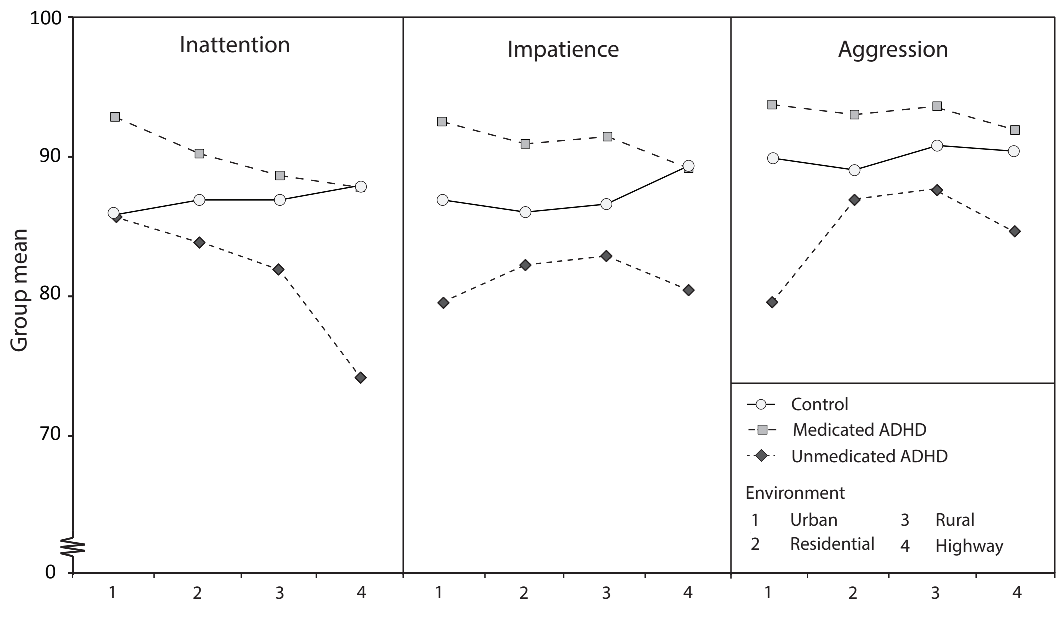

Figure 5. Group mean impaired performance as a result of inattention, impatience, and aggression within each driving environment. Lower scores indicate greater impairment.

A 3 (Group) x 4 (Environment) MANOVA was then conducted to examine group differences across the four driving environments related to inattentive, impatient, and aggressive driving errors. Using Wilks' statistic, a significant effect of group; Λ = .796, F(6, 324) = 6.520, p < .001, and environment; Λ = .839, F(9, 394) = 3.280, p = .001 was shown. A significant multivariate effect across the interaction of group and environment was also shown; Λ = .768, F(18, 458) = 2.497, p = .001. Univariate independent one-way ANOVAs revealed significant main effects of group on inattentive; F(2) = 4.756, p = .010, impatient; F(2) = 13.438, p < .001, and aggressive; F(2) = 4.756, p = .003 errors. Significant main effects of environment were shown for inattentive; F(3) = 5.540, p = .001, and aggressive errors; F(3) = 3.256, p < .05, but not impatient errors.

Environmental demand was not found to influence impaired performance amongst control group drivers, as suggested by the relative stability of mean scores across environments (see Figure 5). During urban driving, the performance of medicated and unmedicated ADHD participants was impaired least by inattentive errors. Impairment increased during residential and rural driving, and was most evident during highway driving for both the medicated and unmedicated ADHD groups. The effect of environment on inattentive driving was not statistically significant amongst the medicated ADHD group. Environment was found to significantly influence inattentive driving however amongst unmedicated ADHD drivers; F(3, 47) = 4.484, p = .008, η_p^2 = .443. More frequent engagement in inattentive errors during highway driving was found to significantly impair performance compared to driving in residential (p = .027) and urban (p = .003) environments.

Although increased demand during urban driving encouraged minimal inattentive errors, engagement in impatient and aggressive driving errors was found to increase amongst unmedicated ADHD drivers. A trend for more frequent engagement in aggressive driving errors relative to that observed during rural (p = .084) and residential driving (p = .084) was revealed, however differences did not reach statistical significance. No significant effects of environment on impatient and aggressive driving were observed amongst the control and medicated ADHD groups.

Driver Aggression

Bivariate correlations were calculated to investigate the relationship between self- and observer-reported driving aggression and performance. Amongst the control group, impatience correlated significantly with maintenance of unsafe speeds, $r = -.50$, $p = .043$, and involvement in crashes, $r = .59$, $p = .012$. Elevated self-reports of engagement in aggressive violations, and excessive speeding were associated with involvement in crashes ($r = .56$, $p = .024$). Excessive speeding was also significantly associated with involvement in crashes; $r = -.81$, $p < .001$, and at fault crashes; $r = -.66$, $p = .004$.

Self-reported aggressive violations amongst the medicated ADHD group were associated with maintenance of unsafe speeds ($r = -.77$, $p = .001$), following distances ($r = -.66$, $p = .011$), and poorer overall performance ($r = -.73$, $p = .003$). Impatience was also associated with maintenance of unsafe speeds ($r = -.98$, $p = .020$) amongst the medicated ADHD group, and with passenger discomfort, $r = .92$, $p = .004$, poor gap selection, $r = -.81$, $p = .029$, and driving at unsafe speeds, $r = -.85$, $p = .016$ amongst unmedicated ADHD drivers. Aggressive errors amongst unmedicated ADHD driver were correlated with poor gap selection, $r = -.86$, $p = .013$, and driving at unsafe speeds, $r = -.83$, $p = .022$. Aggressive violations were associated with maintenance of unsafe speeds ($r = -.70$, $p = .011$), following distances ($r = -.69$, $p = .012$), and poorer overall performance ($r = -.81$, $p = .002$).

Diagnostic Type

The effect of ADHD diagnostic subtype on within group driving performance was explored amongst medicated and unmedicated ADHD drivers using one-way ANOVA (see Figure 6). Compared to Combined type drivers amongst the medicated ADHD group, Predominantly Inattentive type drivers tended to maintain safer following distances ($p = .077$), and commit fewer errors related to impatience ($p = .099$). These differences did not reach statistical significance. Amongst the unmedicated ADHD group, diagnostic type was found to have a significant effect on speed; $F(2, 11) = 4.258$, $p = .050$. Compared to Combined type drivers ($M = 73.72$, $SE = 6.28$), Predominantly Inattentive type drivers ($M = 90.50$, $SE = 4.62$) maintained significantly safer speeds on the road ($p = .043$). Predominantly Inattentive type drivers also tended to perform better on measures of passenger comfort ($p = .083$), and gap selection ($p = .081$) compared to Combined type drivers, however these differences did not reach statistical significance.

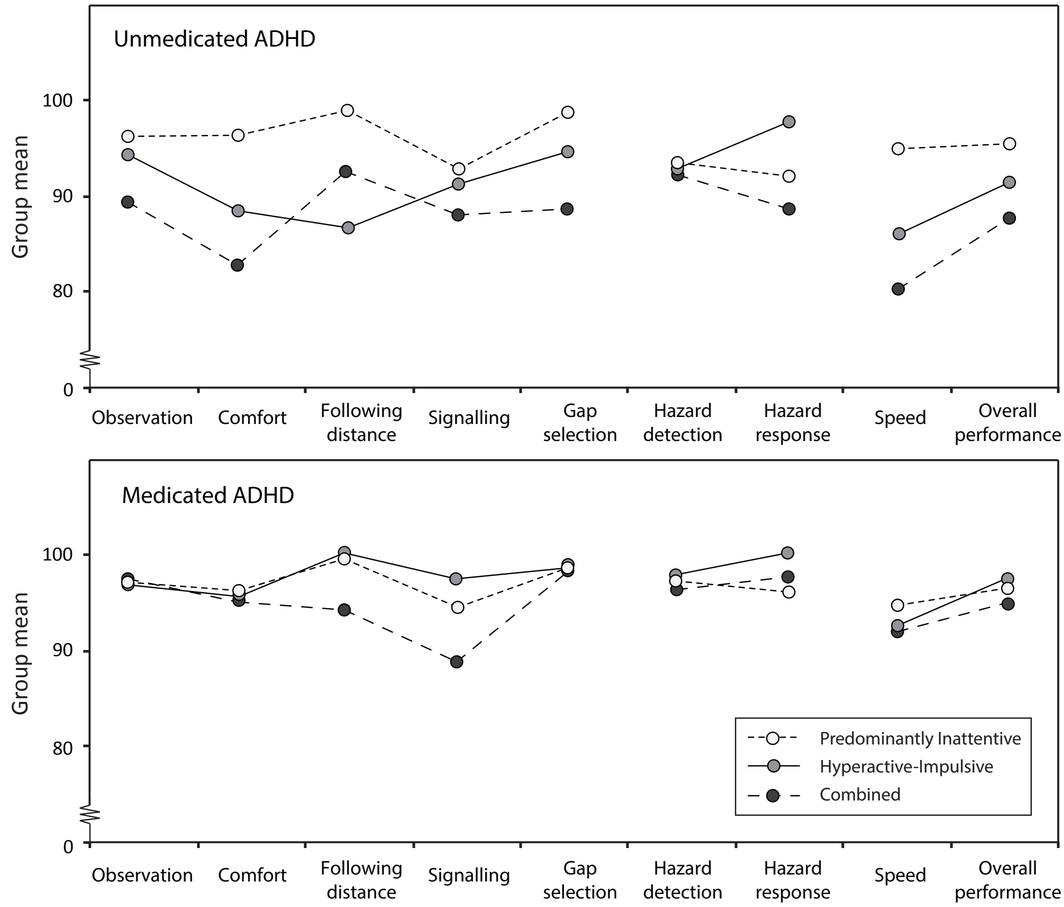

Figure 6. Medicated and unmedicated ADHD group driving skills by diagnostic type.

Symptom presentation.

To investigate the effects of inattentive and hyperactive/ impulsive symptoms on driving, bivariate correlations between symptom subscales of the CAARS and measures of driving performance were calculated (see

Table 9). Amongst the control group, problems with inattention were associated with poor observation, signalling, and hazard response, driving in excess of the speed limit, and poor overall performance. Elevated symptoms of hyperactivity and impulsivity were related to maintenance of unsafe following distances and speeds, and poor overall performance.

Amongst medicated ADHD drivers, elevated symptoms of hyperactivity and impulsivity were associated with poor use of indicators, and driving in excess of the speed limit. Hyperactivity and impulsivity correlated negatively with engagement in inattentive errors, and positively with impatient errors. Elevated symptoms of both inattention and hyperactivity and impulsivity were associated with poor observation, however correlations did not reach statistical significance.

Table 9

Pearson correlations between ADHD symptom severity (CAARS) and measures of on road performance

	Control		Medicated ADHD		Unmedicated ADHD	
	Inattentive	Hyperactive	Inattentive	Hyperactive	Inattentive	Hyperactive
Observation	-.60*	-.32	-.33	-.42	.17	-.21
Following Distance	-.41	-.57*	-.18	-.37	.58*	-.65*
Signalling	-.55*	-.02	-.00	-.51*	-.03	-.44
Gap Selection	.06	-.17	.64**	.54*	.40	-.39
Hazard Detection	-.14	.02	.62*	.44*	.50	-.17
Hazard Response	-.71**	-.27	.05	.34	-.17	-.36
Speed	-.64**	-.48*	-.26	-.63*	.42	-.54*
Overall Performance	-.74***	-.52*	.28	-.01	.38	-.50*
Inattentive errors	.34	.43	.03	-.54*	.12	.73**
Impatient errors	.34	-.00	.36	.68**	-.56*	.56*
Aggressive errors	-.07	.22	.08	.36	-.71**	.36

Note. Pearson's *r*. Inattentive and Hyperactive/ Impulsive Subscales of the CAARS-S: L.
$^{*}p < 0.05$. $^{**}p < 0.01$.

Inattentive and hyperactive impulsive symptom presentations were associated with contrasting performance scores amongst the unmedicated ADHD group. While inattentive symptoms were significantly associated with safe following distances on the road, drivers who reported elevated symptoms of hyperactivity and impulsivity tended to maintain unsafe following distances. Measures of gap selection, hazard detection, speed, and overall performance were also found to correlate positively with symptoms of inattention, and negatively with symptoms of hyperactivity and impulsivity, indicating poorer performance amongst those who reported elevated symptoms of hyperactivity and impulsivity. Several of these correlations did not reach statistical significance.

Elevated inattentive symptoms were significantly associated with reduced engagement in impatient and aggressive driving errors. Symptoms of hyperactivity and impulsivity however were found to correlate significantly with engagement in impatient errors on the road. A trend for increased engagement in aggressive errors was also observed, but did not reach statistical significance.

Discussion

This is the first known study to investigate ADHD driver performance as a function of naturally occurring influences of demand and arousal in real traffic. Returning to the research questions, it was hypothesised that impaired driving would present most amongst ADHD drivers relative to controls. Treatment was expected to result in improved performance amongst medicated ADHD drivers compared to those who were not medicated. It was secondly hypothesised that group differences in self-reported risky driving and driving history, and in the congruence of self and observer-report would present. Environmental factors impacting task demand, such as vehicle transmission, and driving environment were expected to influence performance amongst drivers with ADHD particularly. It was finally hypothesised that driver aggression would be associated with poorer driving outcomes, and although largely unexplored, that distinct driving styles would be revealed amongst the Predominantly Inattentive and Hyperactive-Impulsive subtypes of ADHD.

In keeping with the predicted outcomes, unmedicated ADHD was associated with significantly worse driving performance in real traffic compared to controls. Unmedicated ADHD drivers were more likely to commit driving errors on the road than were drivers amongst the medicated ADHD and control groups. Most often these errors were the result of inattention or impatience. Treatment was associated with better driving performance and less frequent engagement in driving errors. Driving performance scores amongst medicated ADHD drivers were comparable to, if not better than, those of the control group.

While the hypothesised differences in self-reported infringement history were not found, unmedicated ADHD drivers did report involvement in more crashes than drivers without ADHD, and a trend for involvement in more crashes in which they were found to be at fault. This is consistent with previous findings (Merkel et al., 2013; Murphy & Barkley, 1996). It was also revealed that medicated ADHD drivers were 15.19 times more likely; and unmedicated ADHD drivers 18.96 times more likely to be involved in multiple collisions across the lifetime than were controls.

Both ADHD driver groups reported elevated frequencies of engagement in risky driving behaviours, with the medicated group reporting more frequent errors, lapses, and aggressive violations, and the unmedicated group reporting more aggressive violations and total risky driving behaviours compared to controls. In a previous study employing the three-factor DBQ, Fried et al. (2006) also obtained reports of more frequent engagement in errors, lapses, violations, and total risky driving behaviours from ADHD drivers relative to controls.

Despite reporting similar frequencies of risky driving, medicated ADHD drivers were observed engaging in significantly fewer risky behaviours on the road than were drivers amongst the unmedicated ADHD group. Comparisons of self- and observer-reported measures suggest the driver groups tend to perceive and report the extent to which they engage in risky behaviours differently. While the medicated group largely overestimated the severity and frequency of their risky driving, unmedicated ADHD drivers tended to associate less risk with their own risky driving compared to observer-reports. Control group drivers were able to recognise their tendencies for attentional lapses on the road, but apparently underestimated or were unaware of their engagement in aggressive driving errors.

Underreporting of engagement in risky driving behaviours amongst ADHD drivers was related to poorer overall driving performance in the present study. While impaired risk perception and positive illusory bias was apparent amongst unmedicated ADHD drivers, medicated drivers demonstrated elevated awareness of their tendencies for risky driving, even in comparison to the control group. This suggests that stimulant treatment might also mitigate impairments of risk perception evident amongst unmedicated drivers.

Further exploration of driving skills revealed poor observation and gap selection amongst unmedicated ADHD drivers, and more frequent speeding in relation to medicated ADHD drivers. A tendency for poorer performance compared to controls was also observed across measures with just one exception. ADHD drivers from both the medicated and unmedicated ADHD groups demonstrated excellent hazard response skills. While controls tended to identify hazards effectively, responses to those hazards were more likely to be less effective than those of ADHD drivers. This finding might be related to the resulting changes in task demand during hazard situations. In the same way that researchers have utilised auditory white noise (Söderlund et al., 2007), and more difficult driving challenges (Reimer et al., 2010) to increase load, task demand may also increase when a potentially threatening situation is presented in the driving environment, hence increasing driver arousal, and resulting in a more effective hazard response amongst drivers with ADHD.

Several influences of task demand were found to significantly effect performance amongst ADHD drivers. Coinciding with the findings of Cox and colleagues (2006a), drivers of vehicles with a manual transmission performed better than drivers of automatic vehicles amongst the ADHD groups. 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.

Several participants from the medicated and unmedicated ADHD groups noted without any suggestion that they preferred to drive a manual transmission vehicle because it was more engaging, or because they had noticed their mind would wander less compared to when driving an automatic. This may have influenced the increased proportion of manual vehicles amongst the unmedicated ADHD group (50%), compared to controls (28%).

The driving environment was also found to significantly influence driving performance and errors amongst ADHD drivers. Drivers from both the medicated and unmedicated groups were able to sustain attention to the driving task best during urban driving, resulting in reduced impairment to performance as a result of inattentive errors. Inattentive errors increased during residential and rural driving, and were most frequent during highway driving. This supports the hypothesised influence of environmental demand on attention and performance. As environmental demand decreased, drivers with ADHD, particularly those that were unmedicated, demonstrated increased difficulties with sustained attention.

Impatient and aggressive errors were found to occur during periods of sustained attention to the driving task amongst the unmedicated ADHD group. Driving aggression was related to more frequent involvement in crashes, and at fault crashes. This supports the hypothesised increase in adverse outcomes amongst drivers who demonstrate aggressive driving styles or behaviours.

It was also revealed that diagnostic subtypes of ADHD were related to differing driving styles and impairments. Though associated with poorer hazard response amongst both the medicated and unmedicated ADHD groups, participants reporting elevated symptoms of inattention also maintained safer speeds and following distances, and engaged in fewer impatient and aggressive driving errors on the road. Symptoms of hyperactivity and impulsivity were associated with poor gap selection, and more frequent impatient errors amongst medicated drivers, and driving at unsafe speeds, passenger discomfort, and poor gap selection skills amongst unmedicated ADHD drivers. Further, drivers diagnosed as Hyperactive-Impulsive or Combined type ADHD more frequently travelled at speeds in excess of the speed limit, maintained unsafe following distances, and engaged in errors attributable to impatience and aggression on the road.

The apparently divergent presentation of subtype driving styles calls for differential management of on-road risk. It might benefit drivers diagnosed as Hyperactive/ Impulsive or Combined type ADHD to be mindful of the increased likelihood for venting behaviours after periods of frustrating, or low-stimulus driving. Venting may manifest as impulsive and aggressive driving violations such as dangerous overtaking. Such risk-taking behaviours serve as self-stimulation when arousal is low. Drivers diagnosed as Predominantly-Inattentive type ADHD however are much less predisposed toward impulsive driving acts. Adverse outcomes amongst this subgroup of drivers are more likely to result from attentional lapses during low stimulus driving. Awareness of specific vulnerabilities to poor driving outcomes amongst ADHD subtypes, and recognition of the role of environmental factors in shaping such vulnerabilities, is imperative for development of effective and novel strategies of intervention.

Limitations

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 estimates that males represent between 66% and 90% of all paediatric diagnoses of ADHD (Biederman, Faraone, Monuteaux, Bober, & Cadogen, 2004; Coles, 2012; Ohan & Visser, 2009).

Comorbid depression has been linked with reduced responsiveness to stimulant treatment amongst individuals with ADHD (Sobanski, 2006). The prevalence of depression was high amongst stimulant treated ADHD drivers (41.7%), thus the reported performance means amongst this group may not represent the full efficacy of treatment. A high prevalence of depression was also evident amongst unmedicated ADHD participants (66.7%) compared to controls (5.7%), and is consistent with rates reported in a recent study of comorbidities amongst New Zealand adults with ADHD (Rucklidge, Downs-Woolley, Taylor, Brown, & Harrow, 2014).

Comparisons of self- and observer-reports revealed group discrepancies in the way drivers perceive and report the extent to which they engage in risky behaviours. Thus, validating self-reports through attainment of an objective measure of driving history would have facilitated more confident assertion of the presenting group differences.

Despite these considerations, this study has established several important influences of performance amongst ADHD drivers seldom explored in research to date. This research is the first to document the impact of cognitive factors influencing task demand on the performance of drivers with ADHD in real traffic. While it has been indicated that drivers with ADHD are capable of resisting distraction when task demand is high (Biederman et al., 2012b; Reimer et al., 2010), and that demand can be manipulated to encourage such outcomes (Cox et al., 2006b; Forster et al., 2014), the present study was the first to utilise naturally occurring influences of demand within the driving environment, and to demonstrate a significant interaction of demand and driving performance amongst drivers with ADHD in real traffic.

Conclusion

Corroborating previous findings related to the elevated risk for adverse road safety outcomes, unmedicated ADHD drivers were found to employ fewer safe driving behaviours, and engage more frequently in inattentive and impatient driving behaviours relative to controls. Amongst drivers treated for ADHD however, performance was comparable to, if not better than, that of the control group, attesting further to the efficacy of pharmacological treatments in ameliorating driving impairments.

Drivers with ADHD reported involvement in more crashes, and engaging in more frequent risky driving behaviours compared to controls. Comparisons of self- and observer-reported measures were suggestive of group discrepancies in the way drivers perceive and report engagement in risky behaviours on the road. While medicated ADHD drivers largely overestimated the severity and frequency of their risky driving behaviour, unmedicated ADHD drivers tended to associate less risk with their own driving behaviours compared to observer-reports.

Most significantly, the present study was able to register the impact of cognitive factors influencing task demand on ADHD driver performance in real traffic. Driving environment was found to significantly effect performance and errors amongst ADHD drivers. Attention to the driving task was best during high demand, urban driving. As environmental demand decreased however, unmedicated ADHD drivers in particular experienced increased difficulty attending to the driving task, resulting in more significant impairments to driving performance. Transmission was also found to influence performance amongst ADHD drivers, several of whom noted their preference for driving vehicles with a manual transmission because it was more engaging, or because they had noticed their mind would wander less compared to when driving an automatic vehicle. 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.

These findings further support the critical role of task demand in determining the ability of an individual with ADHD to focus attention in the presence of distractor stimuli. Under high demand driving conditions, individuals with ADHD may become fully engaged in the processing of the driving task, with minimal perception of distractor stimuli. Practical intervention strategies that are able to effectively engage this finding; such as choosing to drive a vehicle with a manual transmission, will present a plausible means of relieving the undermining impacts of distraction on ADHD driver performance, hence also encouraging more optimal outcomes for this established high risk driving population.

The present study also revealed an apparent distinction between the driving styles of individuals presenting Predominantly Inattentive, and Hyperactive-Impulsive subtype symptomologies. Further research is necessary however to establish this link, and should target behaviours that relate to the crux symptoms of each subtype, utilising real driving situations and objective measures of arousal, attention, and aggression, given that ADHD and non-ADHD drivers appear to report conflicting engagement in aggressive driving behaviours compared to observer-reports. Better recognition of specific vulnerabilities on the road will also engender development of more pertinent, hence effective, modes of symptom specific intervention.

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Appendices A to G

Appendix A: Studies of the outcome of intervention strategies

Table A1

Studies of the outcome of pharmacological intervention strategies

Study	Treatment	Total sample	Context	Driving route	Outcomes	Comments
Barkley et al. 2005 USA Crossover, double blind, counterbalanced	MPH-IR (10 mg, low) (20 mg, high), Placebo	54 ADHD (2 dropouts), 40 male, 14 female Aged 18-65 Referral population, IQ>80, licensed [a, b, c]	Simulator	5 x 12 min courses involving day and night time driving on highway, rural, urban roads, driving obstacle course. Speed, speed SD, collisions, signalling, lane deviation, time to complete	High dose MPH reduced impulsiveness on the CPT, and improved collisions, steering variability, signalling, and speed	Simulator sickness Single, nonclinical dose of MPH [d]
Barkley et al. 2007 USA Crossover (reversal), double blind, counterbalanced	ATX (1.2 mg/kg), Placebo	18 ADHD (14 dropouts) 8 male, 10 female Newspaper ads, mailing lists. IQ<80, licensed drivers [b]	Simulator	A 12-min drive through highway, country, and city daytime driving environments with verbal directions. Driven at baseline and 4 weeks/ condition (placebo, drug)	ATX resulted in improved self-ratings of ADHD symptoms, impairments, safe driving behaviour, and simulator driving performance. No effect on observer rated driving behaviour and performance.	Partially funded by a pharmaceutical company.
Biederman et al. 2012a USA Parallel, double blind	LDX 30mg to 70 mg (by week 3), Placebo	61 ADHD (8 dropouts) 38 male, 23 female Outpatients, ADHD-diagnosed, IQ>80, [a, c]	Simulator	43-mile route incorporating urban and highway, driven at baseline and 6 wks Speed, speed SD, excessive speed, lateral lane deviation	LDX promoted fewer accidents and faster hazard reaction times compared to placebo.	No control for time of day of assessment [d]
Biederman et al. 2012b USA Parallel, double blind	LDX 30mg to 70 mg (by week 3), Placebo	61 ADHD (8 dropouts) 38 male, 23 female Outpatients, IQ>80 [a, c]	Nil	DBQ (assessed at baseline and after 6 weeks of treatment)	Improvements in DBQ errors and lapses scales, and non-sig trend toward fewer driving violations when administered LDX compared to placebo.	Completely reliant on self-report
Cox et al. 2000 USA Crossover, double blind, counterbalanced	MPH-IR (10mg), Placebo	13 Total 7 ADHD, 6 Control All male, mean age = 22 Admitted to control diet and sleep [a]	Simulator	16-mile route driven at 9:30 and 15:30 Impaired driving score compiling steering and speed control (SD), braking (missed stop signals, collisions)	MPH-IR improves impaired driving compared to placebo. Medicated ADHD drivers performed as well as non-ADHD subjects.	Very small dose of MPH
Cox et al. 2004a USA Crossover, single blind (driving rater blinded)	MPH-OROS (36-72 mg), No drug	12 ADHD Mean age = 17.8 All male, active drivers [a] School referral, advertising	Own car, blind observer	16-mile route driven at 9:30 and 15:30 Impaired driving score compiling steering and speed control (SD), braking (missed stop signals, collision)	MPH significantly improves inattention amongst male ADHD drivers on the road. Impulsive errors also reduced (not sig.)	25% had comorbid conditions [d]
Cox et al. 2004b USA Crossover, single blind	MPH-OROS (18-144 mg), MPH-IR (30-120 mg)	6 ADHD (1 drop out) Aged 16-19 All male	Simulator	20 minute route driven 4x daily (at 2, 5, 8, and 11pm) Simulator performance across the day (MPH-XR and IR effect profiles)	Immediate-release methylphenidate (IR MPH) taken at 08:00, 12:00, and 16:00 is associated with marked decay of driving performance at 20:00 and 23:00, OROS MPH associated with no decay	Small, all male sample [d]

Cox et al. 2006a USA Crossover, double blind, counterbalanced	MPH-OROS (72 mg), MAS-XR (30 mg), Placebo	35 ADHD, Aged 16-19 19 male, 16 female [a, b]	Simulator	15 minute route driven 3x daily (at 5, 8, and 11pm) Impaired driving score compiling steering and speed control (SD), braking (missed stop signals, collisions)	OROS MPH improved performance compared to placebo and MAS XR, reducing time off road, speeding, inappropriate use of brakes. No sig effect of MAS-XR compared to placebo.	6 of 35 had comorbid conditions [d]
Cox et al. 2008 USA Crossover, double blind, counterbalanced	MPH-OROS (72 mg), MAS-XR (30 mg), Placebo	19 ADHD Aged 16-19 All male [a, b]	Simulator, Real traffic (observer)	Simulator: 15min route driven at 1am. Impaired driving score (steering and speed control (SD), braking) On road: A 16-mile route incorporating rural, highway, urban roads driven at 12:00 am	No deterioration of on-road or simulated performance 16-17 hours post-ingestion of OROS MPH. MAS-XR (se-AMPH ER) may be associated with rebound effect compared to placebo, resulting in 2 to 3x more variability late in the evening.	All male subsample of Cox 2006 Very few hyperactive type participants
Cox et al. 2012 USA Crossover, open-label	MPH-MTS (10-30 mg), No-drug	17 ADHD (8 dropouts) 14 male, 3 female Community advertising, active drivers; collision or citation in past 2 years [b]	Real traffic, Own car, camera	3 months of normal driving/ condition (drug, no-drug) with in-car video monitoring, 10s before and after accelerometer detected change in g-force events, Cox Assessment of Risky Driving Scale	Compared with no-medication condition, MTS saw fewer self-reported total ADHD and inattentive symptoms, risky driving behaviors, and less video-recorded collisions/ problematic driving events.	Received up to $600 reimbursement Very low treatment adherence
Kay et al. 2009 USA Crossover, double blind	Cohort 1: MAS-XR (<50 mg), Placebo Cohort 2: ATX <80 mg, Placebo	Cohort 1: 19 ADHD (4 dropouts) 17 male, 2 female Cohort 2: 16 ADHD 14 male, 2 female	Simulator	3x 20 min drive (2, 7, 12h post ingestion) Low and high stimulus driving with embedded tasks, timed challenge in frustrating, heavy traffic. Total citations, braking, steering and speed control (SD)	Adults with ADHD administered MAS-XR improved overall simulated driving performance versus placebo up to 12 hours after dosing. No sig. differences between ATX and placebo.	Side effects included anorexia, weight loss (MAS-XR), nausea, and abdominal pain (ATX) [d]
Mikami et al. 2009 USA Crossover, double blind, counterbalanced	MPH-OROS (72 mg), MAS-XR (30 mg), Placebo	35 ADHD, Aged 16-19 19 male, 16 female	Simulator	3x 15 min drives (at 5, 8, and 11pm) Impaired driving score compiling steering control (SD), braking (missed stop signals, collisions), speed control.	Genders equivalent with regard to treatment efficacy, tolerability, and side effects.	
Sobanski et al. 2013 GER Parallel, single blind	ATX (<80 mg), Waiting-list (no drug)	43 ADHD (26 dropouts), Aged 18-50 22 male (13 ATX), 21 female (9 ATX)	Real traffic, observer	Fixed, 45 min urban route during weekday rush hour History, official driving record Driver Coping Questionnaire 1 week daily driver diary	Treatment with ATX improved driver inattentive errors, risk-related control errors, and driver skills compared to baseline. Improvements with treatment exclusive to ADHD group.	Participants not blind to condition [d]
Verster et al. 2008 NLD Crossover, double blind, 2-way counterbalanced	MPH-IR (10-30 mg), Placebo (6 to 7 day washout period)	18 ADHD (1 dropout), Aged 21-55 11 male, 7 female	Test vehicle, camera	Fixed, 100 km route driven at 95 km/h SD of lateral lane position (primary measure) and speed. Self-reported performance, driving style, mental effort.	Relative to placebo, improvements obtained in lane deviation only. Participants reported driving was improved and less effortful, less dangerous and foolish.	Instructed to maintain speed of 95 km/h. Limited range of skills (all highway driving)

Note. [a]. Screened for comorbidities, [b]. Screened for stimulant intolerance, [c]. Allowed a washout period for medicated participants, [d]. Completely funded by a pharmaceutical company.

Table A2

Studies of the outcome of behavioural intervention strategies

Study	Intervention	Total sample	Method	Comparison measure	Outcomes	Comments
Cox et al. 2006b USA Crossover, Single blind	Manual transmission	10 ADHD, all male Aged 17-21 ($M = 18.5$)[a]	30 min simulated route driven at 16:30, 19:30, and 22:30 in both auto and manual transmission modes.	Impaired driving score compiling steering and speed control (SD), and braking (missed stop signs, crashes).	Impaired driving score improved during manual transmission mode. Improvements similar to those observed with MPH-OROS treatment. Self-reports of more attentive driving	Pilot study with small sample
Forster et al. 2014 USA Between groups	Increased Perceptual Load	34 Total 17 ADHD, clinically referred 17 community controls	Participants identified target stimulus in a letter search display, and ignored colourful distractor images during low perceptual load (simple search), and increased perceptual load (more letters, increased difficulty)	Mean reaction times and percentage error rates	Twice the distractor interference evident amongst ADHD, resulting in poorer RTs compared to controls Increasing perceptual load significantly reduced distractor interference for ADHD and controls	Non-driving study
Poulsen et al. 2010 AUS Between groups	Hazard Perception Training	20 ADHD All male, aged 16-58 Control ($n = 10$) Hazard perception ($n = 10$)	Brief, office based intervention Attending to driving conditions, anticipating behaviours of other road users, and quick identification of hazards in driving environment	Hazard perception testing at baseline and post intervention	Hazard perception training improved hazard awareness and reaction times compared to controls	Small sample
Soderlund et al. 2007 SWE Between groups	Auditory White Noise	42 Total 21 ADHD, all male 21 community controls	Participants completed a high and low memory task in the presence, or absence, of auditory white noise	Number of correctly recalled sentences under noise/ no noise conditions	Noise improved performance amongst ADHD group, but impeded performance of controls. Individuals with ADHD require more noise for optimal cognitive performance compared to controls	Non-driving study

Note. [a]. Screened for comorbidities.

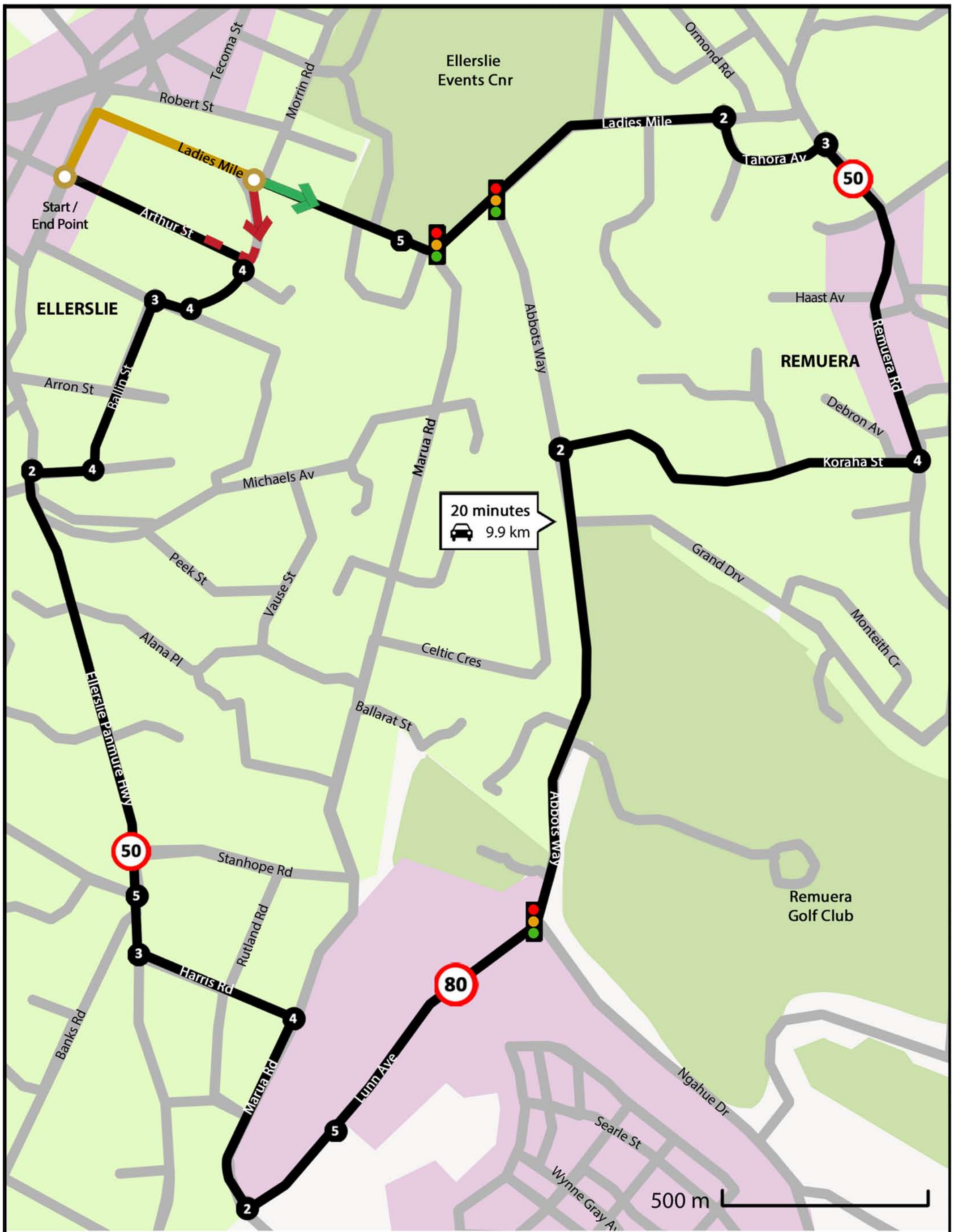
Appendix B: Group Recruitment Posters


School of Psychology
THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato
ATTENTION AND DRIVING
Nastassia Randell
Supervised by Assoc. Prof's Samuel Charlton and Nicola Starkey
LICENSED ACTIVE DRIVERS
NEEDED FOR DRIVING RESEARCH
This 1 hour study will involve answering some questions about your experience of attention and driving, followed by a 20 minute drive.
Drivers will need:
A current restricted or full NZ license
Your own vehicle for the driving part of the study
You will receive a $20 MTA voucher (for fuel and other goods) as a thank you.
All information collected will remain completely confidential.
Please contact Nastassia if you are interested, or have any questions.
Nastassia Randell
n.randell@live.com
0211 866 613
This study has been approved by the University of Waikato Psychology Department Research and Ethics Committee. Ethical concerns can be expressed to Assoc. Prof John Perrone at jpnz@waikato.ac.nz

MAP OF THE BOTANY DOWNS DRIVING ROUTE

- Urban
- Residential
- Rural
- Safety route
- Driving route

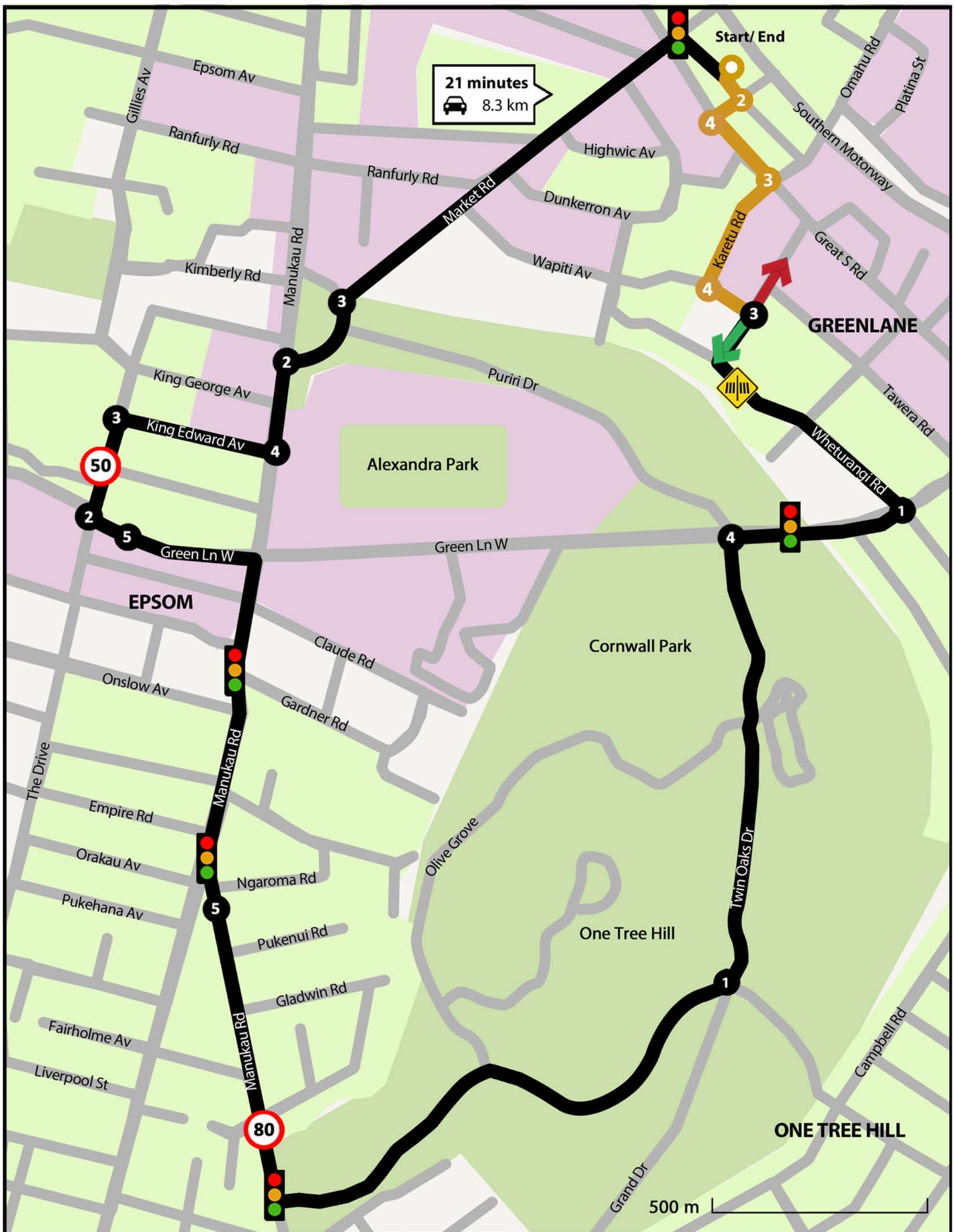
1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right



MAP OF THE ELLERSLIE DRIVING ROUTE

- Urban
- Residential
- Rural
- Safety route
- Driving route

1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right



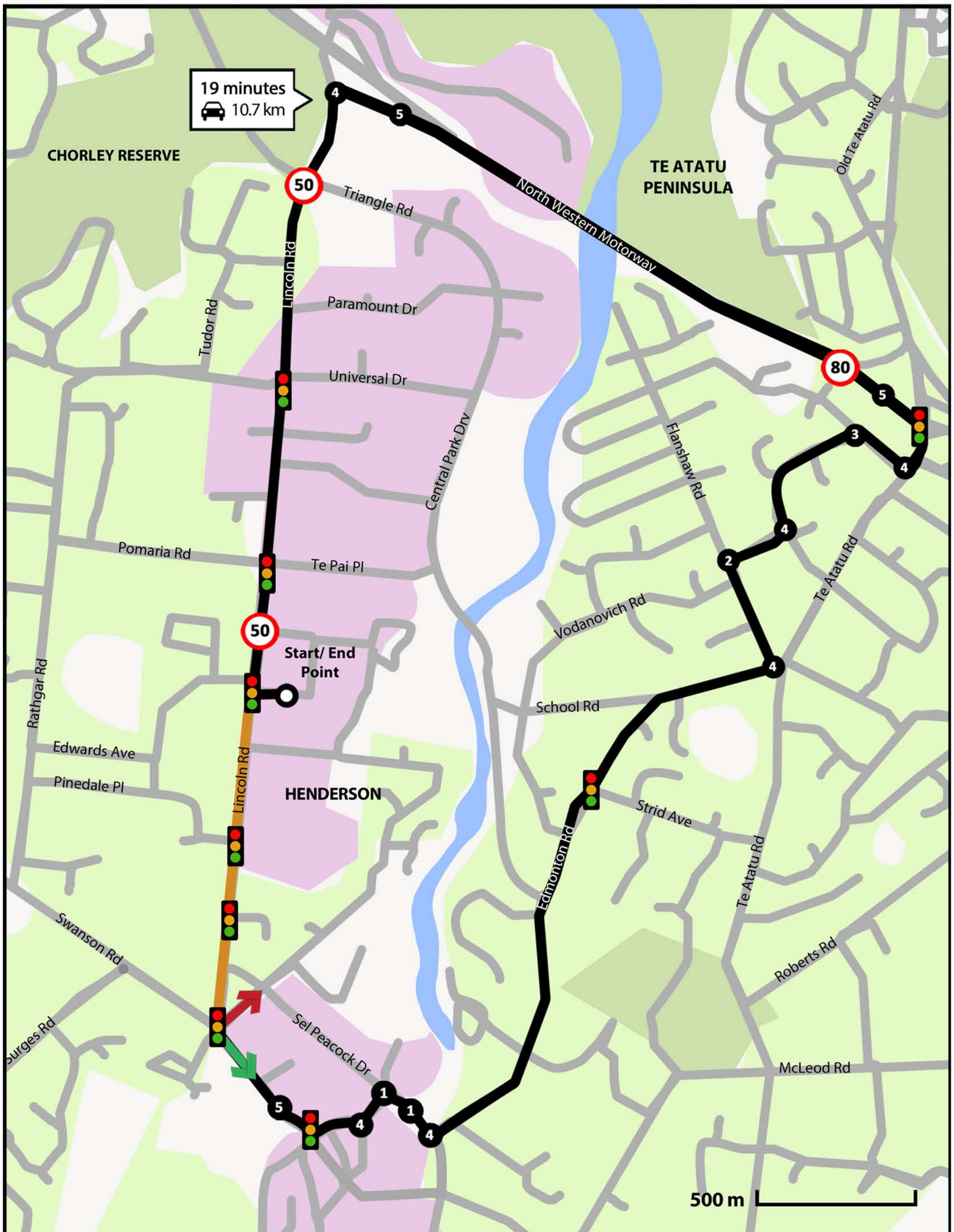
MAP OF THE EPSOM DRIVING ROUTE

- Urban
- Residential
- Rural
- Safety route
- Driving route

1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right

MAP OF THE HAMILTON DRIVING ROUTE

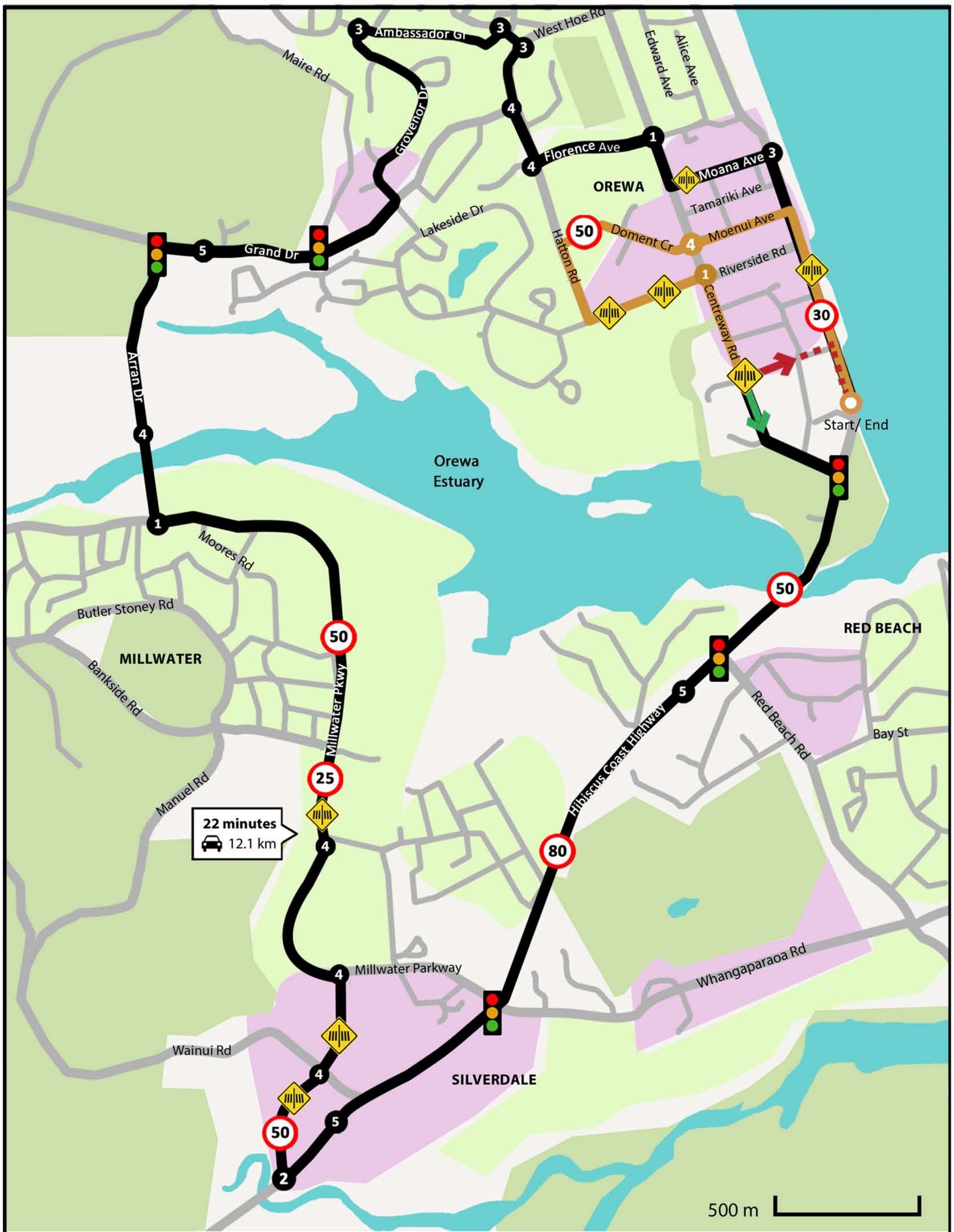
Urban	1 Right turn at a roundabout
Residential	2 Right turn into a side street
Rural	3 Right turn at a controlled intersection
Safety route	4 Left turn at a controlled intersection
Driving route	5 Lane change left or right



MAP OF THE HENDERSON DRIVING ROUTE

- Urban
- Residential
- Rural
- Safety route
- Driving route

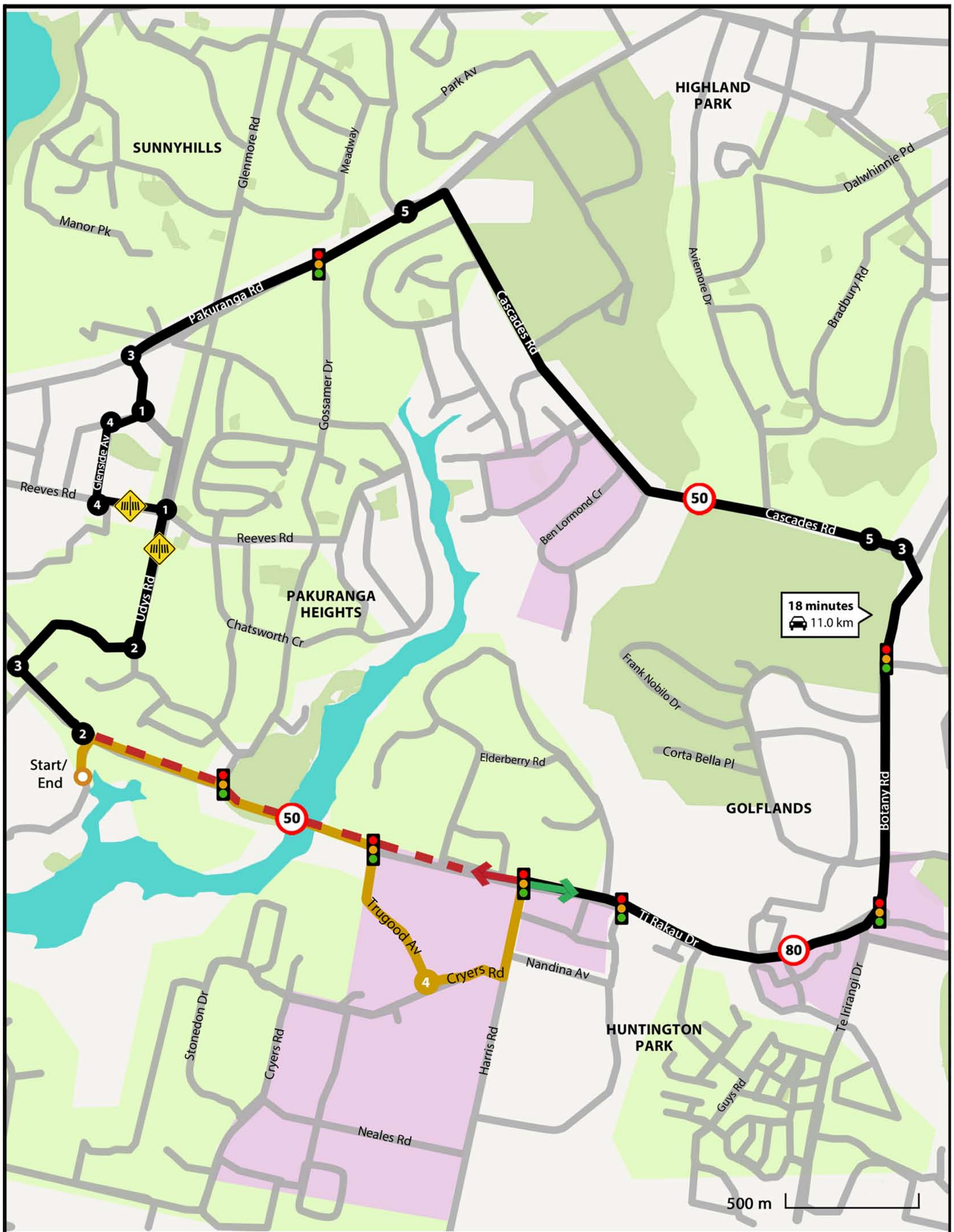
1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right



MAP OF THE OREWA DRIVING ROUTE

- Urban
- Residential
- Rural
- Safety route
- Driving route

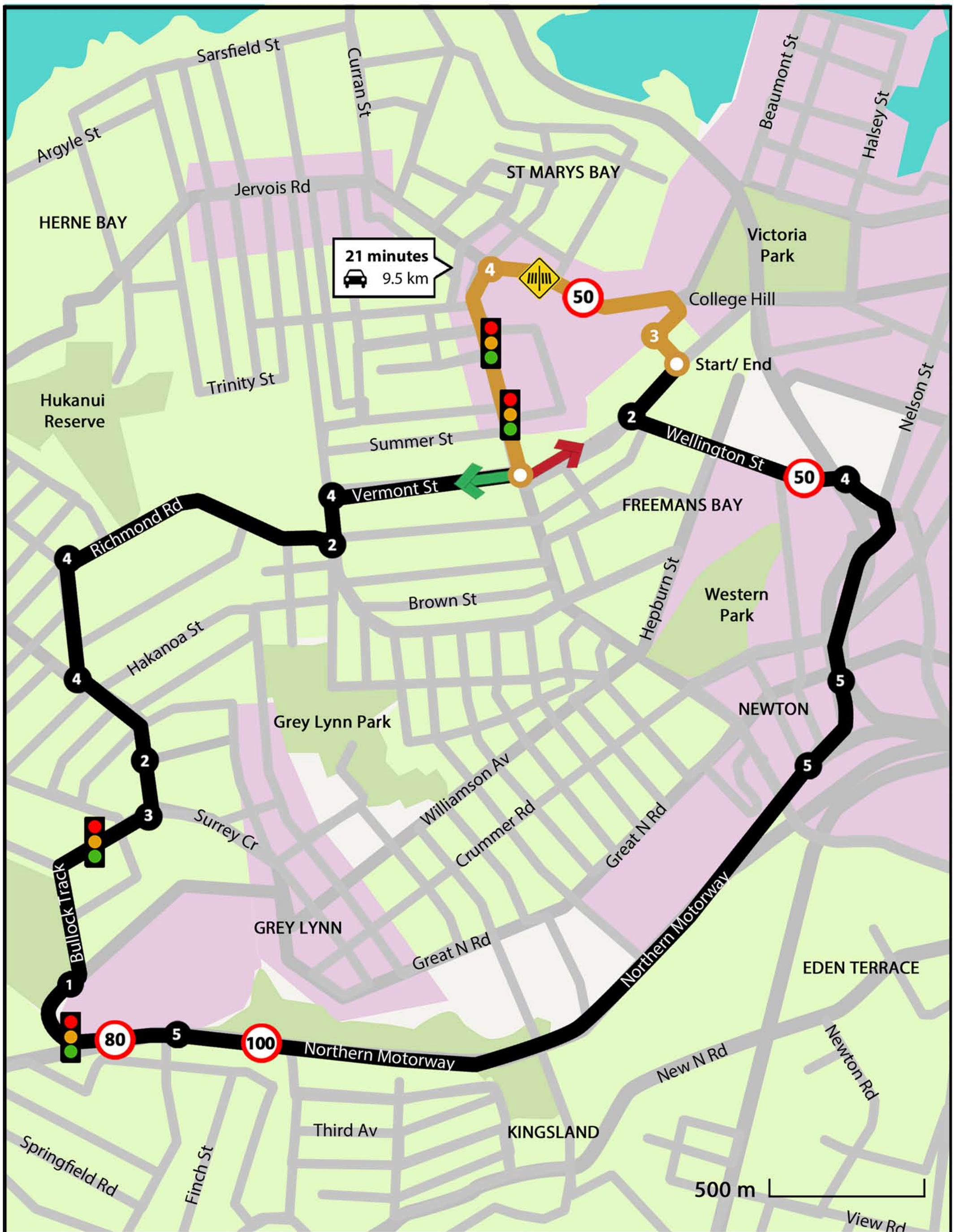
1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right



MAP OF THE PAKURANGA DRIVING ROUTE

- Urban
- Residential
- Rural
- Safety route
- Driving route

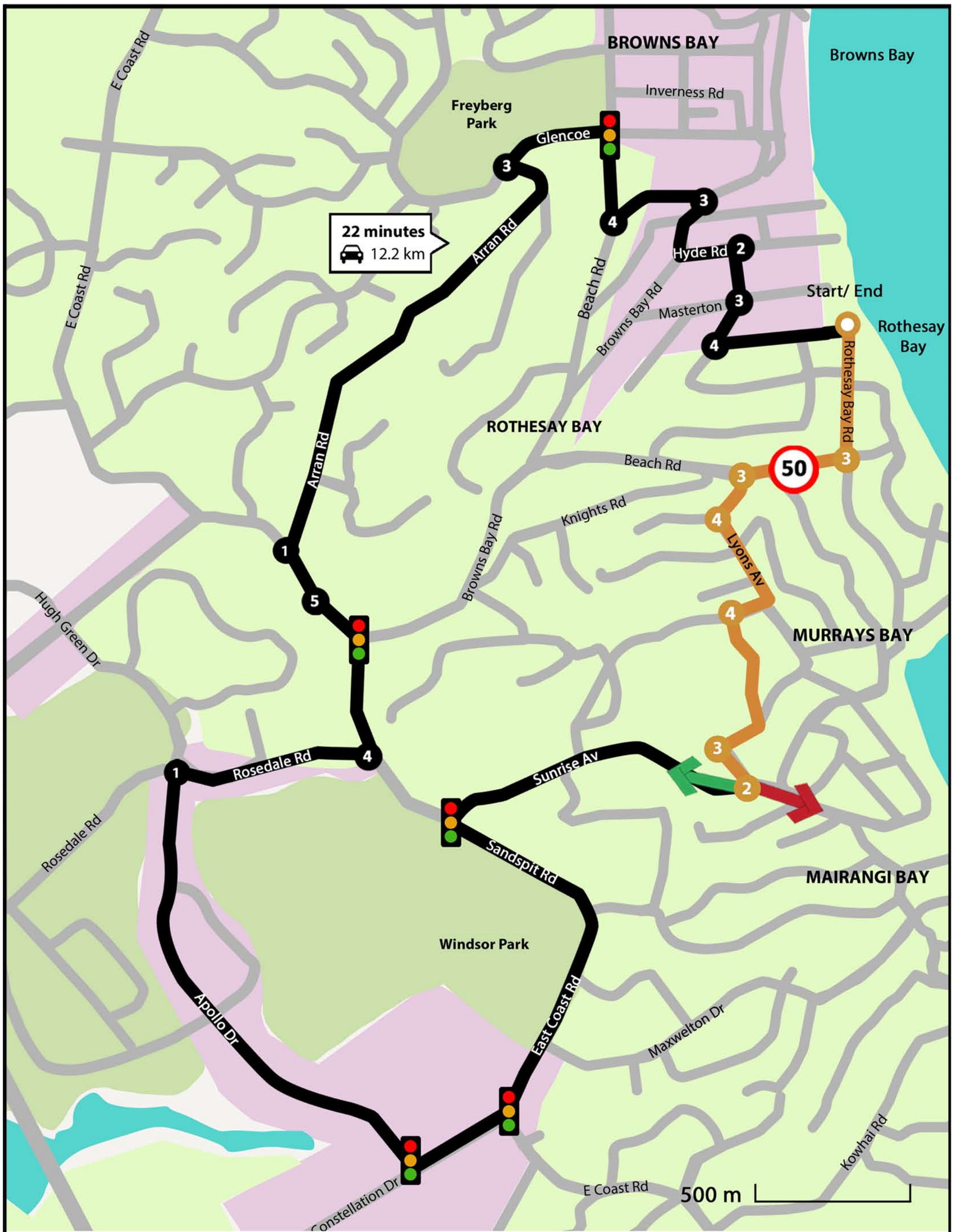
1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right



MAP OF THE PONSONBY DRIVING ROUTE

- Urban
- Residential
- Rural
- Safety route
- Driving route

1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right



MAP OF THE ROTHESAY BAY DRIVING ROUTE

- Urban
- Residential
- Rural
- Safety route
- Driving route

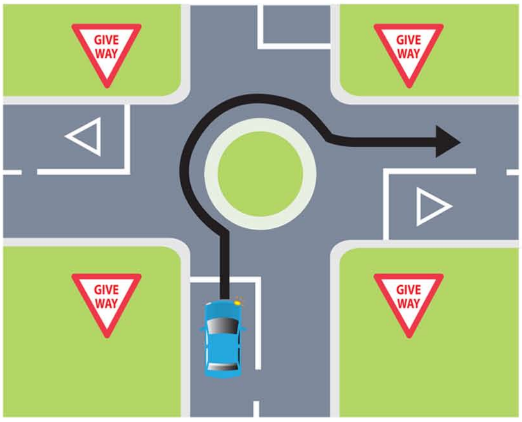
1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right

MAP OF THE TAURANGA DRIVING ROUTE

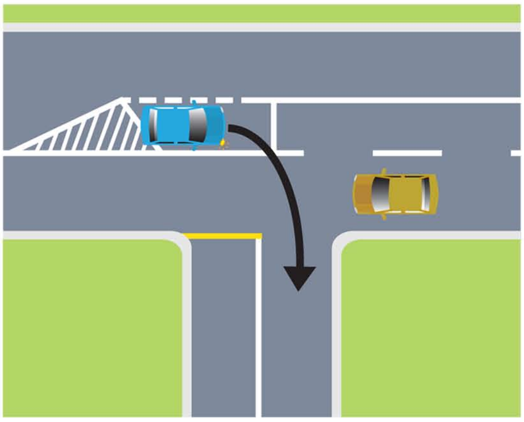
- Urban
- Residential
- Rural
- Safety route
- Driving route

1. Right turn at a roundabout
2. Right turn into a side street
3. Right turn at a controlled intersection
4. Left turn at a controlled intersection
5. Lane change left or right

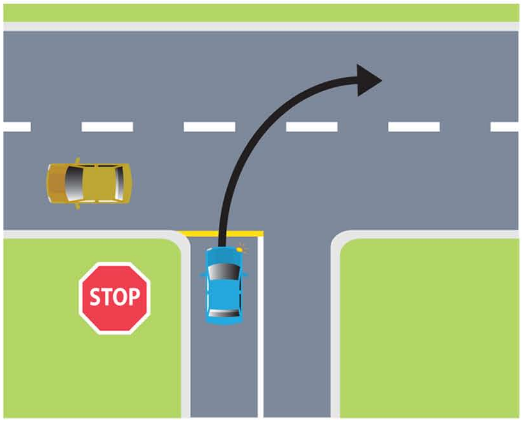
Appendix D: Specific Driving Task Diagrams



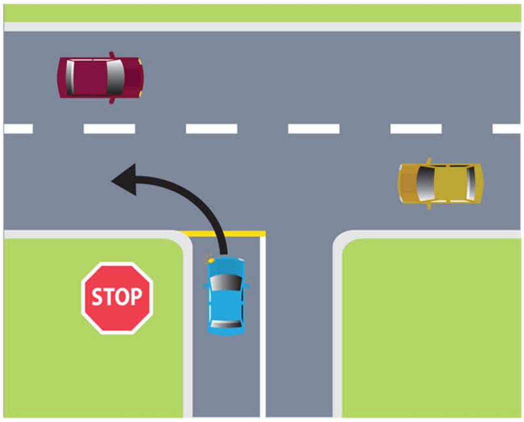
1. Right turn at a roundabout



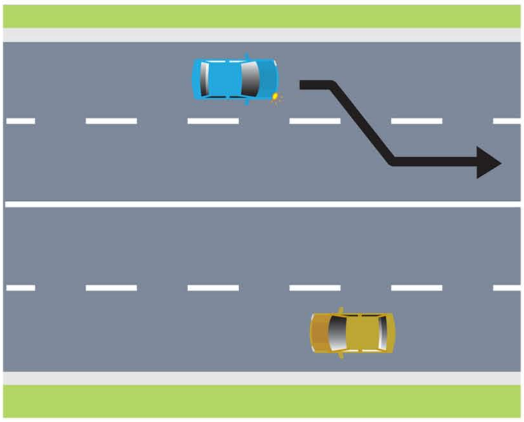
2. Right turn into a side street



3. Right turn at a controlled intersection



4. Left turn at a controlled intersection



5. Lane change left or right

Appendix E: Scoring the Specific Driving Tasks

1. Right turn at a roundabout			
Item	**0 point score**	**0.5 point score**	**1 point score**
Mirror check before signal and brake	Fails to check relevant mirrors		Checks location of tail vehicle and surrounding traffic
Signals right for 3 s on approach	Fails to signal	Signals R for less than 3 s	Signals R for 3 s prior to entry
Head check before turn	Fails to check in either directions before advancing	Head checks right, but fails to look in direction of travel	Checks for traffic from both directions, checks the direction of travel before turn
Selects first available safe gap	Poor confidence, rejects several safe gaps	Hesitant, rejects safe gaps	Recognises and selects first available safe gap
Rejects unsafe gaps	Selects an unsafe gap in the traffic	Indecision, late rejection Selects moderately risky gap	Rejects unsafe gaps
Signals left before exiting	Fails to signal L before exiting RA		Signals L before exiting RA
Performs confidently	Unconfident, noticeably distressed or unsure	Some hesitance demonstrated	Performs task confidently
Performs comfortably	Erratic handling/ speed causes discomfort or displacement	Minimal discomfort as a result of vehicle handling	Corners smoothly and comfortably
Maintains appropriate speed	Exceeds by more than 10 km/h or for longer than 5 s	Exceeds by less than 10 km/h for up to 5 s	Abides by speed limit throughout

2. Right turn into a side street			
Item	**0 point score**	**0.5 point score**	**1 point score**
Mirror check before signal and brake	Fails to check relevant mirrors		Checks distance of tail vehicle and location of surrounding traffic using mirrors
Safe lateral position for turn	Unnecessarily/ dangerously impedes the flow of traffic from either direction		Maintains a safe lateral position to allow traffic flow, uses flush lane where possible
Signals for 3 s on approach	Fails to signal	Signals late or for less than 2 s (some warning)	Activates appropriate signal for 3 s before turning
Head check	Fails to check for traffic before advancing	Checks for oncoming traffic, but fails to look in direction of travel	Checks for both oncoming traffic, and that in the direction of travel
Selects first available safe gap	Lacking confidence, rejects several safe gaps	Demonstrates hesitance, rejects safe gaps	Recognises and selects first available safe gap
Rejects unsafe gaps	Selects an unsafe gap in the traffic	Indecision, late rejection Selects moderately risky gap	Rejects unsafe gaps
Performs confidently	Unconfident, noticeably distressed or unsure	Some hesitance demonstrated	Performs task confidently
Performs comfortably	Erratic handling/ speed causes discomfort or displacement	Minimal discomfort as a result of vehicle handling	Corners smoothly and comfortably
Maintains appropriate speed	Exceeds by 10 km/h on approach, or turns at unsafe speed	Exceeds by < 10 km/h on approach, turns at uncomfortable speed	Abides by speed limit on approach, reduces speed to corner

3. Right turn at a controlled intersection			
Item	**0 point score**	**0.5 point score**	**1 point score**
Mirror check before signal and brake	Fails to check relevant mirrors		Checks distance of tail vehicle and location of surrounding traffic using mirrors
Indicates for 3 seconds on approach	Fails to signal	Signals late or for less than 2 s (some warning)	Activates appropriate signal for 3 s before turning
Abides by Stop/ Give way rules	Fails to follow rule, does not slow on approach	Does not come to a complete stop	Stops as indicated at stop sign or slows to safely give way
Head check	Fails to check for traffic before advancing	Checks for oncoming traffic, but fails to look in direction of travel	Checks for both oncoming traffic, and that in the direction of travel
Selects first available safe gap	Lacking confidence, rejects several safe gaps	Demonstrates hesitance, rejects safe gaps	Recognises and selects first available safe gap
Rejects unsafe gaps	Selects an unsafe gap in the traffic	Indecision, late rejection Selects moderately risky gap	Rejects unsafe gaps
Performs confidently	Unconfident, noticeably distressed or unsure	Some hesitance demonstrated	Performs task confidently
Performs comfortably	Erratic handling/ speed causes discomfort or displacement	Minimal discomfort as a result of vehicle handling	Corners smoothly and comfortably
Maintains appropriate speed	Turns at inappropriate speed	Does not slow appropriately on approach	Abides by speed limit, reduces speed for corner

4. Left turn at a controlled intersection			
Item	**0 point score**	**0.5 point score**	**1 point score**
Indicates appropriately	Fails to signal	Signals late or for less than 2 s (some warning)	Indicates left for 3 seconds
Abides by Stop/ Give way rules	Fails to recognise or follow signs, does not slow on approach	Does not come to a complete stop	Stops as indicated at stop sign or slows to safely give way
Head check	Fails to check for traffic before advancing	Checks for oncoming traffic, but fails to look in direction of travel	Checks for both oncoming traffic, and that in the direction of travel
Selects first available safe gap	Lacking confidence, rejects several safe gaps	Demonstrates hesitance, rejects safe gaps	Recognises and selects first available safe gap
Rejects unsafe gaps	Selects an unsafe gap in the traffic	Indecision, late rejection Selects moderately risky gap	Rejects unsafe gaps
Performs confidently	Unconfident, noticeably distressed or unsure	Some hesitance demonstrated	Performs task confidently
Performs comfortably	Erratic handling/ speed causes discomfort or displacement	Minimal discomfort as a result of vehicle handling	Corners smoothly and comfortably
Maintains appropriate speed	Turns at inappropriate speed	Does not slow appropriately on approach	Abides by speed limit, reduces speed for corner

5. Lane change left or right			
Item	**0 point score**	**0.5 point score**	**1 point score**
Mirror check	Fails to check relevant mirrors	No head check	Checks distance of tail vehicle and intention of traffic in adjacent lanes
Signals 3 s	Fails to signal	Signals late or for less than 2 s (some warning)	Activates appropriate signal for 3 s before turning
Selects first available safe gap	Lacking confidence, rejects several safe gaps	Demonstrates hesitance, rejects safe gaps	Recognises and selects first available safe gap
Rejects unsafe gaps	Selects an unsafe gap in the traffic	Indecision, late rejection Selects moderately risky gap	Rejects unsafe gaps
Resumes safe following distance	Fails to resume a safe distance < 1 s	Slow to resume a safe distance Resumes a distance of 1-2 s	Resumes appropriate distance as soon as safely possible
Performs confidently	Unconfident, noticeably distressed or unsure	Some hesitance demonstrated	Performs task confidently
Performs comfortably	Erratic handling/ speed causes discomfort or displacement	Minimal discomfort as a result of vehicle handling	Corners smoothly and comfortably
Maintains appropriate speed	Exceeds by more than 10 km/h or for longer than 5 s	Exceeds by less than 10 km/h for up to 5 s	Abides by speed limit throughout

Appendix F: Research Information Sheet

Ψ School of Psychology

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

RESEARCH INFORMATION SHEET

Attention and Driver Performance

My name is Nastassia Randell and I am a psychology student at the University of Waikato. I am currently writing my Masters thesis on attention and driver performance. This study will look at the influences of attention, distractibility, and the driving environment on performance.

I require drivers aged 17 and over both with and without attention deficit/hyperactivity-disorder (ADHD) to be involved in my research. Both medicated and unmedicated ADHD drivers are required. All participants must hold a current restricted or full drivers licence.

What is involved?

The testing session will take just over an hour to complete, and consist of several short questionnaires as well as an on-road driving task. The meeting location will be determined when you have confirmed your interest in the research. You will be required to drive your own vehicle for the on-road element of the research whilst directed by an in-car observer.

Participants will receive a $20 MTA voucher (for fuel and other goods) to reimburse expenses. Please ensure you have sufficient fuel for the driving task, and that your warrant of fitness (WOF) and registration are current.

Things to remember about your rights as a participant:

- You have the right to decline participation in any part of the research
- You may withdraw during assessment without penalty
- Your identity will remain confidential
- You may email Nastassia with any questions regarding your participation in the research

Privacy

Your identity will remain completely confidential. After assessment is complete, data will be assigned to groups thus no longer linked to your name, and kept in a locked cupboard or on a password protected computer.

Funding

The researcher has received a scholarship from the Traffic and Road Safety Research Group (TARS) at the University of Waikato.

Results

Information will be used in a Master's thesis, and may be published in a journal, online, or presented in a seminar. Should you wish to receive a summary of these findings you can indicate so on the participant consent form. This will be emailed to you following completion of the research.

Complaints

This research has been approved by the School of Psychology Human Research Ethics Committee. Any ethical concerns can be expressed to Professor Mike O'Driscoll on psyc0181@waikato.ac.nz

Where to from here?

Your participation will be appreciated immensely. If you require further information, or have any questions, please do not hesitate to contact Nastassia on the details provided.

Nastassia Randell	Assoc. Prof Samuel Charlton	Assoc. Prof Nicola Starkey
n.randell@live.com	samiam@waikato.ac.nz	nstarkey@waikato.ac.nz
021 186 6613	(07) 838 4466, ext. 6534	(07) 838 4466, ext. 6472

Appendix G: Research Consent Form

Ψ School of Psychology

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

RESEARCH CONSENT FORM

Researcher copy

Attention and Driver Performance

I have read the information sheet provided, and understand that:

- I have the right to decline participation in any part of the research
- I can withdraw at any time during assessment without penalty
- My identity will remain confidential and will not be disclosed
- Data (excluding my identity) will be used in a Master's thesis, and may be published in a journal, online, or presented in a seminar
- Any ethical concerns can be expressed to Professor Mike O'Driscoll on psyc0181@waikato.ac.nz

I (your name) ________________________________ consent (or otherwise) to the following:

To participate in this study	Yes / No
For the researcher to contact the New Zealand Transport Agency for, and for the NZ Transport Agency to disclose to the researcher, traffic infringement offence history information related to active demerit points recorded on my driver licence record	Yes / No
If yes, please provide NZ Drivers Licence number: ________________ *Date of birth:* __________	
To the use of a small suction-mounted camera for the on-road driving task	Yes / No
To be contacted regarding participation in further research	Yes / No

Please send me a summary of the findings: ☐ Yes (email) ________________________________

☐ No

Participant signature: ____ Date: ____________

Researcher signature: ____ Date: ____________

Ψ School of Psychology

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

RESEARCH CONSENT FORM

Participant copy

Attention and Driver Performance

I have read the information sheet provided, and understand that:

- I have the right to decline participation in any part of the research
- I can withdraw at any time during assessment without penalty
- My identity will remain confidential and will not be disclosed
- Data (excluding my identity) will be used in a Master's thesis, and may be published in a journal, online, or presented in a seminar
- Any ethical concerns can be expressed to Professor Mike O'Driscoll on psyc0181@waikato.ac.nz

I (your name) ____ consent (or otherwise) to the following:

To participate in this study	Yes / No
For the researcher to contact the New Zealand Transport Agency for, and for the NZ Transport Agency to disclose to the researcher, traffic infringement offence history information related to active demerit points recorded on my driver licence record	Yes / No
To the use of a small suction-mounted camera for the on-road driving task	Yes / No
To be contacted regarding participation in further research	Yes / No

Participant signature: ____ Date: ________________

Researcher signature: ____ Date: ________________