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A Driver Training Program Intervention for Student Drivers with Autism Spectrum Disorder: A Multi-site Randomised Controlled Trial

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Running head: AUTISM DRIVING TRAINING PROGRAM

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Abstract

The purpose of this multisite randomised controlled trial was to evaluate the effectiveness of the Driving Training Program, an intervention designed for student drivers with autism spectrum disorder (ASD). Participants were 72 student drivers with ASD (ages 16-31) who were randomly assigned to the intervention or control group. Student drivers received 10 driving lessons with a professional driving instructor and two on-road observational drives via a standardised driving route. The Driving Performance Checklist evaluated driving performance of student drivers taking part in the intervention. Both groups showed an improvement in driving performance, however, the extent of improvement between groups was not significant. Findings showed promising intervention efficacy for training student drivers with ASD to drive.

Key words: Autism Spectrum Disorder, learner drivers, driving training, transportation, community mobility

A Driver Training Program Intervention for Student Drivers with Autism Spectrum

Disorder: A Multi-site Randomised Controlled Trial

Abstract

The purpose of this multi-site randomised controlled trial was to evaluate the effectiveness of a Driving Training Program, an intervention designed for student drivers with autism spectrum disorder (ASD). Participants were 72 student drivers with ASD (ages 16-31) who were randomly assigned to an intervention or control group. Student drivers received 10 driving lessons with a professional driving instructor via a standardised driving route. The Driving Performance Checklist was used as the outcome measure to evaluate the driving performance of student drivers during on-road pre- and post-observational drives. Both groups showed an improvement in driving performance, however, the extent of improvement between groups was not significant. Findings showed promising intervention efficacy for training student drivers with ASD to drive.

Key words: Autism Spectrum Disorder, learner drivers, driving training, transportation, community mobility

1 Individuals with Autism Spectrum Disorder (ASD) can find it challenging to engage in
2 community-based activities in a meaningful way, leaving many to experience isolation,
3 depression and anxiety (Hendricks & Wehman, 2009; Tyler, 2013). Finding ways to remove
4 barriers to community inclusion for individuals with ASD is vital to improving their
5 independence. Transportation requirements and community mobility are among the core
6 issues impacting the low levels of independence outside the home (Precin, Otto, Popalzai, &
7 Samuel, 2012). Transportation challenges create barriers to participating independently in
8 activities that can lead to improvements in the quality of life for individuals with ASD
9 (Hendricks & Wehman, 2009; Lindsay, 2016). For instance, gaining a driver's licence is a
10 critical link to community mobility allowing for the opportunity to engage in education,
11 employment, health care, community participation, social relationships and leisure pursuits
12 (Classen, Monahan, & Wang, 2013; Cox et al., 2016; Lindsay, 2016; Reimer et al., 2013).
13 Gaining a driver's licence is considered a rite of passage during the transition from
14 adolescence to adulthood and learning to drive can play an important role in adolescent
15 development (Cox et al., 2016; Hendricks & Wehman, 2009). However, for individuals with
16 ASD, learning to drive and gaining a licence can be challenging with research suggesting that
17 acquiring safe driving skills can be fraught with complexity (Almberg et al., 2015; Chee, Lee,
18 Patomella, & Falkmer, 2019; Classen, Monahan, & Wang, 2013; Huang, Kao, Curry, &
19 Durbin, 2012; Lindsay, 2016).

20 Driving is a complex task for all individuals to master as it requires developing multiple
21 skills at an operational, tactical, strategic and behavioural level (Peräaho, Keskinen, &
22 Hatakka, 2003). In addition to learning these fundamental skills, individuals with ASD face
23 additional barriers to attaining driving skill mastery and continued on-road safety. Individuals
24 with ASD are less likely to gain their driver's licence when compared to their typically
25 developed (TD) peers; they tend to drive less often and stay closer to their residence once

1 licensed (Almberg et al., 2015; Cox, Reeve, Cox, & Cox, 2012; Cox et al., 2016). These
2 patterns appear to be akin to the characteristics of autism, such as restricted and repetitive
3 behaviours, and social and communication difficulties (American Psychiatric Association
4 2013). Previous studies have also reported that the driving behaviours of individuals with
5 ASD appear to be affected by factors such as executive function deficits (e.g., working
6 memory, planning, mental flexibility, attention, and inhibition), motor-coordination (e.g.,
7 weak central coherence and motor planning), social communication (e.g., reading facial
8 expressions) and emotional regulation (e.g., anxiety) (Almberg et al., 2015; Classen &
9 Monahan, 2013; Cox et al., 2016; Sheppard, Ropar, Underwood, & van Loon, 2010; Wade et
10 al., 2014). Little is known about how these complex issues impact on the driving performance
11 of student drivers with ASD or whether they would benefit from driving training designed to
12 account for potential challenges.
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29 To date, research exploring the driving behaviours and driving performance of
30 individuals with ASD has been dominated by simulator research (Classen, Monahan, &
31 Hernandez, 2013; Classen, Monahan, & Wang, 2013; Cox et al., 2016; Reimer et al., 2013).
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33 Individuals with ASD have been shown to differ in driving performance when compared to
34 TD controls. For example, Cox et al. (2016) reported poorer simulator performance such as,
35 slower reaction times for steering and inconsistent lane position maintenance, suggesting that
36 deficits in working memory play an important role in these performance differences. Classen,
37 Monahan, and Hernandez (2013) compared adolescents with ASD and TD controls on
38 simulated driving skills considered to be critical to driving safety. They found that the group
39 with ASD performed poorer on right eye acuity, cognition, visual motor integration, motor
40 coordination, managing operation skills for controls, speed regulation, lane maintenance,
41 signalling and adjusting to unexpected events. Using a driving simulator, Reimer et al. (2013)
42 found that individuals with ASD shifted their gaze away from more demanding stimuli to less
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1 demanding stimuli in their visual field when tasks involving cognitive demand were
2 increased. Avoiding visual stimuli as cognitive demands increase is problematic and may
3 impact on a driver's ability to perceive hazards and to respond to them in a timely fashion,
4 which is critical to on-road driving safety. Simulator research highlights the need for the
5 development of autism-specific driving training that will improve functional outcomes for
6 driving performance and behaviours (Cox et al., 2016). However, none of these studies were
7 conducted in a real-world, naturalistic context (Lindsay, 2016; Wilson et al., 2018). As such,
8 there is a need for a targeted approach to training individuals with ASD to drive in a real-
9 world environment. To our knowledge, fully tested autism-specific on-road driving training
10 interventions have not been conducted.

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12 This paper reports on a driving training intervention designed as an autism-specific
13 program grounded in what is known to work in driving training and modified to account for
14 the needs of individuals with ASD. Driving training and education designed to accommodate
15 the challenges faced by individuals with ASD may lead to improvements in achieving
16 meaningful community mobility. The aim of this study was to evaluate the efficacy of an
17 innovative Driving Training Program (DTP), an intervention designed to improve on-road
18 driving performance in student drivers with ASD, compared with those who receive
19 conventional driving lessons (treatment as usual driver training). The randomised controlled
20 trial (RCT) was conducted across two sites in Australia (Perth and Sydney) between August
21 2018 and July 2019. The specific research questions were:

- 22 1. Are the student drivers in the intervention group equivalent to those in the treatment
23 as usual group?
- 24 2. Do student drivers who receive the DTP intervention show greater improvement in
25 driving performance compared to student drivers in the treatment as usual group?
- 26 3. Which variables moderated driving performance?

Methods

This study was a parallel-group multi-site RCT. The study was conducted through [REDACTED] universities. Approval was granted by the Research Ethical Committees of [REDACTED] and [REDACTED]. Information sheets were provided to all participants who provided written consent. This research also conformed to the Australian Code for the Responsible Conduct of Research (National Health and Medical Research Council, 2007).

Participants

Participants were 72 student drivers with ASD who held a learner permit licence (38 from Perth and 34 from Sydney). Participants aged 16 years and above were recruited through convenience sampling using posters and expressions of interest generated through autism research events and community organisations that serve people with ASD in greater Perth and Sydney areas. The inclusion criteria for the student drivers with ASD included: (1) self-reported diagnosis of ASD that was verbally verified as being diagnosed by a qualified professional, (2) current valid learner permit licence, (3) visual acuity of 6/12 m (20/40 ft) or better on the Meter 2000 Series Revised ETDRS chart, (4) less than 5 hours driving training with a professional driving instructor, and (5) being able to independently undertake the tasks described in the procedure section (e.g., drive a vehicle and use a computer). Participants were excluded if they held a provisional or full driver licence. The average age of student drivers was 18.5 years (SD = 3.37), with more males ($n = 56$), than females ($n = 14$) or other ($n = 2$) taking part in the study. In total, 82 participants were assessed for eligibility with 77 randomised to take part in the study. The attrition rate was low with 5 participants choosing to not take part in the study prior to commencement and 5 participants dropping out of the study after starting due to various personal reasons such as anxiety, scheduling difficulties and travelling distance (see Consort, Figure 1).

Professional driving instructors were recruited in this study to train the student drivers with ASD to drive. In total, 13 professional driving instructors (6 in Perth and 7 in Sydney) were recruited; all driver instructors held a current recognised driving instructor licence in their state (this included a national police check).

<INSERT FIGURE 1 ABOUT HERE>

Group Randomisation

A randomisation schedule was prepared by external research staff not involved with the program; hence, all researchers were blinded to participant's group allocation. The student drivers with ASD were randomly assigned (1:1) to either the intervention group (number 1) or the treatment as usual control group (number 2) using a random number generator ("RANDOM.ORG," 2019). Upon enrolment in the program the student drivers were allocated a number which was placed into a sealed envelope and opened with the participants after completion of their baseline assessment. The same procedure was repeated for the professional driving instructors who were randomised to instruct student drivers in either the intervention or control group and were informed of their group assignment prior to taking part in a training session. Once all participants were allocated to either the intervention or control group, each student driver was assigned to a professional driving instructor.

Intervention

The DTP intervention delivery consisted of both an on-road driving training component and an on-line reporting component. The research team developed the DTP, to address the driving education and training needs of student drivers with ASD when learning to drive. The intervention development team consisted of occupational therapists, psychologists, and nursing research professionals with extensive experience working in the areas of autism, transportation and people with disabilities. Knowledge of the driving performance and behaviours of people with ASD and autism-specific driving training education practices, were

ascertained via consultation with industry experts, such as occupational therapy driving assessors, driving instructors as well as a scoping review (Wilson et al., 2018) and comprehensive literature searches. This information was used to structure the driving training components of the DTP by combining the driving training recommendations for people with ASD (Tyler, 2013; Wilson et al., 2018), with driving training methods used to teach TD student drivers (Winston et al., 2015) and drivers with disabilities (Falkmer, Gustavsson, Nielsen, & Peters, 2000). The Goals for Driving Education (GDE) framework (Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002; Michon, 1985; Peräaho et al., 2003) and International Classification of Functioning (ICF) framework (Mikami et al., 2018; WHO, 2001) were used to provide an integrated conceptual approach, taking into account all important factors relevant in driving training and education.

Training Manual

A driving training manual was developed consisting of autism-specific information on driving readiness and instructions on how to use five graded modules based on driving environments that started with a focus on basic driving skill mastery and progressed to more complex driving skill mastery. The following modules consisted of multiple activities and tasks designed to guide driving education for student drivers with ASD: (1) *Off Road* module focused on activities and tasks to be done as the student drivers prepare for starting driving lessons, (2) *Closed Circuit* module focused on activities and tasks to be conducted in closed circuit environments (e.g., car park), (3) *On Road Beginning* module focused on beginner level on-road driving skill development in residential environments, (4) *On Road Intermediate* module focused on intermediate level on-road driving skill development in residential and commercial environments, and (5) *On Road Advance* module focused on advance level on-road driving on highways and rural roads (see Figure 2). Prior to the commencement of the RCT, the researchers made modifications to the manual based on feedback via interviews from student

1 drivers with ASD, parents and driving instructors. Modifications included changing the
2 presentation of the information in the manual from predominately text based to visual imagery
3 using coded colour boxes.
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7 <INSERT FIGURE 2 ABOUT HERE>
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9 ***Website Modules***

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12 A website was also designed as an interactive platform using the information and module
13 content developed in the intervention training manual. The website was used by the student
14 drivers and driving instructors to access information and resources, such as informative videos,
15 and to review driving lessons. The participants were required to complete a practical review
16 for each on-road driving lesson. The practical reviews consisted of a 5-point Likert rating scale
17 assessing task mastery, anxiety, confidence, concentration and sensory overload. The lesson
18 reviews were uploaded by the driving instructor upon completion of each driving lesson to be
19 completed by the student. Student drivers were also asked to fill in a personal profile and
20 learning style preferences form prior to commencing lessons, thereby providing the driving
21 instructors with background information to aid in rapport building and lesson planning. The
22 learning style form asked students to identify their personal preferred style of learning such as
23 visual, auditory or kinaesthetic (Colorosa & Makela, 2014). The personal profile contained
24 questions about student's autism specific medical requirements (e.g., experiencing fatigue in
25 the afternoon), personal strengths, challenges, areas of interest, ritualistic behaviours, and
26 experiencing sensory overload (Tyler, 2013). Both the students and driving instructors were
27 emailed their individual log in details and 'how to guides' with step-by-step instructions on
28 how to use the website as it was a closed platform
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53 **Procedure**

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56 In addition to the self-reported ASD diagnosis, as per the Diagnostic and Statistical Manual
57 of Mental Disorders (DSM-5) criteria for ASD (American Psychiatric Association, 2013),
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demographic data were collected via a questionnaire. Information was gathered on age, gender, education level and employment, and the date their learner permit was obtained (see Table 1). Psychological measures were also completed to establish a measure of the student drivers' social, cognitive and anxiety profiles (see Table 2). The demographic and psychological measures were collected during a 2-hour initial baseline assessment conducted at both sites. Once baseline measures were collected, all student drivers were asked to commence 10 driving lessons in an automatic transmission dual controlled car with a professional driving instructor. The student drivers in the intervention group were instructed to drive by driving instructors who were trained in the use of the DTP during a 2-hour training session conducted by the research team. Student drivers in the control condition were exposed to a treatment as usual component of driving training which consisted of 10 conventional driving lessons with driving instructors who were not trained in the use of the DTP intervention. The main provision in the treatment as usual group was that student drivers receive conventional driving training as usually conducted by the control group driving instructors who attended only a brief 30-minute information session to clarify how the logistics for the study were arranged. Driving instructors' demographic information, including the number of years training students to drive, were also collected (see Table 1). The outcome measure of students driving performance was administered during two observation drives conducted at each site. First, a pre-test observation drive was conducted after students commenced their initial driving lessons (mean lessons = 2.28) with the driving instructors. This was to maintain the safety of the public and participants by ensuring that students were competent enough to complete a variety of on-road driving tasks. A post-test observation drive was also conducted upon completion of the 10 driving lessons during a final assessment when the post-test psychological measures were also collected (see Figure 3). <INSERT TABLE 1 & 2 ABOUT HERE>

<INSERT FIGURE 3 ABOUT HERE>

Intervention Fidelity

The research team monitored and verified the adherence of module tasks by sitting in on one lesson per module with each intervention driving instructor, to ensure consistent implementation of the DTP intervention delivery. A total of four intervention fidelity checks were carried out with each driving instructor for quality control of the intervention modules. The researcher was positioned behind the driving instructor in the passenger seat, observing the lesson while completing a fidelity checklist for each on-road module (modules 2–5). Each task within the module being monitored was scored either, yes (task was completed), no (task was not completed) or not applicable (task was not applicable in the lesson; see **Supplementary Figure 1**). High fidelity of delivery was demonstrated by the intervention group driving instructors on all modules. A website fidelity protocol was also designed to monitor lesson review adherence and cross-checking completed lessons with uploaded reviews. Adherence was moderate to high for driving instructors and student drivers, with only one student driver not completing the lesson reviews.

Instruments

The participants were first screened at baseline for visual acuity using the Meter 2000 Series Revised ETDRS chart (Precision Vision, 2000). As a legal driving requirement, participants needed to demonstrate visual acuity 6/12 m (20/40 ft) to be able to drive on the road and therefore take part in the program (Austroads and the National Transport Commission, 2016).

Executive Function Measure

The Cambridge Neuropsychological Test Automated Battery (CANTAB) is a battery of executive function which measures planning, episodic memory and processing speed. The CANTAB was used to gain a profile of participants' executive function (Ozonoff et al.,

2004). Participants completed the CANTAB on an iPad device with a touch-sensitive screen which took approximately 40 minutes to complete. Instructions were given for each subtest and a number of practice trials were done before each task was completed and responses recorded. The following five CANTAB subscales were administered according to instructions: planning efficiency (one touch stockings of Cambridge), working memory (spatial working memory), visual memory (paired associates learning), processing speed (reaction time), and managing conflicting and task-irrelevant information (multitasking test). The CANTAB has been shown to have strong construct validity and internal consistency for subtests (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Luciana, 2003; Ozonoff et al., 2004).

Social Responsiveness Measure - version 2

The social responsiveness scale (SRS-2) was used to measure the presence of impairment in social ability in people with ASD. Consisting of an overall score and five subscales, this test primarily measures difficulties in social awareness, social cognition, social communication, social motivation, and restricted interests and repetitive behaviours (Constantino & Gruber, 2005). The SRS-2 includes 65 items with a four-point Likert scale that measures an informant's (relative or friend) rating of observed social impairment. Informants report how true each statement describes the participant's behaviour in the previous 6 months. A total score of 76 or higher is considered severe and is associated with ASD diagnosis, 66-75 indicates severe to moderate deficiency in reciprocal social behaviour impacting on everyday social interactions and may be indicative of ASD, 60-65 indicates mild to moderate deficits in social interaction, and 59 and below indicates typical range not associated with ASD. The SRS-2 has been shown to have strong interrater reliability scores (0.75-0.91) (Constantino et al., 2003), and Bölte (2012) found the SRS-2 to have strong internal consistency (0.91-0.97) and test-retest reliability (0.84-0.97). For the purpose of this

1 study, both the SRS-2 adult and school age versions were used to account for the range in
2 ages of participants. The SRS-2 adult version has been developed to capture social
3 impairment for individuals over 19 years of age and the SRS-2 school age for individuals
4 aged between 4 and 18 years.
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8 *Anxiety Measure*

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10 The Revised Children's Manifest Anxiety Scale: Second Edition (RCMAS-2) is a self-
11 report measure of trait anxiety areas across four domains, defensiveness, inconsistent
12 responding, physiological and social anxiety, and worry. It is a 49-item questionnaire with a
13 'yes' or 'no' response filled in by student drivers (Reynolds & Richmond, 2008). The
14 RCMAS-2 was used to measure the student driver's overall anxiety, as well as the nature of
15 their experienced anxiety (e.g., performance anxiety), which may impact on students' ability
16 to learn to drive. The RCMAS-2 may be useful in identifying areas of need in driving
17 education or to see if there is a pattern of anxiety among student drivers. The RCMAS-2 has
18 been shown to have high internal consistency (Cronbach's alpha = 0.75-0.92) (Ambler,
19 Eidels, & Gregory, 2015).
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36 *Task Load Index*

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38 The NASA Task Loading Index (NASA TLX) is a widely used measure of mental
39 workload and was used in this study to measure the cognitive demand placed on student
40 drivers during the observation drive. Upon completion of the pre- and post-observation
41 drives, student drivers were asked to fill in the NASA TLX, which consisted of six questions
42 assessing mental, physical and temporal demand, as well as their perceived performance,
43 effort and frustration levels (Hart, 2006). Student drivers rated their response to each question
44 out of 20, from very low to very high or perfect to failure (performance item only). The
45 NASA (TLX) has been shown to have good test-retest reliability (0.77) (Hoonakker et al.,
46 2011).
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Outcome Measures

The Driving Performance Checklist (DPC) (Chee, Lee, Patomella, & Falkmer, 2017; Lee, Cameron, & Lee, 2003), a measure of driving performance was used to rate student drivers' observable on-road driving performance during pre- and post-observation drives. The DPC uses an activity analysis approach breaking down driving tasks into items that can be assessed. For example, at a traffic light intersection, the student drivers were assessed on the following items: (1) decelerate when approaching, (2) stop at appropriate distance to car in front, (3) noticed lights; stopped (red) or go (green) as indicated, and (4) proceed when way is clear. Assessors assigned one point for every correctly performed item, which produced a total score for each driving task (e.g., roundabouts and T-junction turns) (Chee et al., 2017). This scoring system was adapted to account for the on-road driving scenarios at both sites in this study (Chee et al., 2017; Lee et al., 2003). It was important to observe the student driver's performance using a standardised driving route at each site to gain a reliable score on the DPC (Akinwuntan et al., 2002; Chee et al., 2017). As this study was a novel multi-site design, comparing the driving performance of student drivers across two geographical sites was inherently difficult and complex. Due to the complexity of the multi-site design, it was necessary to match the sites as closely as possible in terms of geography, population density, traffic conditions and common driving activities. For this reason, both locations were matched with a comparable mixture of residential, retail and light industrial areas, as well as similar population densities (under 10,000 residence). Each location had a combination of marked and unmarked single and double lane roads, traffic light intersections, roundabouts, pedestrian crossings, and parking areas. The chosen locations ensured that there would be similarities in traffic flow and volume and required drivers to abide by national traffic regulations, such as matched road signage and speed limits. Modifications were then made to

the DPC for both sites taking into consideration the need to observe common driving activities with matching items.

The assessors were seated directly behind the driving instructor in the passenger seat so as to not obstruct the student driver's vision during the observation drive which took approximately 30 minutes. Each student driver was instructed to drive straight unless instructed otherwise. Driving instructors were advised to only provide the student drivers with directions (e.g., turn left or right). For the Perth driving route there were a combination of six right turn and five left turn T-junction intersections, nine roundabouts, four traffic light intersections, and two pedestrian areas included in the adapted DPC. For the Sydney site there were a combination of eight right turn and thirteen left turn T-junction intersections, five roundabouts, eight traffic light intersections, and two pedestrian areas included in the adapted DPC. The assessors at both sites were trained in the observation drive standardised route and use of the DPC. Inter-rater reliability was measured for consistency of scoring among assessors and was found to be high ($r = 0.919$).

Statistical Analysis

The demographic data for the student drivers who completed the study as well as the driving instructors were collected and summarised using means and standard deviations (information obtained from the participants that dropped out of the study was not included in the analysis of the data). All data collected were tested for normal distribution using the Shapiro-Wilkes tests. Independent t -tests for interval level variables or Pearson's Chi Square tests for categorical variables were used to compare the equivalence between groups. Results were deemed significant at a threshold of $p = <0.05$.

To assess the efficacy of the intervention, analyses of the potential changes in driving performance were conducted. First, to make the continuous DPC score data between the two sites (Perth and Sydney) equivalent, the analysis of driving activities was restricted to those

that were common to both sites ($n = 11$). The following driving activities were common across both: car park (left), parking, pedestrian zone, right turn, roundabout (right), roundabout (straight), T-junction (left), T-junction (right), traffic light (left), traffic light (right), and traffic light (straight). An average score for each common activity, for each individual, was created at pre- and post-observation. Change-scores were then calculated by deducting the pre-score from the post-score with between-group and site comparisons made using a mixed model analysis for the common driving activities. Second, the DPC difference scores for each individual from pre to post were averaged across all the common activities creating one average score for each individual and analysed using a general linear model (GLM). Third, to evaluate the change in performance for all common driving activities, additional exploratory analysis of the binary data score difference at pre- and at post-test were run via a generalised estimation equation (GEE) model looking at the change in numbers of students who obtained 100% for each common activity. An odds ratio (OR) less than 1 was interpreted as decreasing the likelihood of obtaining a perfect 100% score on each activity.

Finally, to explore potential moderator variables a series of Pearson correlations were conducted using the average DPC difference score as the dependent variable. Five potential moderating variables were examined, scores on the CANTAB, SRS-2, RCMAS-2, NASA TLX, and the driving instructors' years of training experience. Cohen's d effect sizes were calculated, a small effect size was considered to be 0.2, a medium 0.5, and a large 0.8 (Cohen, 1988). Statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS) version 25 (IBM Corporation, 2017).

Results

In total, 72 student drivers with ASD and 13 driving instructors completed the study. Demographic baseline measures for the participants are presented in Table 1, showing equivalence between groups except for gender ($p = 0.037$). There were more females in the

control group ($n = 10$) compared to the intervention group ($n = 3$). In general, there were less females enrolled in the study, which is reflective of females being underdiagnosed or underrepresented in autism research (Halladay et al., 2015). As the researchers were blinded to group allocation this difference in gender could not be controlled for with four females choosing to discontinue participation in the study after randomisation and prior to commencement of lessons. Baseline total SRS-2 scores showed that most participants (43%) scored in the moderate range (Sever range $[\geq 76] = 12$ (16.5%); Severe-moderate range $[75-66] = 31$ (43%); Mild-moderate $[60-65] = 17$ (24%), and Typical range $[\leq 59] = 12$ (16.5%). The driving instructor's demographic data were also equivalent between the groups (see Table 1).

Driving performance during the on-road observations were measured using the DPC which provided a score with one point assigned to every correct criterion item within each driving activity. The scores were summated for each individual item with a maximum score of 151 for Perth and 170 for Sydney, and for each activity with a maximum of 33 activities in Perth and 42 activities in Sydney. The average score across items and activities gave a score for each individual at pre- and post-observation drive. For the analysis, any driving activities that only appeared at one site were dropped, so that only the activities common to both sites were analysed ($n = 11$). Based on the DPC change score, there was a strong difference in score changes between activities ($p = <0.001$); however, there was no difference between the intervention and control groups ($p = 0.614$) or study sites ($p = 0.842$). Based on the summation of differences across all common activities for each individual there was a significant improvement in the driving performance score changes (pre-post) for both the intervention group (mean increase by 3.39) and control group (mean increase by 3.32). However, the difference between the increases was not statistically significant ($p = 0.934$).

The effect size of the change score difference between the groups was $d = 0.02$, representing a small effect size.

The outcome of the GEE model for DPC common driving activities ($n = 11$) showed that while there was no statistically significant difference between intervention and control groups in obtaining a perfect score for each checklist activity ($p = 0.622$). Both groups showed significant improvement from pre- to post-training, effect size for the intervention group $d = 1.02$ and the control group $d = 1.15$, representing large effect sizes. Furthermore, when comparing the pre- and post-intervention scores for the common driving activities, all driving activities were shown to have a statistically significant improvement in driving training, for example, parking ($p = 0.001$), right turn ($p = 0.002$), roundabout right ($p = < 0.001$), and roundabout straight ($p = 0.001$) (see Table 3).

<INSERT TABLE 3 ABOUT HERE>

Pearson's correlations were explored between the average DPC difference score and moderator variables to investigate potential effects on the intervention. The associations between two of the variables were significant (task load and multi-tasking). However, they demonstrated very weak positive correlations and, given the likelihood of type 1 error due to the number of comparisons, these findings should be interpreted with great caution.

<INSERT TABLE 4 ABOUT HERE>

Discussion

Previous research has suggested that there is a need for autism-specific driving training interventions that provide both support for and knowledge of how to effectively train individuals with ASD (Almberg et al., 2015; Lindsay, 2016; Tyler, 2013; Wilson et al., 2018). The current study begins to address this need by implementing an innovative driving training program intervention aimed at increasing the driving performance of student drivers with ASD. The DTP was designed to account for known barriers associated with autism and

1 driving such as issues with hazard perception, motor coordination, anxiety, executive
2 function, attention, cognitive rigidity, sensory overstimulation and social communication.
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4 The primary purpose of this randomised controlled trial was to evaluate the effectiveness of
5 this intervention for improving the driving performance of student drivers with ASD. In
6 response to the second research question, the results showed that both the intervention group
7 and control group improved significantly in their driving performance (DPC) with large
8 effect sizes, however, the improvements were not significantly greater for the intervention
9 group compared to the control group.
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19 Previously there has been limited research investigating the driving performance of
20 people with ASD in naturalistic environments. The fact that we observed an improvement in
21 driving performance in both the intervention and control groups is a promising finding filling
22 the gap in knowledge around the driving performance of student drivers with ASD in
23 naturalistic environments. Providing professional driving instruction clearly impacted on the
24 improvement of driving performance for all students across all observed driving activities.
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26 Also, the findings showed that the intervention was equally effective as conventional driving
27 instruction, however, counter to our predictions the intervention was not shown to be more
28 effective. We offer three explanations to better understand our findings. The first possible
29 explanation is that sampling bias was introduced due to the self-selection of driving
30 instructors recruited into the study via public advertisements and industry events. Therefore,
31 it is possible that the recruited driving instructors who chose to take part in the project were
32 by their very nature those who had an intrinsic interest in research and autism. It is unknown
33 if the participating driving instructors were equivalent to all driving instructors in the general
34 population who chose not to take part in the project. The driving instructors in this study
35 shared similar demographic profiles. Most were men and all were middle aged, representing
36 individuals with life experiences such as increased driving years and previous careers in
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1 various industries (e.g., business management). All had worked as driving instructors for over
2 two years with some having up to 16 years' experience. Therefore, all instructors in both the
3 control and intervention groups were highly experienced which was evident to the research
4 team during the observation drives. Anecdotally, several of the instructors from both groups
5 in this study expressed an interest in learning about techniques for training people with ASD
6 and a desire to challenge themselves at this stage in their careers. It was therefore impossible
7 to know if the conventional training provided by the instructors in this study is representative
8 of conventional driving instruction in general or how this impacted on the findings. Future
9 studies need to take steps to manage self-selection bias via testing a cohort of driving
10 instructors across a wide demographic range and experience in this role. Further
11 investigations should also consider implementing the DTP via an experimental design
12 assessing parents who choose to train their child with ASD to drive.
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29 In response to the first research question, the student drivers in the intervention and
30 control groups were found to be equivalent on all measured demographics other than gender.
31 A second possible explanation for why the intervention was not found to be more significant
32 than conventional driving instruction, is that we did not screen the student drivers for co-
33 morbid conditions such as attention deficit disorder (ADHD) or anxiety disorders.
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41 Recruitment of the student participants was aimed at individuals with ASD as the main
42 diagnosis, however, comorbidity is common and symptoms associated with other medical
43 conditions may have impacted on students' ability to learn to drive (Almberg et al., 2015;
44 Brooks et al., 2016). Consistent with the first explanation, self-selection of student driver
45 participants choosing to take part in the project could be biased toward parents/caregivers
46 already confident in their child's ability to learn to drive, which may not be representative of
47 all student drivers with ASD. Therefore, it is possible that the participants in this study may
48 have had a higher level of functioning and readiness to learn to drive and performed well,
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1 regardless of the group they were assigned to. Past research has suggested that differences in
2 individuals' levels of functioning may be a confounding variable impacting on driving
3 readiness (Chee et al., 2017). In this study, levels of functioning or autism symptom severity
4 were not measured; important factors for establishing equivalency between groups. Future
5 trails of the DTP intervention will need to measure levels of independent functioning and
6 autism severity. This is important both for generalisability of findings and to determine
7 whether the intervention leads to improvements in driving performance for individuals with
8 varying levels of functioning.
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10 A third explanation is that the training provided by the research team on how to use the
11 intervention was delivered verbally and relied on the driving instructors reading the manual
12 following a 2-hour training session. It is not known how engaged in the manual content the
13 driving instructors were or how successful the training sessions were. To improve future
14 adherence and efficacy of the intervention delivery, providing video-based demonstrations
15 that go through the module content step-by-step may be beneficial. The manual modules were
16 set out for presentation purposes, in a graded sequence from off-road training skills to on-
17 road training skills in varying driving environments. This is in line with driving training
18 developed for TD student drivers. The issue with this is that driving training in a naturalistic
19 setting does not conform to a structured order; it is dynamic and influenced by multiple
20 variables such as the student's unique characteristics and differing driving conditions.
21 Therefore, during each lesson, instructors may work on driving activities from multiple
22 modules. The manual was developed as a guide for lesson planning; however, this may not
23 have been clearly described during the intervention training. Examples of lesson planning
24 based on real-world driving lessons are needed. This study has shed light on the ever-
25 changing natural context of real-world driving lessons that can now be incorporated into
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1 future DTP intervention development, potentially improving future driving training of
2 individuals with ASD.
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4 Social communication issues have been highlighted in previous studies as being a
5 barrier to driving for people with ASD. The focus of discussion has been on how drivers with
6 ASD will manage social communication with other drivers (Almberg et al., 2015; Cox et al.,
7 2012; Lindsay, 2016). Although anecdotal, what was clear from this study was that
8 professional driving instructors unfamiliar with characteristics of autism, such as social
9 communication deficits, were unprepared for working with students who do not communicate
10 verbally. Future driving training interventions need to provide a guide for driving instructors
11 on what to expect when faced with student drivers that demonstrate limited verbal
12 communication. Instructors need to understand that this will not necessarily hinder the
13 student's ability to learn to drive, however, it may impact on the level of feedback received
14 from the student, which instructors need to prepare themselves for (Tyler, 2013). Another
15 issue evident during the course of this study was that there were a small number of students
16 that dropped out of the study deemed to be a risk due to executive function issues, such as
17 unfocused attention and fixated behaviours. Previous research has highlighted executive
18 functioning deficits as being problematic to driving for individuals with ASD (Classen,
19 Monahan, & Hernandez, 2013; Cox et al., 2016). However, currently there is little
20 understanding about these deficits in executive function and how they impact on student's
21 ability to learn to drive, their level of fitness to drive or how to adequately assess for this in
22 clinical settings (Almberg et al., 2015). Future research is needed to address the limited
23 knowledge around fitness to drive to add to driving training interventions.
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25 The demographic and psychological profiles of the student drivers in this study were
26 analysed to determine how they might modify driving performance scores. Factors such as
27 executive function, anxiety, social responsiveness, task loading were not found to moderate
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1 driving performance scores. The driving instructor years of training experience were also
2 analysed as a potential moderator relating to the driving performance scores, this factor also
3 did not moderate the students' driving performance. In response to the third research
4 question, other than two weak positive correlations that should be treated with great caution,
5 there were no factors that moderated the driving performance outcome. However, these
6 findings need to be considered with caution due to the small sample size. Future studies using
7 a larger sample size might reveal other moderator variables.

17 Study Limitations

19 A limitation was that there were significant differences between the control and intervention
20 groups for gender which may limit the generalisability of findings. It is possible that a small
21 number of female student drivers recruited in this study chose to discontinue their
22 involvement in the study due to increased anxiety at the prospect of working with a driving
23 instructor unknown to them. Secondly, considering the small sample size, the participants
24 may not represent the broader population of individuals with ASD. Future studies with a
25 larger sample size including more females are warranted. A third limitation of this study was
26 the potential differences in driving lesson exposure among students prior to the
27 commencement of the program. The inclusion criteria required student drivers to have no
28 more than 5 hours driving lessons with a professional driving instructor. This did not take
29 into consideration previous driving lessons with non-driving instructors such as a parent. The
30 difference was not statistically significant in this study however, needs to be considered in
31 future research. A fourth limitation is that at the time of reporting on the RCT, we did not
32 conduct longer-term follow-up data collection looking at changes in driving performance
33 over time or provisional licensing rates. Nevertheless, we continue to follow-up with
34 participants with respect to outcomes such as changes in their driving licensure status and
35 driving behaviours, which will be reported in a future study. Significant gains in driving

performance for this population may only last for the duration that student drivers are engaging in driving lessons with professional driving instructors. Future research should include a larger-scale RCT of the DTP intervention including long-term follow-ups allowing for further analysis of the efficacy and potential moderators impacting on changes in driving performance. A fifth limitation was the difficulties in managing standardisation of two driving routes between multiple sites. Basing observations on one site rather than working with two sites may have been easier to conduct. Nevertheless, the choice of a multi-site study allowed greater access to a larger population thereby increasing recruitment numbers of student drivers with ASD who have been reported to have generally lower licensing rates (Almberg et al., 2015; Chee et al., 2019). Finally, the use of one outcome measure assessing the driving performance of participants is a limitation in this study. Further investigation employing multiple measurements of the driving performance of drivers with ASD such as the P-Drive, (Chee et al., 2017; Patomella, Tham, & Kottorp, 2006) a standardised observational assessment of driving ability, is recommended for future research.

Conclusion

The purpose of this study was to evaluate the efficacy of an autism-specific driving training program designed to improve the driving performance of student drivers with ASD. Other than gender, where there were more females in the control group, there was equivalence across all other demographic variables. Overall, both the DTP intervention and standard driving training show promise for improving the driving performance of student drivers with ASD and is an important step toward improving the community mobility of individuals with ASD. An economic evaluation of both interventions and a follow-up study to determine success in obtaining a driver's licence and undertaking regular driving are warranted.

Reference List

- Akinwuntan, A. E., Feys, H., DeWeerd, W., Pauwels, J., Baten, G., & Strypstein, E. (2002). Determinants of driving after stroke. *Archives of Physical Medicine and Rehabilitation*, 83(3), 334-341.
- Almberg, M., Selander, H., Falkmer, M., Vaz, S., Ciccarelli, M., & Falkmer, T. (2015). Experiences of facilitators or barriers in driving education from learner and novice drivers with ADHD or ASD and their driving instructors. *Developmental Neurorehabilitation*, 1-9. doi:10.3109/17518423.2015.1058299
- Ambler, P. G., Eidels, A., & Gregory, C. (2015). Anxiety and aggression in adolescents with autism spectrum disorders attending mainstream schools. *Research in Autism Spectrum Disorders*, 18, 97-109.
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: American Psychiatric Association.
- Austroads and the National Transport Commission. (2016). Assessing fitness to drive for commercial and private vehicle drivers: Medical standards for licensing and clinical management guidelines. Retrieved from <https://austroads.com.au/publications/assessing-fitness-to-drive/ap-g56>
- Bölte, S. (2012). Brief Report: The Social Responsiveness Scale for Adults (SRS-A): Initial Results in a German Cohort. *Journal of Autism and Developmental Disorders*, 42(9), 1998-1999. doi:10.1007/s10803-011-1424-5
- Brooks, J., Kellett, J., Seeanner, J., Jenkins, C., Buchanan, C., Kinsman, A., . . . Pierce, S. (2016). Training the motor aspects of pre-driving skills of young adults with and

without autism spectrum disorder. *Journal of Autism and Developmental Disorders*,
46(7), 2408-2426. doi:10.1007/s10803-016-2775-8

Chee, D., Lee, H., Patomella, A.-H., & Falkmer, T. (2019). Investigating the driving
performance of drivers with and without autism spectrum disorders under complex
driving conditions. *Disability and Rehabilitation*, 41(1), 1-8.

Chee, D. Y., Lee, H. C., Patomella, A.-H., & Falkmer, T. (2017). Driving behaviour profile
of drivers with autism spectrum disorder (ASD). *Journal of Autism and
Developmental Disorders*, 47(9), 2658-2670.

Classen, S., & Monahan, M. (2013). Evidence-based review on interventions and
determinants of driving performance in teens with attention deficit hyperactivity
disorder or autism spectrum disorder. *Traffic Injury Prevention*, 14(2), 188-193.

Classen, S., Monahan, M., & Hernandez, S. (2013). Indicators of simulated driving skills in
adolescents with autism spectrum disorder. *The Open Journal of Occupational
Therapy*, 1(4). doi:10.15453/2168-6408.1051

Classen, S., Monahan, M., & Wang, Y. (2013). Driving characteristics of teens with attention
deficit hyperactivity and autism spectrum disorder. *The American Journal of
Occupational Therapy*, 67(6), 664-673. doi:10.5014/ajot.2013.008821

Cohen, J. (1988). *Statistical power analysis for the social sciences*. New York, NY:
Routledge Academic.

Colorosa, S. R., & Makela, C. J. (2014). Integrative literature review: Styles of learning for
autism spectrum disorders and human resource development: informing performance
management. *International Journal of Business and Social Science*, 5(13).

- Constantino, J. N., Davis, S. A., Todd, R. D., Schindler, M. K., Gross, M. M., Brophy, S. L., . . . Reich, W. (2003). Validation of a brief quantitative measure of autistic traits: Comparison of the social responsiveness scale with the autism diagnostic interview-revised. *Journal of Autism and Developmental Disorders*, 33(4), 427-433.
- Constantino, J. N., & Gruber, C. P. (2005). *Social Responsiveness Scale (SRS) Manual*. Los Angeles, CA: Western Psychological Services.
- Corbett, B. A., Constantine, L. J., Hendren, R., Rocke, D., & Ozonoff, S. (2009). Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development. *Psychiatry Research*, 166(2-3), 210-222.
- Cox, N. B., Reeve, R. E., Cox, S. M., & Cox, D. J. (2012). Brief Report: Driving and young adults with ASD: Parents' experiences. *Journal of Autism and Developmental Disorders*, 42(10), 2257-2262.
- Cox, S. M., Cox, D. J., Kofler, M. J., Moncrief, M. A., Johnson, R. J., Lambert, A. E., . . . Reeve, R. E. (2016). Driving Simulator Performance in Novice Drivers with Autism Spectrum Disorder: The Role of Executive Functions and Basic Motor Skills. *Journal of Autism and Developmental Disorders*, 46(4), 1379-1391. doi:10.1007/s10803-015-2677-1
- Falkmer, T., Gustavsson, L., Nielsen, B., & Peters, B. (2000). *Teaching learner drivers with disabilities: An operation manual for driving instructors*: Statens väg-och transportforskningsinstitut., VTI EC research 10.
- Halladay, A. K., Bishop, S., Constantino, J. N., Daniels, A. M., Koenig, K., Palmer, K., . . . Singer, A. T. (2015). Sex and gender differences in autism spectrum disorder:

1 summarizing evidence gaps and identifying emerging areas of priority. *Molecular*
2 *Autism*, 6(1), 36.
3

4
5
6 Hart, S. G. (2006). *NASA-task load index (NASA-TLX); 20 years later* Paper presented at the
7
8 Proceedings of the human factors and ergonomics society annual meeting (Vo.l 50,
9
10 No. 9, pp. 904-908). Los Angeles, CA: Sage publications
11

12
13 Hatakka, M., Keskinen, E., Gregersen, N. P., Glad, A., & Hernetkoski, K. (2002). From
14
15 control of the vehicle to personal self-control; broadening the perspectives to driver
16
17 education. *Transportation Research Part F: Traffic Psychology and Behaviour*, 5(3),
18
19 201-215.
20
21

22
23
24 Hendricks, D. R., & Wehman, P. (2009). Transition from school to adulthood for youth with
25
26 autism spectrum disorders: Review and recommendations. *Focus on Autism and*
27
28 *Other Developmental Disabilities*, 24(2), 77-88.
29
30

31
32
33 Hoonakker, P., Carayon, P., Gurses, A. P., Brown, R., Khunlertkit, A., McGuire, K., &
34
35 Walker, J. M. (2011). Measuring workload of ICU nurses with a questionnaire survey:
36
37 The NASA Task Load Index (TLX). *IIE Transactions on Healthcare Systems*
38
39 *Engineering*, 1(2), 131-143. doi:10.1080/19488300.2011.609524
40
41

42
43
44 Huang, P., Kao, T., Curry, A. E., & Durbin, D. R. (2012). Factors associated with driving in
45
46 teens with autism spectrum disorders. *Journal of Developmental & Behavioral*
47
48 *Pediatrics*, 33(1), 70-74. doi:10.1097/DBP.0b013e31823a43b7
49
50

51
52 IBM Corporation. (2017). *IBM SPSS Statistics (Version 25)*. Armonk, NY: IBM Corp.
53
54
55
56
57
58
59
60
61
62
63
64
65

1 Lee, H. C., Cameron, D., & Lee, A. H. (2003). Assessing the driving performance of older
2 adult drivers: On-road versus simulated driving. *Accident Analysis and Prevention*,
3
4 35(5), 797-803. doi:10.1016/S0001-4575(02)00083-0
5
6

7
8 Lindsay, S. (2016). Systematic review of factors affecting driving and motor vehicle
9 transportation among people with autism spectrum disorder. *Disability and*
10
11 *Rehabilitation*, 1-10. doi:10.3109/09638288.2016.1161849
12
13
14
15

16 Luciana, M. (2003). Practitioner review: Computerized assessment of neuropsychological
17 function in children: Clinical and research applications of the Cambridge
18
19 Neuropsychological Testing Automated Battery (CANTAB). *Journal of Child*
20
21 *Psychology and Psychiatry*, 44(5), 649-663.
22
23
24
25

26
27 Michon, J. A. (1985). A critical review of driving behaviour models: What do we know and
28
29 what we should do? In L. S. Evan (Ed.), *Human Behaviour and Traffic Safety* (pp.
30
31 485-520). Springer, Boston, MA.
32
33
34

35 Mikami, F., Miyazaki, H., Iwado, M., Odagiri, S., Morito, M., Nanba, T., & Takei, Y. (2018).
36 Understanding characteristics of autism spectrum disorder using ICF-CY. *Kawasaki*
37
38 *Journal of Medical Welfare*, 23(2), 31-42.
39
40
41
42

43 National Health and Medical Research Council. (2007). Australian Research Council,
44
45 Committee AV-C. National Statement on Ethical Conduct in Human Research. In
46
47 Council NHaMR (Ed.). Canberra, ACT: Attorney-General's Department.
48
49
50

51
52 Ozonoff, S., Cook, I., Coon, H., Dawson, G., Joseph, R. M., Klin, A., . . . Pennington, B. F.
53
54 (2004). Performance on Cambridge Neuropsychological Test Automated Battery
55
56 subtests sensitive to frontal lobe function in people with autistic disorder: Evidence
57
58
59
60
61
62
63
64
65

- from the Collaborative Programs of Excellence in Autism network. *Journal of Autism and Developmental Disorders*, 34(2), 139-150.
- Patomella, A.-H., Tham, K., & Kottorp, A. (2006). P-drive: Assessment of driving performance after stroke. *Journal Rehabilitation Medicine*, 38, 273-279.
- Peräaho, M., Keskinen, E., & Hatakka, M. (2003). Driver competence in a hierarchical perspective; implications for driver education. *Report to Swedish Road Administration*.
- Precin, P., Otto, M., Popalzai, K., & Samuel, M. (2012). The role for occupational therapists in community mobility training for people with autism spectrum disorders. *Occupational Therapy in Mental Health*, 28(2), 129-146.
- Precision Vision. (2000). Revised 2000 Series ETDRS Charts-- 2 meters: Precision Vision; 2000 Retrieved from <http://precision-vision.com/index.cfm/category/34/etdrs-charts.cfm?CFID=34718261&CFTOKEN=87c96276a5c3005e-78591027-A015-34B9-7B01A7CB930534D5>.
- RANDOM.ORG. (2019). Retrieved from <https://www.random.org/lists/>
- Reimer, B., Fried, R., Mehler, B., Joshi, G., Bolfek, A., Godfrey, K. M., . . . Biederman, J. (2013). Brief Report: Examining driving behavior in young adults with high functioning autism spectrum disorders: A pilot study using a driving simulation paradigm. *Journal of Autism and Developmental Disorders*, 43(9), 2211-2217. doi:10.1007/s10803-013-1764-4
- Reynolds, C., & Richmond, B. (2008). RCMAS-2-Revised children's manifest anxiety scale. *Los Angeles: Western Psychological Services*.

- 1 Sheppard, E., Ropar, D., Underwood, G., & van Loon, E. (2010). Brief report: Driving hazard
2 perception in autism. *Journal of Autism and Developmental Disorders*, 40(4), 504-
3 508.
4
5
6
7
- 8 Tyler, S. (2013). Asperger's Syndrome: The implications for driver training methods and road
9 safety. *Journal of the Australasian College of Road Safety*, 24(1), 55-63.
10
11
12
13
- 14 Wade, J., Bian, D., Zhang, L., Swanson, A., Sarkar, M., Warren, Z., & Sarkar, N. (2014).
15 Design of a virtual reality driving environment to assess performance of teenagers
16 with ASD. In C. Stephanidis & M. Antona (Eds.), *Universal Access in Human-*
17 *Computer Interaction. Universal Access to Information and Knowledge* (Vol. 8514,
18 pp. 466-474): Springer International Publishing.
19
20
21
22
23
24
25
26
- 27 WHO. (2001). *International classification of functioning, disability and health: ICF*. Geneva:
28 World Health Organization.
29
30
31
32
- 33 Wilson, N. J., Lee, H. C., Vaz, S., Vindin, P., & Cordier, R. (2018). Scoping review of the
34 driving behaviour of and driver training programs for people on the autism spectrum.
35 *Behavioural Neurology*, 2018. doi:10.1155/2018/6842306
36
37
38
39
40
41
- 42 Winston, F. K., Mirman, J. H., Curry, A. E., Pfeiffer, M. R., Elliott, M. R., & Durbin, D. R.
43 (2015). Engagement with the TeenDrivingPlan and diversity of teens' supervised
44 practice driving: Lessons for internet-based learner driver interventions. *Injury*
45 *Prevention*, 21(1), 4-9.
46
47
48
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50
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Figure Captions

Figure 1. CONSORT flow chart

Figure 2. Schema of DTP modules

Figure 3. RCT procedure timeline

Table 1. Participant demographic information

Table 2. Results of t-test of psychological measures

Table 3. GEE model results

Table 4. Correlations with DPC pre-post change score

Figure 1. CONSORT flow chart

Figure 2. Schema of DTP modules

Figure 3. RCT procedure timeline

*As some learner drivers had no on road driving experience, the pre-test was delayed for some to ensure that it was safe to undertake the pre-test observation drive.

Table 1. Participant demographic information

Student Drivers	Frequency		Significance	
	Intervention group (n = 37)	Control group (n = 35)	T-test p-value	chi ² p-value
Age (years)			.364	-
Mean (SD)	18.49 (3.40)	18.77 (3.23)		
Range	16-31	16-31		
Driving experience (hours)			.514	-
Mean (SD)	2.89 (7.53)	3.79 (7.04)		
Range	0-44	0-26		
Gender			-	.037*
Male	32 (86.5%)	25 (71.4%)		
Female	3 (8.1%)	10 (28.6%)		
Other	2 (5.4%)	0		
Self-reported anxiety			-	.836
Yes	15 (40.5%)	15 (42.9%)		
No	21 (56.8%)	19 (54.3%)		
Education level			-	.065
Primary	0	0		
Secondary	31 (83.8%)	23 (65.7%)		
TAFE	2 (5.4%)	4 (11.4%)		
Apprenticeship	2 (5.4%)	8 (22.9%)		
University	0	0		
Employed			-	.387
Yes	8 (21.6%)	5 (14.3%)		
No	28 (75.7%)	30 (85.7%)		
Glasses			-	.381
Yes	8 (21.6%)	11 (31.4%)		
No	28 (75.7%)	24 (68.6%)		
Driving Instructors	Intervention group (n = 6)	Control group (n = 7)	T-test p-value	chi ² p-value
Age (years)			.789	-
Mean (SD)	54 (6.98)	55 (5.07)		
Range	45-62	47-64		
Gender			-	.853
Male	4 (66.7%)	5 (71.4%)		
Female	2 (33.8%)	2 (28.6%)		
Training experience (years)			.189	-
Mean (SD)	8 (5.00)	4.93 (2.52)		
Range	3-16	2.5-9		
Experience training students with ASD			-	.898
Yes	3 (75%)	5 (71.4%)		
No	1 (25%)	2 (28.6%)		

* Statistically significant at $p < .05$ level

Table 2. Results of t-test of psychological measures

Measure	Mean (SD)		p-value
	Intervention group (n = 37)	Control group (n = 35)	
Executive function			
Multi-tasking Test	11.22 (14.72)	11.09 (11.63)	.967
One-Touch Stocking of Cambridge	10229.65 (4947.50)	10483 (6750.96)	.856
Paired Associate Learning	9.70 (10.59)	8.89 (11.35)	.753
Reaction Time	356.15 (77.10)	384.06 (82.55)	.142
Spatial Working Memory	6.89 (2.49)	6.2 (2.92)	.283
Social responsiveness			
Restrictive/repetitive	15.92 (5.29)	17.56 (7.35)	.285
Social awareness	10.06 (3.55)	11.35 (3.13)	.110
Social cognition	15.47 (4.61)	17.35 (6.07)	.148
Social communication	28 (10.18)	30.68 (8.86)	.246
Social motivation	16.64 (6.65)	18.09 (6.73)	.368
Anxiety			
Social			
Defensiveness	4.06 (2.53)	3.88 (2.32)	.767
Physiological	4.44 (2.91)	5.88 (2.94)	.044*
Worry	7.83 (4.67)	10.03 (4.51)	.050
Social	5.97 (2.94)	6.88 (3.44)	.056
Task load			
Difference score	4.01 (15.91)	.82 (18.11)	.430

Note. Executive function measured by CANTAB; Social responsiveness measured by SRS-2; Anxiety measured by RCMA5-2; Task load measured by NASA TLX. SRS-2 adult version completed by all participants regardless of age. Both SRS-2 and RCMA5-2 baseline measure of equivalence between groups.

* Statically significant at $p < .05$ level

Table 3. GEE model results

	100% Correct					
Variable	n	N	%	Odds Ratio	95% CI	p-value
Group						
Control	1288	2262	56.9	.92	0.67 - 1.27	.62
Intervention	1358	2365	57.4	1	-	-
Activity						
Car park (Left)	96	144	66.7	.98	0.56 – 1.74	.95
Parking	42	141	29.8	.15	0.08 – 0.30	< .0001**
Pedestrian zone	148	276	53.6	.66	0.41 – 1.0	.07
Right turn	65	138	47.1	.4	0.23 – 0.71	.0017*
Round-about (Right)	129	277	46.6	.33	0.21 – 0.53	< .0001**
Round-about (Straight)	227	488	46.5	.43	0.27 – 0.68	.0003**
T-junction (Left)	714	1230	58.1	.74	0.52 – 1.07	.11
T-junction (Right)	603	895	67.4	1.18	0.82 – 1.69	.37
Traffic light (Left)	203	340	59.7	.65	0.40 – 1.05	.08
Traffic light (Right)	212	348	60.9	.79	0.52 – 1.18	.25
Traffic light (Straight)	207	350	59.1	1	-	-
Timing * Activity						
Post * Car park (Left)	58	72	80.6	3.71	1.86 – 7.39	.0002**
Pre * Car park (Left)	38	72	52.8	1	-	-
Post * Parking	32	72	44.4	4.65	2.11 – 10.21	.0001**
Pre * Parking	10	69	14.5	1	-	-
Post * Pedestrian zone	88	136	64.7	2.41	1.49 – 3.88	.0003**
Pre * Pedestrian zone	60	140	42.9	1	-	-
Post * Right turn	43	70	61.4	3.41	1.71 – 6.78	.0005**
Pre * Right turn	22	68	32.4	1	-	-
Post * Round-about (Right)	90	138	65.2	4.89	2.97 – 8.06	< .0001**
Pre * Round-about (Right)	39	139	28.1	1	-	-
Post * Round-about (Straight)	146	247	59.1	2.89	1.95 – 4.27	< .0001**
Pre * Round-about (Straight)	81	241	33.6	1	-	-
Post * T-junction (Left)	425	614	69.2	2.53	1.78 – 3.60	< .0001**
Pre * T-junction (Left)	289	616	46.9	1	-	-
Post * T-junction (Right)	343	448	76.6	2.34	1.72 – 3.19	< .0001**
Pre * T-junction (Right)	260	447	58.2	1	-	-
Post * Traffic light (Left)	129	172	75	3.78	2.19 – 6.51	< .0001**

Pre * Traffic light (Left)	74	168	44.1	1	-	-
Post * Traffic light (Right)	130	177	73.5	3.06	1.94 – 4.82	< .0001**
Pre * Traffic light (Right)	82	171	48	1	-	-
Post * Traffic light (Straight)	114	178	64	1.58	1.05 – 2.37	.03*
Pre * Traffic light (Straight)	93	172	54.1	1	-	-

Note. N = total number, n = number where the score was 100%, percentage = n/N%, (e.g., N = 2262 activities in total for the control group, n = 1288 completely correct, forming 56.9% of the total). Compared to the reference group in each block (the reference group is explicitly shown as having an odds ratio of 1), the Odds Ratio for each row shows whether it has a higher or lower proportion of results which gained 100%, and the p-value associated with this.

* Statistically significant at $p < .05$ level

** Statistically significant at $p < .001$

Table 4 Correlations with DPC pre-post change score

Variable	N	Correlation co-efficient (<i>r</i>)	<i>p</i> -value
Instructor experience (years)	64	.22	.38
Anxiety			
Social	70	-.001	.99
Defensiveness	70	.09	.45
Physiological	70	.08	.46
Worry	70	.002	.98
Total	70	.03	.82
Social responsiveness			
Restrictive/repetitive behaviour	70	.11	.37
Social awareness	70	.11	.35
Social cognition	70	.13	.29
Social communication	70	.07	.56
Social motivation	70	.06	.58
Total	70	.08	.49
Task load	72	.24	.04*
Executive function			
Multitasking	72	.24	.04*
One-touch Stockings of Cambridge	72	-.001	.13
Paired Associate Learning	72	-.17	.12
Reaction Time	72	.01	.88
Spatial Working Memory	72	-.04	.76
Composite	72	-.008	.99

* Statistically significant at $p < .05$ level

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