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Project Title: Examining Driving Behavior of Adults with Higher Functioning Autism Spectrum Disorders to Develop and Evaluate an Innovative Driving Instructor Training Program

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Disclaimer

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List of Acronyms

ADHD	Attention-deficit/hyperactivity disorder
AQ-10/50	Autism-spectrum Quotient
ASD	Autism spectrum disorder
ANOVA	Analysis of Variance
BP	Behavioral Prediction
BVP	Blood Volume Pulse
CRPD	Convention of the Rights of Persons with Disabilities
DAS-SR	Drivers Attitude Scale Self Report
DCQ	Driving Cognitions Questionnaire
DF	Dividing and Focusing Attention Hazards
DII	Driving Instructors' Inventory
DSM-5	Diagnostic and Statistical Manual of Mental Disorders
ECG	Electrocardiogram
EDA	Electrodermal Activity
EEG	Electroencephalogram
EF	Executive Functioning
EP	Environmental Prediction Hazards
HMC	Hamad Medical Corporation
HR	Heart Rate
IBI	Inter Beat Interval
IPA	Interpretative Phenomenological Analysis
KDS	Karwa Driving School
LCI	Lane Change Initiation
LCT	Lane Change Test
LSD	Least Significant Difference
MDEV	Mean Deviation in Lane Change Path
PBT	Public Bus Transport
PCL	Percentage of Correct Lane Changes
PER	Percentage of Error Rate
PPG	Photoplethysmography
PSS	Perceived Stress Scale
PT	Public Transport
QBRI	Qatar Biomedical Research Institute
QNRF	Qatar National Research Fund
QoL	Quality of Life

QTTSC	Qatar Transportation and Traffic Safety Center
QU-IRB	Qatar University's Institutional Review Board
RANOVA	Repeated Analysis of Variance
RE	Roadway Environment
RI	Roadway Infrastructure
SD	Standard Deviation
SDLP	Standard Deviation of Lateral Position
TAS-20	Toronto Alexithymia Scale
TD	Typical Development
TTC_{min}	Minimum Time to Collision
WM	Working Memory

Executive Summary

In Qatar, attention has been given to improving the high quality of life for individuals with autism, as outlined in the National Health Strategy 2022 and National Vision 2030. Transportation challenges can hinder individuals with autism from functioning in the community independently. Learning to drive, driving a car, and manage mobility independently all contribute to improving the quality of life. In this respect, obtaining a driver's license is an essential step toward accessing education, job opportunity, maintaining social networks, and improving the quality of life for individuals with autism. Obtaining a drivers' license can be stressful for autistic drivers due to the interferences of autism characteristics during their driving training. For example, certain autism-related characteristics can affect driving such as limitations in planning, attention, and monitoring, motor coordination impairments, concentration, communication difficulties, and anxiety issues. Accordingly, the impact of these characteristics may make it more difficult for autistic individuals to drive safely. Due to the absence of an autism-tailored driving training program in Qatar, instructors may lack the expertise and skills to quickly notice autism characteristics in their trainees and fail to apply a personalized approach to those trainees' demands.

This project aimed the development of validated innovative and scientific evidence-based practical guide for the driving instructors to equip them with the knowledge, tools and techniques to effectively develop driving capabilities and safe driving behaviors of driving trainees with autism in Qatar. To develop the validated module, the project followed progressive steps. (1) obtain an in-depth understanding of potential driving difficulties people with ASD in Qatar. (2) based on the outcome of the previous steps, develop practical training guide for driver instructors to tailor their training to trainees with autism. (3) provide training to driving instructors based on the practical guide. (4) evaluate the effectiveness of the practical guide to driving instructors to tailor their driving lesson to trainees with autism.

To achieve those steps, firstly, we comprehensively surveyed and assessed people with autism, their parents, and driver instructors regarding the potential difficulties people with autism might experience when they learn how to drive in the state of Qatar. The psychological characteristics of young adults with autism in respect to driving in Qatar was also investigated to strengthen our in-depth understanding. More importantly, we objectively assessed the driving capabilities individuals with autism using driving simulator, Tobii eye tracking system and E4 wristband. Secondly, a practical guide was prepared, based on empirical evidence derived from studies and literatures addressed in the first step, for driving instructors to help them to tailor their driving lesson to their trainees with autism. Thirdly, based on this practical guide, a one-day training program for driver instructors was conducted. Finally, we evaluated the practices of trained

driving instructors when they train trainees with autism. In this regard, we addressed several issues: (1) evaluating the driving instructors' knowledge and practices regarding autism and driving. (2) assessing the difference in driving instructors' knowledge on autism and driving before and after the training workshop. (3) evaluating the teaching-to-drive process of driving instructors who did and did not receive the training workshop. (4) compare the driving attitudes, perceived stress, and driving concerns of autistic trainees trained by instructors who did or did not attend the training workshop.

1. Introduction

Autism spectrum disorder (ASD) is a type of neurodiverse pervasive developmental condition explained in some criteria, as outlined in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5): (a) stereotyped and repetitive pattern of behavior, and restricted interests, (b) social communication and interaction, (c) manifestations must be presented in early development but may not fully manifest until later or may be masked later in life by learned strategies, and (d) symptoms must cause clinically significant impairment in current functioning (American Psychiatric Association, 2013). As a child, individuals with autism receive many services (e.g., transportation) from their families and caregivers. However, when they turn into adulthood period, they lack access to the adequate services that they received as a child (Liu et al., 2017). In this regard, the transition period of autistic individuals from childhood to adulthood can be challenging (Liu et al., 2017). Smith et al. (2012) indicated that individuals with autism experience unwanted emotions during the transition from school to work.

The ability of persons with autism to use various mode of transport plays a critical role in the lives of young adults with autism in providing linkage to both meaningful opportunities in their community and enabling fulfilment of daily living needs, including employment, education, healthcare, and socially-focused pursuits (Feeley et al., 2015b). However, transportation service is a problem that can lead individuals with autism to experience unwelcome emotions (e.g., depression, isolation, and confidence) (Feeley et al., 2015b). For example, public transportation services may not be convenient to autistic individuals for possible reasons, such as interacting with other passengers, overcrowding, trip planning (Lubin & Feeley, 2016) sensory stimulation challenges (Sheppard et al., 2022). In this regard, access to transport services is often indicated as a challenge to finding a job (Feeley, 2010). Driving could improve autonomy in this population in social and professional areas (Vanvuchelen et al., 2014a), without depending on schedules and routes as in the case of public transportation.

Driving is an important skill for individuals autism that allows them to travel autonomously and function in the community (Cox et al., 2012) by enabling them to fulfil their mobility demands associated with securing a job and maintaining social networks (Ellaway et al., 2003), in turn, promoting their biopsychology and socio-economics wellbeing (Collia et al., 2003). However, as compared to individuals without autism, based on the rate and time to obtain a driving license, individuals with autism obtain licenses at a significantly lower rate and significantly later (Curry et al., 2018). Cox et al. (2017) indicated that the characteristic of autism affects not only driving safely but also the driving training process. For example, figures from the US show that only 24% of young adults with ASD owned a driver’s license in 2007- 2008, compared to 75% for neurotypical adults (Cox et al., 2012). As driving can be a complex task, ASD characteristics may make driving even more difficult (Vanvuchelen et al., 2014a). Individuals with autism may face difficulties in driving due to the possibility that their autism characteristics negatively interfere with their driving training process (Cox et al., 2017).

In a study by Lindsay (2017), driving instructors indicated that teaching autistic individuals how to drive can be challenging. In this respect, driving training program for individual with autism should consider the impact of autism characteristic on the training process that may contribute for trainees with autism to received driving license in lower rate and later. Driving instructors who participated in a study by Tyler (2013) advocated for alternative strategies to enhance the learning-to-drive process for autistic trainees. The same findings were found in a study by Ross, Jongen, et al. (2018), where some of driving instructor participants were in favour of driving lessons have to be tailored to the needs of autistic trainees. In a study by Myers et al. (2019), trained or specialized driving instructors indicated that the driving training approaches should be customized to the training demands of autistic trainees. Wilson et al. (2018) also recommended that an effective training program is required to enhance the learning-to-drive process. However, driving instructors can be challenged to decide on suitable techniques that are tailored to the autistic trainees' needs. In this regard, further support is required to increase the awareness of driving instructors (Lindsay, 2017). By introducing a training program for driving instructors where they learn to tailor their driving lessons to the autistic trainees' needs, a better environment can be created that may have a positive impact on the difficulties that autistic trainees experience when learning to drive.

1.1 Background of project

Driving involves subtasks to be done accordingly in parallel (e.g. shifting gears, steering, changing lanes, and keeping traffic rules into account), it also possible to run into changes in driving conditions (e.g. traffic jams, road blocks and detours). Applied to autonomy, to maintain work and social contacts, it is not only necessary to handle the vehicle appropriately, but also to navigate through rural, urban, and highway traffic environments while concurrently remembering appointments and obeying a schedule. Driving depends on driving experience, perception, as well as cognitive abilities (Veerle Ross, Ellen Jongen, Tom Brijs, et al., 2015). People with ASD were found to show a reduced cognitive efficiency, combined with an underperformance in unexpected circumstances. For instance, they have problems with multi-tasking. An individual's ability to process information visually can cause problems if the driver is unable to process road hazards (Sheppard et al., 2010). Due to issues with planning and executing actions when responding to changes in the environment, this can a reduced speed in driving style (Fournier et al., 2010). Executive dysfunction reduced self-monitoring, mental flexibility and planning abilities (Hill, 2004), can lead to a stressful driving experience that is also dangerous in nature. Another barrier for driving relates to a limited capacity to predict and understand the behavior of others (Chee et al., 2015), potentially leading to inaccurate judgements about other drivers behavior.

Problems while driving for people with ASD increased driving errors (Classen & Monahan, 2013), which was sometimes related to potential cognitive issues. Specifically, Cox et al. (2016), using a sample that ranged from 15 to 23 years of age, showed a different response to working memory load induced by a dual task in ASD. Increased working memory demands induced during a simulated drive by a dual task resulted in decreased steering and braking performance in the ASD group, whereas it resulted in increased steering and braking performance in the control group. Classen et al. (2013) linked increased driving errors (e.g., speed regulation, lane maintenance) to executive function difficulties (e.g., selective and divided attention) in both pre-licensed and licensed adolescents with ASD. Moreover, in the latter study, licensed adults with ASD considered themselves as 'poor drivers' and reported to commit more driving errors than non-ASD participants. Chee et al. (2017) used a driving simulator, the Driving Behaviour Questionnaire, and measures of cognitive and visual-motor ability. They found a worse performance, compared to a typically developing control group, with respect to some measures, i.e., they reported more lapses (i.e., inability to focus and effectively allocate and sustain attention) while driving, and made more driving mistakes and reacted slowed in complex situations during simulated driving. However, they did not show as much tailgating as the control group. Finally, some errors made during the simulated drive could be related to insufficient attention allocation capacities in the ASD group.

Learning to drive (Smigiel, 2020), driving a car, and manage mobility independently (Ross, Jongen, et al., 2018) all contribute to improving the quality of life. In this regard, adequate driving skills help autistic individuals to handle their travel independently and function in the community (Cox et al., 2012). However, it is not always easy autistic individuals to learn to drive (Cox et al., 2012). Certain autism-related characteristics can affect driving such as limitations in planning, attention, and monitoring (Hill, 2004; Luna et al., 2007), motor coordination impairments (Weimer et al., 2001), communication difficulties (Hofvander et al., 2009), problem to extract the whole meaning of perception (Burnette et al., 2005), and anxiety issues (Hofvander et al., 2009). Accordingly, the impact of these characteristics may make it more difficult for autistic individuals to drive safely. For example, they tend to have problems in operational driving skills (Classen et al., 2013), impaired maneuvering quality (Wilson et al., 2018), lower lane keeping (Chee et al., 2017; Lindsay, 2017), and slow perception (Monahan et al., 2013).

Autism characteristics can also negatively affect the process of obtaining a driving license (Almberg et al., 2017). For example, unlike the driving process, which involves a constant assessment of the whole picture of own perception, autistic trainees are more likely to focus on a smaller details which may pose challenges during driving training (Tyler, 2013). Accordingly, as compared to non-autistic individuals, based on the rate and time to obtain a driving license, autistic individuals obtain their license at a significantly lower rate and also significantly later (Curry et al., 2018). Cox et al. (2017) indicated that the characteristic of autism not only affect driving safely but also the driving training process. In this regard, in a study by Tyler (2013), autism characteristics, such as impairments in social skills, poor communication, focus on the hidden meaning of conversations, and limited ability to gestures may lead to misunderstandings between the autistic trainees and instructors during the learning-to-drive process. This may result in the inability of driving instructors to adequately transfer training-related information and obtain the necessary feedback to ensure an effective learning-to-drive process.

As a result, due to autism characteristics, autistic trainees may need longer driving training sessions and more road driving tests than non-autistic individuals (Almberg et al., 2017). Moreover, the learning-to-drive process and period can be very stressful for autistic trainees (Chee et al., 2015). A possible reason may be that the common training approach, in which driving instructors apply the same learning-to-drive process to all trainees, regardless of their differences, may not contain tailored techniques to deal with autistic trainees' demands. By introducing a training program for driving instructors where they learn to tailor their driving lessons to the autistic trainees' needs, a better environment can be created that may have a positive impact on the difficulties that autistic trainees experience when learning to drive.

In a study by Chee et al. (2019a), driving instructors indicated that teaching autistic individuals was challenging, which might be due to autism characteristic interference. The lack of specific training courses tailored to autism characteristics is a barrier to obtaining a driving license for autistic people (Tyler, 2013). To enhance the learning-to-drive process for autistic trainees, in a study by Tyler (2013), driving instructors employed various strategies, including developing rapport with autistic trainees, appropriate communication to trainee with autism, set routines, visual markers to show the judgment of distance from the car in front, crash avoidance space, 'what if? 'scenarios, positive praise, repetitive practice, positive approach, breaking tasks down and working through smaller components in sequence to reduce anxiety. To apply such strategies, driving instructors must have the knowledge and experience regarding handling autistic individuals in the context of a driving training. In this regard, a customized driving training approach may be required to provide instructors insights to help them ease the learning-to-drive process of autistic individuals.

In a study by Myers et al. (2019), driving instructors reported that the learning-to-drive process for autistic individuals required customization to the unique needs of the autistic trainee.

In this case, for example, in the Netherlands and Belgium, driving schools implement a tailored educational module for instructors to deal with the demand of autistic trainees (see Ross, Cox, Noordzij, et al., 2018). However, in many countries, to the best of our knowledge, no attention has been given to autism-tailored instructors' support and training packages to improve the learning-to-drive process for autistic trainees (Wilson et al., 2018). Like many countries, in Qatar, there is no autism-specific training and support for driving instructors.

Qatar was among many leading nations to sign the Convention of the Rights of Persons with Disabilities (CRPD) treaty in 2008 (OHCHR, 2021). In connection to this, in the state of Qatar, attention has been given to improving the high quality of life for all, including autistic individuals, as outlined in the National Vision 2030. In a large-scale study in Qatar by Alshaban et al. (2019) the prevalence rate of autism among children in mainstream schools (6 to 11 years) was estimated at 1.14% or 1 in every 87 children. The prevalence in terms of gender was 1 in 56 boys and 1 in 230 girls (ratio 4:1). Although there has been attention to autism in Qatar, not much is known about autism and driving. As a result, it is not always easy for driving instructors to tailor their lessons to the needs of autistic persons.

To this end, this project targeted the development of validated innovative and scientific evidence-based training modules for the driving instructors to equip them with the knowledge, tools and techniques to effectively develop driving capabilities and safe driving behaviors of novice drivers with ASD in Qatar. To develop the validated module, the study followed progressive steps. (1) obtain an in-depth understanding of potential driving difficulties people with ASD in Qatar. (2) based on the outcome of the previous steps, develop practical training guide for driver instructors to tailor their training to trainees with autism. (3) provide training to driving instructors based on the practical guide. (4) evaluate the practices of trained driving instructors when they train trainees with autism.

1.2 Objectives of this Study

In general, this project aimed the development of a validated practical innovative guide, based on empirical evidence derived from several studies, for the driving instructors to help them to tailor their driving lessons to the needs of trainees' with autism, a better environment can be created that may have a positive impact on the difficulties that trainees with autism experience when learning to drive. To reach this goal, the following objectives were achieved in the project:

Objective 1: To obtain an in-depth understanding of potential difficulties people with ASD might experience when they (learn how to) drive.

Status: This objective was achieved through performing the following empirical works:

(1) comprehensively surveyed and assessed people with ASD, their parents,

and driver instructors about the potential difficulties people with ASD might experience when they learn how to drive in the state of Qatar. (2) Conducted the international literature regarding ASD and driving. (3) investigated the psychological characteristics of young adults with ASD in respect to driving in Qatar. (4) objectively assessed the driving capabilities individuals with ASD using driving simulator, in which Tobii eye tracking system and E4 wristband are included. (Please refer to "Appendix I, J, L, M & N").

Objective 2: Based on the outcome of the objective one, a one-day training program for driver instructors is developed, together with an information folder.

Status: To achieve this objective, practical guide was prepared, based on empirical evidence derived from several studies, for driving instructors to help them to tailored their driving lesson to their trainees with autism. Based on this practical guide, a one-day training program for driver instructors was developed. (Please refer to "Appendix A, B, C & D").

Objective 3: The effect evaluation will focus on outcome measures related to general driving behavior and indications of workload and anxiety.

Status: This objective was achieved through addressing three phases: (1) evaluating the driving instructors' knowledge and practices regarding autism and driving. (2) assessing the difference in driving instructors' knowledge on autism and driving before and after the training workshop. (3) evaluating the teaching-to-drive process of driving instructors who did and did not receive the training workshop. (4) compare the driving attitudes, perceived stress, and driving concerns of autistic trainees trained by instructors who did or did not attend the training workshop. (Please refer to "Appendix E & F").

Objective 4: Finally, the project aims to include an immediate and 3-month follow-up after the driving exam in order to determine the impact on driving behavior (i.e., capabilities in driving and the number of driven kilometers per week), workload, and anxiety (i.e., arousal and apprehension).

Status: To achieve this objective, we addressed several follow-up issues, including the number of training hours each trainee received, the number of driving test each trainee took, the number of trainees who passed and failed the driving test, the driving experience (e.g., confidence, stress) of trainees' who passed the test (who obtained license). (Please refer to "Appendix E & F").

1.2 Project Tasks/Aims

In summary, the project is well executed based on the approved time plan. Regarding the driving instructor training program, the project developed and evaluated an innovative evidence based practical guide for driving instructors to help them to customize their driving lesson to trainees with autism in driving school in Qatar (Please refer to Appendices E). Moreover, a one-day training program document was developed to guide a training workshop on driving and autism. The details of the practical guide and one-day training program document are provided in separate documents attached along with the report (Please refer to Appendices B & C). In terms of publications, the project achieved seven publications of journals and conference proceeding (Please refer to Appendix L) and five (three are indexed) posters with abstracts (Please refer to Appendix O). Furthermore, three journal papers are under-review/ready for submissions (Please refer to Appendix M) while nine journal papers are in preparation (Please refer to Appendix N). The details of the scientific outcomes are provided in separate documents attached along with the report. Below a detailed description of all tasks and work packages that are achieved in the project period.

1.3.1. WP1: Project initiation & Management

Start Month: **3** ***End Month:*** **42** ***Completed?*** Yes ***Completed Percentage:*** 100%

This WP was an ongoing effort during the whole project duration to ensure all tasks and deliverables were completed on time. During the overall project period, an effective coordination was established between the project team in delivering all tasks listed under the work packages. To achieve those work packages, frequents meetings between the team members in Qatar and the international team members in Belgium were conducted both physically and online platforms. In this respect, regular email correspondences were being sent with updates on assigned task progression, which stimulated clear communication on tasks and deliverables. Moreover, a member of the international research team came to Qatar for the project Workshop. To this end, all the tasks were completed smoothly with a remarkable harmony and cooperation between the project team in Qatar University and Hasselt University, copping the impact of COVID-19 restrictions that put most of the project’s tasks on hold.

1.3.2. WP2: Inventory of potential difficulties with respect to ASD and driving

Start Month: 17 ***End Month:*** **28** ***Completed?*** Yes ***Completed Percentage:*** 100%

<u>Task 2.1 Literature Review</u>

Start Month: **3** ***End Month:*** **5** ***Completed?*** Yes ***Completed Percentage:*** 100%

A comprehensive literature review on autism and driving was conducted during the first reporting period. This allowed us to understand and frame the most appropriate study design of the project.

Task 2.2 Development of the questionnaires

Start Month: **3** ***End Month:*** **4** ***Completed?*** Yes ***Completed Percentage:*** 100%

This task was completed and reported in year 1. Three separate surveys were developed, targeting different samples; one survey for driving instructors, one for ASD drivers and one for relatives of ASD drivers. Those surveys were developed based on the literature related to ASD and driving behaviour. The surveys were developed in the English language and translated to Arabic to fit the Arabic culture in the State of Qatar.

Task 2.3 Sampling

Start Month: **5** ***End Month:*** **28** ***Completed?*** Yes ***Completed Percentage:*** 100%

This task was completed and reported in the 3rd year reporting period. This task was planned to be finished in the 2nd year but completed in the 3rd year of the project. In this regard, it is important to remind that due to unforeseen circumstances related to the COVID-19 outbreak, the research team received an official announcement not to engage in activities, i.e., meet with participants, that could lead exposure for COVID-19. Thus, the COVID-19 restriction put many tasks of sampling in delay. However, the project management looked at all possible options to continue the sampling tasks when some restrictions were lifted. In this regard, the project management achieved an excellent work while looking a smaller opportunity (e.g., lifting some COVID-19 restriction before precautions for the second wave were announced) to continue the sampling process.

Task 2.4 Preliminary analysis

Start Month: **13** ***End Month:*** **23** ***Completed? Yes*** ***Completed Percentage:*** 100%

This task was achieved in the second-year reporting period. The preliminary analysis attempted to show the viewpoints of ASD participants and their parents regarding obstacles as well as benefits when people with ASD were learning how to drive. The main challenge was, at that time we did not finish all sampling processes due to COVID-19 restrictions, however we prepared the analysis based on the data collected from available participants at hand using inventories for parents and individuals with ASD.

1.3.3. WP3: Investigating the psychological characteristics of ASD adults in respect to driving

Start Month: **9** ***End Month:*****29** ***Completed?*** Yes ***Completed Percentage:*** 100%

<u>Task 3.1 Development of the Measures</u>

Start Month: **9** ***End Month:*** **10** ***Completed?*** Yes ***Completed Percentage:*** 100%

This task was completed in the first-year reporting period. We translated and back-translated the Autism Spectrum Quotient (AQ-10), Toronto Alexithymia Scale -20 (TAS-20), Driver Attitude Scale-self report (DAS-SR) from the English to the Arabic language to adjust both surveys for the Qatari context. We created online survey for each scale using Qualtrics.

<u>Task 3.2 Sampling</u>

Start Month: **10** ***End Month:*** **28** ***Completed?*** Yes ***Completed Percentage:*** 100

This task was finished and reported in the 3rd year reporting period. As previously indicated, in year 2, the sampling process was put on hold due to COVID-19 outbreak and related precautions. However, in year 3, we accomplished the sampling processes and data collection.

<u>Task 3.3 Data Analyses</u>

Start Month: **12** ***End Month:*** **29** ***Completed?*** Yes ***Completed Percentage:*** 100%

This task was completed in the 3rd year reporting period. Due to COVID-19 restrictions in year 2, this task was put on hold. In year 2, since we did not finish the sampling and data collection processes, we could not completely proceed to the data analysis step. However, in year 3, we 100% completed the data collection and data analysis process.

1.3.4. WP4: Objective driving assessment with use of a driving simulator

Start Month: **12** ***End Month:*** **35** ***Completed?*** Yes ***Completed Percentage:*** 100%

<u>Task 4.1 Development of the driving scenario</u>

Start Month: **12** ***End Month:*** **15** ***Completed?*** Yes ***Completed Percentage:*** 100%

This task was completed in year 2. Three different types of scenarios for emotional regulation, distraction and hazard perception were developed and tested to be ready for experiment.

<u>Task 4.2: Recruitment</u>

Start Month: **14** ***End Month:*** **28** ***Completed?*** Yes ***Completed Percentage:*** 100%

This task was completed and reported in the 3rd year reporting period. As it indicated above, the recruitment process was delayed due to the COVID-19 outbreak in year 2.

<u>Task 4.3: Executing the experiments and collecting data</u>

Start Month: **17** ***End Month:*** **33** ***Completed?*** Yes ***Completed Percentage: 100%***

This task was accomplished during the 3rd reporting period. In year 2, the suspension of sampling processes led to an automatic delay in the subsequent tasks, including executing the experiments and collecting data. However, in year 3, these tasks were completed for 100%.

<u>Task 4.4: Data Analyses</u>

Start Month: **22** ***End Month:*** **35** ***Completed?*** Yes ***Completed Percentage: 100%***

This task was completed and reported in the 3rd year reporting period. Using STISIM Drive 3, data for each participant, each simulation scenario and each experiment was collected in raw files called ".DAT". The collected raw data were converted to excel files and data was extracted for analyses using MATLAB and SPSS. We then were able to complete analyses and statistical modelling for all experiments. Different analyses and statistical models were used for each study.

1.3.5. WP5: Development of training modules for driver instructors

Start Month: 35 ***End Month:*** **37** ***Completed?*** Yes ***Completed Percentage: 100%***

<u>T5.1: Development of the educational materials</u>

Start Month: 35 ***End Month:*** **36** ***Completed?*** Yes ***Completed Percentage: 100%***

This task was accomplished during the 3rd reporting period. We prepared an innovative educational material for driving instructors to help them to tailor their driving lesson to trainees with autism. The educational material was prepared based on empirical evidence derived from several studies using a driving simulator, self-report, and E4-wristband. The material addressed several issues concerning autism, such as the characteristics of autistic persons, theoretical perspectives on autism, autism in general and specifically in Qatar, autism and driving, and detailed practical recommendations about how to deal with the learning-to-drive process for autistic trainees.

<u>Task 5.2: Development of information folder</u>

Start Month: 36 ***End Month:*** **37** ***Completed?*** Yes ***Completed Percentage: 100%***

This task was completed in the 3rd reporting year. We developed an information folder that show detail theoretical information, methodological aspect, and practical tips for driver instructors to tailor their lesson for trainees with autism. This folder is an important guide to conduct workshop training for driving instructors.

1.3.6. WP6: Assessment of the impacts of the developed training modules

Start Month: 37 ***End Month:*** **42** ***Completed?*** Yes ***Completed Percentage: 100%***

<u>Task 6.1: Recruitment of participants</u>

Start Month: 37 ***End Month:*** **37** ***Completed?*** Yes ***Completed Percentage: 100%***

This task was completed during the extension period of the project. We recruited 13 participants: 7 driving instructors and 6 autistic trainees. Each group (instructors and trainees) participants was categorized into experimental and control groups. In this regard, three out of 7 driving instructors were assigned to train 3 trainees with autism, who were assigned to the experimental group. These three driving instructors were received workshop training and the practical guide about how to train trainees with autism about driving. The remaining 4 driving instructors (not included in the training workshop and not received the practical guide) were assigned to train three autistic trainees (control group).

<u>Task 6.2: Measurement of stress and workload levels during driving learning period</u>

Start Month: 38 ***End Month:*** **40** ***Completed?*** Yes ***Completed Percentage: 100%***

This task was completed in the extension period of the project. We measured trainees' driving-related concerns (i.e., panic-related, accident-related, and social concern), perceived stresses (i.e., perceived helplessness and lack of self-efficacy) and attitude towards driving (i.e., attitude towards talking about driving, attitude towards getting ready to drive, and attitude towards when driving). This measurement helped to determine whether learner drivers with autism indeed show decreased stress and driving concerns and increased positive attitudes towards driving when learning how to drive, compared to controls.

<u>Task 6.3: Follow-up data collection</u>

Start Month: 40 ***End Month:*** **41** ***Completed?*** Yes ***Completed Percentage: 100%***

This task was achieved in the extension period of the project. We collected information about the number of training hours each trainee received, the number of driving test each trainee took, the number of trainees who passed the driving test (pass and fail), the driving experience of trainees' who passed the test (who obtained license).

<u>Task 6.4: Data analyses</u>

Start Month: 41 ***End Month:*** **42** ***Completed?*** Yes ***Completed Percentage: 100%***

This task was achieved in the extension period of the project. We conducted several independent t-test analyses. The analyses assisted us to determine the difference of autism tailored driving training practices between control and experimental driving instructors. Moreover, trainees in the control and experimental were compared in their driving-related concerns (i.e., panic-related, accident-related, and social concern), perceived stresses (i.e., perceived helplessness and lack of self-efficacy) and attitude towards driving (i.e., attitude towards talking about driving, attitude towards getting ready to drive, and attitude towards when driving). At the end, the opinions of two trainees, who received license were considered to know their experience about driving.

2. Literature Review

2.1. Autism spectrum disorder (ASD)

Autism spectrum disorder (ASD) is a type of neurodiverse pervasive developmental condition characterized by stereotyped and repetitive pattern of behavior, and restricted interests, social communication and interaction, and manifestations must be presented in early development but may not fully manifest until later or may be masked later in life by learned strategies (American Psychiatric Association, 2013).

The global prevalence of autism is nearly 1 in every 100 children (Zeidan et al., 2022). The estimates in the studies ranged from 1.09/100000 to 436.0/100000 and varied largely between sociodemographic groups (Zeidan et al., 2022). The sex ratio for males to females is estimated at 3:1 (Loomes et al., 2017). However, the sex ratio could be skewed since females tend to mask their autism more than men do. This phenomenon is known as camouflaging, it is defined as the use of explicit techniques to hide social incompetence and preventing others from seeing this (Hull et al., 2017). These authors described it as a combination of masking and compensation behaviours with the goal of fitting in. It requires the use of compensating behaviours, such as staying in groups with peers in order to hide their social challenges (Dean et al., 2017). This behaviour is more accepted in the female social landscape (Dean et al., 2017). Furthermore, females tend to have less stereotyped characteristics such as repetitive behaviour (Kreiser & White, 2014), which, in addition to the camouflaging, might explain the lower diagnostic rate.

Research on ethnic distribution is inconclusive (Dyches et al., 2004; Elsabbagh et al., 2012; Keen et al., 2010). The prevalence of autism is higher for mental health patients (Tromans et al., 2018). Family studies revealed that genes significantly contribute to autism (Gaugler et al., 2014). With more than 100 genes and genomic regions associated with autism (Sanders et al., 2015), it is one of the most heritable common medical conditions (Wang et al., 2017). Other possible causes for autism include, but or not limited to, environmental factors such as chemicals (Landrigan, 2010) and extreme traumatic experiences (Rowland, 2020).

2.2. Quality of life and ASD

The issues that people with ASD experience in social functioning might cause problems in forming friendships, romantic relationships, finding a job and can negatively impact daily-living (Barnhill, 2007). Driving plays a critical role in providing linkage to both meaningful opportunities in the community and enabling fulfilment of daily living needs. For example, employment, education and healthcare (Huang et al., 2012). Mason et al. (2018) state that the overall quality of life (QoL) is lower for adults with an ASD than for the general population. Being employed, receiving social and environmental support and being in a relationship were seen as the significant positive predictors of QoL. Having a mental health condition and a higher severity of social impairment were seen as significant negative predictors of QoL. A study on the economic cost of autism in the United Kingdom showed that the lifetime cost for an individual with an ASD varies between €0.9 million (for people without an intellectual disability) and €1.4 (for people with an intellectual disability). Much of the high cost is due to the lack of autonomy, not being employed and the cost of productivity losses of the parents (Knapp, Romeo & Beecham, 2009).

Driving could improve autonomy in this population in social and professional areas (M. Vanvuchelen et al., 2014), without depending on schedules and routes as in the case of public transportation. However, figures from the US show that only 24% of young adults with ASD owned a driver's license in 2007-2008, compared to 75% for neurotypical adults (N. B. Cox et al., 2012). As driving can be a complex task, ASD features may make driving even more difficult (M. Vanvuchelen et al., 2014), but the relation between ASD and driving has received little attention. Driving involves subtasks to be done accordingly in parallel (e.g. shifting gears, steering, changing lanes, and keeping traffic rules into account), it also possible to run into changes in driving conditions (e.g. traffic jams, road blocks and detours). Applied to autonomy, in order to maintain work and social contacts, it is not only necessary to handle the vehicle appropriately, but also to navigate through rural, urban, and highway traffic environments while concurrently remembering appointments and obeying a schedule. Driving depends on driving experience, perception, as well as cognitive abilities (V Ross et al., 2015). People with ASD were found to show a reduced cognitive efficiency, combined with an underperformance in unexpected circumstances.

Previous research regarding ASD drivers gives reason for concern as a percentage of road accidents are related to drivers with ASD symptoms. This suggests that indeed, drivers with ASD can be subjected to high potential of safety risks while driving. Those with ASD usually experience significant challenges in adulthood and successfully overcoming typical milestones. Those with ASD may lack to establish social support networks. A sense of failures can often impact one's sense of self-esteem and can contribute to psychological effects that impairs personal growth. Those with ASD commonly wish to rely less on family support and to become more independent. The proposed investigation also focuses on training individuals with ASD to better their presence on the road. What's more, gaining further knowledge about the ASD population in Qatar, which may help these individuals, their families, and to better understand the issues they face in order to ultimately improve their quality of life (Kapp et al., 2011a)

2.3. Autism in Qatar

A significant example related to Qatar's ambitions in promoting excellence in equality was in 2007 when they supported the idea of celebrating World Autism Awareness Day, which was later accepted by the United Nations General Assembly (OHCHR, 2021). In this respect, the same report indicated that Qatar was among many leading nations in signing the Convention of the Rights of Persons with Disabilities (CRPD) treaty in 2008 (OHCHR, 2021). The State of Qatar strives for achieving equality and justice for all, as outlined in their National Vision 2030 (Ministry of Public Health, 2020).

It is not a straightforward task to get a clear picture of the prevalence of autism among all segments of society in Qatar. As observed in most Gulf countries, in Qatar, the prevalence of autism demands more nationwide epidemiological research across different age groups. Recently, some studies in Qatar attempted to portray the prevalence of autism, specifically among school-age children. However, the prevalence of autism among adults remains unclear to this date. According to Alshaban et al. (2019) epidemiological studies from the Qatar Biomedical Research Institute (QBRI) estimated that 50.500 children under the age of five and 187.000 youths under the age of 20 have autism in the Gulf region. A nationwide epidemiological study conducted by a research team from the QBRI addressed many school-age students in Qatar. The prevalence rate of autism from 2015 to 2018 among children in the mainstream school (6 to 11 years) is estimated at 1.14%, or 1 in every 87 children. The prevalence in terms of gender is 1 in 56 boys and 1 in 230 girls (ratio 4:1). In sum, the study estimated that around 4.791 individuals aged 1 to 20 years have autism in Qatar.

2.4. The Qatar National Autism Plan

In the context of the Gulf region, many countries have not yet given significant attention to autism. The absence of a national priority for autism can affect the adequacy of services provided to autistic individuals and their family members. Therefore, in 2017, Qatar introduced an autism-oriented nationwide plan to enhance the lives of autistic individuals and their family members. The most recent national strategy tried to address the needs of individuals with a disability was the Qatar National Autism Plan. The national plan aimed to improve the 'day-to-day' lives of all autistic individuals and their families in terms of education, health, social affairs, and quality of life. The milestones for the national plan were when Qatar proposed the idea of celebrating World Autism Awareness Day in 2007, which the United Nations General Assembly later accepted, and when Qatar signed the CRPD treaty in 2008. With this plan, the State of Qatar strives to achieve equality and justice for all, as outlined in Qatar's National Vision 2030.

According to Qoronflesh et al. (2019), the National Autism plan 2017 - 2021 consists of evidence-based recommendations that address many aspects associated with autism in Qatar. The following recommendations are included in the National Autism Plan:

- Promote awareness-raising campaigns regarding autism
- Conduct research to identify appropriate approaches and intervention mechanisms for autistic individuals and their family members in the context of Qatar
- Establish a research center that comprises researchers from diverse fields in the area of autism
- Develop educational websites to provide evidence-based training materials to autistic people and their family members
- Prepare culturally oriented autism diagnostic and assessment tools
- Capacity building for professionals about services to autistic people
- Prepare plans and implement them to provide a wide range of opportunities to individuals with autism

2.5. Common functional difficulties in ASD

It is known that ASD symptoms can be subtle in the way in which they impair individuals' executive functions, such as self-regulation, decision making, planning, and goal-directed thinking (Hill, 2004). While research suggests that improvements occur in early adulthood (Luna et al., 2007), those with ASD function best with predictability, as they find applying expectations to rules challenging (Pijnacker et al., 2009). Prior research suggests that those with ASD have issues in making inferences from previous knowledge (McKenzie et al., 2010). What's more, other investigations suggests that individuals with ASD may not able to understand common situation and their details, needing longer time to choose between presented information in order to make confident choices (Kapp et al., 2011b)

Executive functioning (EF) is a collective term for the higher order processes that are primarily processed by the prefrontal cortex which enables self-regulation and self-directed behavior toward a goal, allowing us to break out habits, make decisions and evaluate risks, plan for the future, prioritize and sequence our actions, and cope with novel situations. They have an influence on the social, emotional, intellectual and organizational aspects of someone's life (Babin et al., 2006). People with ASD often experience problems with executive functioning which stay relatively stable throughout the development (Demetriou et al., 2018).

Various research regarding executive functioning, driving and autism has already been conducted. A study by Ross et al. (2019) compared the performance level of executive functioning, the driving performance and the relation between the driving performance and the

EF of 16 young novice ASD drivers to 18 neurotypical drivers. Results suggested a lower work memory and attention performance in the ASD drivers, no difference was found regarding response inhibition. They also found evidence that once adults with ASD know how to drive, they can be considered as capable drivers and that EF performance is related to the driving performance. Another study by Cox et al. (2016), they compared 17 male ASD drivers to 27 neurotypical peers. Their findings indicate that working memory may be a key mechanism underlying difficulties demonstrated by ASD drivers. Even though executive functioning stays relatively stable throughout the development, some studies suggest that virtual reality driving simulation training can significantly improve the executive functioning and the general driving performance of adults with ASD compared to routine training (Cox et al., 2017).

Executive functioning plays an important role in the driving performance as multitasking and mental flexibility are important to correctly execute the task sequence while driving (Cox et al., 2012). ASD drivers often experience great difficulties with these EF as they are more rule-bound than neurotypical peers. The experience great difficulties with adjusting a rule to the situation which can be dangerous (e.g. crossing a white line because a truck is parked on the street) (Chee et al., 2017). When interviewing ASD drivers, parents and driving instructors, research suggests that they have difficulties with multitasking and mental flexibility as they find it very challenging to react to unforeseen circumstances and situations and they show perfectionism. However ASD drivers have a better traffic rule knowledge, have less traffic fines and they exhibit a safer driving behavior than neurotypical (Ross, Cox, Noordzij, et al., 2018).

Although ASD is not perceived as a syndrome with obvious motor impairments, people with ASD often experience difficulties with gross and fine motor skills and coordination. These impairments are categorized as 'associated symptoms' and they are thought to interfere with the development of adaptive skills (Miyahara et al., 1997). Studies suggest that these problems can reduce over time but overall 51% of the people with ASD (age: 2 – 18 years) experience hypotonia (decreased muscle tension), 41% experience apraxia, both oral and limb muscles and 25% experience toe-walking (Ming et al., 2007).

Before completing a motor act, a motor plan needs to be developed. People with ASD show qualitatively different motor planning deficits rather than problems in the execution stage (Rinehart et al., 2006). Motor planning consists of the sequence of motor commands that enables the person to convert one's body into the desired state to start a (new) action (Sacrey et al., 2014). One way to measure motor planning is by recording the reaction time. When executing tasks, people with ASD typically react slower than neurotypical peers (Nazarali et al., 2009). However, their performance was similar when presented with a simple task, such as drawing a straight line between two dots. A study by Glazebrook et al. (2009) shows that when people with

ASD don't have a fixed point to start from but they have to anticipate on a target's location, people with autism consistently select a central location to start from whereas participants without autism varied their start location which makes their reaction time significantly faster. This indicates that they become stereotyped when they have to use multiple cognitive strategies in order to execute a motor action.

Carrying out a planned task is called the motor execution. The motor cortex sends out commands to the corresponding nerves and muscles in order to perform an action. People with ASD often have difficulties with the sequence of motor acts into global action. Where neurotypical peers modulate their first act by the task difficulty, children with ASD do not tend to do this. They are more likely to perform the tasks step by step rather than thinking about their main goal (Sacrey et al., 2014). Multiple studies found that people with ASD have longer moving times than neurotypical control groups (Stoit et al., 2013). Therefore, people with ASD might experience driving as a complex and difficult task because they have to adapt their behavior to multiple stimuli (e.g. others their behavior, visual information, proprioceptive information etc.) (Ross et al., 2014).

2.6. Individuals with autism and driving

Driving plays a critical role in the lives of young adults with ASD. However, figures from the United States show that only 24% of young adults with an ASD owned a driver's license in 2007-2008, compared to 75% of the neurotypical adults (Reimer et al., 2013). A more recent retrospective cohort study by Curry et al. (2018) indicated that by the age of 21, one in three adolescents with ASD obtained a driver's license in contrast to 83.5% of the neurotypical adolescents. People with ASD also acquired their drivers' license significantly later (Daly et al., 2014). Learning driving skills in a safe way is often difficult for people with an ASD (Huang et al., 2012). Therefore, people with an ASD depend much more on their family and friends to help them with their transportation needs (Veerle Ross, Ellen Jongen, Tom Brijs, et al., 2015). Parents of young ASD drivers reported that their children needed extra time and more patience in order to obtain a driver's license (Ross, Jongen, et al., 2018).

Driving is a complex and goal-directed activity (Kirby et al., 2011). Driving consists of multiple subtasks between which one has to switch quickly. In addition, drivers have to be able to act as fast as possible on unforeseen circumstances such as road traffics, traffic jams etc. Therefore, the execution of the driving task requires perceptual, physical and executive functioning skills (Bouillon et al., 2006). People with autism rate their driving skills as poorer than neurotypical drivers (Daly et al., 2014). Another study by Chee et al. (2015) examined the viewpoints on driving of individuals with and without an autism spectrum disorder. Results showed three main ASD viewpoint: (1) 38% of the ASD drivers perceived themselves as confident and independent drivers, (2) 30% rather took other modes of transportation than driving, (3) and 18% reported that they were anxious while driving and that they would only drive if they had no other options.

Certain characteristics associated with ASD can interfere with driving (Wilson et al., 2018). Brooks et al. (2016) suggest that individuals with an ASD often exhibit deficits in core social behavior, executive functioning, central coherence and motor coordination. They experience more difficulties in complex driving situations, requiring multi-tasking and inducing workload (Classen & Monahan, 2013). Daly et al. (2014) linked increased driving errors to executive functioning problems. Another study by Cox et al. (2016) showed that young drivers with ASD identified fewer social hazards than non-ASD participants. Those with high autistic traits also oriented their attention slower towards road hazards. Driving errors contribute to 70-75% of driver collisions, indicating that driver errors are directly related to traffic safety.

People with ASD function best within predictable environments as they find exceptions to rules challenging (Pijnacker et al., 2009). Related to driving, Jameel et al. (2015) stated that people with ASD have an increased rule-boundedness which can affect them both positively (e.g., fewer traffic fines) and negatively (e.g. not wanting to cross a full line in order to avoid an obstacle).

Many studies regarding ASD and driving included the application of a virtual reality driving simulator (VRDS) but not many on-road studies have been conducted to this date. A study by Chee et al. (2017) assessed and compared the on-road driving performance of drivers with ASD and neurotypical peers. The ASD drivers performed significantly better than their peers at roundabouts and traffic lights. They performed significantly poorer in items of vehicle manoeuvre, especially at left-turns, right-turns and pedestrian crossings. There were no differences found between groups for orientation, following regulations, attending and acting.

2.7. ASD in learning to drive

The problems people with ASD experience may interfere with their learning process. An American study using questionnaires showed that parents and other caretakers that learn young adults with ASD how to drive, experienced much more difficulties when they learned how to drive than neurotypical peers (Cox et al., 2012). In order to successfully obtain a driver's license people with ASD need more but shorter driver lessons. When people with ASD are overloaded with input, their coping switch overloads and this creates fear, frustration, anger and/or stress issues. It is important that the learning process can be adjusted and support mechanisms (e.g. more breaks, use of an automatic gearbox, etc.) can be incorporated. In the same study, driving instructors reported difficulties regarding the communication during the lessons, difficulties with multitasking and the advantages of shorter lessons or more frequent breaks for people with ASD (Ross, Cox, Noordzij, et al., 2018). The same results were found in a study by Almberg et al. (2017) were they collected data regarding the facilitators and barriers in driving education from learner and novice drivers. The young, novice drivers with ASD reported that their biggest challenge when learning how to drive was to translate the theory into practice and adjusting to new and unfamiliar driving situations.

Young people with ASD are at increased risk of anxiety in general (Van Steensel et al., 2011). A study by Hendriks et al. (2013) suggests that the anxiety that people with ASD experience can lead to avoidance behavior and maladaptive coping. ASD drivers show significantly higher skin conductance levels and skin conductance response rates than neurotypical peers during driving (Wade et al., 2017). This in turn can lead to dangerous behaviors while driving such as driving far below speed, stopping in front of a green light. Parents of novice drivers with ASD also report less positive and more negative attitudes towards driving than the parents of neurotypical peers. About half of the parents reported indications of driving apprehension. After a VRDST about one-third of the parents still reported driving apprehension (Cox et al., 2017).

Ross, Jongen, et al. (2018) researched the process of learning how to drive in young persons with ASD. They described that young persons with ASD have a good knowledge of the traffic rules but they experience difficulties when they have to violate traffic rules when necessary, when they have to respond to an unpredictable situation as well when they have to multitask. Cox et al. (2012) examined the parents' experiences to gain a better understanding of driving and ASD. They formulated useful strategies in teaching driving skills: (1) use practice and repetition, (2) teach in small steps, (3) use video games and other driving-like experiences, (4) provide verbal and/or visual scripts prior to starting out on a drive, and (5) be calm and patient. Show emotion, to much talking, giving to much information at one time and learning to drive in different cars were perceived as the least helpful strategies in teaching driving skills.

2.8. Enhancing the learning-to-drive process for trainees with autism

Becoming licensed to drive a car is an important step toward accessing education, job opportunity, maintaining social networks, and improving the quality of life among individuals with Autism Spectrum Disorder (Wilson et al., 2018), a neurodevelopmental disorder characterized by impaired functions in different aspects of life (American Psychiatric Association, 2013). Learning to drive (Smigiel, 2020), driving a car, and manage own mobility independently (Ross, Jongen, et al., 2018) contribute to improving the quality of life for autistic individuals. In this regard, adequate driving skills help autistic individuals to handle their travel independently and function in the community (Cox et al., 2012). However, it is not easy to get adequate driving skills (Cox et al., 2012) due to autism characteristic interference in the learning-to-drive process (Cox et al., 2017). Autism characteristics that affect driving include limitations in planning, attention, and monitoring (Hill, 2004; Luna et al., 2007), motor coordination impairment (Weimer et al., 2001), encounter unusual attentional experiences (Granovetter et al., 2020), impaired communication (Hofvander et al., 2009), problem to extract the whole meaning of perception (Burnette et al., 2005), and high anxiety (Hofvander et al., 2009). Accordingly, the impact of autism characteristics often put autistic individuals in trouble to drive safely by inducing problems in operational driving skills (Classen et al., 2013), impaired maneuvering quality (Wilson et al., 2018), lower lane keeping (Chee et al., 2017; Lindsay, 2017), and slow perception (Monahan et al., 2013).

Autism characteristics could also negatively affect the learning-to-drive process of obtaining a driving license (Almberg et al., 2017). For example, unlike the driving process, which involves a constant assessment of the big picture of perception, autistic trainees are more likely to focus on a smaller detail which may pose challenges during driving training (Tyler, 2013). Accordingly, as compared to non-autistic individuals, based on the rate and time to obtain a driving license, autistic individuals obtain licenses at a lower rate and later (Curry et al., 2018). Cox et al. (2017) indicated that the characteristic of autism affects not only driving safely but also the driving training process. In this regard, in a study by Tyler (2013), autism characteristics, such as impairment in social skills, poor communication, focus on the hidden meaning of conversation, weak eye contact, and limited ability to read facial expressions and gestures may lead misunderstanding between autistic trainees and instructors during the learning-to-drive process. In this case, as Tyler, driving instructors cannot adequately transfer training-related information and get the necessary feedback to ensure an effective learning-to-drive process. Thus, due to autism characteristics, autistic trainees need longer driving training sessions and more road driving tests than non-autistic individuals (Almberg et al., 2017).

Moreover, the learning-to-drive process and period for driving trainees can be very stressful (Chee et al., 2015). The possible reason is that the common training approach, in which driving instructors apply the same learning-to-drive process to trainees regardless of their difference, may not contain possible tailored solutions to deal with autistic trainees' demands. In this regard, the negative impact of autism characteristics on driving training can be reduced by improving the learning-to-drive process for autistic individuals.

In Chee et al. (2019a) study, it was indicated that driving instructors indicated that teaching autistic individuals was challenging. The lack of specific training courses tailored to autism characteristics is a barrier in obtaining a driving license for autistic people (Tyler, 2013). To enhance the learning-to-drive process for autistic trainees, in a study by Tyler (2013), driving instructors employed various strategies, including developing rapport with autistic trainees, appropriate communication, set routines, visual markers to show the judgment of distance with the front car, crash avoidance space, 'what if? 'scenarios, positive praise, repetitive practice, positive approach, breaking tasks down and working through smaller components in sequence to reduce anxiety. To apply such strategies, driving instructors must have the orientation and experience regarding handling autistic individuals in the context of driving training. In this regard, a customized driving training approach may be required to provide instructors insights to help them deal with the learning-to-drive process for autistic trainees.

In a study by Myers et al. (2019), driving instructors reported that the learning-to-drive process for autistic individuals requires customization to the unique needs of the autistic trainee. In this case, for example, in the Netherlands and Belgium, driving schools implement a tailored educational module for instructors to deal with the demand of autistic trainees (Ross, Cox, Noordzij, et al., 2018). However, in many countries, no attention has been given to autism-tailored instructors' support and training packages to improve the licensing requirements for autistic trainees (Wilson et al., 2018). Like many countries, in Qatar, there is no autism-specific training and support for driving instructors.

In a large-scale study by Alshaban et al. (2019), in Qatar, the prevalence rate of autism among children in mainstream schools (6 to 11 years) was estimated at 1.14% or 1 in every 87 children. The prevalence in terms of gender is 1 in 56 boys and 1 in 230 girls (ratio 4:1). In this regard, in the state of Qatar, attention has been given to improving the high quality of life for all, including autistic individuals, as outlined in the National Vision 2030. Although there is attention to autism, it is not known about autism and driving in Qatar. As a result, it is not always easy for driving instructors to tailor their lessons to the needs of autistic persons.

2.9. Summary of literatures in driving and autism

The following section presents the detail summary of literatures that were conducted on different aspects of autism and driving (Table 1)

Table 1. Summary of literature on drivers with ASD

Source (country)	Objective, participants, and design	Key Findings
Chee et al. (2017), Australia	**Objective:** Exploring how symptomatology of ASD hinders or facilitates on-road driving performance **Participants:** N = 37, n_{ASD} = 16, $n_{non\text{-}ASD}$ = 21; **Design**: Observational study design	(1) Drivers with ASD underperformed in vehicle manoeuvring, especially at left-turns, right-turns and pedestrian crossings. (2) Drivers with ASD outperformed the neurotypical group in aspects related to rule-following such as using the indicator at roundabouts and checking for cross-traffic when approaching intersections.
Chee et al. (2015), Australia	**Objective:** Understanding the viewpoints of drivers with autism spectrum disorder (ASD); **Participants:** N = 107, n_{ASD} = 50, $n_{non\text{-}ASD}$ = 57; **Design:** Q-methodology	(1) Some ASD participants perceived themselves as confident and independent drivers, others preferred other modes of transportation such as public transport and walking. Anxiety was also found to be a barrier to driving. (2) The neurotypical group preferred driving as their main mode of transportation and believed that they were competent, safe and independent drivers.
Daly et al. (2014) , USA	**Objective**: Investigating the driving history and driving behaviors between adults diagnosed with an autism spectrum disorder (ASD) as compared to non-ASD adults; **Participants**: N = 172, n_{ASD} = 78, $n_{non\text{-}ASD}$ = 94; **Design**: Questionnaire	(1) Drivers with ASD endorsed significantly lower ratings of their ability to drive, and higher numbers of traffic accidents and citations relative to non- ASD drivers.

Ross, Cox, Reeve, et al. (2018), USA	**Objective**: Measuring the attitudes of novice drivers with autism spectrum disorder as an indication of apprehensive driving by assessing parents; **Participants**: N = 232, n_{ASD} = 66, $n_{non\text{-}ASD}$ = 166; **Design**: Questionnaire	(1) Parents reported autism spectrum disorder drivers to have less positive and more negative attitudes toward driving than parents of neuro-typical drivers. (2) Parents of autism spectrum disorder drivers who received driving training in a safe/low-threat virtual reality driving simulator demonstrated a significant increase in positive attitudes and reduction in negative attitudes, compared to parents of autism spectrum disorder drivers undergoing routine driver training.
Sheppard et al. (2017), UK	**Objective**: Exploring attentional processing of social and non-social stimuli in ASD within the context of a driving hazard perception task. **Participants**: N = 35, n_{ASD} = 18, $n_{non\text{-}ASD}$ = 17 **Design**: A mixed 2 × 2 design	(1) Individuals with ASD demonstrated relatively good detection of driving hazards, they were slower to orient to hazards. (2) Greater attentional capture in the time preceding the hazards' onset was associated with lower verbal IQ.
Sheppard et al. (2010), UK	**Objective:** Investigating whether individuals with ASD (autistic spectrum disorders) are able to identify driving hazards, given their difficulties processing social information; **Participants:** N = 23, n_{ASD} = 21, $n_{non\text{-}ASD}$ = 44; **Design:** Questionnaires, Case study, video	(1) Participants with ASD identified fewer social hazards than the comparison participants. (2) Participants with ASD were also slower to respond than comparison participants.

Bishop et al. (2017), US	**Objective:** Investigated how drivers with ASD respond to social (e.g. pedestrians) and non-social (e.g. vehicles) hazards in a driving simulator compared to typically developing drivers; **Participants:** N = 32, n_{ASD} = 16, $n_{non\text{-}ASD}$ = 16; **Design**: Case study, driving simulator	(1) Participants responded faster to social hazards than non-social hazards. (2) Drivers with typical development reacted faster to social hazards, while drivers with ASD showed no difference in reaction time to social versus non-social hazards.
Almberg et al. (2017), Sweden	**Objective**: To explore the facilitators or barriers to driving education experienced by individuals with ASD or ADHD who obtained a learner's permit, from the perspective of the learner drivers and their driving instructors; **Participants:** N = 42, n_{ASD} = 33, $n_{drivinginstructor}$ = 9; **Design**: Questionnaire	(1) Participants with ASD required twice as many driving lessons and more on-road tests than those with ADHD. (2) Individuals with ASD found translating theory into practice and adjusting to ''unfamiliar'' driving situations to be the greatest challenges.
Curry et al. (2018), USA	**Objective**: Make a comparison the proportion of adolescents with and without autism spectrum disorder who acquire a learner's permit and driver's license, as well as the rate at which they progress through the licensing system; **Participants:** N = 52,172, n_{ASD} = 609, $n_{non\text{-}ASD}$ = 51,563; **Design:** Kaplan–Meier curves and log-binomial regression models	(1) One in three adolescents with autism spectrum disorder acquired a driver's license versus 83.5% for other adolescents and at a median of 9.2 months later. (2) The vast majority (89.7%) of those with autism spectrum disorder who acquired a permit and were fully eligible to get licensed acquired a license within 2 years.

Cox et al. (2012), USA	**Objective:** Gain a better understanding of driving and ASD by surveying parents or caregivers of adolescents/young adults with ASD who were currently attempting, or had previously attempted, to learn to drive; **Participants:** n = 123; **Design:** Questionnaire	(1) Learning to drive presents a substantial challenge for individuals with ASD; complex driving demands (e.g. multi-tasking) may be particularly problematic.
Classen et al. (2013)	**Objective:** To conduct an evidence-based review of intervention studies and predictor studies related to driving outcomes in teens with attention deficit–hyperactivity disorder (ADHD) or autism spectrum disorder (ASD); **Participants: No; Design:** Evidence-based review	(1) Class I studies with Level A recommendations, currently lacking in the literature, are urgently needed to make clear the mechanism underlying driving performance outcomes in ADHD and ASD.
Veerle Ross, Ellen JONGEN, Marleen Vanvuchelen, et al. (2015), Belgium	**Objective:** Surveying driving instructors to explore the driving behavior of youth with an autism spectrum disorder; **Participants:** n = 52; **Design:** Questionnaire	(1) Advice for teaching youth with ASD to drive mainly focused on a need for structure, clarity, visual demonstration, practice, repetition and an individualized approach. (2) The relation between ASD and driving performance might not always be negative but can be positive as well.
Huang et al. (2012), USA	**Objective:** To compare the characteristics of driving and nondriving teens and explore the driving outcomes for teens with higher functioning autism spectrum disorders; **Participants:** n = 297; **Design:** Web-based survey	(1) There were no differences in gender, autism subtype, attention deficit/hyperactivity disorder diagnosis, parental age or education, or access to public transportation. (2) Driving predictors included individualized education plans with driving goals, indicators of functional status (classroom placement, college aspiration, and job experience), and parent experience with teaching teens to drive.

Lindsay (2017)	**Objective:** To critically appraise the literature on factors affecting driving and motor vehicle transportation experiences of people with autism spectrum disorders (ASD) and to provide insight into future directions for research; **Participants:** 22 studies: N = 2919, n_{ASD} = 364, $n_{parents}$ = 2555; **Design:** Systematic review	(1) Several gaps in the research and an urgent need for further transportation-related training and supports for people with ASD.
Myers et al. (2019)	**Objectives:** To examine the perspective of driving instructors with specialized training to teach autistic adolescents to drive; **Participants**: N = 17 **Design:** Semi-structured interview	(1) Parent engagement prepared autistic students to undertake on-road instruction and supported skill development.
Silvi and Scott-Parker (2018), Autstralia	To understand the driving and licensing experiences of youth with autism; **Participants:** N = 117; **Design:** A qualitative study analysis of comments in five online discussion forums	(1) Individuals with ASD appeared to focus on the logistics of licensure, and crashes.

Ross et al. (2019), Belgium	**Objectives:** To investigate (1) if 16 young novice drivers with ASD exhibited a divergent performance on EF tests compared to 18 neurotypical peers, (2) if ASD participants exhibited a divergent driving performance compared to their neurotypical peers, and (3) if differences in driving performance would be related by the performance on the EF tasks. **Participants:** N = 34, n_{ASD} = 16, $n_{non\text{-}ASD}$ = 18 **Design:** Case study, driving simulator, Computer-task battery	(1) Lower working memory and attention performance was found in the ASD group compared to the control group whereas response inhibition was similar across groups.
Ross, Jongen, et al. (2018), Belgium	**Objective:** Exploratory research into barriers and facilitators in the process of learning to drive for young people with ASD. The experiences of the young persons themselves, parents, and driving instructors; **Participants:** N = 128, n_{ASD} = 20, $n_{parents}$ = 29, $n_{driving\ instructors}$ = 79; **Design:** Questionnaires	(1) Young persons with ASD have a good knowledge of traffic rules, experience difficulties in violating traffic rules when necessary, as well as with multitasking and responding to unpredictable situations, and display perfectionism. (2) Young persons with ASD show a need for structure and more – but shorter – lessons. (3) Driving instructors consistently perceived the impact of ASD-related characteristics higher than the other respondents.

Silvi et al. (2018)	**Objective:** To review the extant literature on drivers with autism, and how their driving abilities and experiences are potentially affected by their symptoms; **Participants:** 9 studies; **Design:** Literature review	(1) drivers with autism were less likely to identify social hazards (e.g., pedestrians), had slower reaction times, more tactical driving difficulties, reported more traffic crashes, citations and intentional driving violations, and had poorer situation awareness skills than drivers without autism.
Wilson et al. (2018)	**Objective:** To synthesise synthesises the peer-reviewed literature about the driving characteristics of drivers on the spectrum and driver training available for the cohort; **Participants:** 28 studies; **Design:** Scoping review	(1) individuals on the autism spectrum drive differently from their neurotypical counterparts. (2) There are shortcomings in tactical skills of drivers on the autism spectrum, but the extent to which this affects their own safety or the safety of other road users is unclear. (3) Tactical skills can be improved through training programs.
Monahan et al. (2013), USA	**Objective:** Comparing the pre-driving skills of a teen with ADHD/ASD to an age- and gender-matched healthy control (HC); **Participants:** N = 2, n_{ASD} = 1, $n_{non\text{-}ASD}$ = 1; **Design:** Case study, driving simulator, Clinical tests	(1) The main impairments of the teen with ADHD/ASD were the ability to shift attention, perform simple sequential tasks, integrate visual-motor responses, and coordinate motor responses, whereas the HC demonstrated intact skills in these abilities. (2) The teen with ADHD/ASD had more lane maintenance, visual scanning, and speeding errors compared to the HC.
Shim et al. (2015), UK	**Objective:** Evaluating multimodal driver displays of varying urgency for drivers on the autistic spectrum; **Participants:** n = 20, n_{ASD} = 10, $n_{non\text{-}ASD}$ = 10; **Design:** 7×3×2 mixed design, Case study, driving simulator	(1) There was no difference between groups in the perceived urgency of the warning signals, though the autism spectrum group reported less annoyance with the signals. (2) Both groups showed high accuracy in correctly reporting urgency level, the autism spectrum group performed better. (3) The fastest overall reaction times obtained were by the autism spectrum group when the warning included a visual component, with vision alone producing the quickest response.

Cox et al. (2016), USA	**Objective:** Examining the relationship between driving performance and executive functioning for novice drivers, with and without ASD; **Participants:** N = 44, n_{ASD} = 17, $n_{non\text{-}ASD}$ = 27; **Design:** Case study, driving simulator	(1) ASD drivers demonstrated poorer driving performance overall. (2) The addition of a working memory task resulted in a significant decrement in the performance of ASD drivers relative to control drivers.
Classen and Monahan (2013), USA	**Objectives:** Demonstrating the demographic, clinical, and simulated driving skill Differences of adolescents with ASD and healthy controls (HC); **Participants:** N = 29, n_{ASD} = 7, $n_{non\text{-}ASD}$ = 22; **Design:** Case study, driving simulator, Clinical tests	(1) Adolescents with ASD performed poorer on right eye acuity, cognition, visual motor integration, motor coordination, speeds regulation, lane maintenance, signalling and adjustment to stimuli. (2) Compared to the HC, adolescents with ASD performed worse on visual, cognitive, motor, simulator operational, and fitness to drive skills.
Wade et al. (2017), USA	(1) Examining the use of a novel simulator in two separate studies; (2) Assessing performance and visual attention of teenagers with ASD. **Participants:** Study 1: N = 14, n_{ASD} = 7 , $n_{non\text{-}ASD}$ = 7; **Design:** Case study, driving simulator; **Participants:** Study 2: N = 14, $n_{performance\text{-}based\ feedback\ group}$ = 8, $n_{combined\ performance\text{-}\ and\ gaze\text{-}sensitive\ group}$ = 7; **Design:** Case study, driving simulator	(1) Study 1 demonstrates statistically significant performance differences between individuals with and without ASD with regards to the number of turning-related driving errors. (2) Study 2 shows that both the performance-based feedback group and combined performance- and gaze-sensitive feedback group achieved statistically significant reductions in driving errors following training.

Cox et al. (2017), USA	**Objective:** Investigate how novice drivers with autism spectrum disorder (ASD) differ from experienced drivers and whether virtual reality driving simulation training (VRDST) improves ASD driving performance. **Participants:** N = 51; **Design:** Multi-center study, Case study, driving simulator, Clinical executive functioning tests	(1) ASD drivers showed worse baseline EF and driving skills than experienced drivers. (2) At post-assessment, VRDST significantly improved driving and EF performance over RT.
Brooks et al. (2016), USA	**Objective:** To investigate the utility of using a driving simulator to address the motor aspects of pre-driving skills with young adults with Autism Spectrum Disorder (ASD). **Participants:** N = 41, n_{ASD} = 10, $n_{non\text{-}ASD}$ = 31 **Design:** Case study, driving simulator	(1) Most participants were able to achieve an error-free performance within five trials for all exercises except for the two most difficult ones. (2) Participants with ASD needed more time to complete the tasks. (3) Overall, the interactive exercises and the process used worked well to address motor related aspects of pre-driving skills in young adults with ASD.
Chee et al. (2019b), USA	**Objective**: Assessing the visual scanning and fixation patterns of drivers with and without ASD during a simulated drive. **Participants:** N = 28, n_{ASD} = 14, $n_{non\text{-}ASD}$ = 14 **Design:** Case study, driving simulator	(1) Drivers with ASD were found to fixate and spend significantly more time focusing on the central visual field and less time scanning where hazards potentially emerge. (2) ASD drivers They tended to allocate less visual attention on social stimuli (i.e., involving a person), and failed to stop in time at the red lights. (3) Psychometric profiles confirmed poorer visual scanning and motor processing speed but less risk-taking behaviour in drivers with ASD.

Chee et al. (2019a), USA	**Objective**: Investigating the driving performance of drivers with autism spectrum disorders under complex driving conditions. **Participants:** N = 35, n_{ASD} = 17, $n_{non\text{-}ASD}$ = 18 **Design:** Case study, driving simulator	(1) In comparison with the typically developed group, drivers with autism spectrum disorders reported significantly more lapses in driving, committed more mistakes on the driving simulator, and were slower to react in challenging situations, such as driving through intersections with abrupt changes in traffic lights. (2) ASD drivers were also less likely to tailgate other vehicles, as measured by time-to-collision between vehicles, on the driving simulator.
Patrick et al. (2018), USA	**Objective:** To assess differences in simulated driving performance in young adults with ASD and typical development (TD), examining relationships between driving performance and the level of experience (none, driver's permit, licensed) across increasingly difficult driving environments. **Participants:** N = 100, n_{ASD} = 50, $n_{non\text{-}ASD}$ = 50 **Design:** Case study, driving simulator	(1) Young adults with ASD demonstrated increased variability in speed and lane positioning compared with controls, even during low demand tasks. (2) When driving demands became more complex, group differences were moderated by driving experience such that licensed drivers with ASD drove similarly to TD licensed drivers for most tasks, whereas unlicensed drivers with ASD had more difficulty with speed and lane management than TD drivers.
Reimer et al. (2013), USA	**Objective:** Assessing the actual extent and nature of the presumed deficits associated with ASD. **Participants:** n = 20 n_{ASD} = 10, $n_{neurotypical}$ = 10 **Design:** Case study, driving simulator	(1) The high functioning ASD participants displayed a nominally higher and unvaried heart rate compared to controls. (2) With added cognitive demand, the ASD group also showed a gaze pattern suggestive of a diversion of visual attention away from high stimulus areas of the roadway.

3. Methodology

To achieve the progressive of objectives presented in the section 1.2: "objectives of this Study", the following methodologies were followed for conducting each steps of the study. These include data collection instruments, general procedure of conducting the experiments, and detailed sub-sections, which are provided under section "3.3 specific methodologies for each steps of the study".

3.1. Data collection tools

Several tools were employed to collect the necessary data that address different questions of the study. These tools include self-report questionnaires, the driving simulator, E4 Wristband and Tobbi Eye Tracking system.

3.1.1. Self-report questionnaire

In this project, different self-report questionnaires were employed. These questionnaires include, for example, inventories (three versions per group of participants: individual with autism, their parents and driving instructors), AQ-10, Toronto Alexithymia Scale (TAS-20), Follow-up checklist three versions: experimental group instructor, trainees, and control group instructor), Drivers Attitude Scale Self Report (DAS-SR), Perceived Stress Scale (PSS), Driving Cognitions Questionnaire (DCQ).

3.1.2. Driving simulator

Driving simulators allow for the assessment of driving behavior in controlled, repeated environments without cost to life or property (Shechtman et al., 2009). Driving simulator at Qatar Transportation and Traffic Safety Center, Qatar University (Figure 1) was used to conduct each experiment. It is important to mention that this driving simulator has been validated for external validity (i.e. actual speed & speed perception) and subjective validity (Hussain et al., 2019). The simulator consisted of two main components: a) the driving unit – A fixed-base cockpit of a car (Range Rover Evoque) equipped with speedometer, force-feedback steering wheel, pedals, gearbox (automatic transmission), indicators and b) three large screens with 135 degrees of horizontal field of view, resolution of 5760 x 1080 pixels and a 60 HZ refresh rate. The components are interfaced with STISIM Drive® 3 along with the CalPot32 program, which offers high-speed graphics, and sound processing (Figure 1). The simulator is capable of collecting a wide range of data including speed, lateral/longitudinal acceleration, lateral/longitudinal position, and number of accidents, number of speeding tickets, pedal inputs, reaction time and a lot more.

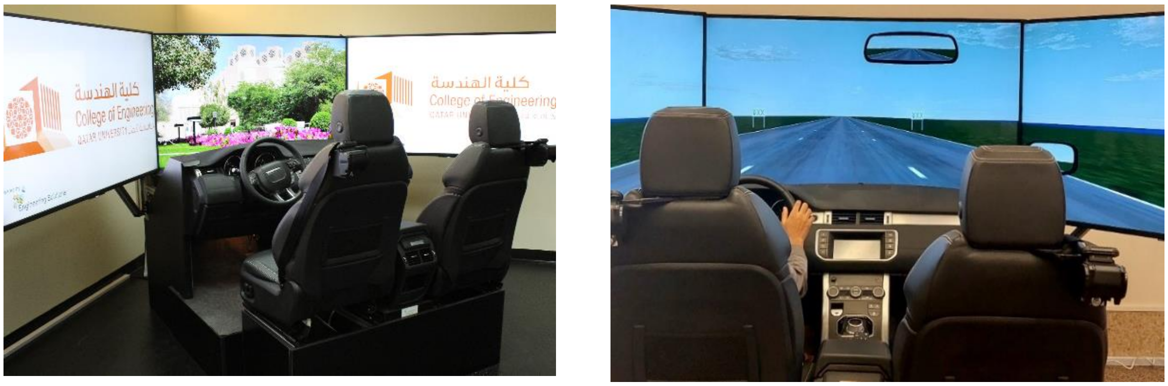


Figure 1 The installed advanced driving Simulator at Qatar University

3.1.3. E4-Wristband

It is a wearable technology allows the monitoring of several psychophysiological responses, like electrodermal activity in real-time and in daily life over a period of days and weeks (Enewoldsen, 2016). The E4 wristband include four sensors: (a) an electrode for Electrodermal activity (EDA), (c) a temperature sensor, (d) a photoplethysmography (PPG), and (b) 3-axis accelerometer to measure blood volume pulse (BVP) from which it derives HR and the inter beat interval (IBI) (Empatica, 2018).

3.1.4. Tobii eye tracking system

A low-cost binocular eye tracker that can detect the presence, attention and focus of the user. It allows for unique insights into human behavior and facilitates natural user interfaces in a broad range of devices (Cheng & Vertegaal, 2004).

E4-Wristband (Figure. 2) and Tobii eye tracking system (Figure. 3) at Qatar Transportation and Traffic Safety Center, Qatar University was applied during conducting each experiment to measure participates physiological signs and gaze behavior respectively.

3.2. Experimental Procedures

The execution of the experiment was aimed to collect data regarding drivers' hazard perception, emotional regulation, and distraction during driving. The process of experiment execution was carried out in two sessions on two different days. On day one, we executed an experiment in which we ran the hazard perception and emotional regulation scenarios. On day two, we conducted an experiment in which we ran the driving distraction scenario.

Figure 2: E4 wristband: watch-like bio sensor

Figure 3: Tobii Pro Eye tracking system

3.2.1. Execution of experiment during Session one

In session one, we experimented with the hazard perception and emotional regulation scenarios designed to assess ASD and neurotypical participants' ability to perceive hazards and manage emotions associated with driving a car. The first day's experiment was divided into parts. The first part was about the hazard perception scenario, which involves the local road and the Corniche road. The second part of the day one experiment was regarding the emotional regulation scenario.

3.2.1.1 Experimental process in session one

In order to manage the experiment execution on day one, we prepared procedures that were employed throughout the experimental processes for both ASD and neurotypical participants. The experimental procedure of session one consisted of five steps, primarily addressing the experimentation of hazard perception and emotional regulation scenarios among participants. In this session, there were also procedures for filling online surveys. In terms of steps, at the beginning, a brief welcome presentation was provided to each participant. At the same time, each participant received detailed explanations about session 1. Once all things about the experiment were clear, each participant was asked to sign the online informed consent form. After signing the form, each participant filled the inventory (only ASD participant who did not fill it), AQ-10, and DAS-SR online surveys. The first step may take 20 minutes on average. A baseline data collection for vital signs or Physiological signals was carried out in step two. In this step, participants were asked to wear E4 Wristband and did body-calming exercises for 'normal' vital signs. The data collector provided body-calming instruction to participants. Once they calmed their body for 2-minutes, the E4 Wristband was opened to record physiological responses for 5-minutes. In the third step, a driving simulator practice was carried out to familiarize participants with driving on a driving simulator.

The fourth step dealt with the experimental procedure of the hazard perception scenario. This step consisted of local road, and Corniche road simulated driving scenarios. We explained to each participant about the hazard scenario before we ran it. When each participant was ready to drive on the simulator, we started to play either the local road or Corniche road part of scenarios (counterbalance was used to determine the orders of local and Corniche for each participant). Each participant was asked to wear E4 Wristband and Tobbi Eye Tracker before driving the scenarios. The orders of those scenario environments were randomized for each participant during simulation running. After driving the scenario, each participant was asked to fill out the post experiment questionnaire for hazard perception. This step lasted for 20 minutes on average. After a few minutes break, the emotional regulation scenario was run for each participant in the last step.

Regarding this scenario, an explanation was provided to participants before we ran the actual test. Before the driving test, each participant was asked to wear the E4 Wristband and Tobii Eye Tracker. Participants filled out the post-experiment questionnaire for emotional regulation after he or she finished the driving test. The last step took 16 minutes on average. After all these processes, we thanked participants for participating in session one.

3.2.1.2. Data collection in session one

The data collection processes of session one was categorized into hazard perception and emotional regulation. As soon as the experiments started, output data of the hazard perception and emotional regulation in response to the different events of the scenarios were collected in a central repository. Although this part focused on the data collection processes for hazard and emotional regulation, we also collected self-report data using online surveys (e.g., AQ-10, DAS-SR, and inventory). Several driving measures were collected during the hazard perception experiment, such as collisions, the standard deviation of lateral position (SDLP), driving speed, speed changes, time to collision, brake reaction time since onset hazard, steering maneuvers (as a reaction to a hazard), physiological signs (via E4 Wristband) and fixation time on the hazard (via eye-tracking). In the case of emotional regulation, we collected different specific and general driving measures, such as following distance towards the school bus, maximum acceleration and deceleration, maximum lane position (deviation from the center of the lane to pass the bus on the left), red-light-running, maximum acceleration, maximum speed, amount of gaps before taking the turn, and maximum acceleration.

3.2.2. Execution of experiment during session two

Session two was concerned about the distraction scenario assigned for day two. Day two experiment aimed to assess drivers' behavior during driving in a situation where there were distractions.

3.2.2.1. Experimental process in session two

The experimental procedure of session two consisted of three steps addressing experimenting with the distraction scenario. There were also procedures for filling online surveys measuring simulation sickness and alexithymia. In terms of steps, a brief welcome presentation was presented to each participant in the beginning. At the same time, each participant received detailed explanations about session 2. After this, each participant was asked to fill out the pre-driving online survey for simulation sickness and Toronto Alexithymia Scale (TAS-20). A driving simulator practice was included in the second step to familiarize participants with driving on a simulator machine. The third step consisted of orientation about Lane Change Test (LCT) and N-back task; and the actual driving test for LCT in which E4 Wristband and Eye tracker were used. Before the actual test, participants received exercises about the N-back task. In this step, the links for Post-test and simulation sickness questionnaire were also provided to each participant. In the end, we thanked each participant for participating in session 2.

3.2.2.2. Data Collection in session two

The data collection process of session 2 was concerned about the distraction of drivers while driving. As soon as the distraction scenario started, output data of drivers' behavior in response to distraction were collected in a central repository. Several driving measures were collected during the hazard perception test. These measures include error ratio for the N-back test, average diversion from the ideal path during the lane change task (standard deviation from the lateral lane position), the distance at which the driver starts the lane change, the distance at which the drivers end the lane change, and the percentage of correct lane changes. We also collected self-report data from each participant using an online survey.

3.3. Specific methodologies for each stage of the study

3.3.1. Stage 1. Self-report assessment of the potential difficulties with respect to ASD and driving

3.3.1.1. Case study 1A: Investigate *self-reported ASD characteristics among individuals*

Introduction

The prevalence of ASD among (young) adults in the State of Qatar is very uncertain (Alshaban et al., 2019), especially among individuals with high functioning ASD). High- High-functioning ASD refers to individuals without a mental impairment, thus those who have a normal to high intelligence level and are not directly noticed to have a mental (health) disability. They often go to normal schools and/or universities where they blend-in and are not easily recognized as having ASD. This often results in individuals with high-functioning ASD not being identified and therefore not getting referred to a specialist for further tests and diagnosis. Not only high-functioning ASD are less likely to get referred, also females with ASD are often not referred to a specialist for diagnosis. This is caused by the common tendency of females with ASD to camouflage their ASD symptoms (Amr et al., 2011; Murray et al., 2017). For example, females with ASD regularly tend to imitate gestures, expression or behaviours from other people in social interactions. Also females have a tendency to tend force their selves to make eye contact in social interactions or they tend to prepare responses or jokes for a conversation on forehand.

Literature has found that the ASD characteristics differ between Males and Females (Amr et al., 2011; Murray et al., 2017). For that reason, it is important to investigate if this gender difference also applies within the cultural context of the State of Qatar. Hence, an comparison should be made between the ASD symptoms reported by males versus the ASD symptoms reported by females. Using the short version of the Autism Quotient (AQ-10), this study is the first initiative to investigate the usefulness of a preliminary screening tool to identify possible signs of ASD in Qatari males and females. With a wider application of this screening tool in the State of Qatar, more Qatari residents with suspected ASD could be referred to a specialist for further assessment. This is important to obtain a clearer picture of the current prevalence in Qatar, among female residents in particular. Furthermore, diagnosed Qatari residents can benefit by seeking out ASD-specific support if needed and it can help to identify possible avenues for further research on behaviour and characteristics of individuals with ASD. The objective of this study are:

1. To get an insight in the self-reported ASD characteristics among males and females in the State of Qatar

2. To investigate the usefulness of preliminary screening tool, comparing males and females

3. To investigate whether AQ-10 is sensitive to female characteristics and camouflaging tendencies often applied by females with ASD.

Measurement

AQ-10, a short version of the Autism Spectrum Quotient, was used as a valid self-report measure of preliminary screening tool for ASD. The AQ-10 has been used to explore autistic features in the general population in a number of investigations. The AQ-10 has 10 items that are scored on a five-point Likert scale, ranging from definitely agree to definitely disagree. If the participant scores more than 6 out of the 10 items, he/she is likely to be classified as suffering from ASD symptoms and requires a referral to a specialist for further diagnosis.

Participants

371 participants were recruited using the availability sampling technique. We distributed the AQ-10 via an online survey among Qatar University students, faculty and staff members. Initially, 371 individuals filled the online AQ-10 survey, but after a data cleaning process, a sample of 294 participants had completed the AQ-10. The AQ-10 was completed in both the English, as well as the Arabic language.

Analysis

For section two, the descriptive analysis was used to understand ASD characteristics across age and gender of the participants who completed the AQ-10. The referral rate was established, by taking the percentage of participants who scored 6 or more out of the 10 ASD symptoms. The referral rates was compared for male and female respondents. In addition, a comparative analysis of all the AQ-10 items was conducted in this study by statistically comparing the answers to each item for male versus female respondents.

3.3.1.2. Case study 2B. Self-report assessment of individuals with ASD and difficulties in driving

Introduction

Autism Spectrum Disorders (ASDs) are among the most common disorders characterized by pervasive impairment in social reciprocity, communication, stereotyped behaviour, and restricted interest (Faras et al., 2010). ASDs are manifested in an early stage of development, and they are often accompanied by abnormal psychological characteristics in cognitive functioning, learning, attention, and sensory processing (Alshaban, 2012). Alshaban et al. (2019) estimated that 187,000 youths under age 20 have ASD in Gulf countries. Qatar was among many leading nations in signing the Convention of the Rights of Persons with Disabilities (CRPD) treaty in 2008

(OHCHR, 2021). The State of Qatar strives to achieve equality and justice for all, as outlined in their National Vision 2030 (Ministry of Development Planning and Statistics, 2015). Another significant example related to Qatar's ambitions in promoting excellence in equality was in 2007 when they supported the idea of celebrating World Autism Awareness Day, which was later accepted by the United Nations General Assembly. Despite their deficiency in common activities, individuals with ASD have the same entitlements and privileges utilized by the rest of society.

The significance of the proposed investigation is directed towards improving the 'day-to-day' lives of all Qatari residents including individuals with ASD and their families, economically, socially, and with respect to their quality of life. The current growing literature indicates that ASD drivers pose a potential danger on the roads, due to their impaired driving capabilities. Driving is a much-needed skill that enables efficient and time-saving travel. The impact of ASD varies according to specific demographic and psychological factors, including age, level of cognition, and ability to cope independently. Previous research regarding ASD drivers gives reason for concern as a percentage of road accidents are related to drivers with ASD symptoms. This suggests that drivers with ASD can be subjected to high potential of safety risks while driving. It is required to propose an investigation to understand and improve ASD capabilities in everyday tasks, such as commuting. Investigating this topic is intended to improve road safety for the Qatari community, especially individuals with ASD. The success of supporting ASD individuals in their mobility cannot be achieved without evidence–based effort.

By taking the above description into account, this study aims to illustrate the preliminary analysis of individuals with ASD and their parents' views about the driving behavior of licensed ASD drivers, learning to drive for ASD individuals, and the impact of ASD on driving.

Measures

Inventories were used to obtain the viewpoints of individuals with ASD and their parents about the impact of ASD on learning how to drive, and driving behavior. The inventories for ASD individuals and parents helped to provide comprehensive and multi-angled views of obstacles and benefits when people with ASD are learning how to drive. Both inventories of ASD individuals and their parents consisted of four parts including background information, driving behavior, learning to drive, and impact of ASD on driving. Each inventory measured a similar thing from different perspectives. Moreover, some additional questions were included in the inventory of ASD individuals to obtain their viewpoints in advance.

Participants

In section one, participants of the report were recruited using the purposive sampling technique from Shafallah center and Hamad Medical Corporation. Individuals with ASD were presented to us from those two organizations, and we then invited them to Qatar University for IQ level test. Along with the IQ test, they were asked to fill inventories. The inventories were completed in both the English, as well as the Arabic language. The profile of fifteen ASD individuals residing in Qatar has been compiled in relation to their age, IQ level, driving license status, educational level and when they were diagnosed with ASD. To be more specific, for example, the age range of these participants was from 17 to 30. The Stanford-Binet intelligence scale was employed to measure the IQ level of ASD individuals. Based on the assessment, the IQ level of those ASD participants is ranged from 61 to 106. In terms of being licensed for driving a car, only 4 out of 15 participants were licensed for driving a car. The educational levels of these participants are ranged from special needs education to bachelor's degree.

Analysis

In the first section, information obtained through inventories from parents and ASD individuals has been analyzed using descriptive analyses. We used descriptive analyses including table, figures and qualitative text analysis. Either implicitly or explicitly the analysis represented two groups of ASD participants (licensed and non-licensed) in relation to driving. The analysis was framed how parents and their children viewed ASD individuals' experiences associated with driving.

3.3.1.3. Case study 1C: The appraisal of roadway environment and infrastructure by drivers with autism: A qualitative study

Introduction

Although negative attitudes, anxiety, and stress are recurring disturbing factors in the driving experiences of ASD drivers, little is known about what specifically influences and contributes to these problems. Roadway environment and infrastructure could be possible contributors to these problems. Previously, multiple quantitative studies have investigated how people with autism react and behave to certain roadway elements (e.g., Chee et al., 2019a; Feeley et al., 2015a; Reimer et al., 2013; Wade et al., 2017). However, previous research was not focused on the appraisal of roadway environment and infrastructure. Instead, they focused on other topics such as gaze patterns, hazard perception, executive functioning, etc. Based on these studies, we can make assumptions about how and why people with ASD react to certain roadway environment and infrastructure elements. However, to this date, no study has researched which specific roadway elements hinder and facilitate ASD drivers, how they experience certain elements, and how they cope with difficult situations. We propose that, among others, stress and anxiety could be negatively influenced by roadway environment and infrastructure design.

The current paper uses the terminology as proposed by Castro (2008) regarding roadway environment and infrastructure. She suggested making a distinction between environment and infrastructure as external factors while driving. The environment consists of all the elements located on and adjacent to the road (e.g., road users, trees, lights, houses, etc.). The infrastructure consists of physical elements that are part of or related to the road (e.g., roundabouts, road markings, etc.). Both the environment and the infrastructure can influence driving behavior. In the next paragraphs, we will focus on the autism-related characteristics and their relationship to the experiences and appraisal of roadway environment and infrastructure. Firstly, people with autism have a higher perceptual capacity than neurotypical persons. They can process more information from a scene, but they also find it harder to filter the irrelevant items. They are more easily distracted by irrelevant stimuli, such as flashing lights or sounds (Remington et al., 2012). These difficulties are exacerbated when complex information is being presented at a fast pace. People with ASD frequently cope with this by processing all details of the environment separately rather than processing it as a whole, which can cause dangerous driving situations (Vanmarcke, 2017). ASD drivers also tend to fixate and spend more time scanning the central visual field and do not focus on other fields where a potential risk may occur (e.g., parked cars on the left side of the road) (Chee et al., 2019b; Reimer et al., 2013). However, it is suggested that, after ASD drivers receive training, they are also able to have proficient scanning patterns (Wade et al., 2016). People with autism frequently report sensory processing problems, such as hyper- and hypo-reactivity (American Psychiatric Association, 2013).

Hyperreactivity is characterized by experiencing intense reactions to sounds, touch, and visual stimuli (Grandin & Scariano, 1986). This can lead to high-stress levels and can often cause sensory overload reactions (Smith et al., 2012; Top Jr et al., 2019). Such sensory overload reactions happen when people receive a higher sensory input than their brain can process or when they feel emotionally or physically overwhelmed (Stewart et al., 2009). Because of their delicate sensory system, most people with ASD get easily overloaded. However, the triggers are different for every person (Crane (Crane et al., 2009). Some suffer from hyporeactivity problems where they react less intensely to certain stimuli than neurotypical persons (Elwin et al., 2013). Elwin et al. (2017) suggested that due to the hypo-reactivity, people with ASD might miss information in the environment.

Both hyper- and hypo-reactivity can influence the experience and appraisal of roadway environment and infrastructure. Drivers may experience particular elements as too intense and therefore experience stress and anxiety. On the other hand, they may not react adequately to certain stimuli because they miss crucial information from the environment and infrastructure. According to Vermeulen (2015), many of the obstacles that people with ASD experience in their daily lives are attributable to difficulties with contextual sensitivity or 'context blindness.' People with ASD experience difficulties in using context when giving meaning. The theory has emphasized the weak central coherence hypothesis (Vermeulen (Vermeulen & Myles, 2012). Central coherence is the ability to integrate information in context for higher-level meaning (Booth & Happé, 2010). To give meaning to a situation while driving, drivers need to use information from both themselves and the environment (Feeley et al., 2015b). However, this may not be easy for ASD drivers, as they may not give enough weight to important elements and give too much weight to unimportant details (Vermeulen, 2015). For instance, you are approaching a traffic light, and the light turns amber. This is a warning that the light is about to turn red and that you should stop if it is safe to do so. The appropriate reaction to that amber light depends on the context: the following distance from the car behind you, your distance to the traffic lights, the speed you are going, etc. In other words, you have to use the context to decide what the appropriate action is, continue, or stop. Because people with ASD experience difficulties using the context when giving meaning, they might be inclined to stop while continuing to drive would have been the better option, for example, if they needed to brake harshly due to the imminent change from the amber to the red phase. Context blindness is also linked to theory of mind and executive functioning.

Theory of mind is the ability to comprehend mental states from others to explain and predict their behavior (Baron-Cohen, 1997). Vermeulen (2015) suggested that theory of mind problems in people with autism arise from difficulties in using the context to actively read others' mental states rather than specific deficits in mind reading. Executive functioning (EF) skills are the higher mental processes that enable us to plan, form abstract concepts, stay focused, etc., to self-monitor our behavior (Liss et al., 2001). People with autism experience deficits in specific EF areas: attention shifting, planning, and cognitive flexibility (Hill, 2004). When understanding others' behavior, taking the context into account is crucial (Klin et al., 2003). However, it is equally important in guiding one's behavior. People with ASD might experience impairments in social interaction resulting in difficulties in using the context to interpret others and guide their behavior (Vermeulen, 2015). In conclusion, we suggest that the experienced problems with contextual sensitivity can influence the appraisal of roadway environment and infrastructure in ASD drivers. They create difficulties in correctly understanding, using, and interpreting the context and environment.

As stated above, it is important to describe experiences and insights from the participants' viewpoint. Hence, by using a qualitative interviewing method, we aimed to obtain a comprehensible picture of the experiences, insights, and reactions of ASD drivers, taking their viewpoint into account (Watkins et al., 2017). Therefore, the current study aimed to:

1) Explore how drivers with an autism spectrum disorder experience certain elements of the roadway environment and infrastructure.
2) Identify potential coping strategies used to deal with interfering roadway environment and infrastructure elements.

Measures

Autism-spectrum Quotient (AQ-50)

The Autism-spectrum Quotient is a self-reported questionnaire to determine to what extent an adult with ASD experiences autistic traits. The instrument consists of 5 domains that are questioned through 50 questions, with a total score ranging between 0 and 50 (i.e., cut-off score: 32). The five domains are social skills, attention switching, attention to detail, communication, and imagination. Each question gets a score of one point if the respondent records the autistic-related behavior, either mildly or strongly, on a four-point scale (Baron-Cohen et al., 2001). The Dutch AQ-50 version's internal consistency was found good (a = 0.71), and test–retest reliability was satisfactory (Hoekstra et al., 2008).

Interview guide

One researcher executed the data collection pre-COVID, which was guided by a semi-structured interview and accompanying photos that supported the in-person interview. The interview guide was developed in collaboration with two other researchers. It included several key concepts regarding roadway design, environment, and infrastructure. The guide is a scheme with open-ended questions, which allows for flexibility of the interviewer. It assisted the researcher in structuring the interview and questioning all the fields of interest. Those fields of interest were the facilitating factors and barriers in roadway environment and infrastructure, the level of disturbing influences of environmental and infrastructural factors on their driving experiences, and the coping strategies which ASD drivers use. However, people with autism can experience difficulties in answering open-ended questions (Frith & Happé, 1994). Therefore, accompanying photos were used to support the interview and the participants by providing them with examples. The interview guide was piloted with two persons with ASD (in possession of a driver's license) before the actual experiment started. The accompanying photos, 14 in total, were aimed at representing the Flemish (i.e., the Dutch-speaking part of Belgium) road context as closely as possible. The photos included roundabouts, road narrowings, cyclists on the road, speed bumps, road surfaces in poor condition, a steep bend, intersections (with and without traffic lights), a quiet street in a residential area, traffic in city centers, a traffic jam on the highway and a streetcar on the roadway.

Participants

The current study aimed to include adults with autism who had already obtained their driver's license or those with a learner's permit with at least 20 h of driving experience. This was done to avoid effects from the process of learning how to drive, as this can influence their experiences with roadway environment and infrastructure. Participants were recruited through convenience sampling. As a result of the voluntary participation, all participants were screened through criterion sampling to obtain a purposive sample. Participants were informed about the study by sending an informative poster via e-mail to organizations that work with people with ASD on a daily basis (e.g., Autism Centraal, Autisme Limburg vzw, etc.). The poster included a link to a questionnaire where potential candidates could register to participate in the study. The questionnaire included the AQ50 and a few questions about their driver profile (e.g., driver's license, kilometers per week, ASD diagnosis, and 17 years or older.). To obtain a purposive sample that represents the target group as closely as possible, a new mail was sent to obtain extra data (e.g., place of residence, date of birth, and date when they obtained their driver's license). The new data enabled the researchers to select participants intentionally. Candidates that did not reply after one week received a reminder e-mail. No number of desired participants was established, as this depended on when saturation was reached (Morse, 1995).

Data gathering and analysis

Interviews were conducted and analyzed until the first researcher, an occupational therapist, could not find new information regarding the research topic (saturation) (Morse, 1995). The phases of data collection and data analysis were intertwined. In the beginning, a few interviews were conducted and thereafter analyzed. The same researcher always carried out the analyses and, after that, these were checked by two senior researchers. Based on the analyses, the interview guide was adapted by the research group. For example, if a question was too difficult to answer (e.g., scale questions), it was adjusted or removed. As the interviews progressed, these analyses became more frequent because saturation was almost reached. All the data were analyzed by NVivo 11 by one researcher, and two members of the research team, a psychologist, and a physical therapist, checked the analyses. The interviews were transcribed ad verbatim and analyzed based on the phenomenological hermeneutical method by (Lindseth & Norberg, 2004). The researcher stayed as close as possible to the original text while analyzing the data without interpreting the made (phenomenological) statements. Thereafter, the (main) themes were interpreted from the participant's perspective and experiences (hermeneutical).

The phenomenological hermeneutical method consists of three steps. In the first step, a naïve reading is executed by the researcher. To this end, the researcher reads the text, and member checks several times to grasp its meaning as a whole. After that, a naïve understanding can be formulated as an initial assumption, which is not yet confirmed by a structural analysis. A thematic structural analysis will be used in the second step to analyze the interview in four steps. (1) The data transcript consists of wholes that convey just one meaning (e.g., a sentence, a paragraph, etc.), i.e., meaning unit. (2) The core of the meaning-unit will be expressed in colloquial language, i.e., condensation. Thereafter, subthemes will be formulated, consisting of iterations in the interview or similar condensation made throughout the interview. The main themes were formed by connecting subthemes. (3) Lastly, a comprehensive understanding is formulated by combining the proposed main themes and reflect them in relationship to the research questions (Lindseth & Norberg, 2004).

3.3.2. Stage 2: Investigating the psychological characteristics of young adults with ASD in respect to driving

3.3.2.1. Study case 2A: Psychological characteristics of adults with ASD in respect to driving

Introduction

Autism Spectrum Disorders are the most common disorders characterized by persistent impairment in social reciprocity, communication, stereotyped behavior, and restricted interest (Faras et al., 2010). ASDs are often accompanied by abnormal psychological characteristics in cognitive functioning, learning, attention, and sensory processing (Alshaban, 2012). For example, alexithymia, a person impaired ability to recognize and describing feeling, and identifying different types of feeling (Taylor et al., 1999), is a common among individuals with autism. According to Kinnaird et al. (2019) the growing body of literature indicated the co-occurring autism and alexithymia. The impact of autism can be manifested on different life aspects (e.g., mobility, driving) of a person.

The ability of persons with ASD to use various mode of transport plays a critical role in the lives of young adults with ASD in providing linkage to both meaningful opportunities in their community and enabling fulfilment of daily living needs, including employment, education, healthcare, and socially-focused pursuits (Feeley et al., 2015a). Driving depends on driving experience, perception, as well as cognitive abilities (Veerle Ross, Ellen Jongen, Tom Brijs, et al., 2015). People with ASD were found to show a reduced cognitive efficiency, combined with an underperformance in unexpected circumstances. For instance, they have problems with multi-tasking. An individual’s ability to process information visually can cause problems if the driver is unable to process road hazards (Sheppard et al., 2010). Due to issues with planning and executing actions when responding to changes in the environment, this can a reduced speed in driving style (Fournier et al., 2010). Executive dysfunction reduced self-monitoring, mental flexibility and planning abilities (Van Eylen et al., 2016), can lead to a stressful driving experience that is also dangerous in nature.

The impact of ASD varies according to specific demographic and psychological factors, including age, level of cognition, and ability to cope independently. Previous research regarding ASD drivers gives reason for concern as a percentage of road accidents are related to drivers with ASD symptoms. This suggests that drivers with ASD can be subjected to high potential of safety risks while driving. It is much needed to investigate towards improving the 'day-to-day' lives of ASD individual and their families, economically, socially, and with respect to their quality of life. It is required to propose an investigation to understand and improve ASD capabilities in everyday tasks, such as commuting. Investigating this topic is intended to improve road safety for the Qatari community, especially individuals with ASD. The success of supporting ASD individuals in their mobility cannot be achieved without such evidence–based effort. By considering the discussion presented above, this report addressed the driving attitude of ASD individuals along with their autistic characteristic and level of alexithymia.

Participant and recruitment

After obtaining ethical clearance approval from the Qatar University's Institutional Review Board (QU-IRB), the research team engaged in the diagnoses and recruitment processes of participants with autism, and neuro-typical. The team first recruited individuals with autism using a purposive sampling technique from Shafallah center and Hamad Medical Corporation (HMC) in Qatar. Two steps were applied to determine whether those participants had autism. First, the team received a list of individuals with autism from Shafallah center and HMC. In the second step, the team invited those individuals to Qatar University for further diagnosis in IQ and autistic characteristics. Once the team finished the diagnosis process, the confirmed participants were invited again to fill the surveys regarding Drivers Attitude Scale-Self Report (DAS-SR) (Ross, Cox, Reeve, et al., 2018), Autism Quotient (AQ-10) (Booth et al., 2013) and Toronto Alexithymia Scale (TAS-20) (Güleç et al., 2009). The profile of 21 ASD individuals residing in Qatar has been compiled in relation to their age, nationality driving license status, IQ level, and source. To be more specific, the age range of these participants is from 17 to 31, with mean of 22.90 and standard deviation 3.77. In terms of being licensed for driving a car, 4 out of 20 participants have driving license.

To recruit the neurotypical participants, who were with typical neurological development and function, the research team involved in an advertisement through social media (e.g., Instagram), website, brochures, letters, and frequent message exchange with potential individuals (e.g., teachers at Qatar University). The recruitment process for the neurotypical sample was carried out based on the project's inclusion criteria. The demographic information (e.g., age range, gender) of ASD individuals was used to set the inclusion criteria to choose the neurotypical participants. A total of 66 neurotypical participants were recruited. Out of this number, 32 and 34 participants were individuals with and without driving licenses respectively. The team collected data from the neurotypical participants using AQ-10, DAS, and TAS-20.

Measures

In this report, three standardized psychological measures were employed to obtain data regarding ASD individuals' attitude towards driving, autism characteristics and difficulties to describe and identify emotions (alexithymia). Namely, this report used Drivers Attitude Scale-Self Report (DAS-SR), Autism Quotient (AQ-10) and Toronto Alexithymia Scale (TAS-20).

Drivers Attitude Scale-Self Report (DAS-SR)

This scale was designed to measure attitudes toward driving by targeting the situations in which ASD drivers think about driving, prepare themselves to drive, and while driving (see Cox et al., 2020; Ross, Cox, Reeve, et al., 2018). Items in this scale were framed to measure emotions that can be expressed cognitively, behaviorally, and physically. The scale was designed in two versions: parent version (Drivers Attitude Scale-Parent Report), where parent evaluate their child's attitude toward driving; and self-report version (Drivers Attitude Scale-Self Report), in which participants assess their own attitude towards driving. The scale consisted of 9 positive items (e.g., when driving, do you become relaxed, calm, and enjoys the experience of driving?) and 9 items negative (e.g., when talking about driving, do you avoid talking about driving?) that were scored in four-point scale ranged from 0 (Not At all) to 3 (A Lot) scale. Drivers Attitude Scale-Parent Report has good internal consistency (ά = 0.92) (Ross, Cox, Reeve, et al., 2018) (ά = 0.85) (Cox et al., 2020). The current study employed Drivers Attitude Scale-Self Report

Toronto Alexithymia Scale (TAS-20)

The Toronto Alexithymia Scale (TAS-20) is self-report scale measuring deficiency in emotional and social proficiencies (Güleç et al., 2009). It consists of 20-items assessing three factors including difficulty identifying feelings (DIF), difficulty describing feelings (DDF) and externally-oriented thinking (EOT) (Cleland et al., 2005). In terms of items number, 7 items, 5 items and 8 items were designed to measure DIF, DDF and EOT respectively. Five items are reversely coded. The total scores of TAS-20 are ranged from 20 – 100. According to the cut-off score was established to TAS-20, a score 51 and below refers to that there is not alexithymia, and a score 61 and above indicates the presence of high alexithymia. The score in the range of 52 -50 refers to the possibility for the presence of alexithymia.

The Autism Spectrum Quotient (AQ-10)

The AQ-10 is short version of the Autism Spectrum Quotient and is a valid self-report measure of ASD characteristics (Booth (Booth et al., 2013) et al., 2013). The AQ-10 has been used to explore the presence of autistic features in the general population (Hoekstra et al., 2008). The AQ-10 has 10 items that are scored on a four-point Likert scale, ranging from definitely agree to definitely disagree. If the participant scores more than 6 out of the 10 items, he/she is likely to be classified as suffering from ASD symptoms and requires a referral to a specialist for further diagnosis. For that reason, the AQ-10 is regularly used as preliminary screening tool for ASD.

Analysis

The data obtained through Drivers Attitude Scale-Self Report (DAS-SR), Autism Quotient (AQ-10) and Toronto Alexithymia Scale (TAS-20) was analyzed using descriptive analyses. The analysis was framed to answer which autism characteristics are common among participants? What is the driving attitude those drivers possess? And what level of alexithymia is found among participants. By considering those questions, we used appropriate descriptive analyses including table, graphs, charts and qualitative text analysis.

3.3.2.2. Study case 2B: Experiences with licensing by autistic drivers

Introduction

Autism, driving, and licensure In Belgium, cars are the most chosen means of transport, with public transport being very limited in rural areas. Yet, despite the importance of driving, many autistic individuals continue to rely on friends, family, and/or public transportation for their travel needs (Reimer et al., 2013). This is because certain features of autism can interfere with (learning to) driving. Autism is often characterized by difficulties with executive functions such as working memory, information processing speed, attention, etc.(Patrick et al., 2020). Executive functions are the higher cognitive processes that enable a person to perform goal-directed behaviors (Gilbert & Burgess, 2008). Multiple studies linked these difficulties to making more driving errors (e.g., decreased steering) (Chee et al., 2019b). Furthermore, autistic individuals have more difficulties with hazard perception, particularly with detecting social hazards (Curry et al., 2021).

In terms of social communication and functioning problems, autistic individuals also estimate their abilities less accurately than non-autistic individuals (DeBrabander et al., 2021). However, it is crucial to assess one's abilities properly to adapt well to task demands. Not estimating accurately can lead to difficulties with maneuvering and uncertainty while driving (de Craen et al., 2007). It also takes autistic individuals longer to learn to drive and develop social communication skills in addition to driving skills (e.g., hand gestures from other drivers) (Curry et al., 2018). Finally, autistic individuals sometimes have motor planning problems (Classen & Monahan, 2013). Anxiety is also a significant problem among autistic individuals, in general, and in relation to driving (Ross, Cox, Reeve, et al., 2018). When autistic drivers are overloaded with input while driving, their coping capacity overloads, which then causes anxiety, stress, and frustration (Dirix et al., 2021). However, the relationship between autism and driving is not necessarily negative. Because autistic individuals are more rule-bound, they may engage in less reckless driving (Huang et al., 2012). This was also confirmed in a recent study by Curry et al. (2021) where the driving performance of non-autistic drivers was compared to autistic drivers. This showed that autistic drivers were only half as likely to have an accident due to speed. Ross et al. (2019) Cox et al. (2020)] showed that despite autistic drivers performing less on cognitive tasks or in the driving simulator, they could be considered capable drivers once the autistic people could obtain their license. With regards to the experiences during licensure, the available literature remains scarce.

A qualitative study by Silvi and Scott-Parker (2018) examined the driving and licensing experiences of autistic youth and the barriers associated with licensure. Their study examined how the possible autism-related problems impacted learning to drive but did not explicitly focus on the licensure themselves. A study examining facilitators or barriers in driving education from learner and novice drivers with ADHD or autism showed that autistic individuals have to take more on-road tests than the general population. Yet, again, little research was done on the experiences during the exams themselves (Curry et al., 2018). Nevertheless, there are several reasons to believe that examinations (and the moments leading up to them) can be challenging for autistic individuals. On the one hand, there are difficulties with social interactions, yet communication is a crucial part of the exam. Communication with the examiner and other road users must occur during the exam (Wilson et al., 2018). On the other hand, autistic persons find it difficult to cope with unfamiliar and unpredictable situations (Hodgson et al., 2017). Previous research showed that exam moments (in general) could cause severe stress and anxiety in autistic persons (Wood & Happé, 2020). Additionally, autistic individuals often find it challenging to cope with stress and anxiety (Gelbar et al., 2015).

Despite the upsurge in research on experiences and/or difficulties of autistic persons while (learning to) driving, studies on experiences during licensure remain scarce. Therefore, the purpose of this study was to obtain initial insights into autistic persons' experiences with the examination moments (i.e., theoretical and practical) to obtain a driver's license. This was done by administering a few questions regarding the licensing process.

Measures

The current study was part of a larger study that investigated the impact of autism on the journeys that individuals make. Other components, such as experiences while commuting or during traveling while on vacation, are not further discussed in this paper. The questions regarding the driving tests included six themes: (1) help in preparing for the tests, (2) experiences while preparing for the tests, (3) number of times the tests were taken, (4) experiences during the tests, (5) components in which difficulties were experienced during the theoretical test, and (6) components in which difficulties were experienced during the practical test. The questionnaire was created and completed in Qualtrics; respondents who could not complete the survey did so on paper. Afterward, their answers were digitized. Respondents who had no driver's license or did not complete this part of the survey were excluded. Because of the few respondents and the nature of the study (i.e., exploratory), descriptive statistics were chosen to describe the sample and reduce the data collected from the participants into a summary number [(Fisher & Marshall, 2009). Afterward, correlations between all questions were calculated on group level (i.e., not for individual cases) to measure associations between the questions (Schober et al., 2018).

Participants

Autistic adults with a driver's license were recruited through convenience sampling. The following inclusion criteria were used: an autism diagnosis, possessing a driver's license, 18 years or older, and Dutch speaking. Participants were recruited through an email to various patient organizations such as Autisme Limburg, Autisme Centraal, Limburg Stichting Autisme, etc. These are all organizations that have a large reach within the autistic community. They, in turn, shared the link to the online questionnaire with their members. In total, 40 respondents were included.

3.3.2.3. Study case 2C: Autism-friendly public bus transport: hearing the voices of individuals with ASD to better understand their needs

Introduction

Despite increasing attention to inclusive transportation, research on Public Bus Transport (PBT) experiences in autistic individuals is sparse. A systematic review on Public Transport (PT) and school buses shows that most studies focus on transportation use, cost, access, and PT safety (Lindsay, 2017). The same review also shows that most studies reflect parents' perceptions of autistic individuals, while few studies focus on the experiences of autistic individuals themselves (Lindsay, 2017). Falkmer et al. (2001) revealed a lack of studies on the experiences and opinions of autistic individuals, while it is crucial to let this target group speak for themselves. Moreover, information about the challenges and needs in PT is insufficiently available. This could impact accessibility policies, which are essential to successfully meeting autistic individuals' needs when using PT (Lubin & Feeley, 2016). By sharing their experiences with the outside world, autistic individuals are given the opportunity to improve the safety of their journeys and increase their opportunities to participate in daily life (Nicolaidis et al., 2011; Pellicano & Stears, 2011). In addition, a recent study by Leadbitter et al. (2021) argues that all stakeholders need to understand autistic people's views and neurodiversity as a movement. In doing so, researchers need to move away from the traditional way of thinking about autism and pay more attention to the experiences of autistic people. This study gives autistic people the opportunity to express their issues while traveling with PBT by asking about their opinions and experiences related to traveling with PBT.

Participants and recruitment

Convenience and criterion sampling was used to obtain a purposive sample consisting of people with ASD that had prior user experience with public transport. The inclusion criteria were set based on the fact that persons with a physical or intellectual disability could have experienced additional difficulties when using public bus transport. Their experiences could therefore be different from the intended target population. The following inclusion criteria were set: age between 18 and 34 years; an official diagnosis of ASD; can take public transportation independently, without assistance from a third party; and has no additional physical and/or intellectual disability (Table 2).

The age range was chosen because not that much is known about the public transport experiences of young adults with ASD. To recruit individuals with ASD, a poster was created and distributed via social media. Autisme Limburg, Vlaamse Liga Autisme, Ergotherapie Vlaanderen, Toerisme voor Autisme and some smaller organizations also shared this recruitment poster with their members.

The second participant group consisted of bus drivers employed by the public transport company 'De Lijn' and was also recruited via convenience and criterion sampling. Participants were recruited through the accessibility coordinator and a driving school instructor from 'De Lijn'. The following inclusion criteria were set:

- works at 'De Lijn' (and not for a subcontracted company);

- has some experience with individuals with ASD while working.

Table 2: Demographics information of participants

	Participants (n = 17)
Gender, n(%)	
Male	10 (58.8)
Female	7 (41.2)
Age, M ± SD	
Male	22.0 ± 4.92
Female	24.9 ± 4.09
Age range	
Male	18 – 33
Female	19 – 30
AQ-score, M ± SD	
Male	34.1 ± 4,97
Female	26.17 ± 11.29

Employees of 'De Lijn' were recruited through the accessibility coordinator and the instructor of the driving school of 'De Lijn'. These individuals had previous experience with persons with ASD using the bus and thus were suitable for inclusion.

Materials

A semi-structured interview format

A semi-structured interview is a combination of open questions and questions specifically designed for the topic under study. The structured questions in the current study were designed based on a pre-prepared topic list (e.g., use of public transport, bus stop, timetable, etc.) and were meant to create structure and predictability in the interview. The topic list was developed based on available literature about and practical experiences with the different steps involved when using a public bus. The list itself and the formulation of certain questions differed per target group as the questions for the employees of the public transport company were asked from a different perspective than those for the ASD participants. In addition to the interview, a photo guide was assembled to create a clear and better idea of the situation in question. Each question was accompanied by a picture that visualized that specific situation. First, two pilot interviews were conducted to ensure all the questions were clear. The first pilot interview was with an individual without ASD, while the second pilot interview was with an individual diagnosed with ASD. This second interview was important to assess whether the semi-structured interview was suitable for individuals with ASD as well, emphasizing the importance of clear communication without suggestive questions. The pilot interview for employees of 'De Lijn' was conducted with a non-autistic person not employed by the company

Procedure

In preparation for the interview, the participants diagnosed with ASD were provided with a list containing the topics that would be discussed during the semi-structured interview in order to create predictability of the interview, which is important for people with ASD. This procedure was adopted after consultation with Autisme Centraal1. In addition, to ensure a secure and trustful atmosphere during the interview, the ASD participants were requested to determine the interview location. If the participant did not select a location beforehand, a specific location with a calm environment without distraction was chosen by the research team to stimulate sharing of information.

Data was collected by one researcher between November 2018 and March 2019. During the interview, the interviewer made sure that the interviewee correctly understood each question. The interviewing speed was adjusted to each participant individually to ensure that they had sufficient time to understand and answer the questions.

The data collected with the semi-structured interviews were processed based on interpretative phenomenological analysis (IPA). In essence, IPA focuses on individuals' interpretation to describe their personal experiences and understand their perceptions (i.e., trying to understand what the participants describe from their own perspective and not from the perspectives of the researchers) (Howitt & Cramer, 2010). For that reason, analysis is not only focused on the description of the experience but also on the interpretation of the experience that causes a specific perception of that situation. An audiotape was used to record the interview.

Data analysis

After the data collection, the information provided by each participant was written ad verbatim, with the inclusion of relevant details and observations (e.g., off-topic answers, gestures, etc.). All data were collected and analyzed in NVivo. In addition, non-verbal reactions of the participants were incorporated in the transcript in case these were assumed to be useful (e.g., shaking no with the head was reported, sneezing was not reported). After the initial development of the transcript, further familiarization with the data was achieved by reading the transcript and the interview notes and by listening to the audiotapes again (Howitt & Cramer, 2010). Accordingly, participants' self-interpreted experiences were evaluated from different perspectives (i.e., the perspective from each participant) to come to a first a naïve understanding. Next, this naïve understanding was further decomposed into several themes representing similar content (Baarda et al., 2001). Subsequently, themes were clustered into 'superordinate themes'.

This familiarization process was repeated until the data of each transcript was placed under the correct theme. The themes were illustrated in this study through various quotes that expressed the self-interpreted experience of the participants. The iterative process of observation, collection, and reflection continued until theoretical saturation (i.e., the same content was found for each section within subsequent interviews, and no new experiences came forward from the new interview transcripts) was reached (Baarda et al., 2001) In this study, no new themes emerged after 15 interviews with the ASD target population and three interviews with employees from 'De Lijn'. Two more interviews were conducted with the ASD target group to make sure that no new information came forward.

3.3.3. Stage 3. Driving simulator assessment of driving capabilities in young adults with ASD

3.3.3.1. Case study 3A: Driving distraction among autistic individuals: A simulator study using an adapted LCT

Introduction

This study aimed to investigate the driving performances of autistic individuals; and compare those performances with non-autistic individuals' driving performance when they were distracted by increasing verbal WM load tasks. In this regard, a driving simulator-based Lane Change Task (LCT), adopted from Ross et al. (2014), was employed to measure the driving performance of the study participants. Previous research that addressed the general population indicated that LCT measures are influenced by verbal WM load (see Engström et al., 2005; Harbluk et al., 2007; Mattes, 2003). Thus, to induce a distraction during driving, we introduced the WM load using an auditory-verbal response-based task called the N-back test, which consisted of different difficulties levels (0-back, 1-back, and 2-back) (Mehler et al., 2009; Wild-Wall et al., 2011). As a baseline, we also included LCT drive without any n-back test. In the simulated LCT (Ross et al., 2014), driving measures include a deviation of the actual course of driving from the normative course of model (ISO 26022, 2010; Young et al., 2011), execution of correct lane change, and lane change initiation (Young et al., 2011) were derived. As we discussed in the introduction, distraction deteriorates drivers' driving performance by interrupting the WM memory capacity. In this case, the characteristic of autistic individuals (e.g., impaired working memory) could degrade their driving performance more. In a driving condition, where distraction is induced, the impaired driving performance of autistic individuals may increase. Following the discussion presented here and in the introduction part, we proposed the following specific objectives.

1. Exploring the driving performances of autistic individuals while they are subjected to auditory-verbal response distraction that induced increasing WM loads.

2. Investigating the autistic individuals' performance on the secondary tasks when verbal WM load increases
3. Comparing the driving and secondary tasks performances of autistic individuals with non-autistic individuals while they are exposed to auditory-verbal response distraction that induced increasing WM loads.

Materials and methods

Participants

A total of 68 adults with autism (n = 21) and without autism (n = 47) were invited to participate in this driving simulator study. Four autistic participants were excluded because they were outliers based on their driving performances. Thus, seventeen autistic participants (5 licensed and 12 non-licensed) were included in the sample (average age = 22.12, SD = 3.89). Corresponding to the size of licensed and non-licensed autistic participants, a proportional analysis was computed to choose the sample from the remaining 47 non-autistic participants (licensed = 23 and non-licensed = 24). Accordingly, 34 non-autistic participants (licensed = 10 and non-licensed = 24) were included in final sample (Mean age: 20.74, SD = 3.61). Therefore, the driving license status distribution did not significantly differ between autistic and non-autistic participants (Chi-Square χ^2.= .001, $P > 0.05$).

Participant recruitment

After obtaining ethical clearance approval from the Qatar University's Institutional Review Board (QU-IRB), the research team engaged in the diagnoses and recruitment processes of autistic and non-autistics participants. The team first recruited autistic individuals using a purposive sampling technique from the Shafallah center and Hamad Medical Corporation (HMC), dedicated intuitions to diagnosis and treating individuals with autism in Qatar. Two steps were applied to determine whether those participants had autism. First, the team received a list of individuals who were diagnosed as autistic by the Shafallah center and HMC. In the second step, the team invited those individuals to Qatar University for further diagnosis of IQ and autistic characteristics. An experienced and licensed clinical psychologist conducted the diagnosis at QU. Once the team finished the diagnosis process, the confirmed participants were invited to the driving simulator experiment room based at Qatar University. To recruit non-autistic participants, who were with typical neurological development and function, the research team was involved in an advertisement through social media (e.g., Facebook, Instagram), website, brochures, letters, and frequent message exchanges with potential individuals. The recruitment process for the non-autistic sample was based on matching criteria (e.g., demographic background) with the autistic participant. The demographic background and driving license status (e.g., age, gender, and driving license status) of autistic individuals were considered to choose the non-autistic participants.

Apparatus

A validated driving simulator based at Qatar University (See Hussain et al., 2020; Hussain et al., 2019) was used to perform the LCT experiment (see Figure 4). The driving simulator comprises two main units, including the driving and the visual units, which are interfaced using STISIM Drive®3 software and the CalPot32 program. The visual unit consists of three large screens around the driving unit cabin with a 135-degree horizontal field of view; a resolution of 5760 X1080 pixels and a 60 HZ refresh rate. The driving unit of the simulator contains the fixed-based Range Rover Evoque cockpit equipped with all tools (e.g., pedal, speedometer, gearbox) that are similar to a real car.

Moreover, like a real car, the simulator can release road noise, which can be heard through the simulation auditory part. More importantly, the driving simulator can gather a wide range of data regarding deriving parameters.

Figure 4: Simulated road with right outer lane change sign

Data collection tools

N-back task

N-back task is a widely used test to measure a working memory (WM) load (Leon-Dominguez et al., 2015; Owen et al., 2005), which can be defined as a cerebral function that permits us to retain, access, and process the ongoing information (Jaeggi et al., 2010; Leon-Dominguez et al., 2015). In the N-back test, participants are presented with a sequence of stimuli (e.g., number) one at a time, and they are asked to compare the current stimulus to one presented 'n' items prior to the sequence (Harbison et al., 2011). The N-back task was originally introduced as a visuospatial task (Kirchner, 1958) and a visual letter task (Mackworth, 1959). In driving context, this study adopted an auditory prompt–verbal response "n-back" task from Ross et al. (2014) work, which replicated the Mehler et al. (2009) study, where the test was designed not to create conflict with the manual and visual processing of the main or primary driving task.

The task consisted of three difficulty levels (i.e., 0-back, 1-back, and 2-back) used to measure continuous recognition for presented numerical values ranging from 0 - 9. In this task, respondents heard a series of numbers from the simulator while driving the LCT scenario, and they were required to repeat out loud those series of numbers. In each task level, sixty-nine different numbers were presented with an inter number interval of 2.25 s. The first level was the 0-back, in which participants loudly repeated immediately the same number they heard (Table 3). For example: when the simulator says number 3, participants say 3. The second level of the task was called the 1-back, participants were asked to remember and repeat out loud the number that came before the last number they heard. For example, participants say nothing when the simulator says 3 in the first place; next when the simulator says 2, participants say 3 (Table 3). The third level of the task was the 2-back, participants were informed to recall and repeat out loud the number that was presented two numbers before the last number they heard. For example, when the simulator says 3, participants say nothing; when the simulator says 2, then participants again say nothing; when the simulator says 6, participants say 3; when the simulator says 7, participants say 2 (Table 3).

Table 3: Sample of N-back test with three levels of complexities (0-back, 1-back and 2-back)

List of numbers	**3**	**2**	**6**	**1**	**7**	**5**	**9**	**0**	**8**	**4**
0-back	**3**	2	6	1	7	5	9	0	8	4
1-back	**Nothing**	3	2	6	1	7	5	9	0	8
2-back	**Nothing**	**Nothing**	3	2	6	1	7	5	9	0

Before the presentation of the main N-back tests, participants practiced 10 samples of numbers in each level of task complexity (see Table 3). Each participant scored a correct response of 9 out of 10 in 0-back, 7 out of 9 in 1-back and 4 out of 8 in 2-back. In the case of failure to score the minimum proficiency level among participants, it was allowed to repeat up to 4 additional tries in which the list of numbers wrote down 2 times in reverse order and then 2 times in the same order. One additional try was presented each time to improve the participant's understanding to the desired point of correct response in each task. All participants scored the desired correct response before the recommended trial chance were tried.

4.4.2. Driving Task

The study adopted the LCT Sim v1.2, which was initially developed within the project ADAM (DaimlerChrysler, BMW) (Mattes, 2003), from a Ross et al. (2014) study on working memory and driving behaviour among the general population using a simulated driving environment programmed with STISIM. The LCT road track was around 3000m with 18 lane changes as indicated by 3 types of signs (see Figure 5).

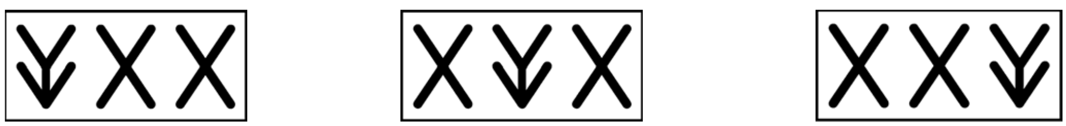


Figure 5: Lane change direction signs to the left, middle and right sides

Participants were instructed to drive with the gas pedal pressed to its maximum, which maintained a constant speed of 60 km/h, resulting in a duration of about 180 s. The average distance between two signs was 150 m, and the mean duration required to finish this distance was around 9 s. Regarding the frequency of lane change, each of the 6 lane changes occurs 3 times throughout the 3 km. There was no other traffic on the simulated 3 lanes road (Figure. 4), and participants were instructed to follow the direction indicated by the down arrow sign while performing the lane-change maneuver (Figure. 5).

Data analysis variables

Driving task measures

The driving performance measures associated with LCT were adopted from Ross et al. (2014) research work that derived those measures from previous literature (see ISO 26022, 2010; Young et al., 2011). This study used driving performance measures of LCT, including lateral control (i.e., mean deviation in lane change path) and event detection measures (lane change initiation and percentage of correct lane changes).

Mean deviation in lane change path (MDEV)

MDEV is the difference between the actual driving course of participants and the LCT baseline or normative course model, as computed based on ISO annex E-standard. Figure 6 shows the symbolic example of the ISO normative course of model. According to ISO 2010, this measure addresses driving performances that increase deviation, namely quality of the manoeuver (slow lane change), lane keeping quality, and perception (late perception of the sign or missing a sign).

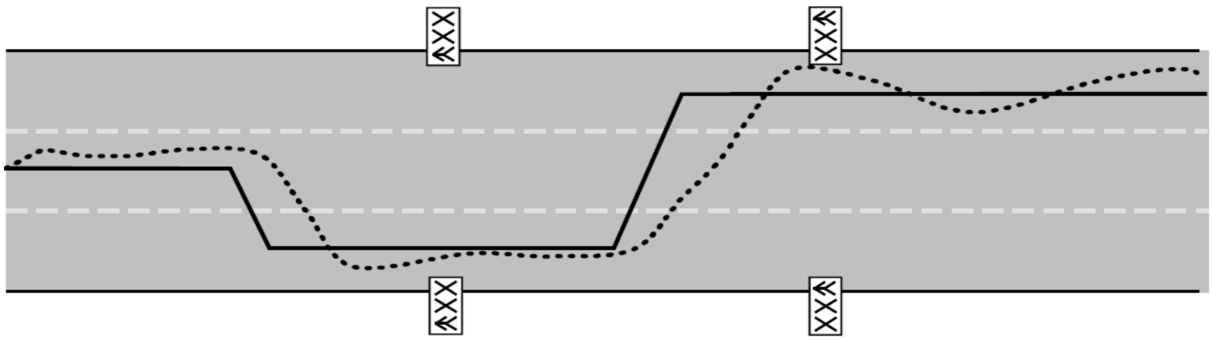


Figure 6:Normative model/lane change path model (solid line) and actual driving course (dotted line)

Percentage of correct lane changes (PCL)

PCL helps to measure the participants' ability to correctly respond to the signs by changing the lane accordingly. While performing PCL, participants engage in lane change sign detection, decision making, preparation, and execution. PCL was computed as the percent of correct lane changes that occurred within 40 m after lane change sign appeared (i.e., without considering missed lane changes and erroneous lane changes) and divided by the total of 18 (i.e., number of lanes).

Lane change initiation (LCI)

LCI refers to the time difference between the lane change sign appearance and participants' initiation of appropriate response to the respective sign. It assesses participants' ability to detect directional information appearing on a sign, select the proper lane, and prepare to make an appropriate lane change. The start of participants' response to the sign was specified when the steering wheel angle became ≥ 3° and ≥ 6° to change one lane position and two lanes positions respectively. The time interval was calculated for each correctly performed initiation among 18 sections. The average of those correctly performed initiations was taken as LCI (in time) to a participant.

Verbal WM load

Percentage of error rate (PER)

The percentage error rate was calculated based on participants' incorrect responses to 0-back, 1-back, and 2-back while they drove the simulated LCT.

Data collection procedure

Before the actual experiment, each participant received a brief orientation regarding the overall processes of the study and signed informed consent. Participants received practical training sessions for both auditory-verbal response N-back task and LCT. They practiced the auditory-verbal response N-back task before performing the actual LCT driving. Moreover, before the experiment, they practiced LCT driving on the simulator. Hence, participants understanding for N-back and LCT instruction was ensured. Participants were instructed not only to focus on the N-back or driving task, but to respond to the N-back tasks while performing the LCT with equal attention as much as possible. To reduce the learning effect on participants, a counter-balanced order was performed across drives accompanied by auditory-verbal response N-back tasks. Once all such processes were completed, four drives accompanied by baseline, 0-back, 1-back, and 2-back tests were run to each participant. In total, each participant drove 12 km with 72 lane changes (each of 24 lane changes occurs 3 times throughout the 12 km). The driving performances of participants were recorded in the simulator, and their responses to the N-back test were recorded using the data collector checklist as well as an eye-tacking audio recording system.

Data Analysis

Raw data was collected in DAT format using STISIM Drive® 3. A MATLAB script was used to convert the raw data into LCT measures by consulting the ISO annex E standards. To analyze the driving performances of autistic and non-autistic participants, as distracted by increasing verbal WM load tasks, within-subject repeated ANOVA (RANOVA) tests were conducted separately for each of the LCT measures, and PER. Pairwise comparisons using Least Significant Difference (LSD) adjustment were conducted to test LCT measures and PER difference between verbal WM load tasks.

Independent samples t-tests were computed to compare LCT measures and PER performances between autistic and non-autistic participants. In this regard, two steps were followed: first, a mean of all scores (baseline, 0-back, 1-back, and 2-back) for each driving measure and error rate was performed to analyze the total mean of MDEV, PCL, LCI, and PER difference between autistic and non-autistic participants. The second step was comparing each LCT measure and PER between autistic and non-autistic participants as a function of each level of tasks. Thus, a mean of MDEV, PCL, LCI, and PER was computed based on the baseline, 0-back, 1-back, and 2-back tasks.

3.3.3.2. Case study 3B: Investigating aggressive driving behavior in autistic individuals: A simulator study

Introduction

The core features of autism include communication deficit, social skills impairment, stereotyped behavior, and restricted interest (American Psychiatric Association, 2013) which are heterogeneous among autistic individuals (Matson & Adams, 2014). In addition to such homogeneous core symptoms, autistic individuals exhibit a variety of comorbid features that result in other debilitating problems than commonly reported problems in autistic individuals (Matson & Adams, 2014). Aggression can be considered as one of such comorbid behaviors that significant number of individuals with ASD exhibit (Mazurek et al., 2013). Suggested that studying the characteristics of aggression among autism and how they express those characteristics have important implications for better understanding of the causes of aggression and prepare tailored interventions (Mazurek et al., 2013). This study aimed to investigate aggression behavior in the context of driving.

Materials and methods

Participants

Sixty-eight participants autism (n = 21) and without autism (n = 47) were invited to participate in this study. Eighteen participants with autism (5 licensed and 16 non-licensed) were included in the sample (average age = 22.12, SD = 3.89). Corresponding to the size of licensed and non-licensed autistic participants, a proportional analysis was computed to choose the sample from the remaining 47 non-autistic participants (licensed = 23 and non-licensed = 24). Accordingly, 34 non-autistic participants (licensed = 10 and non-licensed = 24) were included in final sample (Mean age: 20.74, SD = 3.61). To reduce the risk of being affected by simulation sickness (Kennedy et al., 1993), each participant was informed beforehand to avoid any kind of food or drink (except water) at least two hours prior to the test.

Participant recruitment

Before we started the data collection process, we asked for the ethical clearance approval from the Qatar University's Institutional Review Board (QU-IRB). Once we secured the ethical approval, we collected two groups of research participates: individuals with and without autism. At the beginning, we engaged in the diagnoses and recruitment processes of individuals with autism using a purposive sampling technique from the Shafallah center and HMC. Those participants with autism were checked whether they fulfilled the study's inclusion criteria including IQ level, autism, young and adult. Once we finished the diagnosis process, the confirmed participants were invited to the driving simulator experiment room based at Qatar University. To obtain participants without autism, we advertised through social media (e.g., Facebook, Instagram), website, brochures, letters, and frequent message exchanges with potential individuals. The recruitment process for the non-autistic sample was based on matching criteria with the autistic participant.

Driving stimulator

Driving simulator at Qatar Transportation and Traffic Safety Center, Qatar University was used to conduct the study. It is important to mention that this driving simulator has been validated for external validity (i.e. actual speed & speed perception) and subjective validity (Hussain et al., 2019). The simulator consisted of two main components: a) the driving unit – A fixed-base cockpit of a car (Range Rover Evoque) equipped with speedometer, force-feedback steering wheel, pedals, gearbox (automatic transmission), indicators and b) three large screens with 135 degrees of horizontal field of view, resolution of 5760 x 1080 pixels and a 60 HZ refresh rate. The components are interfaced with STISIM Drive® 3 along with the CalPot32 program, which offers high-speed graphics, and sound processing (Figure 1). The simulator can collect a wide range of data including speed, lateral/longitudinal acceleration, lateral/longitudinal position, and number of accidents, number of speeding tickets, pedal inputs, reaction time and a lot more.

Scenarios designs

School Bus scenario

A narrow two-lane urban road-based scenario, in which a participant's car is jammed by a slow-moving school bus, was designed to induce anger and impatience that may activate aggressive driving behavior among participants. The speed of the school bus was 16km/h. The opposite traffic had successive cars with constant short gaps (5 seconds), which did not allow participants to make passing maneuvers nearly difficult. The school bus became visible (onset) to the participants 70m before its location to merge into the traffic. While driving, participants followed the slow school bus for a 320m distance. In this scenario, as an indication of aggressive driving behavior, several measures, including speed, acceleration/deceleration, the distance between the participant car and the school bus (i.e., spacing), lateral position, Minimum time to collision, crash.

Traffic light scenario

Two consecutive signalized intersections, where each signal turns yellow as participants approaches them were included in the scenario design. The light to remain red in the first and second signalized intersection was 56 and 15 seconds respectively. There was no any traffic in both intersections. In this scenario, the measurements of aggressive driving behavior include whether the participants stopped or accelerated at the intersection after observing the yellow light, and maximum acceleration reached when they stopped.

Left turn scenario

In this scenario participants performed a left turn through traffic moving in the opposite direction in a narrow two-lane road, where the opposite traffic had constant 3 second short gaps and did not stop so participants should make forced crossing. In this regard, if participants would wait without turning left 12 seconds, another vehicle would approach him/her from the back and start beeping and flashing that possible trigger anger and leading to forced crossing.

Data collection procedure

To manage the experiment execution in this study, we prepared procedures that were employed throughout the experimental processes for both ASD and neurotypical participants. At the beginning, a brief welcome presentation was provided to each participant. At the same time, each participant received detailed explanations about the study and all processes related the experiment. Once all things about the experiment were clear, each participant was asked to sign the online informed consent form. Consequently, a driving simulator practice was carried out to familiarize participants with driving on a driving simulator. In the case of emotional regulation, we collected different specific and general driving measures, such as following distance towards the school bus, maximum acceleration and deceleration, maximum lane position (deviation from the center of the lane to pass the bus on the left), red-light-running, maximum acceleration, maximum speed, amount of gaps before taking the turn, and maximum acceleration.

Data Analysis

We collected the data in DAT format using STISIM Drive® 3. A MATLAB script was used to convert the raw data into format that could be easily analyzed. In this regard, we identified driving characteristic that could show aggressive driving behavior, for example, Max. Speed SD Speed, Max. Deceleration, Max. Acceleration, Mean distance to the Bus, Max. Lateral Position SD. Lateral Position, and Crash percentage. Independent samples t-tests were computed to compare the aggressive driving behavior of individuals with and without autism. Moreover, graph illustrations were used to show the driving behavior of each group of participants after and before the events in the scenarios (e.g., before and after onset of school bus).

3.3.3.3. Case study 3C: Hazard perception skill of individuals with autism: A simulator study (paper in preparation)

Hazard perception

Hazard perception can be described as the ability to predict traffic conditions, in special, road hazards (Horswill & McKenna, 2004). Endsley (1995) describes hazard perception as the ability to detect, understand and predict of possible hazards. Hazard perception is considered a critical foundation skill of decision-making (Endsley (Endsley, 1995), 1995). A driver with improved hazard perception skills is better at recognizing potential crash situations and anticipating the risk (Horswill, 2016). Research has shown that hazard perception skills are related to crash rates (Horswill et al., 2015). Unfortunately, young novice drivers take longer to master hazard perception skills since they are more complex than basic vehicle handling skills (Freydier et al., 2016). As novice drivers gain experience, they shift from using largely fixated visual search strategies, to more efficient search patterns. Furthermore, they acquire more knowledge about typical traffic situations and related hazards.

Studies categorize hazards as social and non-social hazards (e.g., Bishop et al., 2017; Sheppard et al., 2010; Sheppard et al., 2017). Another distinction uses three categories: behavioural prediction, environmental prediction, and dividing and focusing attention. Behavioral prediction (BP) hazards focus on the anticipation of events. They require the extrapolation of social elements in the environment to predict possible future events. In this category of hazards, there is a direct link between the precursor and the hazard, e.g. a car pulling up from a side road in front of the participant. Environmental prediction (EP) hazards have an indirect link between the precursor and the hazard. This creates the element of surprise. A certain understanding of statistical probabilities is needed to predict these hazards, e.g. a parked truck behind a blind bend.

Dividing and focusing (DF) hazards occur when there are multiple potential hazards. At first, the drivers have to divide their attention on the different precursors. A precursor is a visual cue, e.g. the current behavior that provides information for what might subsequently happen. After one of the precursors turns into an actual hazard, the driver must focus on this (Crundall et al., 2012). Previous research by Ross et al. (2019) showed that for BP hazards, there is no difference in reaction time and time to collision at the moment of the reaction between the control group and autism group.

Table 4 List of hazards, events and precursors

Scenarios	Hazard type	Precursors	Events
Local	Behavioural prediction hazards (BP)	A cyclist riding on the side of the road	Bike suddenly backs out into the drivers' path
	Behavioural prediction hazards (BP)	A parked truck next to the road.	Car suddenly backs out into the drivers' path
	Behavioural prediction hazards (BP)	Child visible next to the road, between parked cars.	The child steps onto the road.
	Dividing and focusing attention hazards (DF)	Intersection where the participant has the right of way (4 arms). There are cars present on the left and right side of the intersection.	A car coming from the right, that doesn't have the right of way.
	Environmental prediction hazards (EP)	Parked car next to the road.	A pedestrian appears in front of the car and walks onto the road.
Corniche	Environmental prediction hazards (EP)	A tall bus parked next to the road.	A taxi suddenly comes onto to the road in front of the bus.
	Dividing and focusing attention hazards (DF)	Cyclist on the other side of the road + parked car on the right side of the road.	Car suddenly leaves his parking spot, in front of the driver.
	Dividing and focusing attention hazards (DF)	Few people (4 -2 on the left and 2 on the right) are waiting to cross the road at a red light. The participant has a green light.	A pedestrian ignores the red light and crosses the road, coming from the right.
	Environmental prediction hazards (EP)	A blind curve	Right after the curve is a broken-down truck with 4 blinkers on.

The reaction time to EP hazards was smaller for people with autism. The difference in reaction time to BP and EF hazards for drivers with autism can be explained by the explicitness of the situation. The behavioral context is more open to interpretation than the environmental context (Vermeulen & Myles, 2012). Lastly, the drivers with autism performed worse on the DF hazards, as they had a slower reaction time than the non-autistic drivers.

In the current study, the hazard perception skills of drivers with autism and without autism were compared. In this preliminary analysis, the hazard perception skills for individuals with and without autism were measured based on reaction time and minimum Time to Collision (TTC).

Thus, such measurements were compared for both groups when they were subjected to different events that can be categorized into three hazard types: Behavioral prediction (BP), Environmental prediction (EP), and Dividing and focusing (DF).

Materials and methods

Participants

For this preliminary analysis, a total of 93 participants with autism (n = 23) and without autism (n = 70) were participated in this study. Among participants with autism 5 were licensed and the remaining were non-licensed. In the case of participants without autism, 34 and 36 participants were licensed and non-licensed respectively.

Participant recruitment

The same participants recruitment procedures, which were used in the case study 3A and 3B were applied in this study.

Driving stimulator

The same driving simulator, which was used in the case study 3A and 3B, was applied in this study.

Scenarios designs

The hazard perception scenario is selected for this study, because previous literature has indicated the possible difficulties in hazard perception for people with ASD, and potentially mostly for more complex hazard situations. Extending further on these studies, we developed two scenarios that included three hazard types: Behavioural prediction hazards (BP), Environmental prediction hazards (EP), and Dividing and focusing attention hazards (DF).

Moreover, we added different hazard precursors as the ability to recognize and identify hazard precursors distinguishes safer experienced drivers from less safe inexperienced drivers. None of the above-described studies included an investigation of hazard precursors (see Table 5). The first scenario was developed based on the Corniche road designs in Qatar. The second scenario was designed based on infrastructure and road designs that can be considered as manifestation of local road.

Data Analysis

The extracted and formatted "DAT" file was analysed using independent samples t-tests, which were computed to compare the hazard perception skills (i.e., reaction time and minimum Time to Collision) of individuals with and without autism.

3.3.4. Stage 4: Assessment of the effectiveness of the instructor's training module on improving driving skills of ADS adults

3.3.4.1. Case study 4A: Assessment of instructors' knowledge about autism and driving before and after training workshop

Introduction

Driving instructors in Qatar often apply the same driving instructions to all learners regardless of their difference (e.g., autistic and non-autistic people). The possible explanation is that driving instructors lack knowledge and practice concerning training autistic individuals. This explanation was also indicated in the study of the current project. Accordingly, we needed to see the change this workshop could bring to driving instructors' awareness of autism and driving. Thus, we assessed the workshop participants' knowledge about autism and driving before we started the workshop and after we completed the workshop.

Measures

Pre-workshop and post-workshop questionnaire

A self-report questionnaire consisted of 10 items (e.g., autistic people are very rulebound; this negatively affects their driving performance) that assessed participants' knowledge about autism and driving was employed. The authors designed this questionnaire based on the contents of the practical guide material. Each item was designed to be answered on three choices as correct (3) or incorrect (2), or I do not know (1). Each participant completed the same questionnaire before and after the training workshop. A sum score of each participant's accurate response to 10 questions was used in the computing process. If a participant selected 'I do not know', it was considered an incorrect response in the computing process.

Workshop participants and data collection procedure

Senior driving instructors from the KDS were recruited for the workshop. Thirty-one participants (16 on day 1 and 15 on day 2) participated in the workshop. In the beginning, participants were briefly introduced about the workshop's aim. Once we finished this, we distributed the pre-workshop questionnaire to each participant and collected it. We then delivered the workshop. In the end, participants filled out the post-workshop questionnaire. It is important to note that three participants could not fill out the post-workshop questionnaire because they had already left the workshop before the last session in which the questionnaire was distributed. Moreover, one participant did not fill out the pre-workshop questionnaire because he was late to join the workshop.

Training Phase

Tailored driver-training manuals can be developed or adapted to address autism-induced driving-related problems (e.g., anxiety issues, hazard perception ability, and navigation challenges) (Chee et al., 2015). In this regard, in the current study, a practical guide was prepared based on empirical evidence derived from several studies using a driving simulator, self-report, and E4-wristband. In these studies, autistic individuals' hazard perception skills, emotional regulation while driving, distraction in driving, and attitude towards driving were addressed. Moreover, the information found in the practical guide was partly based on the booklet "Yes, I drive!" Autism in traffic: "a practical guide to give persons with autism more opportunities in traffic" (Vanvuchelen et al., 2014b). Qatar University and Hasselt University jointly provided a training workshop, based on an evidence-based practical guide, to 30 senior driving instructors in KDS to help them tailor and adapt their driving lessons to the needs of autistic trainees. The training workshop addressed several issues concerning autism, such as the characteristics of autistic persons, theoretical perspectives on autism, autism in general and specifically in Qatar, autism and driving, and detailed practical recommendations about how to deal with the learning-to-drive process for autistic trainees. The training workshop participant instructors filled out the pre-workshop questionnaire before the training workshop. Once they finished filling out the questionnaire, we asked them to perform exercises in which participants were actively involved in individual activity, group work, in-class group tour discussion, and group work presentation on autism and driving. After such steps, the main parts of the training workshop were delivered to participants using a PowerPoint presentation, brainstorming questions, videos display, quizzes, physical exercises and demonstrations, and question and answer. Moreover, informal dialogue during lunch breaks and testimonial interviews were also used in the training workshop. At the end of the training workshop, participants completed the post-workshop questionnaire.

Data analyses techniques

We employed a paired-sample t-test to determine whether there was a statistically significant difference between the mean score of participants' knowledge about autism and driving before and after the workshop. We computed three paired-sample t-tests to assess the before and after workshop knowledge difference within group one, group two and combined both groups. An independent samples t-test was employed to determine whether there was a difference in the mean score of the pre-workshop and post-workshop knowledge concerning driving and autism between group 1 and group 2. Moreover, we analyzed the data using descriptive statistics, such as percentages and bar charts.

3.3.4.2. Case study 4B: Evaluation of the workshop

Introduction

This workshop for driving instructors on autism and driving was the first to be offered in the Gulf Region Countries. To improve the planning of similar workshops in the future in Qatar and other Gulf countries, we evaluated several aspects of the workshop (e.g., objectives, contents, delivery methods, ways of communication, and workshop organization).

Measurement

Workshop evaluation questionnaire

The workshop evaluation questionnaire involved both Likert scale and open-ended questions. The Likert scale questions addressed three parts of the workshop: information delivered before the workshop (i.e., Before participating in this workshop, were its objectives, content, and methods clear to you?); the way the workshop was delivered (e.g., Are the workshop objectives clear to you now after participating?), and the usefulness of the workshop (e.g., Are you satisfied with the quality of the workshop?). The open-ended questions were designed to collect participants' feedback and comments on each workshop component (e.g., objective, method, organization, and contents).

Workshop participants and data collection

Senior driving instructors from KDS were recruited for the workshop. Thirty-one participants (16 on day 1 and 15 on day 2) participated in the workshop. After the workshop, participants filled out an evaluation questionnaire. Before participants filled out the questionnaire, they were briefly introduced about why we needed to assess the workshop. While filling out the evaluation questionnaire, they were informed to ask the workshop facilitators for more clarity about some questions.

Analyses techniques

The data obtained using the workshop evaluation questionnaire involved both quantitative and qualitative. The quantitative data was analysed using a table and chart, and the qualitative data was analysed using coding and categorizing each participant's response accordingly.

3.3.4.3. Case study 4C: Assessment of the effectiveness of the instructor's training module

Introduction

Driving instructors play important roles in the training to develop safe driving skills (Ross, Jongen, et al., 2018). Due to the impact of autistic characteristics on driving training, instructors should apply a tailored and distinctive approach beyond the conventional training pattern. In relation to this, in a study by Myers et al. (2019), driving instructors believe that innovative and standardized educational approaches are required to deal with the learning-to-drive process for autistic trainees. In this case, there is limited research on the learning-to-drive process for autistic individuals (Smigiel, 2020). A few studies addressed educational materials for instructors regarding driving training of autistic trainees, for example, educational module's effect evaluation on autistic trainees (Ross, Cox, Noordzij, et al., 2018), specialized driving curriculum impact on autistic individuals' driving performance using a driving simulator (Smigiel, 2020), autistic individuals experience of specific facilitators or barriers to driving education (Almberg et al., 2017), understanding autistic individuals' viewpoints to develop driver tailored support and training (Chee et al., 2015), Virtual Reality Driving Simulation Training to evaluate and improve performance for autistic individuals (Cox et al., 2017) and training method for Asperger driver (Tyler, 2013). However, to our knowledge, no literature addresses the learning-to-drive process for autistic trainees in progressive phases. Firstly, assess the knowledge gap among driving instructors regarding driving and autism. Second, improve driving instructors' knowledge and practice regarding autism and driving using an evidence-based tailored practical guide (see part 2.3.2). Thirdly, evaluate the practices of driving instructors, who were and were not subjected to the tailored practical guide, when they train autistic trainees. Moreover, assess driving attitudes, perceived stress, and driving concerns of autistic trainees who received training from the trained and non-trained instructors about autism and driving. Therefore, the current study aims to achieve the following specific objectives:

1. To evaluate the teaching-to-drive process of driving instructors who received and did not receive the training workshop.
2. To compare driving attitudes, perceived stress, and driving concerns of autistic trainees trained by instructors who received and did not receive the training workshop

Participants and recruitment

After obtaining ethical clearance approval from Qatar University's Institutional Review Board (QU-IRB), three-step participant recruitment processes were employed to choose participants for the assessment, training, and practice phases. A total of 96 (90 driving instructors and 6 autistic trainees) were recruited using a purposive sampling technique. Specifically, in the assessment phase, to investigate driving instructors' knowledge regarding autism and driving, 50 male driving instructors were obtained from the Karwa driving school (KDS) based on their seniority and experience in giving training to many driving trainees. In the training phase, 30 senior driving instructors from KDS participated in the training workshop. Finally, 13 participants (7 driving instructors and 6 autistic trainees) were recruited in the practice phase. Each group (instructors and trainees) of participants in the practice phase was categorized into experimental and control groups. In this regard, three out of 7 driving instructors were assigned to train 3 autistic trainees who were assigned to the experimental group. These three driving instructors were recruited from the 30 training workshop participants based on their better performance in pre and post-scores of the training workshop. The remaining 4 driving instructors (not included in the training workshop) were assigned to train three autistic trainees (control group). The six autistic trainees were obtained from the Shafallah center and Hamad Medical Corporation (HMC), responsible institutions for diagnosing and treating individuals with autism in Qatar.

Tools and materials

This study used a paper-pencil format of self-report measures to obtain data from participants in the assessment, training, and practice phases.

Self-report instruments were employed to collect data from driving instructors and autistic individuals who were categorized into the experimental and control groups as trainers and trainees. A checklist and Likert-point scale formats were used for instruments in the practice phase.

Follow-up checklist for experimental group trainers

This checklist was designed to collect information about driving instructors' practices of specific and tailored recommendations for the learning-to-drive process of autistic trainees. The checklist consisted of 28 items (e.g., During driving training, did you give the trainee enough time to process the information you gave him?) in Yes and No format. The authors developed this checklist from the practical guide. The checklist addressed many aspects associated with communication, step-by-step teaching process, repeated practice, breakdown of skills into small partial skills, enough time to process information, expected behavioural appearance, and attention to the trainee's signs of stress and anxiety. Instructors filled out the checklist based on their experience of teaching autistic trainees in the experimental group.

Follow-up checklist for control group trainers

The checklist was designed to collect information about the driving instructors' practices while they instructed autistic trainees in the control group. Except for how they were framed, the items in the follow-up checklist for control group trainers were the same as those in the experimental group trainers' follow-up checklist. Thus, this checklist included 28 items (e.g., During driving training, you, the instructor, gave the trainee enough time to process the driving-related information you gave him?) in the Yes and No format. Instructors filled out the checklist based on their experience of teaching autistic trainees in the control group.

Follow-up checklist for autistic trainees

The authors developed this checklist to collect information from autistic trainees about whether their instructors applied the tailored recommendations to autism characteristics in the context of their learning-to-drive process. This checklist was the same as the follow-up checklist for the experimental and control group trainers, except for contextualizing them for autistic trainees. Thus, it consisted of 28 items (e.g., During the learning-to-drive process, did your instructor give you enough time to process the information he gave you?) in Yes and No format. Autistic trainees filled out each item of the checklist based on their experience with their instructors.

Drivers Attitude Scale Self Report (DAS-SR)

This scale was designed to measure attitudes toward driving by targeting the situations in which autistic trainees talking about driving, getting ready to drive, and when driving (see Cox et al., 2020; Ross, Cox, Reeve, et al., 2018). The scale was designed in a self-report format, in which participants assessed their attitudes towards driving. The scale consisted of 9 positive items (e.g., when driving, do you become relaxed, calm, and enjoy the experience of driving?) and 9 negative items (e.g., when talking about driving, do you avoid talking about driving?). Each item was rated on a four-point scale ranging from 0 (Not At all) to 3 (A Lot). For computing purposes, all 9 negative items were reversely coded to create positive items. Thus, six items measuring each of three factors, including positive attitude towards talking about driving, positive attitude towards getting ready to drive, and positive attitude towards when driving, were employed.

Perceived Stress Scale (PSS)

This scale was employed to assess the degree to which autistic trainees perceived the situation in their learning-to-drive process as unpredictable, uncontrolled, and overloading. The scale was initially developed by (Cohen et al., 1983) and later used by other authors (e.g., Andreou et al., 2011; Kechter et al., 2019; Örücü & Demir, 2009). The scale consisted of 10 items to be rated on a 5-point Likert scale, ranging from never (0) to very often (4). PSS-10 comprised two subscales: perceived helplessness, which measures participants' feeling of unable to manage their situation, and lack of self-efficacy, which assesses participants' perceived lack of ability to handle problems Taylor (2015) related to their driving training. The perceived helplessness was measured using six items, and the remaining four items measured lack of self-efficacy (e.g., During your driving training, how often have you felt that the training was going as you expected?) (Taylor, 2015). In this study, original items were adapted to the context of the learning-to-drive process, for example, from ‘In the last month, how often have you felt nervous and stressed?' to 'During your driving training, how often have you felt nervous and stressed?'. In the computing process, four items were reversely coded (Cohen et al., 1994).

Driving Cognitions Questionnaire (DCQ)

This questionnaire was employed to measure three areas of driving-related concerns: panic-related (e.g., I will not be able to think clearly), accident-related (e.g., I will injure someone.), and social concerns (e.g., People will think I am a bad driver) (Ehlers et al., 2007). DCQ consisted of 20 items to be rated in a five-point Likert ranging from Never (0) and to always (4) (Taylor et al., 2021). Autistic trainees were asked to respond to how often each thought or idea passed through their minds while they were under driving training.

Data collection processes and procedures

Convenient data collection processes and procedures were applied based on the study's assessment, training, and practice phases.

Practice Phase

Driving instructors and autistic trainees were separately categorized into experimental and control groups. Instructors in the experimental group were assigned to train autistic trainees in the experimental group, and instructors in the control group were assigned to train autistic trainees in the control group. Instructors who trained the autistic trainees in the experiment group were selected from instructors who participated in the training workshop. In addition to the training workshop, the instructors in the experimental group received a practical guide for their preparation before they started the training for autistic trainees in the experiment group. These instructors confirmed (hereafter, trained driving instructors) whether they addressed the material before giving the training. Instructors in the control group received no training and no practical educational guide (hereafter, non-trained driving instructors). Each group of driving instructors trained the respective autistic trainee group for 28 days (one-hour session per day) about how to drive an automatic car. Once they finished the training sessions, instructors in the experimental and control groups were asked to fill out the instructors' follow-up checklist. Autistic trainees in both control and experimental groups also completed four questionnaires, including the trainee's follow-up checklist, DAS-SR, PSS-10, and DCQ.

Data analyses

An independent sample t-test was employed to determine the statistically significant difference between trained and non-trained instructors on the sum of scores in the follow-up checklist. In this regard, the sum of 'correct' responses (i.e., recommended practices for autistic trainees) to 28 checklist items were taken in the computing process. For autistic trainees, independent sample t-tests were computed to find out the statistically significant difference between autistic trainees in the experimental and control group on the mean scores of DAS-SR (positive attitude toward talking about driving, getting to drive, and while driving), PSS-10 (lack of self-efficacy, and perceived helplessness), DCQ (panic-related, accident-related, and social concerns) and sum score of follow-up checklist questions.

4. Discussion of Results

4.1. Case study 1A: Investigate self-reported ASD characteristics among individuals

4.1.1. Results

Descriptive analysis

A descriptive analysis of the sample, in order to get an understanding of the age and gender of the participants that have completed the AQ-10 in the State of Qatar.

Results show that among the 296 participants who have successfully completed the AQ-10, the average age is 29 years, ranging from 18 to 63 years of age. As visible from Figure 7, the gender division among the participants was inequal with more females (59%) in comparison to males (41%) who have completed the AQ-10.

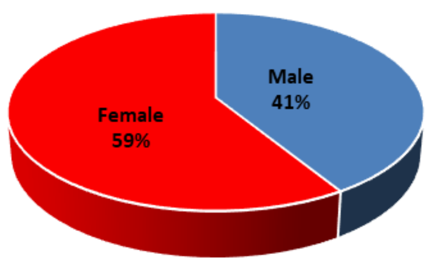


Figure 7: Gender division among the 296 participants who have completed the AQ-10

Among the AQ-10 items, the referral rate is 4.3%, because out of the 296 individuals who completed AQ-10, 13 individuals score 6 or more out of 10 ASD symptoms to be a characteristic of their behaviour. Figure 8 reveals the comparison between male and female respondents and this shows that females are less likely to be referred to a specialist based on their self-reported symtpoms, when compared to males. Females have a referral rate of 1.1% and males have a referral rate of 3.2%.

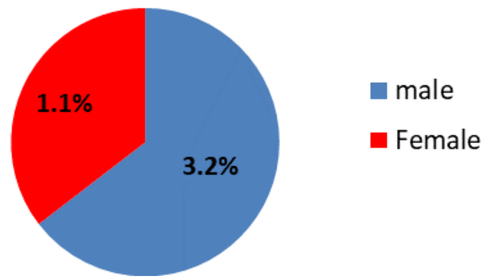


Figure 8: Referral rate based on self-reported ASD symptoms from the AQ-10, comparing male and female respondents

Comparative analysis

A comparative analysis of all the AQ-10 items was conducted in this study by statistically comparing the answers to each item for male versus female respondents. Results are displayed in Figure 9, revealing the AQ-10 items with the highest percentages being reported. The AQ-10 items that are most likely to be reported by both male and female respondents are Questions 1: "I often notice small sounds when others do not", Question 8: "I like to collect information about categories or things" and Question 10: "I find it difficult to work out people's intentions".

Figure 8 also shows the percentage of females and males who self-reported each AQ-10 item. The AQ-10 items each represent an ASD symptom, either by scoring a 'Definitely or slightly agree' score (Questions 1, 7, 8 and 10) or by scoring a 'Definitely or slightly disagree' (Questions 2,3,4,5,6 and 9). The ten AQ-10 items are described below, including the gender division among each question.

For some of the AQ-10 items that describe ASD characteristics, the female participants show to be more likely to report that specific symptom. For instance, Question 1 describing ASD characteristic 'often noticing small sounds when others do not' is found to be slightly more reported by female respondents (69%) in comparison to male respondents (68%)". Question 2, describing ASD characteristic 'usually not concentrating on the whole picture but rather on the small details' is found to be more reported by female respondents (25%) in comparison to male respondents (20%). Question 4, describing ASD characteristic ' if there is an interruption, not being able to switch back to what they were doing very quickly' is found to be slightly more reported by females (24%) in comparison to males (23%). Question 6, describing ASD characteristic 'not knowing how to tell if someone listening to me is getting bored, is slightly more reported by female respondents (11%) than male respondents (8%). Finally, Question 8, describing ASD characteristic 'I like to collect more information about categories of things' is slightly more reported by females (70%) in comparison to males (69%).

For the other AQ-10 items that represent ASD characteristics, the male participants show to be more likely to report that specific symptom. For instance, Question 3, describing the ASD characteristics ‘not finding it easy to do more than one thing at once’ is much more reported by males (34%) than females (19%). Question 5, describing the ASD charactistics ‘not finding it easy to read between the lines when somebody is talking to you’ is reported a little more by male (6%) in comparison to female (3%) respondents. Question 7, describing the ASD characteristic ‘when reading a story, finding it difficult to work out the characters intentions’ is reported more by males (22%) than females (17%). This is in line with Question 10, describing the ASD characteristic ‘finding it difficult to work out peoples intentions’ which is also more self-reported by males (59%) than females (55%). Finally, Question 9, describing the ASD characteristic ‘finding it difficult to work out what someone is thinking or feeling just by looking at their face’ is reported much more by male respondents (23%) in comparison to female respondents (9%).

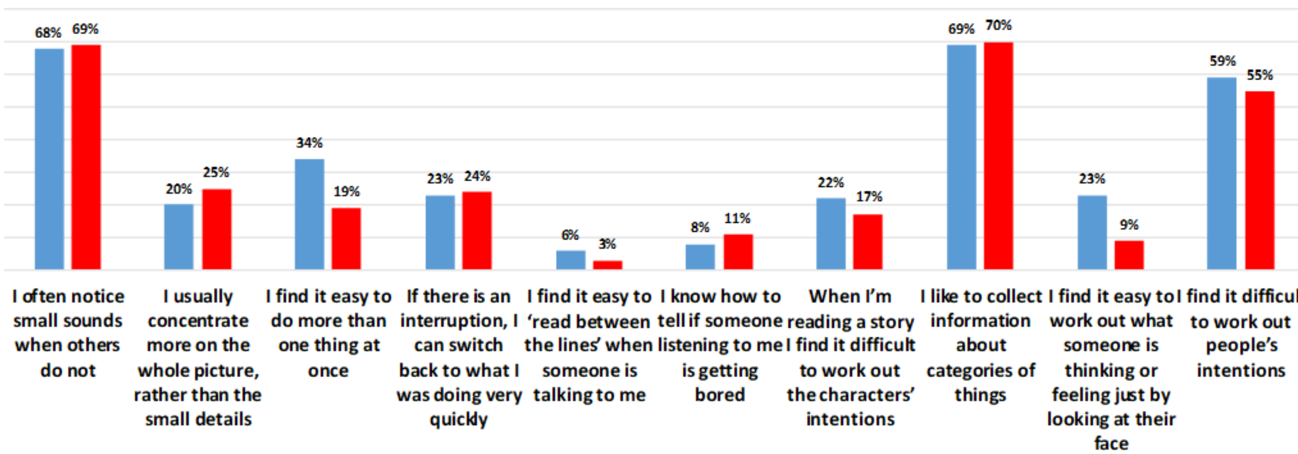


Figure 9: Self-reported ASD symptoms for each of the AQ-10 items, comparing male (N=121) and female (N=175) respondents

After this comparative analysis, a chi-square analysis was applied to investigate the significant differences between males and females for each AQ-10 item. This analysis will reveal which ASD characteristics are scored significantly more by either the male or female respondents. Results reveal that for two out of the ten AQ-10 items, a significant gender difference can be determined. First, question 9, describing the ASD symptom ‘finding it difficult to work out what someone is thinking or feeling just by looking at their face’ is significantly more self-reported by the male participants in comparison to the female participants (p=.002). Secondly, question 3, describing the ASD symptom ‘finding it difficult to do more than one thing at once’ is also significantly more self-reported by males in comparison to females (p=.012).

4.1.2. Discussion

The AQ-10 questionnaire in this sample of respondents in the State of Qatar reveals a referral rate of 4,3%, indicating that a small number of respondents score a high number of ASD symptoms (6 or more out of 10 items) and require a referral to a specialized Clinical psychologist to further assess and confirm a possible ASD diagnosis. The AQ-10 items that are most likely to be reported by both male and female respondents are the ASD symptoms: “I often notice small sounds when others do not”, “I like to collect information about categories or things” and “I find it difficult to work out people’s intentions”. Despite the AQ-10 questionnaire being completed by more females than males, two AQ-10 items are significantly more self-reported by male respondents in comparison to female respondents. However, none of the AQ-10 items reveal significantly higher self-reported ASD characteristics for female respondents. Furthermore, the AQ-10 in general shows a higher referral rate for the male respondents in comparison to the female respondents among this study sample in the State of Qatar. These results do question whether the Arabic translation of the AQ-10 is gender sensitive. Hence, for further research purposes, it is interesting to investigate in more details whether the AQ-10 is sensitive to female characteristics and camouflaging tendencies. This could be done by investigating if it is beneficial to develop a survey with additional questions based on the literature on female specific ASD characteristics, such as camouflaging. This is important, because the development of an Arabic pre-liminary ASD screening tool with female sensitive symptoms could help to increase the referral rate for females with possible ASD. Increased referral rates and gender sensitive diagnosis is required to help diagnose females with ASD, so they can benefit by seeking out ASD-specific support if needed.

4.2. Case study 2B. Self-report assessment of individuals with ASD and difficulties in driving

4.2.1. Results

Psycho-motor profile of ASD participants

In the introduction part we noted that Autism Spectrum Disorders (ASDs) are among the most common disorders characterized by pervasive impairment in social reciprocity, communication, stereotyped behaviour, and restricted interest (Faras, Al Ateeqi, & Tidmarsh, 2010). The characteristics of ASD are manifested at early stage and they are often accompanied by abnormalities in cognitive functioning, learning, attention, and sensory processing (Alshaban, 2012). In this regard, parents of individuals with ASD were asked to reflect about their child’s speech, language, motor and cognitive development (Figure 10). They were also asked to indicate the age when their child was diagnosed with ASD. In a similar sense with Alshaban, (2012, the majority (11 out of 15) of ASD participants were diagnosed with ASD at their early stage of development, whereas the remaining were diagnosed in their later stage (i.e., 10 and above years old) of development. One of the manifestations of ASD individuals is a delay in cognitive development compared to 'normal' individuals. In this report, as indicated by their parents, out of 15 participants, 11 were showed cognitive development delay in their early stage, whereas the rest 4 experienced normal cognitive development (Figure 10).

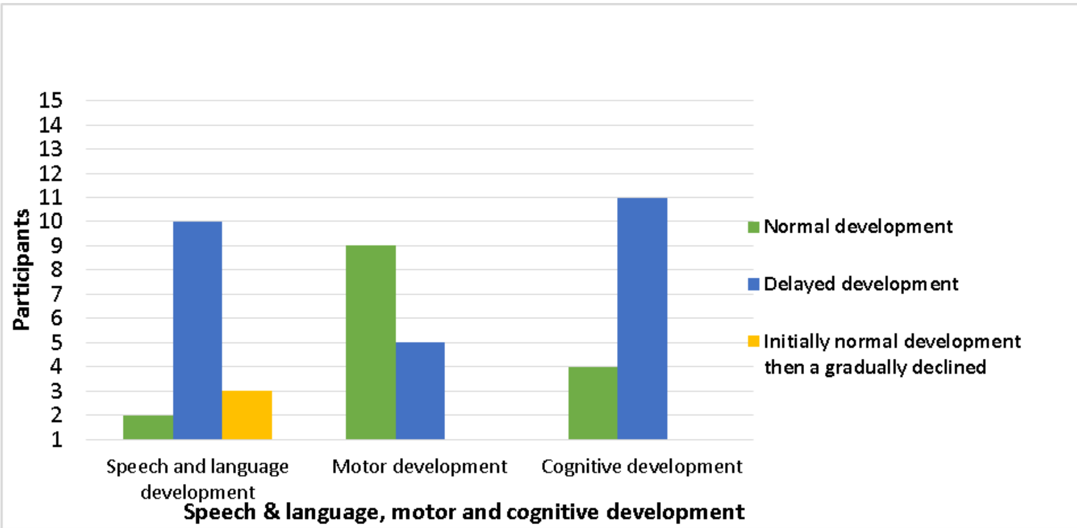


Figure 10: Speech, language, motor and cognitive development of ASD participants – Parents Perspective

Similar information was obtained from parents about the speech and language development of ASD participants, 10 of them were delayed in these skills during their early period of development, and three participants experienced normal speech and language development at the early stage; however these skills gradually declined when participants got older. The development of such skills was normal for two participants. In contrast to the cognitive and language development of ASD participants, the majority of participants (9 out of 15) experienced normal motor development, whereas the rest 5 participants experienced a delay in their motor development.

Impact of ASD on driving

In order to understand the impact of ASD on driving, ASD participants were asked to express their feeling about the extra efforts they have to make while driving compared to their peers. In this regard, non-licensed participants were asked to imagine themselves as licensed drivers while responding to this question. Seven participates reported that sometimes they feel they have to make extra efforts as compared to their peer. The possible reasons they think to make extra efforts may include avoiding unintentional hit of the gas pedal, reducing fear to drive, being focused while driving, safety, and keeping patience (Table 5).

Table 5: ASD individuals feeling regarding their driving in comparison to their peers

Do you feel you have to make extra efforts while driving compared to your peers?	**Number of participants choose the Likert scale**	**Why do you think you need to make extra efforts while driving (compared to your peers)?**
Never	4 participants	-
Sometimes	7 participants	1. Because sometimes I do not know that I hit the gas pedal so the car is going fast. 2. For safety and keep my patience 3. To be more focused on the road and other cars 4. I do not yet have a driver's license and my experience being driven around in Qatar has given me fears about being out on the road due to possible road accidents caused by others or by a mistake on my part. 5. Because I am afraid
Regularly	3 participants	1. I have slow processing skills so I need more practices compared to my peer 2. They are better drivers than me. So, I want to try to prove myself and keep practicing. 3. Because I need to take more time to train myself.

Three participants reported that they regularly feel that they have to make extra efforts compared to their peers while driving. They further reported that the possible reasons they think to make extra efforts may include having slow mental processing skills, less confidence in driving than peers, need time to make more practices. The remaining four participants indicated that they never feel that they have to make extra efforts compared to their peers while driving.

AS indicated in Table 6 below, ASD participants were asked to report their thinking and concern about the impact of the mental limitation on their way of driving. It is essential to mention that non-licensed participants were asked to imagine themselves as licensed drivers while responding to these questions. Seven participants reported they think the mental limitation associated with ASD does not affect the way they drive, whereas 3 participants indicated that the mental limitation very affects the way they drive. The remaining 4 participants indicated that they think the mental limitation associated with ASD affects (slightly to moderately) the way they drive.

Table 6: ASD related mental limitation impact of ASD participants way of driving

To what extent do you think ASD has impacts on the way you drive?	**Number of participants who choose the given Likert scales**
Not at all	7
Slightly	2
Moderately	2
Very	3
To what extent are you concerned about the impact of ASD on your way of driving?	**Number of participants who choose the given Likert scales**
No worried at all	5
Slightly worried	5
Moderately worried	1
Very worried	2
Extremely worried	1

Regarding ASD participants' concern about the impact of the mental limitation on their way of driving; 5 participants reported that they were not concerned, whereas 4 participants indicated that they worried moderately and above. The remaining 5 participants responded that they were slightly worried about the impact of mental limitation associated with ASD on their drive.

To obtain the parents' perspective regarding the impact of ASD on their child way of driving, we asked them questions related to the degree to which they think that their child is worried about the impacts of ASD on the way he/she drives; and the extent to which are parents worried about the impacts of ASD on the way their child drives. More than half of participant parents think that their child is worried about the impact of ASD on his/her way of driving (Table 7). Five parents indicated that they think that their child is slightly worried about the impact of ASD on his/her way of driving, whereas five parents reported as they think not worried at all. The remaining 3 and 2 parents think that their child is moderately and very worried about the impact of ASD on his/her way of driving respectively. When we came to the degree to which are parents worried about the impacts of ASD on the way their child drives, eight parents reported that they are no worried at all, whereas the remaining 5 and 2 parents indicated they slightly and moderately worried about the impacts of ASD on the way their child drives.

Table 7: Parents' perspective regarding the impact of ASD on their child way of driving

To what extent do you think that your child worried about the impacts of ASD on the way he/she drives?	**Number of participants who choose the given Likert scales**
Not worried at all	5
Slightly worried	5
Moderately worried	3
Very	2
To what extent are you worried about the impacts of ASD on the way your child drives?	**Number of participants who choose the given Likert scales**
No worried at all	8
Slightly worried	5
Moderately worried	2

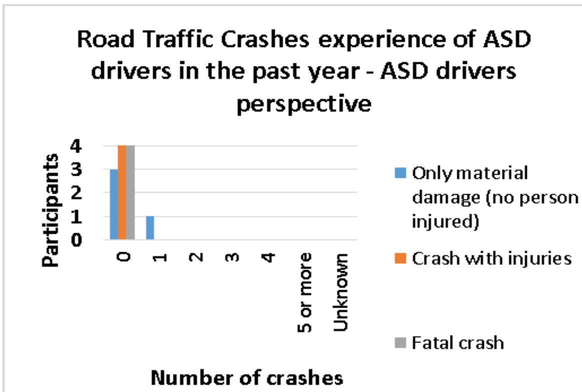
An open-ended question was presented to parents to obtain their practical views about how to train ASD people to drive. Parents viewed this question from different perspectives in relation to strategies to better train ASD drivers. They suggested that working on a unique driving instructional material would better help people with ASD. They further suggested that conditions need to be arranged for ASD individuals to teach them specific driving skills, such as deciding to enter and exile in a roundabout, helping them to manage stressful situations and multi-tasking driving, and getting long time to practice.

Driving behavior of drivers

Traffic crash experiences of ASD drivers

Adults drivers with ASD may experience worse performance, compared to a typically developing control group, concerning some measures, i.e., they reported more lapses (i.e., inability to focus and effectively allocate and sustain attention) while driving, and made more driving mistakes and reacted slowed in complex situations during simulated driving (Chee, Lee, Patomella, & Falkmer (2017). In this report, ASD individuals were asked to report the traffic crash experience ASD drivers faced in the past year. Four licensed ASD drivers gave their responses.

In this regard, as indicated in Figure 11 below, 3 ASD drivers reported that they experienced no traffic crash in the past year. However, 1 ASD driver reported that he engaged in a crash that resulted in material damage. ASD drivers were also asked to indicate whether it was their mistake for a traffic crash they experienced. One out of 4 licensed drivers indicated that he was responsible for a crash he did.



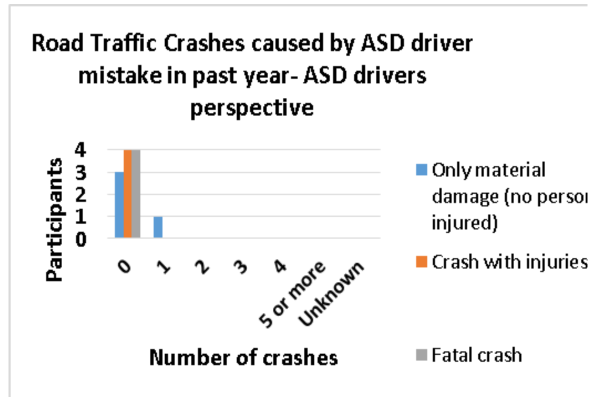


Figure 11: Traffic cash experience (Left) and number of crash caused by driver own mistake (Right)

The driving experiences of ASD drivers associated with near-crash, violation, driving interest, importance of driving and image about own driving have been presented in Table 8. Except for 1 driver, who experienced six near-crashes events in the past two weeks, the remaining 3 participants reported that they experienced no near-crash events in the past two weeks. All 4 drivers indicated that they did experience no traffic violation and fines in the past year. Participants were asked to indicate the extent to which they do like driving. In this regard, 3 participants reported that they slightly and moderately prefer to drive, whereas a driver indicated that he very likes driving a car. In terms of the importance of driving, 3 participants reported that driving a car is important (very and extremely levels) to them, while the remaining one driver indicated that driving a car is moderately important to him.

Table 8: The driving experience of ASD drivers associated with near-crash, violation, driving interest, the importance of driving and image about own driving

ASD drivers	"Near crashes" experience in the past 2 weeks?	Traffic fines experienc e in the Past year?	Traffic violation experience with during the past year	To what extent do they like Driving?	How is important driving a car to them?	How good do they think about their driving?
P6	6	0	0	Slightly	Extremely	Good
P8	0	0	0	Moderately	Very	Fair
P10	0	0	0	Slightly	Moderately	Good
P11	0	0	0	Very	Very	Very good

In the end, participants were asked to report their thinking about their driving. Except for one driver, who had fair thinking about his driving, the remaining 3 participants reported they had very to very good level of thinking about their driving.

Driving related emotional experience of ASD participants

In previous work, it was reported that drivers with ASD experience stress and anxiety during driving a car (Reimer et al., 2013). Executive dysfunction reduced self-monitoring, mental flexibility, and planning abilities (Hill, 2004; Van Eylen et al., 2011), which can lead to a stressful driving experience that is also dangerous in nature. In this report, we attempted to understand the stress, fear/panic, and anger experiences of ASD drivers while driving a car. We looked at this aspect from both ASD drivers and their parents' perspectives. As shown in Figure 12, parents of 3 ASD drivers responded that their children experience a moderate stress level during driving. However, one of the ASD driver's parents indicated that his/her child experiences no stress during driving. When we come to ASD drivers' response to stress experience during driving a car, 2 drivers reported that they experience a very high level of stress, whereas the remaining 2 experience no stress during driving a car.

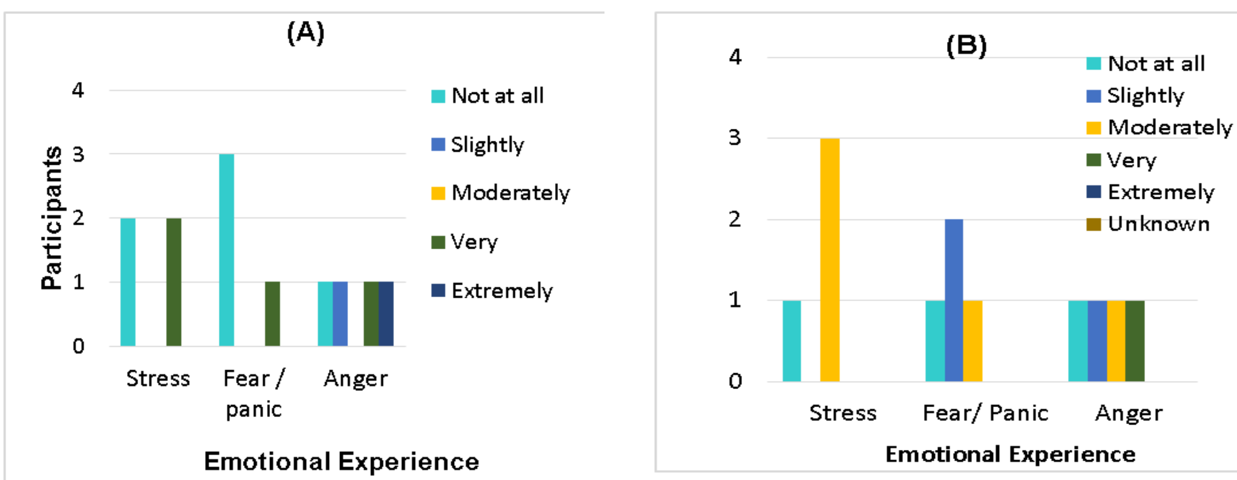


Figure 12: Emotional experience of ASD drivers while driving a car- ASD drivers perspective (A) and Parents perspectives (B).

In terms of fear/panic experience of ASD drivers during driving, unlike one ASD driver who reported that he fears at a high level during driving, the rest three indicated that they experience no fear while driving a car. In this regard, two parents reported that their children slightly fear when they drive. Moreover, one parent indicated that his/her child moderately experiences fear, whereas the remaining one parent indicated that his/her child experiences no fear when driving a car. Regarding anger emotion experience during driving, both ASD individuals and their parents reported that the anger level of each ASD driver distributed from the level of very to not at all (See Figure 12).

Travel history of Licensed ASD drivers

In Table 9, we documented the travel history of ASD drivers. To obtain such information, we asked them questions, including how often they drive a car? how many km do they drive per day? How many hours do they drive in weekdays and weekends? Which route do they mainly drive? And so forth (Table 9). In this regard, except for one participant, who daily drives, the remain 3 participants drive multiple times per week and once a month. All 4 participants drive a bit higher km on weekdays than weekends days. Regarding the route they drive, 3 out of 4 participants often drive the same route on both weekends and weekdays, whereas one ASD always drives the same route. The purpose of driving during weekdays is uniform for all 4 ASD participants. They reported that driving during weekday is to travel from home to school and return from school to home. This is different for the case of weekends i.e., 3 participants reported that they drive on the weekend for leisure purposes, whereas the remaining one participant indicated he drives on weekends for education purposes.

Table 9: Travel history of licensed ASD drivers

Licensed ASD participant	How often do they drive a car?	How many KM do they drive per day		How many hours do they drive per day in..?		Which route do they mainly drive?		What is the main purpose they do drive a car?	
		Week days	Weekend days	Week days	Weekend days	Weekdays	Weekend days	Weekdays	Weekend days
P6	Daily	40km	30km	1.5h	1h	Always the same route	Always the same route	Home to work	Leisure
P8	Once in a month	20km	15km	1h	1h	Often the same route	Often different routes	Home to school	Leisure
P10	Multiple times per week	50km	15km	1h	3h	Always the same route	Often the same route	Home to school	Leisure
P11		6.8km	5.4km	1h	1h			Home to work	Home to school

In the end, we asked participants which area do they mainly drive?. Three of them reported that they mainly drive in urban and highway areas, whereas the remaining one mainly drives on highways.

Difficulty of performing different driving behavior among ASD participants

A list of driving tasks were provided to licensed ASD drivers and their parents to rate the extent to which ASD drivers experience difficulties in performing those driving behaviors listed in Table 10.

Table 10: List of driving activities presented to licensed ASD individuals and their parents to

No	Specific driving behavior to be rated as Not at all, or Slightly, or Moderately, or Extremely, Unknown
1	Driving in the dark
2	Driving new traffic routes
3	Driving long distances (longer than two hours without stopping)
4	Sudden, unexpected traffic situations (e.g. traffic jam, diversion)
5	Staying focused and not being distracted by your own thoughts while driving
6	Staying focused and not being distracted by the environment
7	Visual overstimulation (e.g. caused by lights traffic signals, billboards)
8	Auditory over-stimulation (e.g. car horns, passing motorcycles, etc.)
9	Cognitive over-stimulation: having to process too much information at the same time
10	Emotional over-stimulation: having to deal with too many emotions while driving (e.g. simultaneously experiencing anxiety, stress and anger)

Two ASD participants reported that they face difficulty (in a range of slightly to very level) of perform driving behavior, including driving in the dark environment and new traffic routes, stay focused without distracted by own thought and the environment, long distances driving, and tolerate auditory over-stimulation (e.g. car horns). One driver rated that driving tasks, such as driving long distances, unexpected traffic situations, visual and cognitive over-stimulation, are moderately difficult driving behaviors to perform.

Different from responses presented above, one driver rated that it is extremely difficult to perform driving behavior, such as driving in new traffic routes, unexpected traffic situations (e.g. traffic jam, diversion), staying focused, visual overstimulation (e.g. caused by lights traffic signal), tolerate cognitive and emotional over-stimulation. In contrast to this, an ASD driver rated that driving tasks, such as driving in the dark, driving long distance, stay focused, visual, emotional and cognitive overstimulation are not difficult driving behavior to perform.

The report of ASD participants' parent indicated that 2 out of 4 parents reported that except driving long distance, stay focused, and not being distracted by own thoughts while driving, the remaining list of driving behavior (mentioned in Table 10) are difficult for their child in a range of not at all to an extreme level. To be specific, these parents reported that driving in the dark, visual, and cognitive over-stimulation are not difficult tasks for their children, whereas emotional over-stimulation is extremely difficult to perform. Other tasks, such as driving in new traffic routes and unexpected traffic situations, were also reported as moderately difficult tasks. They also reported that staying focused and not being distracted by the environment and auditory over-stimulation are slightly difficult for their ASD children. Each of the remaining 2 parents reported those tasks (listed in Table 10) are difficult for each of their child in a range of not at all to unknown level.

Learning to drive

Potential difficulties when learning how to drive may predispose people with ASD to fear the prospect of independent driving, discouraging the pursuit of licensure and potentially interfering with both the learning and application of safe driving skills (Ross et al., 2017).

Evidence suggests that people with ASD are more likely to experience anxiety in general (van Steensel, Bögels, & Perrin, 2011; Vasa & Mazurek, 2015). This increased level of anxiety can interfere with daily life functioning (MacNeil et al., 2009), potentially further contributing to apprehensive driving. A list of driving skills (Table 11) was provided to licensed ASD drivers and their parents to rate the extent to which ASD drivers experience difficulties in learning those driving skills listed in Table 11. Three out of four ASD participants reported that they face (not at all to very levels) difficulty learning driving skills, such as smooth steering, driving straight on, smooth and decisive driving without hesitation, and compensate for traffic mistakes committed by other drivers. Two ASD drivers reported most driving skills (listed in Appendix 2) are difficulty (with the level of not at all to extremely) to learn, however, this is not applied for driving skills, such as changing lanes, safe and adequate overtaking, adequate anticipation by changing to the correct lane before taking a turn or when entering a roundabout, initiate the appropriate driving action at the correct moment, quick and timely noticing of changes in the traffic situation, predicting the behaviour of other road users based on their driving actions, and using GPS / navigation tools. Those driving skills mentioned above were rated by only one ASD drive as difficulty (not at all to unknown levels) to learn.

In terms of ASD parents' responses about learning difficulties of driving skills, 3 parents indicated that driving skills, such as driving straight on, active use of mirrors, correctly estimating the size of your own vehicle can be difficult to learn for ASD individuals. The remaining lists of driving skills were rated by two or one parents as difficult tasks to learn for ASD individuals.

Table 11 Learning difficulty for several driving skills

List of driving skills to be rated as Not at all, or Slightly, or Moderately, or Extremely, Unknown	
Adequate lane positioning	To start and drive off
Smooth and decisive driving, without hesitation	Smooth steering
Correctly estimating the size of your own vehicle	Driving straight on
Operate the vehicle automatically, without conscious awareness or attention	Gradual and smooth acceleration
Simultaneously performing multiple actions, also known as “multitasking” (e.g. determine the speed of other vehicles at the same time you are merging onto the highway)	Gradual and smooth braking
Adjusting driving speed based on the traffic situation	Turning the car on the road
Drive at the permitted speed limit as much as possible	Parking
Adequate change of visual focus (e.g. changing between looking far ahead, closely, left and right)	Driving in reverse
Initiate the appropriate driving action at the correct moment	Driving out of an exit
Quick and timely noticing of changes in the traffic situation	Crossing the street
If required, compensate for mistakes, violations or dangerous actions committed by other drivers	Active use of mirrors
Making contact with other road users (e.g. eye contact or gestures)	Changing lanes
Learning to make contact with other road users for the sake of traffic safety and the application of traffic rules (e.g. gesturing to a pedestrian that he has priority to first cross)	Using GPS / navigation tools
Predicting the behaviour of other road users based on signals or gestures they give you (e.g. hand gestures by other road users)	Safe and adequate overtaking
Predicting the behaviour of other road users based on their driving actions, without them giving you specific signals or gestures	Applying traffic rules
Ignoring traffic rules for the sake of general safety (e.g. driving on the other half of the road to avoid a road obstacle)	Following driving instructions
Convert/transform a series of driving instructions into the appropriate actions (e.g. Instructions like: “When turning left, give a signal by putting your blinker, check if other cars are approaching and change to the left lane, before you reduce speed to make the turn”)	Adequate anticipation by changing to the correct lane before taking a turn or when entering a roundabout

As indicated in Figure 13, parents were asked to rate the extent to which they think it was difficult for their children to learn driving and pass practical and theoretical tests.

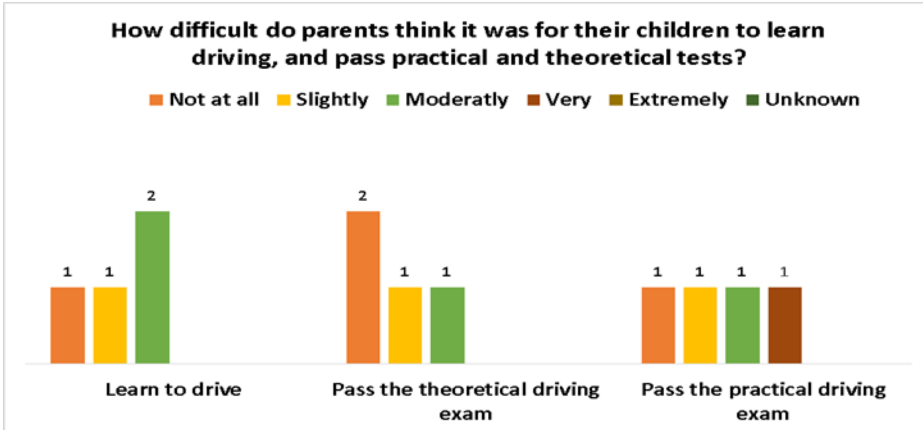


Figure 13: Difficulty to learn, pass theoretical and practical exams for ASD drivers – Parent's perspective

Two parents reported that learning to drive and pass the theoretical driving exam were moderately and not all difficult for their ASD child respectively. The remain each of two parents rated that learning to drive and pass the theoretical exam was difficult in a range of not at all to moderately.

4.2.2. Discussion

This report focuses on driving associated psychological characteristics of ASD individuals residing in Qatar. Inventories of ASD individuals and their parents were used to illustrate the preliminary analysis about the driving behavior of licensed ASD drivers, learning to drive for ASD individuals, and the impact of ASD on driving. Most ASD participants of the study were diagnosed for the delay of speech, language and cognitive development at the early stage of their development. In this report, we specifically addressed ASD drivers driving related emotional states (e.g., fear and stress), travel history (e.g., hours and km driver per week) of licensed ASD drivers, learning different types of driving behavior, and difficulty of performing various driving skills and so forth. The findings in section one may have implications for ASD individuals to manage driving-related negative emotions, perform different driving skills, learn challenging driving skills efficiently, and behave appropriately while driving. Therefore, driving-related emotions (e.g., fear and stress) management training can be recommended to ASD drivers to reduce the impact of the negative emotions on driving. Along with such emotional management training, others' skills such as controlling own thoughts and environmental distraction; and tolerate cognitive and auditory over-stimulation can be added. In terms of driving skills and behavior, findings in section one may have implications to train ASD individuals in advance about specific driving skills, such as multi-tasking driving, concentration while driving, predicting the behavior of other road users, and so on forth.

4.3. Case study 1C: The appraisal of roadway environment and infrastructure by drivers with autism: A qualitative study

4.3.1. Results

Sample selection

Figure 14 shows a flowchart of the selection process. Each potential participant received an e-mail in case they were excluded. The 11th interviewed participant did not add any new information that contributed to the research aims. A 12th participant was interviewed as a control but added no further information. Thereafter, we concluded that saturation was reached after 12 interviews. Only drivers with a driver's license were included because no one with a learner permit applied to participate in the current study. Adults between 31 and 39 years of age were included in the current study.

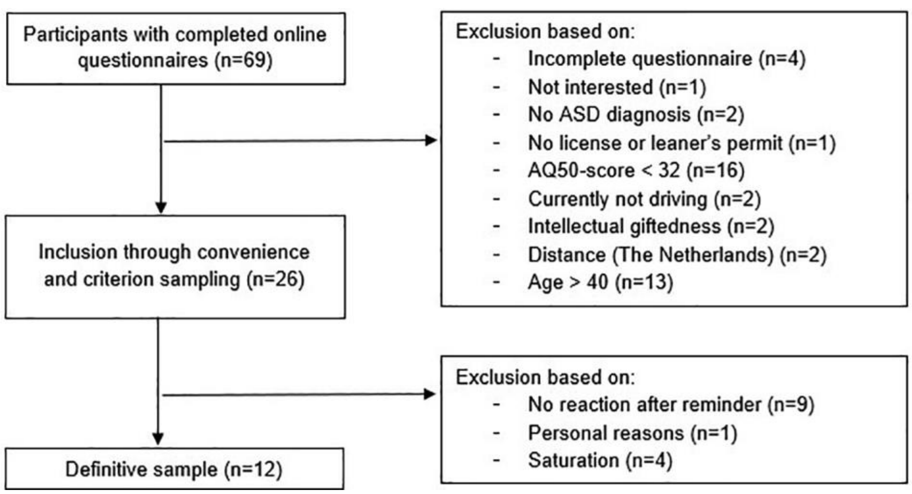


Figure 14: Flowchart selection process

During the data collection, the interview guide was modified based on the mentioned themes because of this study's exploratory character. The original guide included two scale questions where participants had to give a score between 0 and 10 regarding the influence of roadway environment and infrastructure on their driving behavior. After conducting approximately two-third of the interviews, it became clear that these questions had no added value. Participants reported that they experienced difficulties with answering these questions as they were not specific enough. Therefore, these were removed. Consequently, these questions' results were not usable and, therefore, not used in the analysis. Similarly, additional questions were added based on participants' feedback (e.g., coping with detours, driving in the dark, noise, etc.).

Exploratory results

Naïve understanding

A first member check was completed on the spot by summarizing what the participant had said several times during the interview. At the end of each interview, the interviewer made another global summary, which was then confirmed or corrected by the participant. We sent a second member check to the participant after conducting their interview. Nine participants confirmed their findings; three have not done yet. The first assumptions were formulated after carefully reading the member checks and interviews. Participants identified stress, anger, and frustration as the primary emotions that they experienced while driving. Factors that influenced these emotions were crossroads, roundabouts, road cracks, road curves, road narrowing, speed bumps, and other road obstacles. Other factors that complicated driving were noise, lights, and driving in the dark. Advertising signs and other eye-catching items distracted them the most. However, roadway environment (e.g., traffic signs) and infrastructure (e.g., road markings) did not always negatively influence the driving experiences of ASD drivers. It could also help ASD drivers under certain conditions: (1) signing consistency, (2) clarity, (3) uniformity, (4) properly indicated, and (5) the situation had to be logical and clear. The ASD drivers reported difficulties with understanding and predicting other road users. Multiple participants reported that everyone experiences both the positive and negative factors in a unique way. In general, the more distracting items presented while driving, the more attention was required, the more con- centration was needed, and the more the driver experienced the drive as exhausting. The main coping strategies of ASD drivers to deal with challenging roadway environment and infrastructure situations were driving more slowly and more carefully, using public transport, or riding along as a passenger instead of driving themselves.

Thematic structural analysis

After creating a naïve understanding, the interviews were analyzed according to the thematic structural analysis. Table 12 shows examples of the way of analyzing.

Table 12 offers a summary of the main themes and the sub-themes that were identified by analyzing the data. The main themes are placed in the left column. The right column contains sub-themes that were most frequently discussed.

When comparing the main themes and themes with the naïve understanding for validation purposes, the structural the- matic analysis confirmed the naïve understanding.

Table 12: Examples of thematic structural analysis.

Meaning unit	Condensation	Subtheme	Theme
‘‘.. .when the sun shines, and you have some streets where the sun shines through the trees or something like that.. .”	Flashes of light through trees are exhausting	Light distracts	Lighting is an important distracting element while driving
‘‘.. .you cannot see much already.. ., you can only see like a few meters in front of you.. . and that causes stress.. .”	Indistinctness in the dark causes stress	Driving in the dark is difficult	It is less distracting but more challenging to drive in the dark

Theme 1: Positive feelings while driving due to roadway environment and infrastructure elements

Each participant reported that some roadway environment and infrastructure elements could help them feel safe and calm while driving. The roadway infrastructure can create a safe feeling (e.g., speed bumps, separate bike paths). Both road- way environment (e.g., traffic signs, lighting in busy places, instructions above the highway, etc.) and infrastructure (e.g., clear roadway markings, roundabouts with one lane, etc.) can create calmness as they provided clarity for the drivers. Table 13 offers a complete overview of the roadway environment and infrastructure elements that evoked positive feelings while driving, as reported by the participants in the current study.

R.A.: ‘‘Or like the bike paths, it is safer when they are separated, but that is also more clear. However, this is my own opinion. I think that they should do this here as well.”

Theme 2: Negative feelings while driving due to roadway environment and infrastructure elements

All participants reported stress and insecurity due to the roadway environment (e.g., traffic jams, overtaking other drivers, etc.) and infrastructure (e.g., narrowing road, crossroads). Participants sometimes perceived the roadway infrastructure as confusing. Parking their car caused stress for most of them as they had to take many factors into account (e.g., rules, other drivers, not being able to find a parking space, etc.). Especially situations where participants had to depend on others made them feel insecure and anxious. For example, they experienced stress at a crossroads without traffic lights where they had to rely on other road users to notice the traffic signs and road markings so they would be able to stop in time.

Table 13: Main and subthemes derived from the analysis

Main theme	Sub-themes
1. Positive feelings while driving due to roadway environment and infrastructure elements (n = 12	- Feeling safe while driving due to the roadway infrastructure (RI) - Feeling calm due to the clarity of the RI while driving - Feeling calm while driving due to the roadway environment (RE)
2. Negative feelings while driving due to roadway environment and infrastructure elements (n = 12)	- Stress and insecurity while driving caused by the RE - Stress and insecurity while driving caused by the RI - Stress and frustration while driving due to the RE - Frustration while driving due to the RI - Confusion while driving due to RI ambiguities - Confusion while driving due to the RE - Fear and feeling unsafe while driving due to the RI - Fear, stress, and feeling unsafe while driving due to the RE
3.Negative feelings while driving due to other road users (n = 11)	- The unpredictability of other road users complicates driving - Feeling uncomfortable caused by other road users - Frustration caused by the behavior of other road users
4. Factors that complicate driving (n = 12)	- Street lighting is an important distracting element while driving - Noise distracts while driving - Difficulties with driving in the dark - Distracting elements in the RE
5. Inefficient application of traffic rules caused by complex traffic situations (n = 10)	- Traffic rules are important, but other road users do not com- ply with these rules - Creating dangerous situations due to complicated traffic situations - There must be logic in traffic - Lack of uniformity in traffic rules and reflection in traffic
6. Rush and chaos put pressure on the driving performance, information processing, and observation process (n = 12)	- Multiple elements distract while driving - Selecting the right elements in a chaotic environment is stressful - Driving behavior and driver are put under pressure by thoughts and chaos on the road - More attention needed in complex situations - Driving is exhausting due to crowded situations
7. Experience and automatization (n = 10)	- Experience is important - Driving is an automated behavior - Experience in driving differs between individuals
8. Adapting behavior to different traffic situations (n = 12)	- Adapting the driving style to the environment and situation - Eliminating stimuli - Creating predictability - Using distracting elements as a tool

9. Using alternatives to get around (n = 5)	- Using alternative means of transport - Trusting other people to drive - Taking a passenger along
10. Avoidance behavior in specific traffic situations (n = 8)	- (Temporarily) avoiding driving - Avoiding situations in certain circumstances

R.S.: ''Oh yes, that narrowing road makes me frustrated because it means that the road will be too narrow for two cars, so when the other car comes from the other direction, and I cannot see that because of corn plants that have grown very tall, then I already know that I will not be able to continue and I will have to get out of the way*, and there are puddles* next to the road*, and I don't know if that is a brook and that stresses me out.*"

Table 14 Overview of elements that evoke positive feelings while driving

Infrastructure	Environment
Road markings	Well-lit intersections
Traffic signs painted on the road	Not using abbreviations on traffic signs
Yield line/give-way line	Consistently indicating the direction
Road centerlines	Clear separation between what is on the road and what is adjacent to the road
Designated parking spaced	
Intersections with arrows painted on the ground	Traffic lights
	Limit to essential traffic signs
Scramble intersections	Mile markers with speed indication
Roundabouts with one lane	Unambiguity of traffic signs
Reflecting roadway markings	Well-maintained roads
Separated bike paths	Lighting in busy places
Quiet asphalt	Instructions above the highway
Separated public transport lanes	
Speedbumps	
Clear roadway markings	

Roadway environment elements that created stress and frustration were related to pedestrians' invisibility in the dark and detours. These elements were perceived as being confusing and lacking conspicuity. Roadway infrastructure created frustration as well. Nine participants perceived speed bumps as difficult because of their shock when entering and exiting; it broke their drive's rhythm. Using different materials, colors, heights, etc., in the roadway design was confusing to them.

J.S.: ''I find speedbumps very annoying; I am always worried that I will drive my car to pieces there. And you always have to slow down for them … and then you are out of your rhythm. and that scares and frustrates me."

Especially ambiguity in the road infrastructure created confusion in ASD drivers. Clear roadway markings could create calmness. However, these markings could be perceived as unclear and confusing (e.g., difficult to see when it rains, difficult to read, etc.). Ambiguity, when using their GPS because of the large number of stimuli they received while driving, led to additional confusion and stress.

D.L.H.: ''When driving on a large roundabout, I just do something, but when there are cars in front or behind me, and I do some- thing wrong, or I don't know where I have to go because it is not clear, then I get really frustrated and if I could, I would immediately pull over my car and get out!"

Furthermore, ASD drivers experienced roadway infrastructure as scary and unsafe. Road cracks made them anxious because of the cracks, their sound, and previous negative experiences. Road curves provoked unsafe and anxious feelings as they can induce a sense of losing control. Apart from the roadway infrastructure, the roadway environment also made them feel anxious and unsafe. Especially other pedestrians, bikers, and parked cars were mentioned as some ASD drivers were afraid of crashing into them. Lastly, unknown and crowded situations made some people with ASD feel anxious and unsafe as well.

S.A. : ''It is about new situations; for me, that is always a bit stressful, and then I need someone sitting next to me, and I don't get used to it quickly. I notice that I don't get used to it soon."

Theme 3: Negative feelings while driving due to other road users

Each participant, except for one, reported that other road users (i.e., roadway environment) made them feel uncomfortable and frustrated. The unpredictability of other road users can make driving a difficult task. Some ASD drivers experienced difficulties in predicting others' behavior and their intentions. Estimating their distance to other roadway users was perceived as challenging as well. Roadway infrastructure can contribute to these feelings of frustration and discomfort (e.g., roundabout, road narrowing, etc.). The higher the number of other road users present in the roadway environment, the more uncomfortable feelings the ASD drivers experienced as they felt like they had less control over the situation. ASD drivers also experienced frustration due to the behavior of other drivers. They perceived others as aggressive and individualistic. Other drivers did not obey the rules, and therefore, they can be considered dangerous.

S.B. : ''Yes, of course, the less traffic there is, the less you have to do, like taking everything into account, of course, the calmer *and comfortable I am.*"

Theme 4: Factors that complicate driving

All participants reported sound and lighting as complicating factors while driving. Sounds can hinder them while driving (e.g., trains, air conditioning, sound of the car, etc.). All participants emphasized their need for silence and quietness while driving. Lighting or illumination could be fatiguing when drivers constantly had to switch between lit and unlit parts. A stroboscope effect (e.g., sun shining through trees) and too much street lighting could be tiring as well. Not only was street lighting indicated as fatiguing, but also car lights, Christmas lights, the flash of a speed camera, and neon signs. ASD drivers experienced driving in the dark as difficult because many roadway environment and infrastructure elements were not clearly visible. On the other hand, they were less affected by other elements that can be considered distracting in daylight. Participants also reported difficulties with detecting signs above the road or that were not located in their visual field. They would often miss these signs, which hindered them (e.g., taking the wrong exit, driving too fast, etc.).

P.G.: ''No, it just bothers me, and then if there is a sound and I know that it comes from my car, then this has to stop, then I want to find where it comes from, but you don't always have the possibility to look for that, or it is rattling in the trunk. Then I try not to pay attention to it anymore, but I listen to it anyway, and that distracts me, and I don't want that."

D.L.H.: ''I always find it more difficult to drive in the dark because I can't see the road markings, or I don't see them. When it is

dark, and it rains, I just drive somewhere, but yeah, I find it so unclear and so chaotic that I don't know what is expect of my driving anymore. Furthermore*, when it is dark, you don't see the signs that* well *anymore, and when there are also neon lights, no, then I am 10 times more distracted.*"

Theme 5: Inefficient application of traffic rules caused by complex traffic situations

Ten out of twelve participants reported that they got frustrated when road users did not obey the traffic rules. They reported that the discrepancy between traffic rules and other road users' adherence to them is too high. The traffic code is reported as an important guide as it provided clarity and structure. Moreover, ASD drivers experienced difficulties in analyzing new or complex traffic situations. They only focused on specific elements. This could result in unsafe driving behaviors (e.g., driving more slowly, sudden stops, etc.). The ASD drivers valued traffic rules but found it frustrating that these were not always very logical, and therefore, situations were not always clear to them. Another frustration they experienced was the lack of uniformity in traffic rules, material usage (e.g., concrete speed bumps, plastic speed bumps, rubber speed bumps, etc.), and organization of roadway elements (e.g., speed bumps, parking, road narrows, etc.). Therefore, ASD drivers were not able to drive efficiently.

V.A.: ''Yes, but for me, it's reassuring (the traffic code), but for other drivers, it is more flexible; they apply it more flexibly, and that makes it difficult for me."

Theme 6: Rush and chaos put pressure on driving performance, information processing, and observation process

Various elements draw the attention of all participants while driving. Especially advertising boards were distracting to our sample of ASD drivers. However, whether an element was distracting or not depended on the person and his or her interests. Although traffic signs could clarify the situations, a proper distribution was reported as important as too little or too many traffic signs caused confusion and chaos. ASD drivers also reported that there were too many different traffic signs, they stood too close together, and occasionally, there was too much information on one sign. ASD drivers experienced filtering the right aspects from the environment (e.g., various and many traffic signs, too many other traffic participants to determine which ones are extra important to pay attention to (other cars, cyclists, pedestrians), etc.) as stressful and many relevant elements disappeared in the chaotic environment. Rush hour, crowded environments, and distraction by their own thoughts put pressure on the driving performance of the ASD drivers and created a more negative feeling after driving. Depending on the situation, people with ASD needed to invest more attention and concentration to cope with all stimuli (e.g., unknown, crowded situations, etc.). In conclusion, driving was perceived as an exhausting activity as it always required a lot of concentration to cope with all stimuli.

V.K.: ''Because it is quite fatiguing, so I, it is okay, and I don't really mind to drive a car but is demands*, it* drains *quite a lot of energy.*"

Theme 7: Experience and automatization are important while driving

The majority of participants reported that they had difficulties with learning how to drive. These difficulties did not necessarily persist in the current driving experience. Yet, all participants agreed that they had a lot of driving experience; and a few participants even stated that they felt comfortable while driving in traffic. Their accumulated driving experience helped ASD drivers while encountering new situations and enabled personal growth as a driver. All participants agreed that certain subtasks of driving and driving itself became automated due to their driving experience. This allowed them to shift their attention to other stimuli in the roadway environment. On the other hand, participants suggested that automatization of the driving task combined with a roadway environment of low complexity could cause a lack of attention or mind- wandering, which may lead to dangerous situations

V.N.: ''That is correct, my dad used to do that, he raced on the fields, and he told me he wanted that for me too: 'You have to learn fast, it will be easier for your exam, then you can focus on other things instead of thinking about switching gears."

D.L.H: ''Yes, and because I think that I know my car by now and I have been driving my car for a long time by now, and I don't know how it is and yes, I do, I drive a little less careful because I don't have to think about everything, think about these actions you know."

Theme 8: Adapting behavior to different traffic situations

Each participant reported adapting their driving style to the environment and situation (e.g., driving more slowly in bad weather conditions, during rush hour, etc.). They used eye-catching environmental or infrastructural elements to remember their route. When they found themselves in busy situations, when they needed more concentration or were distracted, they simplified the task by reducing incoming stimuli (e.g., turning off the radio or GPS). To create predictability, they planned their routes or tried to predict known situations. The use of a GPS can allow for predictability for ASD drivers. Roadway infrastructure can aid when providing clear directions (e.g., road arrow markings, direction signs, etc.). On the other hand, ASD drivers also reported using commonly distracting elements as a tool (e.g., radio, GPS, etc.) to distract them from their thoughts. Other, less mentioned, coping strategies were: screaming out of frustration, early departure (to avoid time pressure and to provide additional margin to anticipate unforeseen circumstances), wearing orange glasses in the dark, and using the sunshade to avoid the street lights.

R.A.: ''I find the radio annoying; I try to turn it off as much as possible. But yeah, when you have other people in your car, almost everyone wants the radio on, so yeah. I then try not to turn up the radio too loud because it distracts me."

P.G: ''The radio is on, yes. Because otherwise, it is too quiet, and I start thinking in my head." Theme 9: Using alternatives to get around

Five out of twelve participants reported that they frequently used alternative means of transport. Three participants used public transportation (e.g., train, tram, etc.). In contrast, two other participants experienced public transport as uncomfortable and stressful. Therefore, they chose to ride along as a passenger or take a passenger with them while driving as an extra reassurance.

D.L.H.: ''Because yes, then yes, that's an extra pair of eyes*, those people also aren't allowed to sleep when they are sitting next to me in the car, but it helps when there is someone accompanying me. Because yes, otherwise, I wouldn't do that (driving to the sea).*"

Theme 10: Avoidance behavior in traffic situations

Participants reported that they avoided driving when they felt physically or mentally tired. When they experienced stress levels or anxiety that were excessively high while driving, they pulled their car over so they could pick themselves up or to become calm and relaxed again. Some ASD drivers avoided specific situations regarding both roadway environments (e.g., rush hour, traffic jams, city centers, etc.) and infrastructure (e.g., speed bumps, driving in the dark, etc.).

D.L.H.: ''I don't like driving in the city. That is way too busy and too much. Yeah, yeah, I always miss important things, and I always do things wrong when I drive in the city. Yeah, I don't do that anymore now, driving to, I go to Antwerp, my parents

live there, but I never use my car to get there."

Comprehensive understanding

Main themes one to seven underpinned the primary study aim: 'explore how drivers with ASD experience roadway environment and infrastructure.' Main themes eight to ten underpinned the secondary study aim: 'identify the coping strategies used to deal with interfering roadway environment and infrastructure elements.'

After summarizing and reflecting on the main themes and sub-themes in relation to the research question and the con- text of the study, we arrived at a comprehensive understanding which enabled us to interpret the results as a whole. As a result, specific main themes were grouped into broader categories.

- Themes 1 to 3 were named 'Positive and negative feelings while driving.'
- Themes 4 to 6 were named 'Situations that negatively affect driving experiences.'
- Theme 7 was named 'Experience and automatization.'
- Lastly, themes 8 to 10 were named 'Coping strategies.'

Figure 15 offers a schematic representation of how all the main themes connect. The figure clearly shows that roadway environment and infrastructure could provide both environmental facilitators and barriers while driving and also shows how ASD drivers coped with these barriers. The inner circle represents theme 1, the positive feelings that participants experienced while driving. Both roadway environment and infrastructure could contribute to a safe feeling, calmness, and clarity. These elements were the facilitators that reduced the stress levels of the autistic drivers. This theme is placed in the middle because the goal is for ASD drivers to have a pleasant driving experience.

Theme 2 to 6 contain elements that directly threaten these positive feelings, and they are listed in the second circle. The second circle elements created environmental barriers while driving and might have negatively influenced the stress levels that ASD drivers experienced during their trip. A first factor were the negative feelings while driving that were provoked by roadway environment and infrastructure. The environment and infrastructure were often perceived as confusing and illogical. This caused stress, uncertainty, frustration, confusion, and an unsafe feeling in ASD drivers. Other road users could also evoke negative feelings as their behavior was perceived as being unpredictable. As a result, participants felt as if they had less control over the situation.

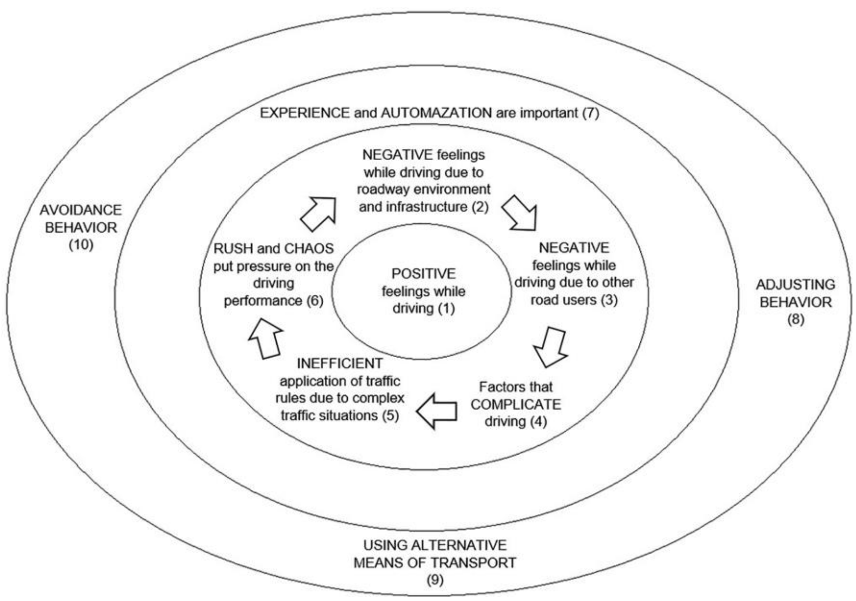


Figure 15: Schematic representation of the main themes

In the current study, people with ASD highly valued traffic rules. Yet, other drivers did not always obey these rules, and as a result, ASD drivers could not see the logic in the situation and were not able to drive efficiently. Participants also noticed other disturbing factors that complicated the driving task, such as noise, lighting, and driving in the dark. All negative factors combined could create rush and chaos while driving, which complicated driving even more and put extra pressure on the driving performance. This pressure, and the stress and frustration it evoked, could also negatively influence the analysis of complex traffic situations. As a result, a vicious cycle could be created in which all factors influenced each other continuously.

The third circle includes automatization and experience; both concepts were reported to positively influence the driving experience and behavior of ASD drivers. Therefore, it could reduce their stress and other negative feelings caused by the second circle's elements. The outer circle contains personal facilitators or the coping strategies that ASD drivers used to handle all the factors listed in the second and third circles. These strategies could reduce the participants' stress levels and evoked positive feelings while driving."

4.3.2. Discussion

To the best of our knowledge, this study is the first of its kind, aiming specifically to explore the appraisal of roadway environment and infrastructure by autistic drivers and the coping strategies they use to deal with distracting roadway elements. With or without autism, every individual experiences roadway environment and infrastructure from their viewpoint, resulting in different judgments and statements. Nevertheless, all participants did report similarities as well. Individual characteristics can partly explain these differences and similarities. On the other hand, autism is a 'spectrum' disorder, which means that they show a wide variation in the severity and type of symptoms, which could add to the explanation.

The results of the current study were obtained from semi-structured interviews. When the participants were asked for their feedback after the interview, they indicated that the semi-structured interview guide and the photos were useful prompts as it inspired them. They reported that they often experience difficulties when they have to generate ideas themselves to discuss their experiences. Difficulties with answering interview questions might arise from the theory of mind problems as it is difficult for people with autism to picture abstract things and explain this to another person (Frith & Happé, 1994). Additionally, there is a clear relationship between ASD and alexithymia. Alexithymia indicates the lack of terms to express emotions and moods (Poquérusse et al., 2018). We believe that the use of photographs made the questions less abstract and, therefore, more comfortable to deal with and to answer(Rao & Gagie, 2006). Despite previously reported issues with open-ended questions in people with ASD (Watkins et al., 2017), the participants expressed that the usage of open-ended questions was one of their main motivations to participate in this study. In the current study, they felt as if they could explain and nuance their answer in more details and could still describe concrete situations. Yet, participants reported difficulties with answering the two included scale-questions because they were not specific enough in their opinion. Therefore, these questions were removed from the interview after conducting approximately two-thirds of the interviews, and this data was not used in the analysis. Even though participants indicated that they were motivated by the open-ended questions, they indicated that the scale questions were too difficult to answer as they were too broad. As a result, participants might have no longer been able to answer them comfortably (Frith, 1994; Watkins et al., 2017). Nevertheless, further studies could make use of video-stimulated recall methodology instead of using photos to guide a semi-structured interview. This is a research technique where the participants are recorded during a specific situation while driving, which can be specifically useful for follow-up studies. Afterwards, the recordings are used as stimuli during an interview to help them recall their thoughts, emotions, ideas, etc., about the encountered situations (Consuegra et al., 2016).

The interview guide was specifically designed for the current study based on various books and identified concepts, but these findings were not thoroughly tested before starting the data collection. However, fewer questions regarding the used coping strategies were included compared to the questions on the appraisal of roadway environment and infrastructure, which might have influenced the results. Nevertheless, saturation was reached, and results were found of the appraisal of roadway environment and infrastructure in ASD drivers.

A more thorough discussion of each category derived from the comprehensive understanding is provided below.

Theme 1 – 3: Positive and negative feelings while driving

Participants reported both positive and negative feelings while driving due to the roadway environment and infrastructure. It stood out that there is only a fine line between the roadway environment and infrastructure elements perceived as positive and the elements perceived as negative. Positive feelings could easily switch to negative ones due to small infrastructural or environmental inconsistencies, others' actions, etc. When roadway environment and infrastructure were clear and guiding, it evoked positive feelings. An important factor herein relates to the concept of self-explaining roads in which the environment and infrastructure provoke the right driving behaviors (Castro, 2008) and thus create predictability and clearness for ASD drivers. However, negative feelings appeared to be present to a greater extent. Studies have shown that the objective road situation does not always correspond with the perceived state of that environment on the part of the individual within it, and this could lead to inappropriate driving behavior (Walker et al., 2013) which could make ASD drivers stressed, frustrated, anxious and confused. Various other studies reported issues concerning the emotional experience of people with ASD while driving. For example, studies reported that ASD drivers felt less self-confident while driving (Lindsay, 2017), felt anxious about driving (Chee et al., 2015), and reported less positive and more negative attitudes towards driving (Ross et al., 2018). In the current study, various negative feelings were related to other roadway users. It is suggested that ASD drivers experience difficulties in understanding others' intentions, unexpected changes while driving (Cox et al., 2012), and interacting with other road users (Almberg et al., 2017). People with ASD experience context blindness and contextual sensitivity issues. They use the context less when giving meaning to a situation than non-autistic people (Vermeulen, 2015). However, contextual sensitivity is vital in under- standing human behavior and actions (Zibetti & Tijus, 2005) and for flexibility in problem-solving and reacting to unpredictable events (Kokinov & Grinberg, 2001). This could explain why participants reported difficulties predicting others' behavior and trusting other drivers. Respondents also described problems when unpredicted events occurred, such as detours. The current results coincide with findings from Ross et al. (2018). In that study, ASD respondents also reported difficulties with unpredictable situations, difficulties in violating traffic rules, etc.

Theme 4–6: Situations that negatively affect driving experiences

Respondents all reported both social (e.g., inefficient application of traffic rules, rush, chaos created by other roadway users, etc.) and non-social (e.g., sound, lighting, driving in the dark, road signs, etc.) situations that complicated driving. People with ASD experience sensory stimuli either more intense or less intense than neurotypical persons (Ben-Sasson et al., 2009). We suggest that these sensory difficulties might have affected how the participants in the current study perceive and cope with certain stimuli like lighting, noise, chaos, and rush. Feeley et al. (2015) suggested that ASD drivers are more easily distracted by distracting elements adjacent to the road (e.g., billboards, etc.) than other drivers, which was confirmed by our participants. Driving requires high-order executive functions to respond to unexpected and unpredictable situations (Wilson et al., 2018; Classen et al., 2013). People with ASD show various executive function problems such as working memory difficulties, a slower speed of information processing, selected and divided attention, a decreased hazard perception, etc. (Patrick et al., 2018), which might have influenced how our participants perceived situations. Even though our participants mentioned that they were easily distracted by distracting elements while driving during the interviews, they also indicated that they experienced difficulties noticing traffic signs that were not located within their central visual field. When comparing visual search patterns from ASD drivers with non-autistic peers, research showed that ASD drivers fixated and spent more time in the central visual field and had the tendency to focus less on relevant stimuli (e.g., direction signs, their speedometer) (Chee et al., 2019). This might arise from the weak central coherence they experience. People with ASD tend to focus more on details and not on the greater part because they process information more slowly and less efficiently, which complicates driving (Vanmarcke, 2017). Participants also reported that they became frustrated when other road users did not obey the traffic rules. In support, a study by Ross et al. (2018) showed that ASD drivers had a good knowledge of the traffic rules. However, ASD drivers experienced difficulties when violating traffic rules, even if necessary. It did not only frustrate ASD drivers, but it also provoked anxiety. Furthermore, an on-road study by Chee et al. (2017) showed that despite a general underperformance of ASD drivers, they outperformed neurotypical peers in aspects related to rule-following. More- over, a study by Daly et al. (2014) also showed that ASD drivers were more rule-bound.

Theme 7: Experience and automatization

The study participants deemed automatization while driving to be very important. If a behavior is not automated, an increased demand of conscious attention during driving and maneuvering is required, which could exhaust the mental resources to cope with the critical demand of information processing in driving (Hatakka et al., 2002). Possibly, drivers with ASD need more time for this automatization process. Studies suggested that learning to drive is more difficult for people with ASD compared to NT peers (Cox et al., 2012; Cox et al., 2016; Ross et al., 2019). It is emphasized that novice ASD drivers need more lessons (Almberg et al., 2017; Ross et al., 2018), adapted training modules (Chee et al., 2015; Wilson et al., 2018; Ross et al., 2015), and shorter lessons (Ross et al., 2018) to reach the same driving level as their peers. Various authors suggest that specific training can enhance the driving performance of ASD drivers (Wade et al., 2016; Cox et al., 2017; Brooks et al., 2016) and that, after the learning phase, ASD drivers are as capable drivers as neurotypical drivers (Ross et al., 2019). This might suggest that experience and automatization are important factors in the driving behavior of people with ASD, as it is indicated that training can enhance their overall performance.

Theme 8 – 10: Coping strategies

All participants reported the use of coping strategies when dealing with interfering roadway environment and infrastructure elements. Although the DSM-V (American Psychiatric Association, 2013) suggested that people with ASD show restricted and repetitive behavior patterns, participants indicated that they could adapt their behavior to a particular situation. Our findings confirmed this; all twelve ASD drivers reported that they adjusted their behavior to create predictability and eliminate irrelevant stimuli.

The second identified and least used coping strategy is the use of alternative means of transport. Few other studies reported using alternative means to cope (Feeley et al., 2015; Curry et al., 2017). However, participants in these studies experienced certain difficulties in driving as a passenger or using public transport. They reported that they missed activities due to the unavailability of persons or public transport, had trouble getting to the station without help, or had difficulties with planning a public transport trip.

The last identified coping strategy was avoidance behavior. This is supported by Daly et al.'s (2014) research; their participants indicated that they avoided the rush hour, bad weather, driving in the dark, and gave themselves self-imposed restrictions on driving. The same coping strategy is found in multiple studies on older drivers. They self-regulate their driving behavior by avoiding certain situations like parking their car, driving at night or in the rain, etc. (Conlon et al., 2017).

4.4. Study case 2A: Experiences with licensing by autistic drivers

4.4.1. Results

Responses to the question related to preparing for the theoretical test were somewhat mixed. A similar number of people prepared via the driving school or practiced with their parents. Most of those who used another method prepared themselves through self-study. In terms of practice for the practical test, it could be observed that abouthalf of the respondents learned to drive with the help of a driving school (Table 15).

Concerning the level of difficulty for the preparation for the exams, there is a noticeable difference between the theoretical and practical tests. 22.5% indicated that they found preparing for the theoretical test (very) difficult, in contrast to 43.5% who found the preparation for the practical test (very) difficult (Table 16). The same percentages could also be found in the experience during the exams, where only 27.5% found the theoretical test (very) difficult compared to 51.3% who experienced the practical exam as (very) difficult. Furthermore, it showed that the vast majority (82.5%) passed the theoretical test on the first try. Approximately half of the participants passed the practical test on the first try.

Table 15: Help with preparations

	Parents (%)	Trustee (%)	Driving school (%)	Combination (%)	Other (%)
Who helped you prepare for your theoretical test?	30.8	10.3	33.3	0	25.6
Who helped you prepare for your practical test?	28.2	10.3	48.6	10.3	2.6

Participants reported the lack of predictability as the biggest problem during the exams (Table 16). About half of the respondents experienced issues with time pressure during the theoretical test. Half of the respondents also indicated difficulties with communicating with the examiner. Some respondents also reported other problems. However, most respondents did not indicate which these problems were.

Table 16: Experiences with tests and preparations

	Very difficult (%)	Difficult (%)	Neutral (%)	Easy (%)	Very easy (%)
How did you experience the preparations for the theoretical test?	7.5	15	30	30	17.5
How did you experience the preparations for the practical test?	17.9	25.6	30.8	23.1	2.6
How did you experience the theoretical test?	5	22.5	30	25	17.5
How did you experience the practical test?	13.5	37.8	32.4	13.5	2.7

Table 17: Problem experiences during tests

	Yes (%)	No (%)
Did you experience any time pressure problems during the theoretical test?	46.2	53.8
Did you have any problems with the way questions were asked during the theoretical test?	38.5	61.5
Did you have any other problems during the theoretical exam?	7.1	92.9
Did you experience any problems with the lack of predictability during the practical exam?	62.2	37.8
Did you experience any problems with the communication with the exam instructor during the practical exam?	48.6	51.4
Did you experience any problems other problems during the practical exam?	32.1	67.9

Correlations

After performing the descriptive statistics, the Pearson correlation coefficient was computed to calculate the correlations between the different questions. A total of seven significant correlations were found ($p < .05$) between the different questions. All significant correlations had a moderate to a high degree of correlation ranging from -.524to .612. Table 18 shows the significant correlations between the different questions.

For both the theoretical and practical tests, it appeared that those who found the preparation for the tests more difficult also found the tests themselves more complex. In addition, it emerged that those who perceived the preparation for the exams as more difficult also had to take the tests themselves more often. Similarly, it appeared that the participants who found the tests easy actually had to take them fewer times to pass. Participants who experienced time pressure during the theoretical test also perceived the test itself as more difficult. Finally, the analyses also showed that those who experienced time pressure also had more issues with the way questions were formulated during the theoretical test.

Table 18: Significant correlations between questions

Questions	r	Sig. (2-tailed)
Experience of preparation for theoretical test with number of times theoretical test was taken	-.513	<.001
Experience of preparation for theoretical test with experience during theoretical test	.612	<.001
Experience of preparation for practical test with number of times practical test was taken	-.415	.011
Experience of preparation for practical test with experience during practical test	.608	<.001
Number of times theoretical test was taken with experience during theoretical test	-.524	<.001
Number of times practical test was taken with experience during practical test	-.455	.005
Experience during theoretical test with time pressure problems during theoretical test	.423	.006
Time pressure problems with the way questions were asked during theoretical test	.325	.043

4.4.2. Discussion

Participants in this study reported multiple difficulties with the (preparation of) the exams. Certain of these experienced difficulties can be linked to core traits of autism. For example, 62.2% of participants reported difficulties with the unpredictability of the exam. In fact, research shows that autistic individuals predict the environment differently than non-autistic individuals making everything highly unpredictable for them (Cannon et al., 2021). The same was found by (Ross et al., 2018), who found that reacting and dealing with unpredictable situations is one of the most commonly reported problems in autistic learner drivers. Furthermore, about half of the participants said they experienced communication problems with the examiner. Autism is often characterized by communicating in a different way (Tyler 2013) which can make communicating with others (i.e., the examiner) more difficult (Almberg et al., 2015). Autistic individuals often experience overall stress and anxiety (Vasa et al., 2013). Consequently, many experience the fear of exams, and they also find it harder to cope with this than non-autistic peers, leading to chronic stress (Hirvikoski & Blomqvist, 2015). The fact that many experienced the preparation for and the practical exam itself as (very) difficult can also partly be explained by the stress they experienced. Nevertheless, driving tests are stressful events for everyone with or without autism (Brand et al., 2021). Finally, because of executive function problems, time management can be challenging for autistic persons (Gurbuz et al., 2019), which may explain why nearly half of all respondents reported time pressure issues while taking the theoretical test.

When comparing the results on how autistic individuals learn to drive and how they experience between the current study to a recent questionnaire study in the general population, it appears that the percentage of individuals who have only learned to drive with free supervision (e.g., parents) is significantly lower among autistic individuals.The recent study showed that 47.9% of candidate drivers preferred to learn to drive with free guidance, while in the current target group, only 28.2% chose this. A possible explanation is that autistic individuals experienced difficulties learning to drive Chee et al., 2019b; Curry et al., 2021) and therefore were more likely to seek professional help. However, other studies show that when they received customized lessons, they also get to the same level of non-autistic peers more easily and quickly (Wilson et al., 2018). Although many chose to take driving lessons, both the preparation for and the practical exam itself were rated as difficult to very difficult by many participants. This is in line with a study by Silvi & Scott-Parker, where autistic individuals frequently associated the word "difficult" with driving. Moreover, a study in which parents of autistic and non-autistic learner drivers were required to indicate their children's attitudes toward driving found that parents of autistic children reported more negative and less positive attitudes toward driving than those of non-autistic peers (Ross, Cox, Reeve, et al., 2018). Finally, Almberg et al. showed that autistic individuals require more driving lessons and find it difficult to translate theory into practice and adapt it to unfamiliar situations.

Despite the reported difficulties, it appears that autistic individuals do not perform worse during their driving tests. Recent data from the government shows that about 53% of all candidate drivers pass the practical driving test from the first time (Parlement, 2020) . This is in line with the current study's findings, where 51.4% of the participants passed on the first try. A previous study also showed that 89.7% of autistic drivers who began obtaining a driver’s license also succeeded in getting it, meaning that whoever started had a good chance of obtaining a driver's license (Almberg et al., 2017). This relates to previous studies by Ross et al. (2019) and Cox et al. (2020). They showed that, despite autistic drivers experiencing more secondary problems, they can still be considered capable drivers after training.

4.5. **Study case 2C: Autism-friendly public bus transport: hearing the voices of individuals with ASD to better understand their needs**

4.5.1. Results

General overview

Three main themes emerged that were considered as important to create a more comfortable experience when individuals with ASD take the bus (see Table 19): creating predictability (i.e., provision of an overview, act consistently, and correct and clear display of information), limiting stimuli, and communication specifically tailored to individuals with ASD. While some experiences frequently recurred across participants, other experiences were less unanimously shared. Interestingly, several participants, both individuals with ASD and employees of 'De Lijn', indicated that more autism friendly bus transportation would improve accessibility for all travelers, not only for individuals with ASD.

Table 19: Themes and subthemes derived from analysis

Themes	Sub-themes
1. Creating Predictability	Providing overview Consistency Information accuracy
2. Limiting stimuli	
3. Communication tailored to individuals with ASD	

Theme 1: Predictability

Three sub-themes were identified that could contribute to the creation of predictability: overview (1), consistency (2), and accuracy of information before, during, and after the journey (3). An employee of

'De Lijn' confirmed these findings.

"Yes, more predictability that they are kept informed of: look, it's like this or like that, if the bus doesn't come, they are going to panic anyway but that they know anyway..." (Bus driver 'De Lijn')

"What I do find is that it is less predictable when they (the buses) arrive. Sometimes there is a traffic jam, or yes, sometimes there is no traffic jam at all, and not many people get on, so then it goes faster… then it would be convenient if I could check where we are at any time." (female, 30 years)

Overview

The subtheme ‘overview’ relates to four different areas: (1) the bus stop, (2) the passenger seats, (3) the ticketing system, and (4) the information panels at the bus stop.

Bus stop

Participants mainly indicated that bus stop name signs allow keeping track of the bus ride and maintaining an overview, also helping them to decide when to get off the bus. However, many participants indicated that due to the letter font and size, they experience difficulties in reading those signs while being on the bus. Increasing text size on the bus stop signs so that they are readable while riding the bus would be an improvement. Some participants also suggested illuminating the nameplates so that they be clear at any time of the day. A bus driver additionally confirmed this.

"Yeah, it's just like that, they have to start counting the stops, and then if you haven't looked once, you might have missed a stop, the letters are mega small on the stop, you can't read it clearly either... yeah." (bus driver at 'De Lijn')"

Many bus stop shelters in Flanders are equipped with large advertising boards that take up the entire side panel of the bus stop. This severely limits the road view, which in turn can cause problems, given that a person who wants to take the bus in Flanders has to alert the bus driver by raising a hand, meaning the bus should pull over and stop to pick up the passenger. Several participants indicated that the limited visibility often causes tension and is experienced as stressful. Many bus stops shelters are also located further away from the road, making participants feel like they do not stand out enough to the bus driver.

"I usually don't find the shelters very convenient because I'm really afraid they're going to pass me. Some shelters are really out of sight, and then I sometimes find it difficult to actually sit there and be reassured of..." (female, 19 years)

Bus seats

Participants indicated that they carefully choose where they want to sit on the bus. Most participants prefer to sit as close to the door as possible. Some participants also indicated that they prefer to sit at the front to keep an overview of the road, immediately rely on the bus driver when necessary, and be close to the front doors. Some participants said they never sit right behind the driver because they face a grey area (i.e., a dark gray plastic plate to shield the driver) and do not have sufficient overview.

"Yes, to actually get as quickly as possible from where I need to be so that I can get out quickly, and that I don't have to pass too many people and squeeze in between them." (male, age 18).

Depending on how crowded the bus is, participants prefer to sit by the window because it gives them a clear overview of the road. Elevated seats, if available (for example, seats above the wheels or the bus's engine), also help in keeping an overview. By doing so, they better know where they are and when they have to get off. However, sometimes this overview is obstructed by advertisement stickers on the bus windows. These advertisements are considered very annoying by some participants. Unfortunately, often mostly, all the windows are stickered, leaving participants with little choice in terms of appropriate seating.

"I don't find that very pleasant, because then I can't see well and especially when I don't know the ride I'm doing then. That stresses me out." (male, 33 years)

Ticketing system

The organization of the ticket system often causes stress. Since 2015, all public transport companies in Belgium have incrementally introduced a new ticketing system called 'MOBIB'. This electronic chip card can be used on all public transport vehicles (train, tram, bus, metro, etc.). Previously, a separate ticket had to be purchased for each mode of transport. Most participants indicated that they found this approach more convenient and less stressful. Furthermore, a few participants indicated that it is annoying one cannot see the expiration date on the MOBIB card. It is only indicated if the card is still valid when the card is scanned while boarding. In case the scanner is not working, one cannot verify the ticket and must then either disembark again, purchase another type of ticket, or hope that the ticket is still valid and continue the trip as planned. This issue is a clear illustration of how the principle of predictability sometimes gets compromised, resulting in lower levels of confidence.

"They are constantly changing the system, I have a bus pass, and you have to scan it, but often the scanners don't work, and then you are just standing in front of them..." (Male, 25 years)

Information signs at the bus stops

Participants' experiences varied widely depending on the type of information board available to consult the timetable. For example, one participant stated that the information boards at a single bus stop pole are less convenient than those at a bus stop shelter because they contain very limited information. Furthermore, several participants indicated that a map including an overview of the entire bus line is helpful. This overview can be found both at certain bus stops and in the smartphone application of 'De Lijn'. It is essential that this map offers a correct outline.

Finally, about half of the participants indicated that they rely on Google Streetview (via Google Maps) to prepare or further plan their trip (e.g., What to do after getting off the bus?).

"Gosh, I find it useful to know which buses are running there (at one bus stop.) and how they are running." (female, 25 years). "I check the app of De Lijn to know the timing, and then I check; yes, if I don't know the stops or something, I check via Google Maps. (woman, 29 years).

Consistency

The importance of consistency was mentioned by participants in reference to timetables and the naming of bus stops or lines.

Timetables

Multiple participants mentioned that different formats offered to consult timetables (i.e., app ‘De Lijn’, website, bus stop/station) do not always correspond with each other. This mismatch creates a sense of distrust. As a result, participants indicated that they checked the timetable several times again after having checked the first time to be more confident. Transport company employees confirmed that such issues in consistency between different timetables indeed exist.

"At some stops, that is what we also hear from the customers, that sometimes the information that is displayed there is not correct, that is certainly something that is confronting for those people, for normal people too for that matter..., but they are going to react to that event differently and panic more and more..." (bus driver 'De Lijn')

Even though most participants find the app accessible, it is notable that many are not aware of all the possibilities in the application. For example, there is some confusion among the participants regarding the real-time information of bus lines displayed in the app. Some participants indicated that the development of a manual could provide a solution for this. The aim should be to optimize the app's operation so that travelers can use it at any time. The information offered should be consistent and offer confidence to users (with ASD).

"Yes, I think so, now, I did have occasions where the app thought that I was on a different bus because one bus had overtaken the other. That was kind of annoying, but in the end, yeah..." (Female, 30 years)

Names of bus stops and lines Some participants indicated that, on occasion, the naming of the stops or the lines is confusing. For example, sometimes the central station is the final stop of a certain bus line, while at other times, the final stop is already a few stops before the central station or in a completely different location. Yet, all buses use the same number and designation of this line. This confusion causes participants to do extra checks at their stop, for instance, by looking at the complete overview of the bus line. Although one participant spontaneously described the difficulties he had with matching information offered by the app and the bus stop name, others did not necessarily experience this as tricky but acknowledged this when being asked about it during the interview.

"Yeah, if just the name of the destination in the app would match the name on the stop sign... or if they just know 48a is that way, 48b is that way, and then those names may still be different lol." (male, 19 years)

What participants experienced as positive in terms of consistency was the fact that line numbers are always strongly visually represented. Each bus line in Flanders has its own color on the bus stop sign, the timetable, the app, and also on the newer buses. De Lijn also tries to keep the overlap between these colors in one area to a minimum to create more consistency (e.g., use the color orange only once in one region). *“What I also think is clear are those colors of the line number, I think it always is, that those colors match the colors on the stop sign. That's very visually clear...that's a positive sign.” (Male, 19 years)*

In short, although De Lijn acts on consistency and predictability of the information it communicates to its passengers, There is still room for improvement, which is confirmed by one of the interviewed bus drivers.

"And also, just making it consistent, sometimes you have what's at the top of the bus, sometimes the line number is with a color behind it, sometimes it's not. On the old buses, then again it's not, there again it is... why don't they make that the same everywhere... that's just a shame. I think little things like that would just make it clearer." (bus driver at 'De Lijn').

Information accuracy

Most participants indicated throughout the interview that information is not always accurate. They mentioned that the use of clear catchphrases in announcements or more extended presentation time of certain information on the bus display could be possible ways to improve message transfer.

"The timetables are pretty clear, except that you, often for the special services, which are the services with an extra letter to the number of the line, that the accompanying description is only clear if you really know the route. Because it is often like this: 'route limited to that stop', then you have to know exactly whether that stop is before or after the stop where you have to get off. Then you have to look it up, and that's irritating. It could be clearer." (woman, 25 years)

Furthermore, interviewees indicated that it is often not clearly shown at the bus stop, in the app of 'De Lijn' or on their website when a certain bus stop is (temporarily) not being served.

Moreover, some participants felt that such a message alone is not enough and that in such cases, supplementary information is required on how to address the problem further (e.g., What is the nearest stop being served? How does one get to that stop? How long is the bus stop not being served?).

"I didn't know the bus was making a detour, and a gentleman asked me, 'does the bus still makes a detour?' I'm like, 'yeah, I don't know that.' There was no indication anywhere on the bus shelter if the bus made a detour or not, so it was also a bit of a guess. And then I think that sometimes they make it easy for themselves, actually." (woman, 25 years)

A more recent way of providing real-time information to passengers is through electronic timetable boards at the bus stop. Unfortunately, not every bus stop in Flanders is equipped with these boards. Usually, they are only found in large stations and near tourist attractions. Although many stops are not equipped with such boards, most participants still reported positive experiences.

"Sometimes then yes, I find it more difficult when there are not such screens because then I have less confidence, I always think or yes I am never sure that I have not missed the bus then and if I am at the right stop and so on of those things." (woman, 30 years)

Nevertheless, these positive experiences hold under a certain condition: the electronic boards that display the timetable need to be adequately maintained and updated to give correct information to every traveler at all times. However, this is not always the case. Some participants indicated that the boards do not always work (correctly) or that the information is not up to date, which creates distrust. Uncertainty is also created when in some cases, 'the supposedly arrived bus' disappears on the electronic board while not arrived yet.

"I find it especially annoying sometimes that the minutes are not always right (...), especially if it is something like that on a route that I do not know and I want to see where we are and where I have to get off and when I have to call, then I find that difficult because I never have the certainty then, even if it is right, or will it be right and will I get off at the right place?" (woman, 19 years)

Theme 2: Limiting sensory stimuli

Participants clearly described a hypersensitivity to sensory stimuli during the interviews.

"It's mostly the crowds that make it for me. Someone with autism who is standing there alone waiting at the stop and he's probably there on time too, then he has time to read everything calmly but when there are people in front of it and so on..." (male, 23 years)

Some participants indicated that it takes a lot of energy to process all the stimuli they encounter while traveling by bus, which results in fatigue. A journey becomes even more stressful when one has to sit on the bus for a long time and/or when the connection between different bus lines does not match. For example, the majority indicates that it would be more comfortable if the connection between the buses but also between bus and train were shorter. Now the journey often takes a very long time, causing a lot of sensory stimuli that could have been avoided. Furthermore, crowding is also a limiting and exhausting factor when participants use public transport. The majority of the participants indicated that they find it difficult to cope with crowdedness because it makes them feel oppressed. Minor adjustments could already alleviate this. For example, the public transport company can make sure that timetables are visible from different perspectives so that travellers do not have to go through the crowd to check them. It is experienced as positive when a bus stop has a shelter where one can take a seat. Such a shelter not only offers protection from bad weather during the wait but also from unnecessary stimuli. Notwithstanding, people with ASD quickly become over-stimulated when there are other people in the bus shelter.

"Personally, I never sit in that shelter, because you know, there are people standing there or there are people next to you who can talk to you or get too close, or in your personal space... in terms of touching and so on. That triggers me, and yeah... therefore, I am always standing outside." (male, 18 years)

A few people with ASD indicated that it would be more comfortable if larger buses were deployed at busy times. Or, an indication of bus occupancy would already be helpful and have a calming effect. Additionally, some participants mentioned that they find it more enjoyable to ride new vehicles than older buses because they are less noisy.

"It actually depends again on where I ride the bus... Sometimes when it are old buses but sometimes also, if I'm lucky then, then it are new buses. If it's an old bus, then the sounds of the people but also of the bus itself bother me more. If it's a new bus, then I notice this less quickly or something like that." (male, 33 years)

Some participants specifically indicated that they purposely look for a single seat or put their backpack on the seat next to them to prevent that someone will sit next to them. When someone does come and sit next to them, the individuals with ASD from our study often use coping strategies to avoid stimuli that accompany their fellow traveller as much as possible (e.g., noise-cancelling headphones). Related to this, the majority of participants reported listening to music while traveling or using noise-cancelling headphones or earplugs.

"I also recently had custom earplugs made, and my intention is to start using those more because sometimes I really do, then I'm sitting there with one finger in my ear like that ... But that's something I should use, not just on the bus but in multiple situations." (woman, 29 years)

Lastly, regular use of the bus or other public transportation modes creates a certain routine which is helpful to better process sensory stimuli during the trip.

"Through my years of experience in public transport, I have actually cultivated an elephant skin, yes, I will say it, to better cope with all the stimuli that come at me." (male, 33 years)

Theme 3: Communication tailored to individuals with ASD

Many respondents indicated that there is hardly any communication with the driver of the bus. In case participants do not know where to get off, this may cause stress as they often feel as if they should not talk to the bus driver. Each participant described his/her own experiences regarding communication and dealt with this in his/her own way. For example, some indicated that they always choose tickets that do not require contact with other people (for example: via the app or text message). When a problem does occur during the ride (e.g., not knowing where they currently are), most people do call on the bus driver. Furthermore, participants indicated that they mainly asked to be warned to get off at the right stop. As already mentioned in the previous theme, most participants try to avoid contact with other travellers.

"You always have to keep an eye on where you are and on long distances, especially if you have never taken the bus, the only thing you can rely on is the bus driver. You can ask the driver, 'will you tell me when to get off?', but otherwise, you know nothing." (male, 24 years)

Bus drivers from 'De Lijn' mentioned that communication with persons with ASD is not considered difficult. However, they acknowledged a need for more affinity with that group. All employees of 'De Lijn' receive training on 'diversity' during their employment but learning to deal with people with ASD is currently not included. It would be good if this training could be further expanded, also covering interaction with people with ASD. Interviewees with ASD confirmed the need for a better understanding of ASD among employees of 'De Lijn'.

"That would be a help, that the drivers know that there are people who have autism and that they know how to deal with it. That they know that when they get angry that it is not meant that way, that this is their way of expressing what is not right, that is maybe not okay, but they cannot do otherwise. And that they then respond to that in some way, and that can only be done if the drivers are trained for that." (bus driver 'De Lijn')

4.5.2. Discussion

This study sought to investigate bus use experiences of individuals with ASD. These experiences were somewhat mixed among the participants with ASD. This corresponds to what was found by Falkmer et al. (2015), where they identified the viewpoints of people with ASD regarding public transport usage. These conflicting opinions within the participant group can be logically explained by the fact that autism is a spectrum condition that can manifest itself in many different ways (Volkmar et al., 2019).

Despite diverse experiences, all participants felt that accessible public transport would allow them to be part of the community, and they were willing to take this transportation opportunity. This corroborates previous research on the link between public transport use and social inclusion (Falkmer et al., 2015; Lubin & Deka, 2012; Feeley, 2010; Scott & Horner, 2008; Kenyon et al., 2002). A recent study by Pfeiffer et al. (2021) examined the barriers and facilitators to public transportation use in people with intellectual and developmental conditions (including ASD) and aligns with the current study's findings. The authors stated that public transportation use allows individuals to perform jobs that otherwise would be out of reach from a logistical point of view. While not every participant diagnosed with ASD feels comfortable taking the bus in Pfeiffer's study, public bus transportation is still a regularly used mode of transport among the participants. This makes the challenge to create an autism-friendly bus transport even more

important, which echoes previous literature and practice (Falkmer et al., 2004; Pfeiffer et al., 2015; Falkmer et al., 2015).

Discussion of the different themes

A first theme that emerged from the analyses was that individuals with ASD have a need for predictability. A lack of predictability is often seen as a barrier to take public bus transportation. A possible explanation could be that the strong preference for predictability is often seen as a core symptom of ASD (Trapp et al., 2015; Ogawa & Watanabe, 2011). Moreover, a recent study by Goris et al. (2020) confirmed a relationship between autistic traits and preference for predictability. However, the interviews show that there is still much room for improvement in Flanders. For example, participants described that they rely on the timetable during their bus trip. However, buses are often late and do not show up, which then causes stress, anger, and frustration within the target group. Results showed that the most problematic for ASD passengers are: no up-to-date timetable, a not clearly visible bus number, inconsistences of the scheduled route, a not clearly visible timetable, inconsistency in the timetable displayed, the bus only stopping in case of a signal from passengers, and lengthy transfers. This is in line with Pfeiffer et al. (2021), who found that timetable planning, navigation, anxiety, and wait time are often barriers for people with ASD to use public transport. As for coping strategies, participants in both this study and the one performed by Pfeiffer et al. (2021) mentioned preparation of the bus route beforehand, asking bus drivers to warn them, and personal verification of each stop on the bus route to ensure where to get out and press on the stop signal button in time. This need for predictability is a common characteristic for individuals diagnosed with ASD. Predictability reduces tension and allows one to remain independent and flexible (Degrieck, 2009). An important prerequisite, however, is that information is clear and correct, which corresponds to a previous study conducted by Falkmer et al. (2015).

The interviews revealed that many passengers with ASD are sensitive to sensory overload while traveling by bus. Indeed, many individuals with ASD are confronted with hyperreactivity, i.e., incoming sensory stimuli being experienced overly strong (Chien et al., 2019; Grandin & Scariano, 2015). Moreover, the current study shows that crowded buses or crowdedness at the bus stops create an oppressive and tense feeling. Coping strategies mentioned are wearing noise-reducing headsets and avoidance of crowded buses or purposely selecting a specific seat to prevent someone can sit aside. This confirms previous research on the use of public transport by individuals with ASD, where crowded situations were also found to be experienced as oppressive and tense (Falkmer et al., 2015; Lubin & Feeley, 2015). The use of noise-reducing headsets and avoidance of crowded places are coping strategies adopted by autistic persons that have also been found in past studies outside the field of transportation (Ikuta (Ikuta et al., 2016) et al., 2016; Kerns et al., 2016). Additionally, results show routine is important for individuals with ASD as it makes the bus trip more pleasant. This confirms a study from Lubin and Feeley where both people with ASD and their caretakers expressed the need for a reliable and consistent public transport service (Lubin & Feeley, 2016). A more recent study by Pfeiffer et al. (2021) also found that one of the main downsides of using public transportation for people with ASD is that it is too crowded. Interconnectivity (i.e., better coordination between and with other forms of public transportation) was also raised by our ASD participants as an important issue, which is supported by available literature (Pfeiffer et al., 2021)

Communication tailored towards individuals with ASD is considered very important when they take public bus transportation. Clear catchphrases when notifying travellers make participants feel safer and less stressed. Consistent use over time of such catchphrases creates a routine and a safer feeling, which in turn makes riding the bus more enjoyable. These findings are in line with Lubin & Feeley (2016), who identified transportation problems among individuals with ASD by means of focus groups and found that traveling via an unfamiliar route was not considered a significant barrier by most participants as long as they could adequately prepare themselves and the information they received was correct. Trip related information as well had to be accurate and up-to-date.

Employees of 'De Lijn' indicated that they had insufficient understanding of the autism target group, which was confirmed by some participants. The bus drivers stated that they would be more capable of adapting their communication if they knew more about the target group. Previous studies also found that communication with other passengers on the bus (Lubin & Feeley, 2016) or with the drivers (Deka et al., 2016) is often a concern of parents of persons with ASD (Kersten et al., 2020). Kersten et al. (2020) also indicate that it is important that interventions are designed to improve communication between individuals with ASD and others in the community.

4.6. Case study 3A: Driving distraction among autistic individuals: A simulator study using an adapted LCT

4.6.1. Results

Table 20 presents descriptive statistics of the LCT measures and PER for autistic and non-autistic groups. The result part is structured in two main parts. First, the results for performances difference in LCT measures and PER within each autistic and non-autistic group were presented. Second, comparisons between autistic and non-autistic groups on performances in LCT measures and PER were shown.

Within group performances on LCT driving measures and PER

Table 21 illustrates the results of Repeated ANOVA (RANOVA) analysis for MDEV, PCL, LCI and ER difference within each autistic and non-autistic group, as verbal WM loads increase.

MDEV

Autistic participants' MDEV score increased with the degree of the complexity in verbal WM load tasks increased, as indicated in Table 21 in RANOVA significant results ($F(2, 29) = 16.70$, p =.000, η_p^2 =. 51). This implies the deviation between the position of the normative course model and the actual driven course of autistic participant showed increasing while the level of difficulty in the secondary tasks increased (Figure 16). Table 22 provides pairwise comparisons of MDEV in driving with four verbal WM load tasks (including baseline) were conducted with LSD adjustment. Except the MDEV between 1-back vs. 2-back (p = .67), the comparison of MDEV between the remaining conditions i.e., baseline vs. 0-back, baseline vs. 1-back, baseline vs. 2-back, 0-back vs. 1-back were significantly different at (p < .01).

In the RANOVA result, the MDEV scores within the non-autistic group significantly increased with increasing verbal WM load tasks ($F(2, 68) = 58.25$, $p = .000$, $\eta_p^2 = .64$). To have a close look at the details, a further specific investigation was performed on MDEV in four driving conditions within the non-autistic group using LSD adjustment. The pairwise comparisons of MDEV score between baseline vs. 0-back, baseline vs. 1-back, baseline vs. 2-back, 0-back vs. 1-back, 0-Back vs. 2-back, 1-back vs. 2-back were significantly different at ($p < .01$), as indicated in Table 22.

Table 20: Descriptive statistics of driving measures (MDEV, LCI and PCL) and PER ($n_{autistic} = 17$; $n_{non\text{-}autistic} = 34$)

Variables	Autistic		Non-autistics	
	Mean	**SD**	**Mean**	**SD**
MDEVB	.36	.10	.31	.07
MDEV0	.54	.21	.39	.15
MDEV1	.90	.49	.57	.21
MDEV2	.93	.55	.77	.30
Total	.68	.45	.51	.27
PCLB	100	.00	100	.00
PCL0	93.46	11.82	99.35	3.81
PCL1	75.82	24.13	90.03	12.21
PCL2	76.14	26.70	79.58	17.82
Total	86.36	21.39	92.24	13.68
LCIB	1.34	.34	1.41	.26
LCI0	1.31	.33	1.36	.24
LCI1	1.34	.27	1.40	.24
LCI2	1.34	.38	1.51	.29
Total	1.33	.33	1.42	.26
ER0	12.02	25.73	.09	.35
ER1	44.72	31.01	10.94	10.79
ER2	75.41	22.19	46.41	25.33
Total	44.05	36.89	19.15	25.36

Note: b: baseline; 0: 0-back; 1: 1-back, 2: 2-back

PCL

The percentage of correct lane changes reduced with increasing the complexity of verbal WM load tasks within the autistic participants. As indicated by the RANOVA result, there was a statistically significant difference between the means of PCL within the autistic participants ($F(2, 34) = 10.83$, $p < .000$, $\eta_p^2 = .40$) while the difficulty of N-back tasks increased (Figure 18). A pairwise comparison results showed significant difference ($p < .04$) between baseline vs. 0-back, baseline vs. 1-back, baseline vs. 2-back, 0-back vs. 1-back, 0-Back vs. 2-back, 1-back vs. 2-back. However, there was no difference between1-back vs. 2-back (p = .95).

Regarding the non-autistic group, the percentage of correct lane changes diminished with increasing the complexity of verbal WM load tasks, as indicated by a significant RANOVA test ($F(2, 57) = 32.32$, $p < .000$, $\eta_p^2 = .50$). Regarding pairwise comparison, except the PCL between baseline vs. 0-back (p = .33), PCL in the remaining pairs, i.e., baseline vs. 1-back, baseline vs. 2-back, 0-back vs. 1-back, and 1-back vs. 2-back was significantly different at (p < .01).

Table 21: Analysis of LCT driving measures and PER: within autistics and non-autistics RANOVA test (Greenhouse-Geisser).

Group	*Variables*	*F*	*Dfs*	*p*	η_p^2
Autistics	MDEV	16.70	2,29	.000	.51
	PCL	10.83	2,34	.000	.40
	LCI	0.17	2,37	0.88	.01
	PER	38.93	1, 23	.000	.71
Non-autistics	MDEV	58.25	2,68	.000	.64
	PCL	32.32	2,57	.000	.50
	LCI	7.61	2,79	.000	.19
	PER	100.74	1,41	.000	.75

LCI

The lane change initiation as a function of increasing the complexity of verbal WM load tasks within the autistic participants did not show a significant difference ($F(2, 37) = 0.17$, $p = .088$, $\eta_p^2 = .01$). Therefore, further pairwise analysis for looking at significant differences of LCI across each pair of N-back tasks was not performed.

The RANOVA analysis result for the non-autistics group showed that the LCI significantly changed with respect to increasing the difficulty level of verbal WM load tasks ($F(2,79) = 7.61$, $p = .000$, $\eta_p^2 = .19$) but regardless of LCI in baseline condition (Table 20 & Table 21). Unexpectedly, the mean score of LCI in baseline (M = 1.41 s) was higher than in 0-back (M = 1.36 s) and 1-back (M = 1.40 s). In the pairwise comparison results, except the insignificant difference between baseline vs. 0-back, and baseline vs. 1-back (p ≥ .05), LCI in the remaining pairs, i.e., baseline vs. 2-back, 0-back vs.1-back, 0-back vs.2-back, 1-back vs. 2-back was significantly different at (p < .05) (Table 22).

Table 22 Pairwise comparison for significantly different variables in Table 21: Bold p-values are significant at 0.05 significance level).

Group	Variables	Conditions	Pairwise comparison			
			Baseline	**0-Back**	**1-Back**	**2-Back**
Autistics	MDEV	Baseline	1	**.001**	**.000**	**.000**
		0-Back		1	**.001**	**.002**
		1-Back			1	.67
		2-Back				1
	PCL	Baseline	1	**.04**	**.001**	**.002**
		0-Back		1	**.001**	**.008**
		1-Back			1	.95
		2-Back				1
	PER	0-Back	n.a.	1	**.002**	**.000**
		1-Back			1	**.000**
		2-Back				1
Non-autistics	MDEV	Baseline	1	**.001**	**.000**	**.000**
		0-Back		1	**.000**	**.000**
		1-Back			1	**.000**
		2-Back				1
	PCL	Baseline	1	.33	**.000**	**.000**
		0-Back		1	**.000**	**.000**
		1-Back			1	**.000**
		2-Back				1
	LCI	Baseline	1	.13	.88	**.02**
		0-Back		1	**.02**	**.000**
		1-Back			1	**.003**
		2-Back				1
	PER	0-Back	n.a.	1	**.000**	**.000**
		1-Back			1	**.000**
		2-Back				1

n.*a. – not applicable*

PER in WM load tasks

The RANOVA analysis result showed that PER significantly increased with increasing complexity of verbal WM load tasks within autistic ($F(1, 23)$ **= ,** 38.93, p = .000**,** η_p^2 = .71) and non-autistic ($F(1, 41)$ **=** 100.74**,** p **=** .000, η_p^2 = .75) groups (see Table 21 and Figure 17). The LCT was constant across all verbal WM load tasks. Pairwise comparisons were conducted to closely examine the details between the score of PER in each autistic and non-autistic group across the combinations of verbal WM load tasks. The comparison results showed that PER in the pair between 0-back vs. 1-back, 0-back vs. 2-back, and 1-back vs. 2-back was significantly different (p < .01) in each of autistic and non-autistic group (Table 22).

Between groups' performances in LCT measures and PER

The between-group analyses were performed to examine if autistic and non-autistic groups show a difference in LCT measures (i.e., MDEV, PCL, and LCI) and PER. The comparisons were made based on total and individual mean scores of LCT measures and PER derived from a whole LCT drive, and task types.

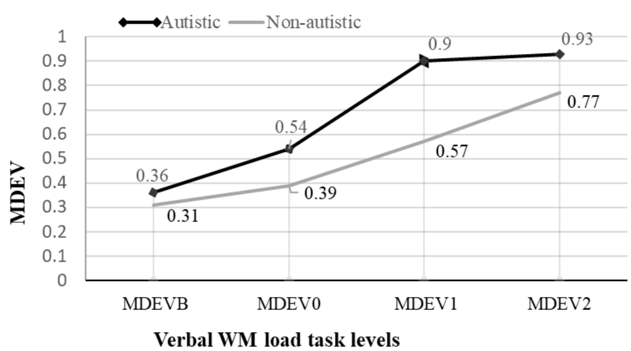


Figure 16: MDEV within and between groups based on task levels

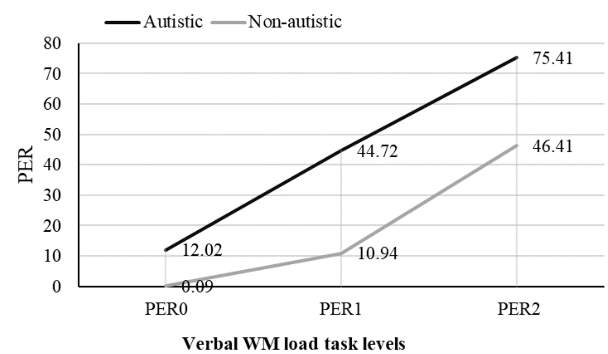


Figure 17: PER within and between groups based on task levels

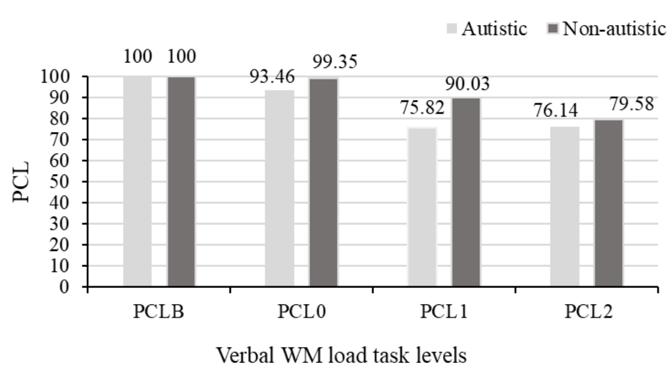


Figure 18: PCL within and between groups based on task levels

MDEV

The independent samples t-test analysis showed that autistic participants performed a significantly higher MDEV than non- autistic group t(*202*) = 3.41, p = .001), as indicated in Table 23. To closely examine the group differences in individual MDEV scores based on verbal WM load tasks, separate independent samples t-test analyses were performed. The result showed that, except insignificant result in 2-back t(*49*) = 1.35, p = .19), autistic group significantly performed more MDEV than non-autistic group in baseline t(*49*) = 2.19, p = .03), 0-back t(*49*) = 2.98, p = .005), 1-back t(*49*) = 3.32, p = .002).

PCL

Compared to the non-autistic group, based on the correct lane change, autistic group performed significantly lower PCL than non-autistic participants t(*202*) = *-2.38*, p = .02) (Table 23). Regarding examining the group differences in individual's PCL score based on verbal WM load tasks, autistic group was significantly lower in PCL than non-autistic in 0-back t(*49*) = 2.66, p = .01); 1-back t(*49*) = 2.81, p = .007), but not significant for 2-back t(*49*) = .55, p = .59). Different from the above, the PCL difference between autistic and non-autistic groups in baseline condition was not computed because both groups performance was the same (M = 100%).

Table 23: Independent samples t-test analyses of group difference based of total mean of each driving measure and PER

Variables	Between autistic and non-autistics		
	Dfs	*t*	*P (2-tailed)*
MDEV	202	3.41	.001
PCL	202	-2.38	.02
LCI	202	-2.17	.03
PER	151	4.89	.000

LCI

Compared to the non-autistic group, based on the performance of LCI measures, autistic group performed significantly faster t(*151*) = *4.89*, p = .000). However, further task based specific investigation using a separate independent samples t-test analysis of group difference on LCI did not show significant difference in Baseline (t = .80, p = .43), 0-back (t = .71, p = .48), 1-back (t = .97, p = .34) and 2-back (t = 1.75, p = .09). Although those comparisons were not significant, the mean scores of LCI for autistic group showed shorter than non-autistic group in all four conditions (Table 20).

Table 24: Independent samples t-test analyses of group difference on individuals mean score driving measures and PER based on verbal WM load task

Variables	Conditions	Between autistic and non-autistics	
		t	*P (2-tailed)*
MDEV	Baseline	2.19	.03
	0-Back	2.98	.005
	1-Back	3.32	.002
	2-Back	1.35	.19
PCL	Baseline	Na	na
	0-Back	2.66	.01
	1-Back	2.81	.007
	2-Back	.55	.59
PER	0-Back	2.73	.009
	1-Back	5.74	.000
	2-Back	4.01	.000
LCI	Baseline	.80	.43
	0-Back	.71	.48
	1-Back	.97	.34
	2-Back	1.75	.09

Note: Degree of freedom = 49

PER

The independent sample t-test analysis showed that the autistic group was significantly higher than the non-autistic group in PER t(*151*) = *4.89*, p = .000) (Table 23). A separate independent sample t-test analysis showed that the autistic group was significantly higher in PER than the non-autistic group in 0-back t(*49*) = 2.73, p = .009), 1-back t(*49*) = 5.74, p = .000), and 2-back t(*49*) = 4.01, p = .000).

4.6.2. Discussion

This study mainly investigated driving and secondary task performances of autistic individuals when the verbal WM load tasks' difficulty increased; and compare those performances with the non-autistic individuals' performances. Specifically, the study addressed the following objectives: (1) exploring the driving performances of autistic individuals in LCT measures as distracted by increasing verbal WM load tasks; (2) investigating autistic individuals' performance on the secondary task when verbal WM loads increase: and (3) comparing the driving and secondary task performances of autistic individuals and non-autistic individuals when verbal WM loads increase. The study findings were discussed below based on within-group and between groups differences in the performance of driving measures and secondary tasks.

Within group study in LCT measures and PER performances

To the best of our knowledge, no study has addressed distracted driving among autistic drivers. In this regard, the current study can be the first to address this issue among autistic individuals using LCT and verbal WM load tasks with four levels of complexity. Many studies indicated that autism characteristics often interfere with autistic individuals performances (e.g., Baron-Cohen et al., 2010; Chee et al., 2017; Granovetter et al., 2020; Habib et al., 2019; Murphy et al., 2014). As indicated in the introduction, autistic individuals are characterized by impaired working memory, an important aspect of executive function that resists and handles the impact of distraction while performing the main activity. Moreover, such impaired WM level can be highly reduced when secondary tasks appear in increasing complexity patterns. In this regard, Cox et al. (2016) indicated that autistic individuals' driving performances can be further impaired when WM tasks are introduced. A study by Ross et al. (2014) showed that the verbal WM load induced cognitive distractions by degrading the WM resource, that reduced performance on the LCT measures. Such cognitive workload significantly decreases lane-keeping (Son & Park, 2011), which reflects LCT measures (e.g., MDEV).

In the current study, as compared to the LCT normative path model, the deviation of autistic participants' driving course increased as a function of the verbal WM load tasks complexity increased. This finding is in line with LCT-based studies by Ross et al. (2014); Harbluk et al. (2007); (Young et al., 2011) and (Burns et al., 2005), secondary tasks, which create verbal WM load, increase the MDEV. Another non-LCT-based study (e.g., Regan et al., 2011) also supported that distraction impaired the drivers' longitudinal and lateral control of a car. To find a link between this LCT measure and autism, a further breakdown of the MDEV process may be important. MDEV can be reflected in perception, maneuvering, and lane-keeping qualities (Ross et al., 2014; Young et al., 2011). These MDEV's manifestations can be impaired due to autism characteristics interference. For example, previous research showed that autistic drivers exhibited lower maneuvering quality (Chee et al., 2017; Wilson et al., 2018), errors in lane maintenance (Chee et al., 2017; Classen et al., 2013; Lindsay, 2017; Monahan et al., 2013), slow perception (Classen & Monahan, 2013), problem in vehicle control (Veerle Ross, Ellen JONGEN, Marleen Vanvuchelen, et al., 2015) and increased variation from the desired lane positioning (Patrick et al., 2018).

MDEV difference in paired tasks, there was a trend of MDEV significant increasing in the condition of the difficult task compared to each other, except for the insignificant difference of MDEV between 1-back and 2-back. It can be argued that the 2-back task might appear to demand high cognitive effort. Accordingly, participants might fail to come up with such effort, so the 2-back task might not be adequately loaded onto WM in a way that could be significantly different from 1-back in terms of MDEV.

A reduced percentage of correct lane change during cognitive tasks can be interpreted as a sign of driver overloaded and increased risk of inaccurate decisions. In the current study, increased verbal WM load tasks led to degraded PCL. This finding supports previous results from Ross et al. (2014) study, conducted in the general population, in which the percentage of correct lane changes decreased with an increasing function of verbal WM load tasks. PCL assesses various aspects, including detecting lane change signs, responding to the sign accordingly, preparing to change lanes, and executing the actual lane change. Engström and Markkula (2007) indicated that cognitive distraction could affect PCL's manifestations, such as detection and response selection. Due to verbal WM load tasks, autism characteristics (e.g., impaired WM capacity because of load) may interfere with performing such PCL aspects. As a result, autistic individuals might experience incorrect event detection (Zalla et al., 2013), altered sensory responses to stimuli (Granovetter et al., 2020), cognitive inflexibility to respond to changing events (Pellicano et al., 2017), impaired planning, attention, monitoring, shifting and executing (Hill, 2004; Luna et al., 2007). These could be possible reasons for autistic participants, based on simulator driving, to show impaired operational driving skills (Classen et al., 2013), limitation in detecting and responding to traffic events while they are under an increased attentional demanding condition (Reimer et al., 2013), decrease situational awareness skills and lapses like sign misread (Silvi et al., 2018).

PCL difference in paired tasks, like MDEV, there was a trend of PCL increasing in the condition of the difficult tasks compared to each other, except for the insignificant difference PCL between 1-back and 2-back. In this regard, the possible explanation given for MDEV insignificant result between 1-back and 2-back could also be applied to the case of PCL.

In contrast to Harbluk et al. (2007) and Ross et al. (2014), the study's findings for LCI did not show a significant change as a function of secondary task complexity levels. LCI is mainly reflected in the process of event detection, response selection, and preparation of the target lane change (see Ross et al., 2014). Unlike the current study, cognitive load degraded those manifestations in LCI, as evident by previous studies; for example, it reduces drivers' object or event detection ability (Angell et al., 2006; Recarte & Nunes, 2003), identification (Recarte & Nunes, 2003), increase response times, but for sudden obstacle (Son & Park, 2011), and recognizing memory of roadside object (like signs) (Strayer et al., 2003).

As event detection measures, LCI and PCL shared all manifestations except a complete execution of correct lane change. Question could be raised regarding why the cognitive workload did bring an impact on PCL but not on LCI. In this regard, a possible explanation is that the WM loads might not significantly affect some initial processes (i.e., detection, response selection, preparation, and initiation) that occurred before the correct lane change (i.e., last stage of PCL) was achieved. Further studies must address such aspects of event detection measures for a better conclusion.

In the case of the secondary task, autistic participants made an increased error rate in the secondary task performance when the verbal WM loads increased. The impaired WM can be attributed to increased errors that autistic participants showed on the N-back task performance. In Ross et al. (2014) study, participants with low WM capacity showed a higher error on the secondary task. Moreover, the presence of the driving task (LCT) interferes with autistic participants responding to verbal WM load tasks. Hence, task performance diminishes while two or more tasks are executed concurrently (Koch et al., 2018).

Although this study focuses on autistic participants, it would be interesting to look at how non-autistic participants also perform in LCT driving and secondary tasks. Thus, we provided this short summary concerning their driving and secondary task performance as distracted by an increasing verbal WM load. Non-autistic participants' driving performances, including MDEV, PCL, and LCI (regardless of baseline condition), increased as a function of verbal WM load tasks complexity levels increased. These findings align with previous research, such as MDVE, LCI (Harbluk et al., 2007; Ross et al., 2014), and PCL (Engström & Markkula, 2007; Ross et al., 2014).

Between groups difference in LCT measures and PER performances

Compared to non-autistic participants, based on cognitive load impact on driving, autistic participants demonstrated impaired driving performance results from tasks that induce WM load (Cox et al., 2016; Reimer et al., 2013). The current study was the first to compare LCT-based driving performances as a function of verbal WM loads between autistic and non-autistic individuals. The performances between groups were compared based on their driving under each task level and a whole LCT drive regardless of dividing it into task type. The whole driving comprised all types of WM load tasks ranging from baseline (low demanding) to 2-back high (more demanding). Driving under low and high demand environment leads to low (e.g., fatigue) and high cognitive (multiple tasks) workloads that result in impaired driving performances (Brookhuis & De Waard, 2010).

Due to executive dysfunction (O'Hearn et al., 2008), the WM capacity of autistic participants is lower than non-autistic participants (Habib et al., 2019). Participants with lower WM capacity performed higher in MDEV (Mäntylä et al., 2009; Ross et al., 2014) and lower in PCL (Ross et al., 2014) than participants with high WM capacity. In the current study, autistic participants showed more MDEV and less PCL than non-autistic participants in a whole LCT drive regardless of task type.

Regarding task difficulty levels, except for MDEV and PCL in 2-back and PCL in baseline, under the remaining task types, autistic participants performed higher MDEV and lower PCL than non-autistic participants. Although there was no significant difference between groups in MDEV and PCL in the 2-back level, the mean scores for autistic participants in this level were higher in MDEV and lower in PCL than non-autistic participants. The insignificant findings might be a result of verbal distractor was not fully loaded or maintained in participants' WM. Participants might reduce their engagement in responding to the 2-back task because, unlike other N-back tasks, it required a longer time to respond (i.e., inter number interval was 2.25s, so for the 2-back task, the required time to give a response was 5s). Thus, 2-back may demand a larger memory load (Braver et al., 1997) and cognitive effort. In this regard, the task might not truly create a WM load that affects participants' driving performance. In the case of PCL in baseline drive, both groups performed the same with no incorrect lane change. This may imply that in LCT, when there is no verbal cognitive distraction, autistic participants can execute lane changes the same as non-autistic participants.

In contrast to Ross et al. (2014) study, participants with lower verbal WM capacity were slower in initiating lane change than participants with high verbal WM capacity; autistic participants in the current study were faster in initiating lane change than non-autistic participants in a whole LCT drive regardless task type. In this regard, the driving performance of autistic drivers could not always be impaired compared to non-autistic individuals. An on-road study by Chee et al. (2017) indicated that autistic participants performed safer driving than other drivers on applying indicator. Baron-Cohen et al. (2010, p. 1377) argued that autistic individuals are commonly good at '*recognizing repeating patterns of stimuli'.* Soulières et al. (2010) also indicated that there are autistic individuals with excellent abilities to estimate the occurrence of stimuli. In this regard, the current study's autistic participants might be good at visualizing and mentally imaging lane change signs. In a complete LCT drive, they might create a mental image for the frequency of lane change consisting of 24 lane changes occurring 3 times throughout the 12 km (i.e., per task: 6 lane changes occur three times throughout the 3 km). In this case, they might anticipate the next lane change sign and respond more quickly when the sign appears than non-autistic participants. In terms of LCI as a function of task type, autistic participants showed faster initiation of lane change than non-autistic, but not significantly different.

In Ross et al. (2014) study, participants with low WM capacity performed higher errors on the verbal WM load tasks. In line with this study, the current study indicated that autistic participants had a higher error rate than non-autistic participants. Such error differences were observed in each task and a whole drive regardless of task type. This difference can be attributed with WM capacity for autistic individuals is lower than non-autistic, and the presence of concurrent task (i.e., driving task) interferes and reduces WM capacity in responding to verbal WM load tasks.

4.7. Case study 3B: Investigating aggressive driving behavior in autistic individuals: A simulator study

4.7.1. Results

This section presents the preliminary results of one scenario (school bus). The descriptive data showed the mean scores of participants with autism for Max. LP (M = 2.65), Max. Speed (M = 8.78), SD Speed (M = 1.53), Max. Deceleration (M = -4.68), Max. Acceleration (M = 2.27), Mean Distance to the Bus (M = 21.92), SD. LP (M = .24) are higher than the mean score of participants without autism Max. LP (M = 2.45), Max. Speed (M = 7.08), SD Speed (M = .81), Max. Deceleration (M = -3.49), Max. Acceleration (M = 1.73), Mean Distance to the Bus (M = 18.27), SD. LP (M = .17) (Table 25). The independent t-test analyses showed the difference between these groups on SD Speed, Max. Deceleration, Mean distance to the Bus were significant at alpha .05. The mean scores of variables, such as Max. Speed, Max. Lateral Position and SD. Lateral Position were significantly different at alpha level .10 among participants with and without autism. The mean scores for the remaining variables, i.e., Max. Acceleration was not significant between the groups (Table 25).

Crash percentage between autistic and non-autistic: Autistic participants 6 (26.08%) experienced more crashes than non-autistic participants 3 (7.69%) between a distance of the bus onset until the intersection where the bus became no longer blocks a participant car.

Table 25: Mean and SD for aggression driving behavior measures

Scenarios	Aggressive driving behavioral measures	Autistic		Non-autistics	
		Mean	SD	Mean	SD
The school bus scenario	Max. Lateral Position	2.65	.45	2.45	.30
	Max. Speed	8.78	4.02	7.08	2.24
	SD Speed	1.53	1.42	.81	.22
	Max. Deceleration	-4.68	2.01	-3.49	1.37
	Max. Acceleration	2.27	1.42	1.73	1.13
	Mean Distance to the Bus	21.92	6.20	18.27	3.51
	SD. Lateral Position	.24	.19	.17	.08

Table 26: Independent t-test analyses for aggression driving behavior measures difference between autistic and non-autistics

Scenarios	Variables	Between autistic and non-autistics		
		Dfs	**t**	**P (2-tailed)**
School Bus	Max. Speed	53	2.02	.059
	SD Speed	53	3.00	.004
	Max. Deceleration	53	-259	.012
	Max. Acceleration	53	1.53	.131
	Mean distance to the Bus	53	2.79	.007
	Max. Lateral Position	53	1.97	.054
	SD. Lateral Position	53	1.85	.070

4.7.2. Discussion

This paper is under preparation. The discussion part has not yet been started.

4.8. Case study 3C: Hazard perception skill of individuals with autism: A simulator study

4.8.1. Results

Preliminary analyses were conducted to compare individuals with autism and without autism on their perception skills across several events in the Environmental Prediction hazards (EP), Dividing and Focusing attention hazards (DF), and Behavioral Prediction hazards (BP).

Environmental Prediction hazards (EP)

Individuals with autism and without autism were compared on minimum time to collision (TTC_m) and reaction time (RT) in three environmental hazard types using an independent T-test test. Compared to individuals without autism, based on TTC_m and RT, individuals with autism performed significantly slower RT $t(74) = 3.11$, $p = .003$) and high TTC_m $t(91) = -2.30$, $p = .024$) on a hazard type that refers to a pedestrian appears in front of the car and walks onto the road. In the second hazard (i.e., a taxi suddenly comes onto to the road in front of the bus), individuals with autism performed significantly (when alpha was below 0.1) slower RT than individuals without autism $t(78) = 1.90$, $p = .06$). As shown in Table 28 independent t-test analyses for the remaining TTC_m and RT of environmental hazard were not significant.

Behavioral Prediction hazards (BP)

The independent sample t-test analysis showed that individuals with autism were significantly slower RT and high TTC_m than those without autism in the two behavioral hazards (i.e., bike suddenly backs out into the drivers' path, a car suddenly backs out into the drivers' path) (Table 3). In the case of the third behavioral hazard (i.e., the child steps onto the road), individuals with autism were significantly slower RT (when alpha was 0.10) and insignificant high TTC_m than the individuals without autism (Table 27).

Dividing and Focusing attention hazards (DF)

Individuals with autism and without autism were compared on RT and TTC_m in three dividing and focusing attention hazards (DF); the independent t-test result showed no significant results except RT in the first DF hazard (i.e., a car coming from the right, that doesn't have the right of way) and TTC_m in the third DF hazard (i.e., a pedestrian ignores the red light and crosses the road, coming from the right). In this regard, individuals with autism showed significantly faster RT in hazard one and less TTC_m in hazard three than individuals with without

Table 27: Mean and SD for aggression driving behavior measures

Scenarios	Hazard type	Events	Parameter	ASD		Neurotypical	
				Mean	SD	Mean	SD
Local	BP	Bike suddenly backs out into the drivers' path	RT	.96 (17)	.33	.81 (61)	.25
			MTTC	1.40 (23)	.57	1.70 (70)	.43
	BP	Car suddenly backs out into the drivers' path	RT	.81 (19)	.33	.66 (66)	.13
			MTTC	1.47	.64	1.76	.34
	BP	The child steps onto the road.	RT	2.40 (14)	1.73	1.86 (60)	1.10
			MTTC	1.24	.87	1.53	.59
	DF	A car coming from the right, that doesn't have the right of way.	RT	.86 (16)	.35	1.10 (62)	.28
			MTTC	.75	.71	.68	.51
	EP	A pedestrian appears in front of the car and walks onto the road.	RT	1.02 (15)	.50	.79 (59)	.16
			MTTC	.88	.65	1.20	.54
Corniche	EP	A taxi suddenly comes onto to the road in front of the bus.	RT	.92 (18)	.44	.77 (62)	.21
			MTTC	2.16	1.12	2.38	.64
	DF	Car suddenly leaves his parking spot, in front of the driver.	RT	.63 (19)	.12	.65 (63)	.16
			MTTC	2.13	.66	2.26	.47
	DF	A pedestrian ignores the red light and crosses the road, coming from the right.	RT	1.98 (12)	1.10	2.04 (37)	1.01
			MTTC	.84	.51	1.13	.56
	EP	Right after the curve is a broken-down truck with 4 blinkers on.	RT	1.03 (14)	.71	.86 (31)	.46
			MTTC	.77	.38	.85	.37

individuals with autism was significantly slower RT (when alpha was 0.10) and insignificant high MTTC than the individuals without autism (Table 28).

Table 28: Independent t-test analyses for aggression driving behavior measures difference between autistic and non-autistics

Scenarios	Hazard type	Events	Parameters	Dfs	T	P (2-tailed)
Local	BP	Bike suddenly backs out into the drivers' path (1BP).	RT	76	1.94	.05
			MTTC	91	-2.69	.008
	BP	Car suddenly backs out into the drivers' path (2PB).	RT	83	2.83	.006
			MTTC	91	-2.74	.007
	BP	The child steps onto the road (3PB).	RT	72	1.48	.14
			MTTC	91	-1.82	.07
	DF	A car coming from the right, that doesn't have the right of way (1DF).	RT	76	-2.85	.006
			MTTC	91	.46	.65
	EP	A pedestrian appears in front of the car and walks onto the road (1EP).	RT	74	3.11	.003
			MTTC	91	-2.30	.024
Corniche	EP	A taxi suddenly comes onto to the road in front of the bus (2EP).	RT	78	1.90	.06
			MTTC	91	-1.16	.25
	DF	Car suddenly leaves his parking spot, in front of the driver (2DF).	RT	80	-.35	.72
			MTTC	91	-1.03	.31
	DF	A pedestrian ignores the red light and crosses the road, coming from the right (3DF).	RT	47	-.18	.86
			MTTC	91	-2.20	.03
	EP	Right after the curve is a broken-down truck with 4 blinkers on (3EP).	RT	43	.99	.33
			MTTC	91	-.82	.42

Dividing and Focusing attention hazards (DF)

Individuals with autism and without autism were compared on RT and MTTC in three dividing and focusing attention hazards (DF), the independent t-test result showed no significant results except RT in the first DF hazard (i.e., a car coming from the right, that doesn't have the right of way) and MTTC in the third DF hazard (i.e., a pedestrian ignores the red light and crosses the road, coming from the right). In this regard, individuals with autism showed significantly faster RT in hazard one and less MTTC in hazard three than Individuals with without (Table 28).

4.8.2. Discussion

This paper aimed to present the preliminary analysis about hazard perception skills of individuals with autism in the simulated driving environments. Nine events that were categorized into three hazards (EP, BP and DF) were included. As measurement of participants hazard perception skills, MTTC and RT were employed. In EP, this study did find differences between the individuals with autism and without autism for both MTTC and RT in a condition where a pedestrian appears in front of the car and walks onto the road, and RT in an event where a taxi suddenly comes onto to the road in front of the bus. Individuals with autism showed slower reaction time and higher risky to crash than individual without autism. In a study by Ross et al. (2019) the opposite was reported i.e., in EP hazard, individual with autism was faster in reaction time than individual without autism. In the case of DF, individuals with autism showed significantly faster RT in a car coming from the right, that doesn't have the right of way and less MTTC in a pedestrian ignores the red light and crosses the road, coming from the right than Individuals without autism. In contrast to this, in Ross et al. (2019), it was indicated that individual with autism showed a slower reaction to DF hazards than the control group. In BP, individuals with autism showed slower RT and high MTTC than individuals without autism when a bike suddenly backs out into the drivers' path, and a car suddenly backs out into the drivers' path. Such results appeared in contrast to a some studies, for instance, in a study by Ross et al. (2019) there was no difference in RT in BP hazard, and in Bishop et al. (2017), no difference in reaction time to social hazards between the control group and the autistic group.

4.9. Case study 4A: Assessment of instructors' knowledge about autism and driving before and after training workshop

4.9.1. Results

The result of chapter one contained an assessment of participants' knowledge about autism and driving before and after the workshop.

Knowledge on autism and driving before and after the workshop in group one

The percentage of correct scores out of ten questions that participants in group 1 answered are shown in the following Figure. As shown in Figure 19, participants in group 1 showed improvement in correctly answering most questions after the workshop than before. However, such improvement was not observed in participants' responses to some questions, including Q1 (i.e., Most autistic persons will exhibit the same behavior), Q4 (i.e., An autistic person will always remain a poorer driver than a non-autistic person), Q10 (i.e., Driving training tailored to autistic individuals' needs is necessary to give them the same opportunities as non-autistic learner drivers). In the feedback session, participants indicated that some items in the questionnaire were not easy to understand. We assumed this could be the possible explanation for participants not showing improvement in those questions indicated above.

A paired-sample t-test analysis was computed to examine a statistically significant mean score difference between participants' knowledge before and after the workshop. From the analysis, the mean score difference between the participants' knowledge before and after the workshop in group 1 indicated a statistically no difference (($t(11) = -1.33$, $p = 0.21$). This result indicated that participants did not perform significantly better in the post-workshop than in the pre-workshop.

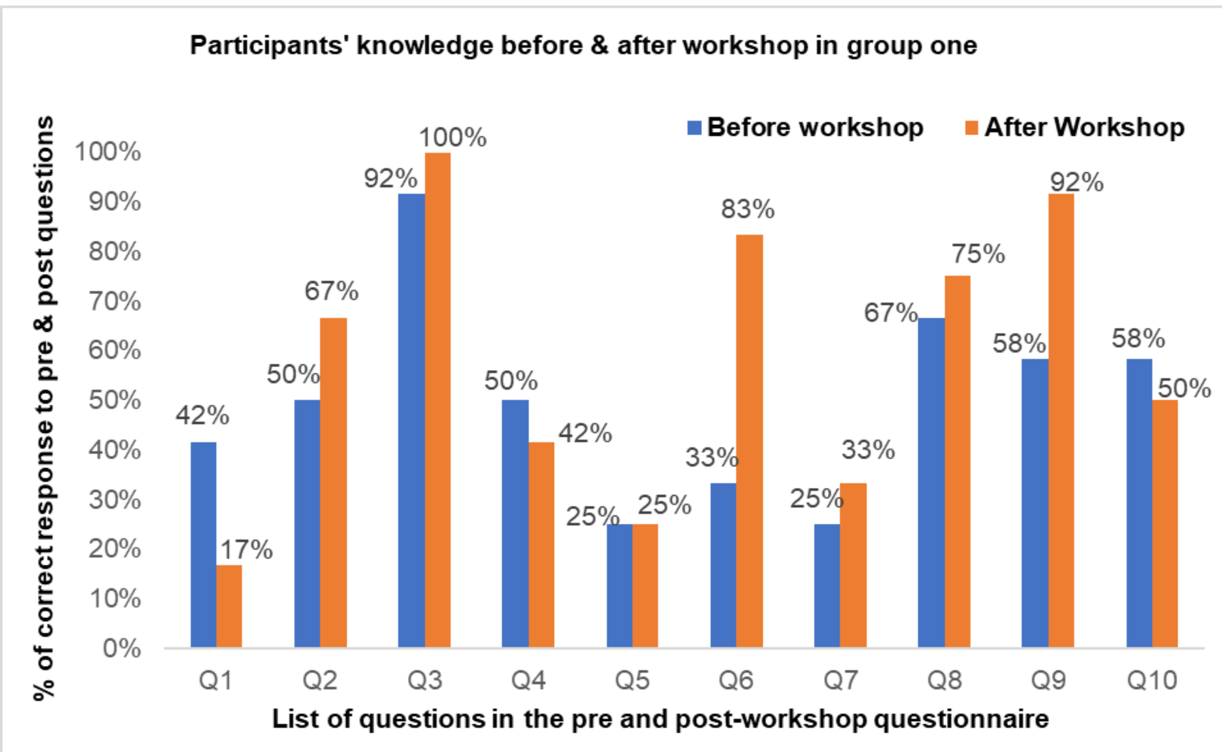


Figure 19: Percentage of participants' correct response to 10 questions before and after workshop in group one

Although the result showed a statistically no significant difference, the mean score of participants' knowledge in group one after the workshop ($M = 5.83$, $SD = 1.62$) was slightly higher than the means score before the workshop ($M = 5.08$, $SD = 1.27$).

Knowledge on autism and driving before and after the workshop in group two

Figure 20 showed the percentages of correct scores out of ten questions that participants in group 2 answered. As indicated in Figure 20, participants in group 2 showed improvement in correctly answering most questions after the workshop than before the workshop. However, such improvement was not observed in participants' responses to a few questions, including Q3 (i.e., An autistic person might have difficulties using the context to give meaning to something), and Q6 (i.e., When your autistic driver shows during the driving lesson that he can correctly merge on the highway, it is common for the autistic driver that he forgets how to do it next time).

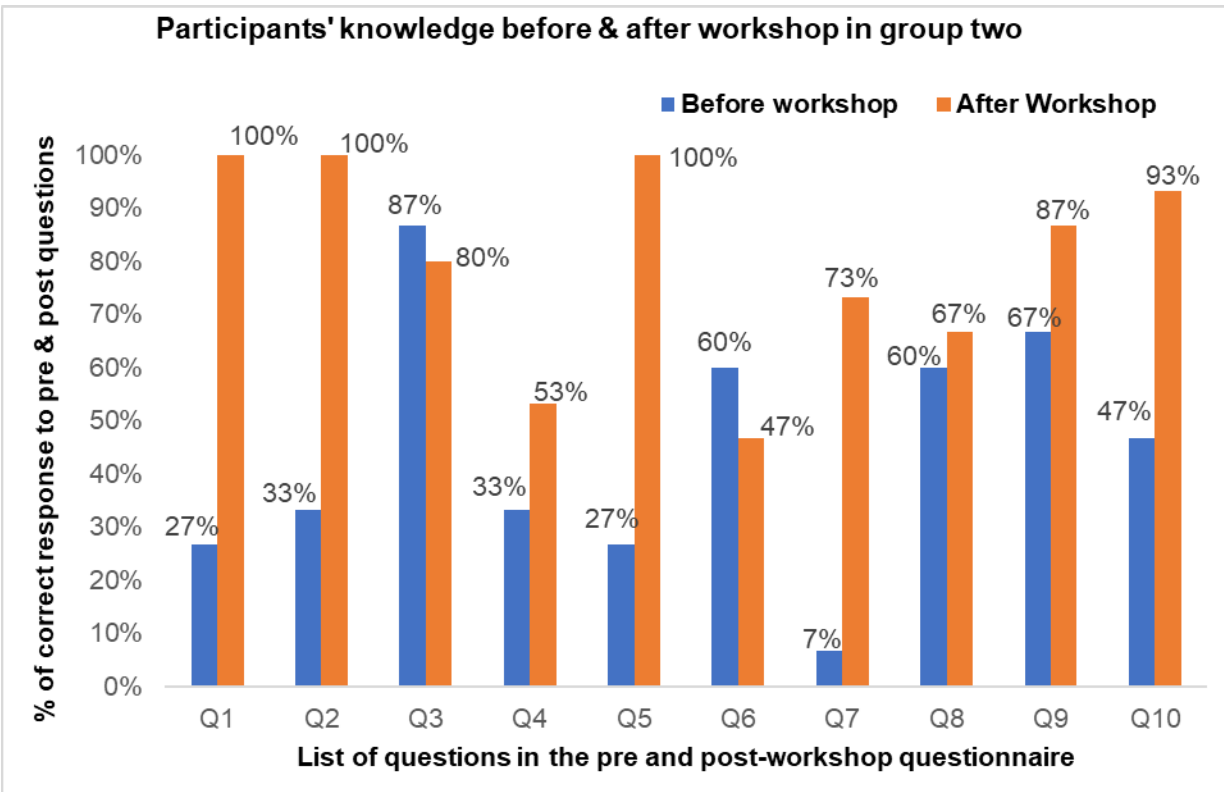


Figure 20: Percentage of participants' correct response to 10 questions before and after workshop in group two

Like we did for participants in group 1, a paired-sample t-test analysis was computed to test a statistically significant mean score difference between participants' knowledge before and after the workshop. In contrast to the paired-sample t-test for group 1, the analysis for group 2 indicated the mean score of pre-workshop knowledge ($M = 4.47$, $SD = 1.55$) and post-workshop knowledge ($M = 8.00$, $SD = 1.31$) showed statistical significant difference ($t(14) = -8.34$, $p = 0.001$). Accordingly, workshop participants showed significantly better knowledge in the post-workshop than in the pre-workshop. Thus, this refers to the workshop might bring significant change to the pre-existing knowledge of participants concerning autism and driving.

Knowledge on autism and driving before and after the workshop among the combined groups

The percentages of correct scores out of ten questions that participants in the combined group answered are shown in the following figure. Unlike the results observed above, as shown in Figure 21, the current results indicated that participants in the combined group showed better improvement in the correct response to nearly all questions after the workshop than before. However, participants did not improve their response to Q 3 (i.e., An autistic person might have difficulties using the context to give meaning to something) after the workshop.

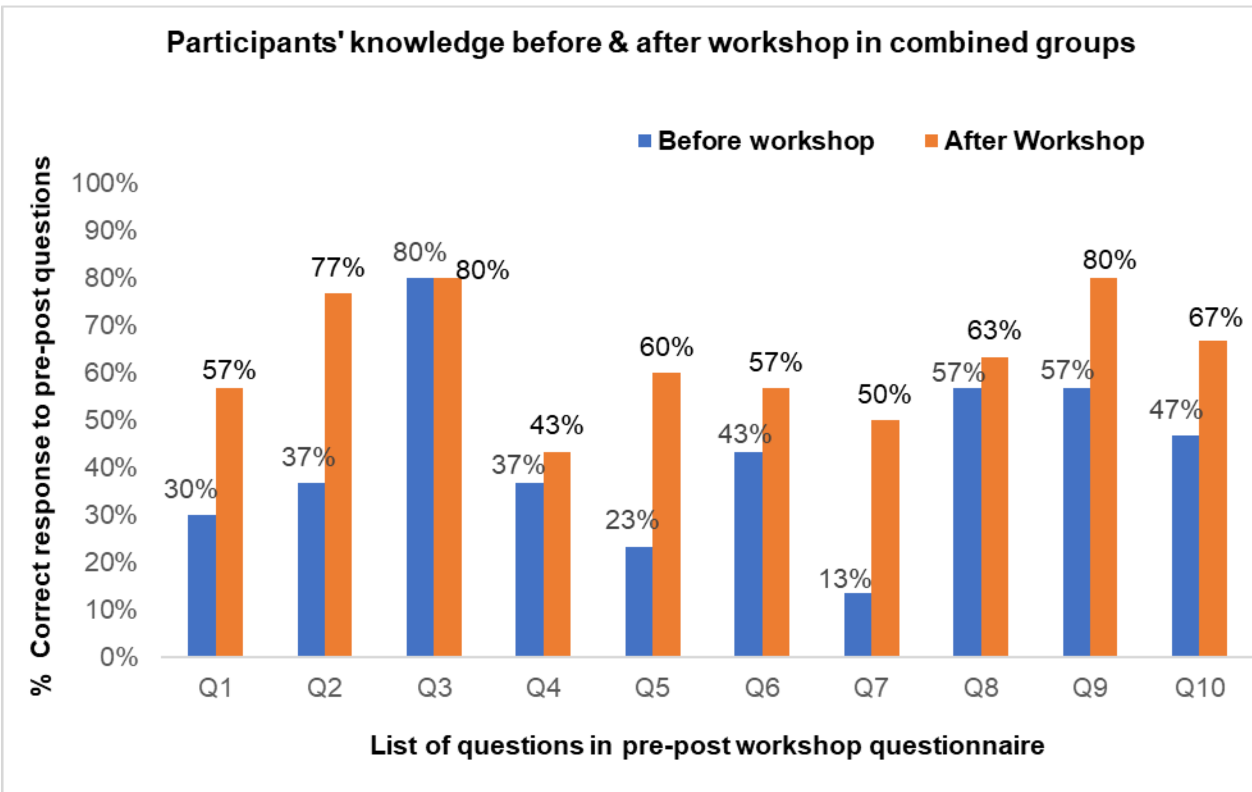


Figure 21: Percentage of participants' correct response to 10 questions before and after workshop in combined groups

A paired-sample t-test analysis results indicated a statistically significant mean score difference within participants of the combined groups in their pre and post workshop knowledge concerning autism and driving ($t(26) = -5.30$, $p = 0.01$). The result further indicated that the mean score of participants' after workshop knowledge ($M = 7.04$, $SD = 1.80$) was significantly higher than the mean score of their knowledge before the workshop ($M = 4.74$, SD 1.58). From the result, we can infer that participants showed better knowledge after the workshop than in the pre-workshop. This result refers that the workshop may significantly impact participants' knowledge concerning autism and driving.

Knowledge difference on autism and driving between group one and group two

We employed an independent samples t-test to determine whether there was a difference in the mean score of participants' knowledge concerning driving and autism before and after the workshop among group 1 and group 2. The mean score of participants' knowledge in group 2 (M = 4.47, SD = 1.55) for before the workshop was statistically no difference than the mean score (M = 5.08, SD = 1.62) participants' knowledge in group 1 (t(25) = 1.01, p = 0.32). Unlike the independent sample t-test result in before the workshop, the mean score of participants' knowledge after the workshop in group 2 (M = 8.00, SD = 1.31) was significantly higher than the mean score of participants' knowledge (5.83, SD = 1.27) in group 1 (t(25) = -4.33, p = 0.001).

4.9.2. Discussion

This case study aimed to assess the knowledge difference among participants concerning autism and driving before and after the workshop. More specifically, the assessments were conducted to see the knowledge difference between pre-workshop and post-workshop among participants in group 1, group two, and combined. Moreover, examining the differences between group 1 and group 2 in their knowledge during pre-workshop and post-workshop was carried out.

The overall result showed that the workshop brought significant improvement in participants' knowledge of autism and driving after completing the workshop. In group 1, although the change was not significant, a slight improvement was observed after the workshop. Unlike group 1, participants in group 2 showed a significant improvement from pre-workshop to post-workshop. The knowledge difference of all participants (combining groups 1 and 2) before and after the workshop was significantly improved.

Participants in group 1 and group 2 were not significantly different in their knowledge concerning autism and driving before the workshop. However, they differed in their knowledge after the workshop, i.e., participants in group 2 knew better than participants in group 1. After correcting the questionnaires from the feedback on the first day, we noticed that some participants gave correct responses to nearly all questions. Moreover, on the first day, some participants were in a hurry when filling out the questionnaire because they had to leave. Therefore, we allowed more time to fill out the questionnaire on the second day. We also read and explained all questions in class to avoid language problems or that participants wanted to complete the questionnaire quickly (and consequently inaccurately). As a result, we saw that the scores for those on the second day improved significantly better than the participants' scores on the first day. We recommend reading the questions aloud in the future to achieve more reliable results.

4.10. Case study 4B: Evaluation of the workshop

4.10.1. Results

Data evaluation workshop

After the workshop, participants filled out an evaluation questionnaire. The results in part two are divided into three sub-parts. The first part shows the scores for all participants per question. The second part gives an overview of the mean scores per question (including the minimum and maximum scores and the standard deviations). The third part briefly addresses the qualitative data. An independent samples t-test was used to compare whether the mean scores on the different sub-questions differed between groups one and two, but no significant differences were observed. Therefore, it can be assumed that both groups similarly evaluated the workshops. As a result, only the combined data (group one and group two together) was discussed in this part.

Percentage scores per question

From the Figure 22, it can be seen that more than 90% of the participants gave a score of 5 (the maximum score) on 9 out of 13 questions.

These questions are:

1. Before participating in this workshop, were its objectives, content, & methods clear to you?
2. Are the workshop objectives clear to you now after participating?
5. How appropriate was the workshop's content given your prior learning and knowledge level?
6. Were the learning methods used appropriately?
7. How would you judge the trainers' overall contribution?
8. Were the materials/media used appropriately?
9. Was the workshop well organized?
10. Are you satisfied with the quality of the workshop?
13. How likely will your institution/employer benefit from your participation in the activity?

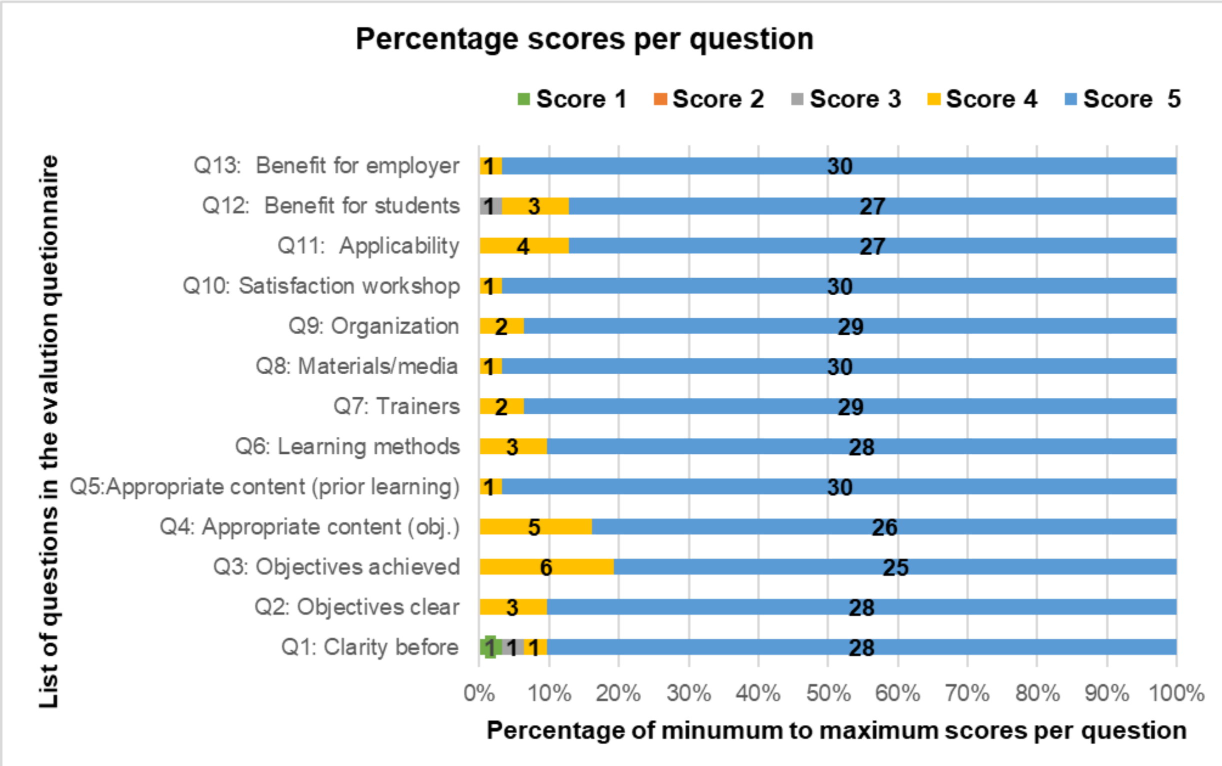


Figure 22: Participants' percentage score per question

Only 2 of the 13 questions received a score of 5 from over 85% of the participants. These questions are:

11. How likely is it that you will apply what you have learned?
12. How likely will your students benefit from your participation in the activity?

Only 2 of the 13 questions received a score of 5 from more than 80% of the participants. No question received a score of 5 from less than 80% of all participants. These questions are:

3. To what extent were the workshop objectives achieved today?
4. Given the workshop's objectives, how appropriate was the workshop's content?

Except for two questions, participants gave a minimum score of 4 out of 5. Question 1: "Before participating in this workshop, were its objectives, content, and methods clear to you?" received a score of 1 out of 5 from one participant and 3 out of 5 from one participant. However, the participants did not further clarify why they gave these lower scores in the qualitative part of the questionnaire. One participant scored 3 out of 5 for question 12: "How likely will your students benefit from your participation in the activity?" He, too, did not provide any further explanation in the qualitative part of the questionnaire.

Overview of the mean scores per question

From the Table 29 below, it can be seen that participants gave a mean score of 4.95 or higher on 4 of the 13 questions. 4 of the 13 questions had a mean score of 4.90 to 4.94. 4 of the 13 questions had a mean score of 4.80 to 4.89. Only one question (regarding clarity of objectives for the workshop) had a mean score of 4.77.

Table 29: The mean, Standard deviation, minimum and maximum scores per question

No	Workshop components	Minimum	Maximum	Mean	Std. Deviation
1.	Clarity before	1	5	4.77	0.81
2.	Objectives clear	4	5	4.90	0.30
3.	Objectives achieved	4	5	4.81	0.40
4.	Appropriate content (obj.)	4	5	4.84	0.37
5.	Appropriate content (prior learning)	4	5	4.97	0.18
6.	Learning methods	4	5	4.90	0.30
7.	Trainers	4	5	4.94	0.25
8.	Materials/media	4	5	4.97	0.18
9.	Organization	4	5	4.94	0.25
10.	Satisfaction workshop	4	5	4.97	0.18
11.	Applicability	4	5	4.87	0.34
12.	Benefit for students	3	5	4.84	0.45
13.	Benefit for employer	4	5	4.97	0.18

Qualitative data

After completing the quantitative part of the questionnaire, participants were also asked to give their additional opinions about the workshop. Overall, we received excellent responses. The participants did not provide any points for improvement on the following items:

- Clarity of the workshop content
- Workshop delivery methods
- Organization of the workshop
- Activities in the workshop

One participant indicated that the objectives should be explained more at the beginning of the workshop. In terms of material, four participants from group 1 indicated that more videos should be included in the workshop. On the second day, more videos were shown, and no one mentioned this as a point for improvement on the second day. In total, 29 out of 31 participants indicated that they found the workshop good to excellent and that it will help them in their future careers as driving school instructors. Finally, 5 out of 31 instructors indicated that they would like to attend similar workshops in the future.

6.10.2. Discussion

This workshop for driving instructors on autism and driving was the first of its kind to be offered in the state of Qatar. Overall, the workshop was received well by both the driving instructors and the course facilitators. Except for one question, the average satisfaction scores were between 4.80 and 4.97 out of 5. Only in the area of objectives clarity in advance, the average score was 4.77. We recommend that the objectives shall be made clear before the workshop starts.

Regarding the open-ended questions, 29 out of 31 participants indicated that they found the workshop good to excellent. They further indicated that it will help them in their future careers as driving school instructors. Finally, based on the qualitative feedback from the participants on the first day, it was decided to add more videos to the PowerPoint. The participants considered this positive as none of the participants from the second day indicated this as an area for improvement.

Based on the participants' and the trainers' feedback, the PowerPoints and manual were modified to provide the best possible training in the future. In this way, individuals within KDS will also be able to provide similar training in the future to train even more driving school instructors, so they are also able to guide autistic individuals when they learn to drive. This workshop was a crucial step towards more inclusion for autistic individuals to improve their daily lives and to ensure that they are provided with the same opportunities as non-autistic individuals.

4.11. Case study 4C: Assessment of the effectiveness of the instructor's training module

4.11.1. Results

Assessment Phase

Descriptive data showed that driving instructors average age and driving experience in the assessment phase was M = 44.3 with SD = 9 and M = 6.90 with SD = 5.79 respectively (see Table 30). Based on driving instructors' responses to the question, "as a driving instructor, do you have any experience giving driving instructions to autistic trainees?" only 3 out of 50 driving instructors responded that they had experience instructing trainees with autism. However, the remaining surveyed driving instructors indicated they had no prior knowledge about autism.

Training phase

The results of a paired-sample t-test indicated a statistically significant sum score difference between driving instructors' knowledge on autism and driving before and after the training workshop ($t(29) = -5.67$, $p = 0.000$). The result further indicated that the sum score of driving instructors' post-workshop knowledge ($M = 6.87$, $SD = 1.68$) was significantly higher than the sum score of their knowledge in the pre-workshop ($M = 4.67$, $SD = 1.47$). As a result, it can be reported that driving instructors had more knowledge on autism and driving after the workshop than they had before the workshop.

Practice phase

Independent sample t-test analysis result showed that trained instructors scored significantly higher on the 28-item checklist related to autism tailored practices when teaching autistic trainees ($t(5) = 9.26$, $p = .000$) (see Table 30 & 31). As for the scores of autistic trainees group on the 28-item checklist, an independent sample t-test analysis indicated that the sum score of trainees in the experimental group was significantly higher than trainees in the control group on the autism-tailored practices ($t(4) = 7.84$, $p = .001$) (Table 30 & 31).

Concerning the other assessment instruments (i.e., DAS-SR, PSS-10 and DCQ) for the autistic trainees, independent sample t-tests were conducted to compute the differences between the experimental and control groups on attitude toward driving, perceived stress related to driving training, and driving concerns.

In the case of attitude toward driving (DAS-SR) independent sample t-tests analysis showed that the scores of the autistic trainees in the experimental group were significantly higher than the scores of autistic trainees in the control group on (positive attitudes toward talking about driving ($t(4) = 3.00$, $p = .04$); positive attitudes toward getting ready to drive ($t(4) = 6.33$, $p = .003$); and positive attitudes toward when driving ($t(4) = 7.00$, $p = .002$)) (Tables 30 & 31).

Compared to the autistic trainees in the control group, based on the mean scores in PSS-10 sub-scales, autistic trainees in the experimental group experienced significantly less lack of self-efficacy ($t(4) = 3.88$, $p = .018$) and insignificant but less perceived helplessness ($t(4) = .92$, $p = .41$) (Table 30 & 31).

Table 30: Descriptive statistics of measures in the assessment, training and practice phases

Phases	Measures		Mean		SD	
Assessment phase	Age		44.3		9	
	Experience as instructors		6.9		5.79	
Training phase	Measures		Pre-training workshop		Post-training workshop	
	Instructors' knowledge about autism and driving before and after training		Mean	SD	Mean	SD
			4.67	1.47	6.87	1.68
Practice phase			Experimental group		Control group	
	Measures		Mean	SD	Mean	SD
	Instructors' practice: instructors' responses		28.33	1.53	18.50	1.29
	Instructors' practice: Trainees' responses		24.33	1.53	15.67	1.15
	DAS-SR	Positive attitude toward talking about driving	2.39	.35	1.33	.50
		Positive attitude toward getting ready to drive	2.72	.25	1.72	.10
		Positive attitude toward when driving	2.44	.10	1.67	.17
	PSS-10	Perceived helplessness	1.22	.25	1.78	1.02
		Lack of self-efficacy	.58	.29	1.75	.43
	DCQ	Panic concerns	.14	.14	1.19	.33
		Accident concerns	.90	.64	1.24	1.16
		Social concerns	.39	.53	1.61	.25

With regard to the driving concerns (DCQ), the independent samples t-tests analysis showed that the mean scores of the autistic trainees in the control group were significantly higher than the scores of the autistic trainees in the experimental group on panic-concern ($t(4) = 505$, $p = .007$), social-concern ($t(4) = 3.57$, $p = .023$), insignificant but higher in accident-concern ($t(4) = .43$, $p = .67$)) (Tables 30 & 31).

Table 31: Independent samples t-tests and paired sample t-test analyses of group differences

Phases	Measures		Within group (Paired-sample t-test analysis)		
			Dfs	*t*	*P (2-tailed)*
Training Phase	Instructors' knowledge about autism and driving before and after training		29	-5.67	0.000
	Measures		Between autistic and non-autistics (Independent sample t-test)		
			Dfs	*t*	*P (2-tailed)*
Practice phase	Instructors practice	Instructors' responses	5	9.26	.000
		Trainees' responses	4	7.84	.001
	DAS-SR	Positive attitude toward talking about driving	4	3.00	.04
		Positive attitude toward getting ready to drive	4	6.36	.003
		Positive attitude toward when driving	4	7.00	.002
	PSS	Perceived helplessness	4	.92	.41
		Lack of self-efficacy	4	3.88	.018
	DCQ	Panic-related	4	5.05	.007
		Accident-related	4	.43	.69
		Social concerns	4	3.57	.023

4.11.2. Discussion

This study attempted to address three main objectives: (1) assess driving instructors' knowledge regarding autism and driving, (2) evaluate driving instructors' knowledge before and after the training workshop, and (3) compare instructors' teaching-to-drive process for autistic trainees. These objectives were addressed phase-wise: (1) the assessment phase, (2) the training phase, and (3) the practice phase. Findings from each stage will be discussed below based on their respective phase.

Assessment phase

Driving instructors' awareness of specific characteristics of autistic individuals and how they may affect the learning-to-drive process (both theoretically and practically) may enable instructors to use customized methods that enhance learning effectiveness (Almberg et al., 2017). Moreover, the lack of knowledge about autism among driving instructors is a barrier to obtaining a driving license for autistic individuals (Lindsay, 2017). Consequently, such a gap in knowledge and experience may result in more autistic people experiencing challenges and discomfort during the learning-to-drive process (Tyler, 2013) and not even start driving lesson at all. In the current study's *assessment phase,* except for three instructors, none of the surveyed participants reported that they had prior knowledge and experience about autism and driving. These knowledge and experience gaps about how to deal with autistic trainees might result in instructors that they do not use techniques that are tailored to the needs of autistic people. In this case, it can be argued that overcoming the knowledge gap about autism and driving among driving instructors may help them tailor their training lessons to the needs of autistic trainees.

Training phase

In a study by Lindsay (2017), driving instructors indicated that teaching autistic individuals how to drive can be challenging. Moreover, instructors who participated in a study by Tyler (2013) advocated for alternative strategies to enhance the learning-to-drive process for autistic trainees. The same findings were found in a study by Ross, Jongen, et al. (2018), where some of driving instructor participants were in favour of driving lessons have to be tailored to the needs of autistic trainees. However, driving instructors can be challenged to make a decision on suitable techniques that are tailored to the autistic trainees' needs. In this regard, further support is required to increase the awareness of driving instructors (Lindsay, 2017). In the current study, *a training phase* was provided to improve instructors' knowledge and practice regarding autism and driving. The training phase findings showed that instructors significantly enhanced their knowledge of autism and driving after they completed the training workshop. Such awareness and being trained instructors may contribute to them applying customized strategies during driving lesson to the autistic trainees. For example, in a study by Myers et al. (2019), trained or specialized driving instructors indicated that the driving training approaches should be customized to the training demands of autistic trainees. In this regard, Wilson et al. (2018) also recommended that an effective training program is required to enhance the learning-to-drive process.

Practice phase

Driving instructors are an essential resource to provide learning-to-drive support for individuals in driving training, so they can develop safe driving skills (Myers et al., 2021), and to reduce potential difficulties in driving (Ross, Cox, Reeve, et al., 2018). Autistic individuals may face difficulties in driving due to the possibility that their autism characteristics negatively interfere with their learning-to-drive process (Cox et al., 2017). Such challenges in obtaining driving licenses can be minimized using appropriate support from driving instructors (Lindsay, 2017). In this case, instructors need to use a more tailored approach for autistic trainees to achieve better results in the driving training (Tyler, 2013). Hence, specialized or trained driving instructors are important to implement an autistic trainees' tailored learning-to-drive process

(Myers et al., 2019). In the current study's *practice phase,* we looked at the teaching-to-drive process of trained and non-trained instructors. Compared to non-trained instructors, trained instructors showed better practices based on handling the learning-to-drive process for autistic trainees. This difference between the two instructor groups could be attributed to the training workshop and reading the practical guide presented to the instructors who were assigned to teach trainees in the experimental group.

As part of the practice phase, autistic trainees instructed by trained and non-trained instructors were compared in their attitude toward driving (DAS-SR), perceived stress related to driving training (PSS-10), and concerns associated with driving (DCQ). Based on the autistic trainees' experiences, the learning-to-drive processes for the control and experimental groups were likely different in the current study. For example, as showed below, autistic trainees in the experimental group showed a better attitude toward driving, experienced less perceived stress related to the driving training, and had less driving panic concerns and social concerns than autistic trainees in the control group. Instructors who knew how to deal with autistic trainees, as indicated in Tyler (2013), could apply customized strategies (e.g., breakdown of tasks into components, communication rapport, repetition in practice) that helped to reduce training difficulties (e.g., anxiety) among autistic trainees.

Based on the results of the DAS-SR, autistic trainees in the experimental group reported a more positive attitudes toward talking about driving, getting ready to drive, and when driving compared to these in the control group'.. An explanation for these differences could be that experimental group instructors' knowledge about autism and driving and the tips they received on how to teach autistic trainees, might have helped them to better tailor their lessons to the individual demands of the autistic trainees. Individualized driving training instructions can contribute to autistic trainees experiencing a more positive training experience (Almberg et al., 2017). As reflected in this study, a lack of knowledge on how to tailor a driving lesson to the needs of autistic trainees may make driving instructors unaware of what factors (e.g., cognitive overloading) can contribute to autistic trainees experiencing discomfort. For example, Dirix et al. (2022) indicated that when autistic individuals' sensory is overloaded during driving, it can lead to them experiencing anxiety, frustration, and stress.

In the current study, compared to autistic trainees in the control group, based on results of DCQ, autistic trainees in the experimental group reported fewer panic and social driving concerns. Customized training sessions given by the trained instructors can be a possible reason for less driving concern experiences (i.e., panic and social concern) reported by trainees in the experimental group than trainees in the control group. Similarly, in a study by Tyler

(2013), an autistic trainee, trained by an instructor who applied an autism-tailored strategy, showed calmed, relaxed, and remained focused throughout the driving.

Emotion dysregulations (e.g., increased anxiety while driving) can challenge autistic individuals to pass the driving license test Chee et al. (2015). In the current study, in the case PSS-10, autistic trainees in the experimental group showed less lack of self-efficacy than autistic trainees in the control group. Such a difference might be found because autistic trainees that received training from trained instructors were better mentored and as a result were more confident about their driving skills. For example, in a study by Tyler (2013), the instructor employed 'what if?' scenarios to improve the trainee's understanding of unpredictable road users by exposing him to a broader range of traffic situations. As Tyler, such a strategy helped the trainee build his mental archive of 'what ifs?' which contributed greatly to the trainee developing more confidence and less anxiety in his driving performance.

5. Potential Beneficiaries

Below we presented the potential beneficiaries in two sections including the communication and exploitation of results; social, health, economic and environmental impact.

5.1. Communication and exploitation of results

The deliverables of this project are very valuable in practice, especially the developed evidence based practical guide or booklet to help driving instructors to make their lesson tailored to the training needs of trainees with autism (please refer to Appendix A). In this regard, the deliverables help the planning of driving training program for trainees with autism in driving schools in Qatar and countries in the Gulf region. Furthermore, the developed one-day training manual (please refer to Appendix B) can be utilized by driving schools to train their driving instructors about how to tailor their lesson to the needs of trainees with autism. The significance of the developed guide is directed towards improving the ‘day-to-day’ lives of Qatari and residents including individuals with ASD and their families, economically, socially, and with respects to their quality-of-life

The following entities in Qatar will directly benefit from the deliverables of this project:

1. Driving Schools (Karwa Driving School, Dallah Driving Academy, etc.)
2. Shafallah Center for Children with Special Needs
3. Hamad Medical Corporation (as well as all private medical and mental health institutions)
4. Ministry of Transport and Communication
5. Ministry of the Interior (Traffic Department)

6. Ministry of Education and Higher Education
7. The ASD community
8. Academic institutions for individuals with autism

5.2. Social, health, economic, and environmental impact

The project will have a substantial impact in several areas. First, by distributing the developed evidence based practical guide, we expect that more people with ASD will be able to attend a driving training to obtain a driving license, hereby enhancing their level of autonomy as they will not be dependent on friends and family anymore for their transportation needs. Second, the project comes with an economic impact as more people with ASD will be able to obtain a driver's license, and consequently, more people will be able to pursue vocational goals. Furthermore, the driver instructors will be able to attract more learner drivers who experience difficulties with learning how to drive due to their ASD diagnosis. Third, the utilization of driving simulators in traffic safety and operation studies in Qatar is quite novel and it will significantly enhance the understanding of driver behavior in specific target groups such as people with ASD. Driver instructor training module is novel and expected to have a national, and regional practical and scientific impact regarding autism and driving. The study's results can be evidence to driving schools (e.g., KDS) in Qatar to establish tailored training program that may attract more autistic students to the driving school. Having well-trained instructors in a specific driving school may result in parents being more eager to send their children to this driving school. The results of this project also have the potential to impact practitioners and policy makers. The results could lead to changes in the driver education curriculum in order to better fit the specific needs of learner drivers with ASD. Furthermore, possible safety countermeasures can be developed based on this project, for instance, regarding distraction, emotion, and hazard perception.

6. Recommendations

Based on the outcome of the project, the recommendation section is divided into two sub sections i.e., the recommendations provided for future research in the area autism and driving, and the recommendations provided for creating a new driving training program tailored to trainees with autism in driving school in the state of Qatar.

6.2. Practical implication on driving training for trainees with autism

1. Th results of our studies showed that parents indicated that their children with autism face difficulties with multitasking in driving, as well as with concentration, violation of traffic rules, and inability to predict other road users' behavior. More in detail, parents mentioned that their children faced challenges in performing the following specific driving tasks, including smooth steering, going straight, smoothing acceleration and deceleration,

crossing streets, active use of a mirror, changing lanes, keeping lane positioning, noticing changes in the traffic situation, responding to visual signs, predicting traffic behavior. Concerning autistic individuals who have not yet been licensed, parents are not interested in sending them to a driving school because they are afraid that their children may face danger while driving. Therefore, working toward an evidence-based and better-tailored strategy (e.g., applying the current project training program) to teach those drivers with autism can be a solution to reduce such adverse effects of autism on individual mobility.

2. Currently individuals with autism in driving Schools in Qatar receive a driver training in a "conventional" way, the instructional methodology is the same across all trainees regardless of their difference (e.g., individual with autism and without autism. In this regard, we recommend to introduce our training program (based on the evidence-based manual) for driving instructors who can give driving training that is more tailored toward the needs of autistic individuals
3. The results of the project's study established that driving school instructors in Qatar self-declared that they lack knowledge and practice concerning giving training to autistic individuals. These knowledge and experience gaps about how to deal with autistic trainees might result in instructors that they do not use techniques that are tailored to the needs of autistic people. In this case, therefore, overcoming the knowledge gap about autism and driving among driving instructors helps them tailor their training lessons to the needs of autistic trainees.
4. Driving schools in Qatar do not have a training program to their driving instructors to equip them with the knowledge and experience of how to customize their lesson to the training needs of trainees with autism. Therefore, we recommend that driving schools in Qatar to introduce our training package for driving instructors who can give driving training that is more tailored toward the needs of autistic individuals. In a more structured way, the training shall start from the need or knowledge gaps assessment, i.e., exploring prior driving instructors' knowledge about autism and driving. Once such gaps are assessed, the next step can be providing training (i.e., using an evidence-based training manual developed for the current study) to instructors to help them to customize and individualize their instructions and techniques to the autistic trainees' needs. A follow-up on customizing a driving lesson shall also be taken to improve service for prospective autistic trainees.
5. According to our studies outcomes, autistic individuals believe that driving is an essential skill to fulfill day-to-day activities associated with mobility in the state of Qatar. If autistic individuals can drive independently, they can manage their mobility without experiencing the social anxiety resulting from social interaction while using public transport in Qatar.

Although driving is necessary for autistic drivers, many frequently experience negative feelings (e.g., stress and panic while driving). Such feelings are more pronounced among drivers with autism than among non-autistic drivers. Moreover, the attitude of autistic drivers toward driving is more negatively oriented than non-autistic individuals. In this respect, the learning-to-drive process for individuals with autism in Qatar should consider ways to reduce the negative condition they experience while driving as well as getting training. Therefore, the implementation of the training program developed in this project can help to produce trained driving instructors, who know the impact of autism on the process and how to customize driving lesson to needs of trainees with autism,

6.1. Recommendation on future research

- ✓ Traffic police play an essential role in testing the driving skills of driving trainees. Thus, they determine the driving test passing rate and obtaining of a license of those in driving training. In this respect, as we did for driving instructors, the traffic police's knowledge about autism and their experience with testing autistic trainees should receive attention in future studies.
- ✓ The sample size, especially the autistic trainees and instructors, was very small while validating the evidence-based training manual. The cost associated with the driving training was the main reason for not including more participants. For this study, autistic trainees were registered in the KDS as learner drivers, and the expensive cost of their training was covered by the KDS as a collaboration to facilitate their learning-to-drive process. Therefore, it is essential to include a representative sample size in the future studies.
- ✓ In this project, we employed a range of instruments that measure both subjective and objective data. These instruments include several self-report questionnaires, driving simulator, E4-wristband, and Tobii eye tracking system. In this respect, to advance our understanding about autism and driving, it is important to integrate the driving simulator with other additional instruments. For example, head (Elektro-EncefaloGram EEG) and heart (Elektro-CardioGram ECG) sensors for mental and psychological monitoring of the drivers such as, distraction, attention, fatigue, drowsiness, and concentration loss etc. as shown in (Figure 23).

Figure 23: The electroencephalogram (EEG) sensors used for studying drivers' fatigue (Ma et al., 2018)

6.2 Recommendation on the implementation of the evidenced based-training program to the Gulf region and traffic police

1. The project only focused on driving instructors to improve the learning-to-drive process for trainees with autism. However, it did not address the traffic police, who play an essential role in the driving test passing rate and obtaining a license. In KDS, the driving test is handled by the traffic police department, which is different from the driving training department with which we collaborated to conduct the project. In this regard, we could not perform all phases we did on driving instructors to traffic police to help them about how to approach autistic trainees during the driving test. Therefore, to ensure the long-term effectiveness of this training program, traffic police (responsible for carrying out the driving test for trainees) should be targeted to receive the training package regarding how to approach driving test takers with autism.

2. Except for KDS, all driving schools (including private driving schools) in Qatar do not have information about this innovative and evidence-based driving training program for trainees with autism. Thus, awareness creation tasks are required to introduce such a program in those driving schools to help their driving instructors tailor their lessons to the needs of trainees with autism. Implementing this evidence-based training program should also go beyond driving schools in Qatar. Therefore, a plan is required to create awareness about this program among driving schools in the Gulf region. Such an effort may increase interest among those driving schools in the Gulf to introduce this program to their driving instructors.

7. Conclusions

The conclusions are provided in three sections. The first section focuses on the conclusions made based on the outcome of the project. In the second section a list of deliverables according to the approved proposal by QNRF are provided, while in the last section the scientific outcomes of the project are listed.

7.1. Concluding statements

The list of concluding statements is provided based on different case studies considered in the project.

- Participants with autism believe that driving is an essential skill to fulfil day-to-day activities associated with mobility in the state of Qatar.
- Although driving is necessary for autistic drivers, many frequently experience negative feelings (e.g., stress and panic while driving). Such feelings are more pronounced among drivers with autism than among non-autistic drivers. Moreover, the attitude of autistic drivers toward driving is more negatively oriented than non-autistic individuals.
- Participants autistic drivers faced difficulties associated with driving activities in terms of driving performance. Some examples are: driving on a new or busy traffic routes and passing through dark environments, unexpected traffic situations, long-distance driving, staying focused without being distracted by their thoughts and the environment, and tolerating auditory over-stimulation (e.g., car horns), visual and cognitive over-stimulation.
- Participants with autism reported that they have to make an extra effort (compared to a non-autistic peer) while driving. The reasons for making an extra effort by autistic individuals include properly managing the gas pedal, keeping the fear associated with driving to a minimum, and staying focused and calm while driving.
- Moreover, in the simulated studies, autistic individuals showed more deviation from the ideal roadway position and more incorrect lane changes. They also experienced more stress and showed greater mistakes on other concurrent driving tasks than non-autistic people. More in detail, these differences are observed when they drive while engaging in other activities of different complexity levels (e.g., responding to passengers' questions ranging from simple to complex conversations) in a simulated environment. Moreover, autistic individuals showed higher crashes, riskier approaches to the front car, higher speed nearby hazards, and unstable speed variations compared to non-autistic individuals.
- Parents indicated that their autistic children face difficulties with multitasking in driving, as well as with concentration, violation of traffic rules, and inability to predict other road users' behavior. More in detail, parents mentioned that their children faced challenges in performing the following specific driving tasks, including smooth steering, going straight, smoothing acceleration and deceleration, crossing streets, active use of a mirror,

changing lanes, keeping lane positioning, noticing changes in the traffic situation, responding to visual signs, predicting traffic behavior.

- Concerning autistic individuals who have not yet been licensed, parents are not interested in sending them to a driving school because they are afraid that their children may face danger while driving. Working toward an evidence-based and better-tailored strategy to teach those drivers with autism can be a solution to reduce such adverse effects of autism on individual mobility.
- Driving school instructors in Qatar self-declared they lack knowledge and practice concerning training autistic individuals. Consequently, instructors often apply the same training to all driving students. For example, some driving instructors from Mowasalat's Karwa Driving School were surveyed about their knowledge and practice related to autistic individuals in the context of driving. It was noted that almost none of them had prior knowledge about autism.
- Due to the absence of autism-tailored driving lessons, instructors may lack the expertise skills to quickly notice learner drivers with autism characteristics and fail to apply the required instruction according to those students' demands.
- Participant instructors, who received the training workshop based on the evidence-based material, showed significantly better knowledge about autism and driving after the training workshop than before the workshop.
- Driving instructors who received training and read the practical guide materials showed better tailored their lessons to autistic trainees' needs than instructors who did not receive information about autism and driving.
- Based on the autistic trainees' experiences, the learning-to-drive processes for the control and experimental groups were likely different regarding their driving attitude, training related to perceived stress, and driving concerns.
- Autistic trainees in the experimental group, who received training from the trained instructors, reported a more positive attitude toward talking about driving, getting ready to drive, and when driving than autistic trainees in the control group.
- Autistic trainees in the experimental group indicated less panic concern and less social concern associated with driving than autistic trainees in the control group.
- As compared to the control group, autistic trainees in the experimental group reported less lack of self-efficacy.

7.2. List of deliverables achieved in the project

Table 32:List of deliverables achieved in the project as per approved proposal by QNRF

Deliverable title	Type of deliverable	Delivery date	Status
Developed questionnaires for the assessment of driving difficulties in Young adults with ASD	Report	Month 9	Achieved and attached as an Appendix – H
Validated psychological reliable measures for young adults with ASD on the Qatari cultural context	Publications and Report	Month 13	Achieved and attached as an Appendix – I
Norms of psychological characteristics of the Qatari youth with ASD	Publications and Report	Month 13	Achieved and attached as an Appendix – J
Simulated driving scenarios to assess driving capabilities in people with an autism spectrum disorder (ASD).	Comprehensive Summary of experimental scenarios, along a soft copy of the scenarios.	Month 23	The summary is in Appendix – K. The driving scenarios are not attached here because the files are very large and to open them STISIM Drive 3 is required.
Prototype training modules for driving instructors	Report	Month 34	Achieved and attached as an Appendix – A
Information folder	Folder (and downloadable .pdf)	Month 34	Achieved and attached as an Appendix – B
Validated training modules and scientific output for driver instructors to improve driving in adults with ASD	Publications and Report	Month 41	Achieved and attached as an Appendix - E

7.3. Practical and Scientific outcomes of the project

This section presents the summarized list of practical and scientific outcomes of the project, as included in a separate appendix file of this report. It consists of the practical manual (the main outcome of the project) and scientific outputs.

Booklet, training manual and PowerPoints

1. Alhajyaseen, W., Dirix, H., Mamo, W., Ross, V., Brijs, K., Brijs, T., Soliman, A., Hussain, Q. (2022). Autism and driving in Qatar: A practical guide for the learning process of autistic drivers.

2. Alhajyaseen, W., Dirix, H., Mamo, W., Ross, V., Brijs, K., Brijs, T., Soliman, A., Hussain, Q. (2022). Autism and driving in Qatar: Educational material guide for a one-day workshop

3. Alhajyaseen, W., Dirix, H., Mamo, W., Ross, V., Brijs, K., Brijs, T., Soliman, A., Hussain, Q. (2022). Autism and driving in Qatar: PowerPoint collections for a one-day workshop

Published Journal

4. Timmermans, C., Alhajyaseen, W., Soliman, A., Brijs, T., Bedair, K., & Ross, V. (2020). Effect of ADHD traits in young drivers on self-reported deviant driving behaviours: an exploratory study in the Arab gulf region. *Journal of Transport & Health*, *17*, 100857. https://doi.org/10.1016/j.jth.2020.100857
5. Dirix, H., Ross, V., Brijs, K., Vermeiren, E., Timmermans, C., Alhajyaseen, W., ... & Spooren, A. (2021). The appraisal of roadway environment and infrastructure by drivers with autism: A qualitative study. *Transportation research part F: traffic psychology and behaviour*, *78*, 280-298. https://doi.org/10.1016/j.trf.2021.01.016
6. Almallah, M., Hussain, Q., Reinolsmann, N., & Alhajyaseen, W. K. (2021). Driving simulation sickness and the sense of presence: Correlation and contributing factors. *Transportation research part F: traffic psychology and behaviour*, *78*, 180-193. https://doi.org/10.1016/j.trf.2021.02.005
7. Ross, V., Reinolsmann, N., Lobbestael, J., Timmermans, C., Brijs, T., Alhajyaseen, W., & Brijs, K. (2021). Relating Reactive and Proactive Aggression to Trait Driving Anger in Young and Adult Males: A Pilot Study Using Explicit and Implicit Measures. *Sustainability*, *13*(4), 1850. https://doi.org/10.3390/su13041850
8. Dirix, H., Ross, V., Brijs, K., Bertels, L., Alhajyaseen, W., Brijs, T., Wets, G., & Spooren, A. (2022). Autism-friendly public bus transport: A personal experience–based perspective. *Autism*, *0*(0). https://doi.org/10.1177/13623613221132106
9. Dirix, H., Brijs, K., Huysmans, E., Neven, A., Brijs, T., Jongen, E., ... & Ross, V. (2022). Experiences with licensing by autistic drivers: An exploratory study. *Procedia Computer Science*, *201*, 330-337. https://doi.org/10.1016/j.procs.2022.03.044
10. Mamo, W. G., Ross, V., Alhajyaseen, W. K., Reinolsmann, N., & Brijs, K. (2022). A study on the determinants of Ethiopian minibus taxi drivers' speeding behaviour: An application of the 'major theorists' model. *Procedia Computer Science*, *201*, 189-196. https://doi.org/10.1016/j.procs.2022.03.027

Under-Review & Ready for Submissions

11. Mamo et al., (2022). Speeding attitudes, perceived safe speed behavioral control, and speed associated traffic fines among Ethio-Telecom drivers in Ethiopia **(Submitted*)***
12. Enhancing the learning-to-drive process for autistic trainees in Qatar. *Transportation Research Procedia World Conference on Transport Research - WCTR 2023 Montreal 17-21 July 2023*
13. Driving distraction among autistic individuals: a simulator study using LCT and n-back test

Poster presentations

14. Alhajyaseen, W., Timmermans, C., Soliman, A., Brijs, T., Bedair, K., Ross, V., & Mamo, W. G. (2021). Impact of Attention Deficit Hyperactivity Disorder on Driving among Drivers in Qatar. http://hdl.handle.net/10576/24375
15. Wondwesen Mamo, Wael Alhajyaseen, Kris Brijs, Dirix, H., Tom Brijs, Abdrabo Soliman, Qinaat Hussain, Cox Daniel, Veerle Ross. Exploring Driving Attitudes of Autistic Individuals in Qatar: A Comparison Study. Qatar University (QU) Annual Research Forum and Exhibition 2021. (DOI assignment is under process)
16. Wondwesen Mamo, Wael Alhajyaseen, Kris Brijs, Helene Dirix, Tom Brijs, Abdrabo Soliman, Qinaat Hussain, Cox Daniel, Veerle Ross. Exploring Driving Attitudes of Autistic Individuals in Qatar: A Comparison Study. Qatar University (*QU*) *Annual Research Forum and Exhibition 2022*. (DOI assignment is under process)
17. Timmermans, C., Alhajyaseen, W., Soliman, A., Helen Drix, K., Brijs, K, Brijs, T & Ross, V. (2020). *The level of self-reported ASD characteristics in a sample of male and female residents in the State of Qatar.* Conference name: The 1st Gulf Autism Conference (GAC 2020). Oral presentation.
18. Dirix, H., Ross, V., Brijs, K, Ellen, V., Chantal, T., Wael, A., Brijs, T., Geert, W., Annemie,. S., (2020). *A qualitative study into the appraisal of roadway environment and infrastructure by adult drivers with an Autism Spectrum Disorder.* 1st Gulf Autism Conference (GAC 2020). E-poster presentation

Papers in Preparations

19. Investigating aggressive driving behavior in autistic individuals in Qatar: A simulator study
20. Hazard perception skills of autistic drivers in Qatar: a simulator study
21. Parents' subjective evaluation of their autistic children's hazard perception skills
22. Adjusted AQ-10: whether this adjusted questionnaire is more sensitive and better suited to the female autistic community
23. Hazard perception skills of autistic children in the Jakarta metropolitan area
24. Prospective memory study: determine the relationship between the prospective memory and driving in autism

25. Lane Change Task in autistic novice drivers
26. Hazard perception in autistic novice drivers in Belgium
27. Systematic review

8. Bibliography

Almberg, M., Selander, H., Falkmer, M., Vaz, S., Ciccarelli, M., & Falkmer, T. (2017). Experiences of facilitators or barriers in driving education from learner and novice drivers with ADHD or ASD and their driving instructors. *Developmental neurorehabilitation*, *20*(2), 59-67. https://doi.org/https://doi.org/10.3109/17518423.2015.1058299

Alshaban, F. (2012). Effect of social and environmental factors on the prevalence of autism in Qatar. Qatar Foundation Annual Research Forum Volume 2012 Issue 1,

Alshaban, F., Aldosari, M., Al-Shammari, H., El-Hag, S., Ghazal, I., Tolefat, M., Ali, M., Kamal, M., Abdel Aati, N., & Abeidah, M. (2019). Prevalence and correlates of autism spectrum disorder in Qatar: a national study. *Journal of Child Psychology and Psychiatry*, *60*(12), 1254-1268. https://doi.org/https://doi.org/10.1111/jcpp.13066

American Psychiatric Association. (2013). Diagnostic and statistical classification of mental disorders. 5th edn Arlington. *VA: Author*.

Amr, M., Raddad, D., El-Mehesh, F., Mahmoud, E.-H., & El-Gilany, A.-H. (2011). Sex differences in Arab children with Autism spectrum disorders. *Research in autism spectrum disorders*, *5*(4), 1343-1350.

Andreou, E., Alexopoulos, E. C., Lionis, C., Varvogli, L., Gnardellis, C., Chrousos, G. P., & Darviri, C. (2011). Perceived stress scale: reliability and validity study in Greece. *International journal of environmental research and public health*, *8*(8), 3287-3298. https://doi.org/https://doi.org/10.3390/ijerph8083287

Angell, L. S., Auflick, J., Austria, P., Kochhar, D. S., Tijerina, L., Biever, W., Diptiman, T., Hogsett, J., & Kiger, S. (2006). *Driver workload metrics task 2 final report*.

Baarda, D. B., de Goede, M. P. M., & Teunissen, J. (2001). *Basisboek kwalitatief onderzoek: praktische handleiding voor het opzetten en uitvoeren van kwalitatief onderzoek* (Vol. 2). Stenfert Kroese Amsterdam, The Netherlands.

Babin, S. L., Hood, A. J., Jeter, C. B., & Sereno, A. B. (2006). Executive functions: eye movements and neuropsychiatric disorders. *Encyclopedia of Neuroscience (2009)*, *4*, 117-122.

Barnhill, G. P. (2007). Outcomes in adults with Asperger syndrome. *Focus on autism and other developmental disabilities*, *22*(2), 116-126. https://doi.org/https://doi.org/10.1177/10883576070220020301

Baron-Cohen, S. (1997). *Mindblindness: An essay on autism and theory of mind*. MIT press.

Baron-Cohen, S., Ashwin, E., Ashwin, C., Tavassoli, T., & Chakrabarti, B. (2010). Talent in autism: Hyper-systemizing, hyper-attention to detail and sensory hyper-sensitivity. *Autism and talent*, 41-51. https://doi.org/https://doi.org/10.1098/rstb.2008.0337

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, malesand females, scientists and mathematicians. *Journal of autism and developmental disorders*, *31*(1), 5-17.

Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S. A., Engel-Yeger, B., & Gal, E. (2009). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *Journal of autism and developmental disorders*, *39*(1), 1-11.

Bishop, H. J., Biasini, F. J., & Stavrinos, D. (2017). Social and non-social hazard response in drivers with autism spectrum disorder. *Journal of autism and developmental disorders*, *47*(4), 905-917. https://doi.org/https://doi.org/10.1007/s10803-016-2992-1

Booth, R., & Happé, F. (2010). "Hunting with a knife and… fork": Examining central coherence in autism, attention deficit/hyperactivity disorder, and typical development with a linguistic task. *Journal of experimental child psychology*, *107*(4), 377-393.

Booth, T., Murray, A. L., McKenzie, K., Kuenssberg, R., O'Donnell, M., & Burnett, H. (2013). Brief report: An evaluation of the AQ-10 as a brief screening instrument for ASD in adults. *Journal of autism and developmental disorders*, *43*(12), 2997-3000.

Bouillon, L., Mazer, B., & Gelinas, I. (2006). Validity of the cognitive behavioral driver's inventory in predicting driving outcome. *The American Journal of Occupational Therapy*, *60*(4), 420-427.

Brand, P. L., Jaarsma, A. D. C., & van der Vleuten, C. P. (2021). Driving lesson or driving test? *Perspectives on medical education*, *10*(1), 50-56.

Braver, T. S., Cohen, J. D., Nystrom, L. E., Jonides, J., Smith, E. E., & Noll, D. C. (1997). A parametric study of prefrontal cortex involvement in human working memory. *Neuroimage*, *5*(1), 49-62. https://doi.org/https://doi.org/10.1006/nimg.1996.0247

Brookhuis, K. A., & De Waard, D. (2010). Monitoring drivers' mental workload in driving simulators using physiological measures. *Accident Analysis & Prevention*, *42*(3), 898-903. https://doi.org/https://doi.org/10.1016/j.aap.2009.06.001

Brooks, J., Kellett, J., Seeanner, J., Jenkins, C., Buchanan, C., Kinsman, A., Kelly, D., & 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. https://doi.org/https://doi.org/10.1007/s10803-016-2775-8

Burnette, C. P., Mundy, P. C., Meyer, J. A., Sutton, S. K., Vaughan, A. E., & Charak, D. (2005). Weak central coherence and its relations to theory of mind and anxiety in autism. *Journal of autism and developmental disorders*, *35*(1), 63-73. https://doi.org/https://doi.org/10.1007/s10803-004-1035-5

Burns, P. C., Trbovich, P. L., McCurdie, T., & Harbluk, J. L. (2005). Measuring distraction: Task duration and the lane-change test (LCT). Proceedings of the Human Factors and Ergonomics Society Annual Meeting,

Cannon, J., O'Brien, A. M., Bungert, L., & Sinha, P. (2021). Prediction in autism spectrum disorder: a systematic review of empirical evidence. *Autism Research*, *14*(4), 604-630.

Castro, C. (2008). *Human factors of visual and cognitive performance in driving*. CRC Press.

Chee, D. Y.-T., Lee, H. C.-y., Falkmer, M., Barnett, T., Falkmer, O., Siljehav, J., & Falkmer, T. (2015). Viewpoints on driving of individuals with and without autism spectrum disorder. *Developmental neurorehabilitation*, *18*(1), 26-36. https://doi.org/https://doi.org/10.3109/17518423.2014.964377

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. https://doi.org/https://doi.org/10.1007/s10803-017-3178-1

Chee, D. Y. T., Lee, H. C. Y., Patomella, A.-H., & Falkmer, T. (2019a). Investigating the driving performance of drivers with and without autism spectrum disorders under complex driving conditions. *Disability and rehabilitation*, *41*(1), 1-8. https://doi.org/https://doi.org/10.1080/09638288.2017.1370498

Chee, D. Y. T., Lee, H. Y., Patomella, A.-H., & Falkmer, T. (2019b). The visual search patterns of drivers with Autism Spectrum Disorders in complex driving scenarios. *Journal of Transport & Health*, *14*, 100597. https://doi.org/https://doi.org/10.1016/j.jth.2019.100597

Cheng, D., & Vertegaal, R. (2004). An eye for an eye: a performance evaluation comparison of the lc technologies and tobii eye trackers. Proceedings of the 2004 symposium on Eye tracking research & applications,

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. https://doi.org/https://doi.org/10.1080/15389588.2012.700747

Classen, S., Monahan, M., Brown, K. E., & Hernandez, S. (2013). Driving indicators in teens with attention deficit hyperactivity and/or autism spectrum disorder: indicateurs de la conduite automobile chez les jeunes ayant un déficit de l'attention avec hyperactivité ou un trouble du spectre autistique. *Canadian journal of occupational therapy*, *80*(5), 274-283. https://doi.org/https://doi.org/10.1177/0008417413501072

Cleland, C., Magura, S., Foote, J., Rosenblum, A., & Kosanke, N. (2005). Psychometric properties of the Toronto Alexithymia Scale (TAS-20) for substance users. *Journal of psychosomatic research*, *58*(3), 299-306. https://doi.org/https://doi.org/10.1016/j.jpsychores.2004.11.002

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of health and social behavior*, 385-396.

Cohen, S., Kamarck, T., & Mermelstein, R. (1994). Perceived stress scale. *Measuring stress: A guide for health and social scientists*, *10*(2), 1-2.

Collia, D. V., Sharp, J., & Giesbrecht, L. (2003). The 2001 national household travel survey: A look into the travel patterns of older Americans. *Journal of Safety Research*, *34*(4), 461-470. https://doi.org/https://doi.org/10.1016/j.jsr.2003.10.001

Conlon, E. G., Rahaley, N., & Davis, J. (2017). The influence of age-related health difficulties and attitudes toward driving on driving self-regulation in the baby boomer and older adult generations. *Accident Analysis & Prevention*, *102*, 12-22.

Consuegra, E., Engels, N., & Willegems, V. (2016). Using video-stimulated recall to investigate teacher awareness of explicit and implicit gendered thoughts on classroom interactions. *Teachers and Teaching*, *22*(6), 683-699.

Cox, 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, D. J., Brown, T., Ross, V., Moncrief, M., Schmitt, R., Gaffney, G., & Reeve, R. (2017). Can youth with autism spectrum disorder use virtual reality driving simulation training to evaluate and improve driving performance? An exploratory study. *Journal of autism and developmental disorders*, *47*(8), 2544-2555. https://doi.org/https://doi.org/10.1007/s10803-017-3164-7

Cox, D. J., Owens, J. M., Barnes, L., Moncrief, M., Boukhechba, M., Buckman, S., Banton, T., & Wotring, B. (2020). A pilot study comparing newly licensed drivers with and without autism and experienced drivers in simulated and on-road driving. *Journal of autism and developmental disorders*, *50*(4), 1258-1268.

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*, 2257–2262.

Cox, S. M., Cox, D. J., Kofler, M. J., Moncrief, M. A., Johnson, R. J., Lambert, A. E., Cain, S. A., & 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. https://doi.org/https://doi.org/10.1007/s10803-015-2677-1

Crane, L., Goddard, L., & Pring, L. (2009). Sensory processing in adults with autism spectrum disorders. *Autism*, *13*(3), 215-228.

Crundall, D., Chapman, P., Trawley, S., Collins, L., Van Loon, E., Andrews, B., & Underwood, G. (2012). Some hazards are more attractive than others: Drivers of varying experience respond differently to different types of hazard. *Accident Analysis & Prevention*, *45*, 600-609.

Curry, A. E., Metzger, K. B., Carey, M. E., Sartin, E. B., Huang, P., & Yerys, B. E. (2021). Comparison of motor vehicle crashes, traffic violations, and license suspensions between autistic and non-autistic adolescent and young adult drivers. *Journal of the American Academy of Child & Adolescent Psychiatry*, *60*(7), 913-923.

Curry, A. E., Yerys, B. E., Huang, P., & Metzger, K. B. (2018). Longitudinal study of driver licensing rates among adolescents and young adults with autism spectrum disorder. *Autism*, *22*(4), 479-488. https://doi.org/https://doi.org/10.1177/1362361317699586

Daly, B. P., Nicholls, E. G., Patrick, K. E., Brinckman, D. D., & Schultheis, M. T. (2014). Driving behaviors in adults with autism spectrum disorders. *Journal of autism and developmental disorders*, *44*(12), 3119-3128. https://doi.org/10.1007/s10803-014-2166-y

de Craen, S., Twisk, D., Hagenzieker, M., Elffers, H., & Brookhuis, K. (2007). Overestimation of skills affects drivers' adaptation to task demands. Proceedings of the 4th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle,

Dean, M., Harwood, R., & Kasari, C. (2017). The art of camouflage: Gender differences in the social behaviors of girls and boys with autism spectrum disorder. *Autism*, *21*(6), 678-689. https://doi.org/https://doi.org/10.1177/1362361316671845

DeBrabander, K. M., Pinkham, A. E., Ackerman, R. A., Jones, D. R., & Sasson, N. J. (2021). Cognitive and social cognitive self-assessment in autistic adults. *Journal of autism and developmental disorders*, *51*(7), 2354-2368.

Deka, D., Feeley, C., & Lubin, A. (2016). Travel patterns, needs, and barriers of adults with autism spectrum disorder: report from a survey. *Transportation research record*, *2542*(1), 9-16.

Demetriou, E. A., Lampit, A., Quintana, D. S., Naismith, S. L., Song, Y. J., Pye, J. E., Hickie, I., & Guastella, e. A. (2018). Autism spectrum disorders: a meta-analysis of executive function. *Molecular psychiatry*, *23*(5), 1198-1204.

Dirix, H., Brijs, K., Huysmans, E., Neven, A., Brijs, T., Jongen, E., Alhajyaseen, W., Wets, G., & Ross, V. (2022). Experiences with licensing by autistic drivers: An exploratory study. *Procedia Computer Science*, *201*, 330-337. https://doi.org/https://doi.org/10.1016/j.procs.2022.03.044

Dirix, H., Ross, V., Brijs, K., Vermeiren, E., Timmermans, C., Alhajyaseen, W., Brijs, T., Wets, G., & Spooren, A. (2021). The appraisal of roadway environment and infrastructure by drivers with autism: A qualitative study. *Transportation Research Part F: Traffic Psychology and Behaviour*, *78*, 280-298. https://doi.org/https://doi.org/10.1016/j.trf.2021.01.016

Dyches, T. T., Wilder, L. K., Sudweeks, R. R., Obiakor, F. E., & Algozzine, B. (2004). Multicultural issues in autism. *Journal of autism and developmental disorders*, *34*(2), 211-222.

Ehlers, A., Taylor, J. E., Ehring, T., Hofmann, S. G., Deane, F. P., Roth, W. T., & Podd, J. V. (2007). The driving cognitions questionnaire: Development and preliminary psychometric properties. *Journal of anxiety disorders*, *21*(4), 493-509. https://doi.org/https://doi.org/10.1016/j.janxdis.2006.08.002

Ellaway, A., Macintyre, S., Hiscock, R., & Kearns, A. (2003). In the driving seat: psychosocial benefits from private motor vehicle transport compared to public transport. *Transportation Research Part F: Traffic Psychology and Behaviour*, *6*(3), 217-231. https://doi.org/https://doi.org/10.1016/S1369-8478(03)00027-5

Elsabbagh, M., Divan, G., Koh, Y. J., Kim, Y. S., Kauchali, S., Marcín, C., Montiel-Nava, C., Patel, V., Paula, C. S., & Wang, C. (2012). Global prevalence of autism and other pervasive developmental disorders. *Autism Research*, *5*(3), 160-179. https://doi.org/https://doi.org/10.1002/aur.239

Elwin, M., Ek, L., Kjellin, L., & Schröder, A. (2013). Too much or too little: Hyper-and hypo-reactivity in high-functioning autism spectrum conditions. *Journal of intellectual & developmental disability*, *38*(3), 232-241.

Elwin, M., Schröder, A., Ek, L., Wallsten, T., & Kjellin, L. (2017). Sensory clusters of adults with and without autism spectrum conditions. *Journal of autism and developmental disorders*, *47*(3), 579-589.

Empatica. (2018). *E4 wristband User's manual*. Retrieved at 10.21.2022 from https://empatica.app.box.com/v/E4-User-Manual

Endsley, M. R. (1995). Measurement of situation awareness in dynamic systems. *Human factors*, *37*(1), 65-84.

Enewoldsen, N. (2016). *Analysis of the quality of electrodermal activity and heart rate data recorded in daily life over a period of one week with an E4 wristband* University of Twente].

Engström, J., Johansson, E., & Östlund, J. (2005). Effects of visual and cognitive load in real and simulated motorway driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *8*(2), 97-120. https://doi.org/https://doi.org/10.1016/j.trf.2005.04.012

Engström, J., & Markkula, G. (2007). Effects of visual and cognitive distraction on lane change test performance. Driving Assesment Conference,

Falkmer, T., Anund, A., Sörensen, G., Falkmer, M., & Gerland, G. (2001). THE TRAVEL SITUATION FOR CHILDREN WITH AUSTISM-SPECTRUM DISORDERS. *VTI Rapport*(469).

Faras, H., Al Ateeqi, N., & Tidmarsh, L. (2010). Autism spectrum disorders. *Annals of Saudi medicine*, *30*(4), 295-300. https://doi.org/https://doi.org/10.4103/0256-4947.65261

Feeley, C. (2010). Evaluating the transportation needs and accessibility issues for adults on the autism spectrum in New Jersey. 89th annual meeting of the transportation research board, Washington, DC,

Feeley, C., Deka, D., Lubin, A., & McGackin, M. (2015a). Detour to the right place: A study with recommendations for addressing the transportation needs and barriers of adults on the Autism Spectrum in New Jersey. *Rutgers University*.

Feeley, C., Deka, D., Lubin, A., & McGackin, M. (2015b). Detour to the right place: A study with recommendations for addressing the transportation needs and barriers of adults on the autism spectrum in New Jersey. *Rutgers The State University of New Jersey*.

Fisher, M. J., & Marshall, A. P. (2009). Understanding descriptive statistics. *Australian critical care*, *22*(2), 93-97.

Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor coordination in autism spectrum disorders: a synthesis and meta-analysis. *Journal of autism and developmental disorders*, *40*(10), 1227-1240.

Freydier, C., Berthelon, C., & Bastien-Toniazzo, M. (2016). Does early training improve driving skills of young novice French drivers? *Accident Analysis & Prevention*, *96*, 228-236.

Frith, U., & Happé, F. (1994). Autism: Beyond "theory of mind". *Cognition*, *50*(1-3), 115-132.

Gaugler, T., Klei, L., Sanders, S. J., Bodea, C. A., Goldberg, A. P., Lee, A. B., Mahajan, M., Manaa, D., Pawitan, Y., & Reichert, J. (2014). Most genetic risk for autism resides with common variation. *Nature genetics*, *46*(8), 881-885. https://doi.org/https://doi.org/10.1038/ng.3039

Gelbar, N. W., Shefcyk, A., & Reichow, B. (2015). A comprehensive survey of current and former college students with autism spectrum disorders. *The Yale journal of biology and medicine*, *88*(1), 45.

Gilbert, S. J., & Burgess, P. W. (2008). Executive function. *Current biology*, *18*(3), R110-R114.

Glazebrook, C., Gonzalez, D., Hansen, S., & Elliott, D. (2009). The role of vision for online control of manual aiming movements in persons with autism spectrum disorders. *Autism*, *13*(4), 411-433.

Grandin, T., & Scariano, M. (1986). *Emergence: labeled autistic*. Arena Press Novato, CA.

Granovetter, M. C., Burlingham, C. S., Blauch, N. M., Minshew, N. J., Heeger, D. J., & Behrmann, M. (2020). Uncharacteristic task-evoked pupillary responses implicate atypical locus ceruleus activity in autism. *Journal of Neuroscience*, *40*(19), 3815-3826. https://doi.org/10.1523/JNEUROSCI.2680-19.2020

Güleç, H., Köse, S., Güleç, M. Y., Çitak, S., Evren, C., Borckardt, J., & Sayar, K. (2009). Reliability and factorial validity of the Turkish version of the 20-item Toronto alexithymia scale (TAS-20). *Klinik Psikofarmakoloji Bulteni*, *19*(3), 214.

Gurbuz, E., Hanley, M., & Riby, D. M. (2019). University students with autism: The social and academic experiences of university in the UK. *Journal of autism and developmental disorders*, *49*(2), 617-631.

Habib, A., Harris, L., Pollick, F., & Melville, C. (2019). A meta-analysis of working memory in individuals with autism spectrum disorders. *PloS one*, *14*(4), e0216198. https://doi.org/https://doi.org/10.1371/journal.pone.0216198

Harbison, J., Atkins, S. M., & Dougherty, M. R. (2011). N-back training task performance: Analysis and model. Proceedings of the Annual Meeting of the Cognitive Science Society,

Harbluk, J. L., Burns, J. C., Lochner, M., & Trbovich, P. L. (2007). Using the lane-change test (LCT) to assess distraction: Tests of visual-manual and speech-based operation of navigation system interfaces. Driving Assesment Conference,

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

Hendriks, S. M., Spijker, J., Licht, C. M., Beekman, A. T., & Penninx, B. W. (2013). Two-year course of anxiety disorders: Different across disorders or dimensions? *Acta Psychiatrica Scandinavica*, *128*(3), 212-221.

Hill, E. L. (2004). Executive dysfunction in autism. *Trends in cognitive sciences*, *8*(1), 26-32. https://doi.org/https://doi.org/10.1016/j.tics.2003.11.003

Hirvikoski, T., & Blomqvist, M. (2015). High self-perceived stress and poor coping in intellectually able adults with autism spectrum disorder. *Autism*, *19*(6), 752-757.

Hodgson, A. R., Freeston, M. H., Honey, E., & Rodgers, J. (2017). Facing the unknown: Intolerance of uncertainty in children with autism spectrum disorder. *Journal of applied research in intellectual disabilities*, *30*(2), 336-344.

Hoekstra, R. A., Bartels, M., Cath, D. C., & Boomsma, D. I. (2008). Factor structure, reliability and criterion validity of the Autism-Spectrum Quotient (AQ): a study in Dutch population and patient groups. *Journal of autism and developmental disorders*, *38*(8), 1555-1566.

Hofvander, B., Delorme, R., Chaste, P., Nydén, A., Wentz, E., Ståhlberg, O., Herbrecht, E., Stopin, A., Anckarsäter, H., & Gillberg, C. (2009). Psychiatric and psychosocial problems in adults with normal-intelligence autism spectrum disorders. *BMC psychiatry*, *9*(1), 1-9. https://doi.org/https://doi.org/10.1186/1471-244X-9-35

Horswill, M. S. (2016). Hazard perception in driving. *Current directions in psychological science*, *25*(6), 425-430.

Horswill, M. S., Hill, A., & Wetton, M. (2015). Can a video-based hazard perception test used for driver licensing predict crash involvement? *Accident Analysis & Prevention*, *82*, 213-219.

Horswill, M. S., & McKenna, F. P. (2004). Drivers' hazard perception ability: Situation awareness on the road. *A cognitive approach to situation awareness: Theory and application*, 155-175.

Howitt, D., & Cramer, D. (2010). Introduction to qualitative methods in psychology.

Huang, P., Kao, T., Curry, A. E., & Durbin, D. R. (2012). Factors associated with driving in teens with autism spectrum disorders. *Journal of Developmental & Behavioral Pediatrics*, *33*(1), 70-74. https://doi.org/10.1097/DBP.0b013e31823a43b7

Hull, L., Petrides, K., Allison, C., Smith, P., Baron-Cohen, S., Lai, M. C., & Mandy, W. (2017). Putting on my best normal: Social camouflaging in adults with autism spectrum conditions, journal of autism and developmental disorders. https://doi.org/ 10.1007/s10803-017-3166-5

Hussain, Q., Alhajyaseen, W. K., Brijs, K., Pirdavani, A., & Brijs, T. (2020). Innovative countermeasures for red light running prevention at signalized intersections: A driving simulator study. *Accident Analysis & Prevention*, *134*, 105349. https://doi.org/https://doi.org/10.1016/j.aap.2019.105349

Hussain, Q., Alhajyaseen, W. K., Pirdavani, A., Reinolsmann, N., Brijs, K., & Brijs, T. (2019). Speed perception and actual speed in a driving simulator and real-world: A validation study. *Transportation Research Part F: Traffic Psychology and Behaviour*, *62*, 637-650. https://doi.org/https://doi.org/10.1016/j.trf.2019.02.019

Ikuta, N., Iwanaga, R., Tokunaga, A., Nakane, H., Tanaka, K., & Tanaka, G. (2016). Effectiveness of earmuffs and noise-cancelling headphones for coping with hyper-reactivity to auditory stimuli in children with Autism Spectrum Disorder: a preliminary study. *Hong Kong Journal of Occupational Therapy*, *28*(1), 24-32.

ISO 26022. (2010). Road vehicles – Ergonomic aspects of transportation information andcontrol systems – Simulated lane change test to assess in-vehicle secondarytask demand. .

Jaeggi, S. M., Buschkuehl, M., Perrig, W. J., & Meier, B. (2010). The concurrent validity of the N-back task as a working memory measure. *Memory*, *18*(4), 394-412. https://doi.org/https://doi.org/10.1080/09658211003702171

Jameel, L., Vyas, K., Bellesi, G., Cassell, D., & Channon, S. (2015). Great expectations: The role of rules in guiding pro-social behaviour in groups with high versus low autistic traits. *Journal of autism and developmental disorders*, *45*(8), 2311-2322.

Kapp, S. K., Gantman, A., & Laugeson, E. A. (2011a). Transition to adulthood for high-functioning individuals with autism spectrum disorders. *A comprehensive book on autism spectrum disorders*, 451-478.

Kapp, S. K., Gantman, A., & Laugeson, E. A. (2011b). Transition to adulthood for high-functioning individuals with autism spectrum disorders. In *A comprehensive book on autism spectrum disorders*. InTech.

Kechter, A., Black, D. S., Riggs, N. R., Warren, C. M., Ritt-Olson, A., Chou, C.-P., & Pentz, M. A. (2019). Factors in the perceived stress scale differentially associate with mindfulness disposition and executive function among early adolescents. *Journal of child and family studies*, *28*(3), 814-821. https://doi.org/https://doi.org/10.1007/s10826-018-01313-4

Keen, D., Reid, F., & Arnone, D. (2010). Autism, ethnicity and maternal immigration. *The British Journal of Psychiatry*, *196*(4), 274-281.

Kersten, M., Coxon, K., Lee, H., & Wilson, N. J. (2020). Independent community mobility and driving experiences of adults on the autism spectrum: a scoping review. *The American*

Journal of Occupational Therapy, *74*(5), 7405205140p7405205141-7405205140p7405205117.

Kinnaird, E., Stewart, C., & Tchanturia, K. (2019). Investigating alexithymia in autism: a systematic review and meta-analysis. *European Psychiatry*, *55*, 80-89.

Kirby, A., Sugden, D., & Edwards, L. (2011). Driving behaviour in young adults with developmental co-ordination disorder. *Journal of Adult Development*, *18*(3), 122-129.

Kirchner, W. K. (1958). Age differences in short-term retention of rapidly changing information. *Journal of experimental psychology*, *55*(4), 352. https://doi.org/https://doi.org/10.1037/h0043688

Klin, A., Jones, W., Schultz, R., & Volkmar, F. (2003). The enactive mind, or from actions to cognition: lessons from autism. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *358*(1430), 345-360.

Koch, I., Poljac, E., Müller, H., & Kiesel, A. (2018). Cognitive structure, flexibility, and plasticity in human multitasking—An integrative review of dual-task and task-switching research. *Psychological bulletin*, *144*(6), 557. https://doi.org/https://doi.org/10.1037/bul0000144

Kokinov, B., & Grinberg, M. (2001). Simulating context effects in problem solving with AMBR. International and Interdisciplinary Conference on Modeling and Using Context,

Kreiser, N. L., & White, S. W. (2014). ASD in females: are we overstating the gender difference in diagnosis? *Clinical child and family psychology review*, *17*(1), 67-84. https://doi.org/https://doi.org/10.1007/s10567-013-0148-9

Landrigan, P. J. (2010). What causes autism? Exploring the environmental contribution. *Current opinion in pediatrics*, *22*(2), 219-225. https://doi.org/10.1097/MOP.0b013e328336eb9a

Leadbitter, K., Buckle, K. L., Ellis, C., & Dekker, M. (2021). Autistic self-advocacy and the neurodiversity movement: Implications for autism early intervention research and practice. *Frontiers in Psychology*, 782.

Leon-Dominguez, U., Martín-Rodríguez, J. F., & León-Carrión, J. (2015). Executive n-back tasks for the neuropsychological assessment of working memory. *Behavioural brain research*, *292*, 167-173. https://doi.org/https://doi.org/10.1016/j.bbr.2015.06.002

Lindsay, S. (2017). Systematic review of factors affecting driving and motor vehicle transportation among people with autism spectrum disorder. *Disability and rehabilitation*, *39*(9), 837-846. https://doi.org/https://doi.org/10.3109/09638288.2016.1161849

Lindseth, A., & Norberg, A. (2004). A phenomenological hermeneutical method for researching lived experience. *Scandinavian journal of caring sciences*, *18*(2), 145-153.

Liss, M., Fein, D., Allen, D., Dunn, M., Feinstein, C., Morris, R., Waterhouse, L., & Rapin, I. (2001). Executive functioning in high-functioning children with autism. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *42*(2), 261-270.

Liu, G., Pearl, A. M., Kong, L., Leslie, D. L., & Murray, M. J. (2017). A profile on emergency department utilization in adolescents and young adults with autism spectrum disorders. *Journal of autism and developmental disorders*, *47*(2), 347-358. https://doi.org/https://doi.org/10.1007/s10803-016-2953-8

Loomes, R., Hull, L., & Mandy, W. P. L. (2017). What is the male-to-female ratio in autism spectrum disorder? A systematic review and meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, *56*(6), 466-474. https://doi.org/https://doi.org/10.1016/j.jaac.2017.03.013

Lubin, A., & Feeley, C. (2016). Transportation issues of adults on the autism spectrum: Findings from focus group discussions. *Transportation research record*, *2542*(1), 1-8. https://doi.org/https://doi.org/10.3141/2542-01

Luna, B., Doll, S. K., Hegedus, S. J., Minshew, N. J., & Sweeney, J. A. (2007). Maturation of executive function in autism. *Biological psychiatry*, *61*(4), 474-481. https://doi.org/https://doi.org/10.1016/j.biopsych.2006.02.030

Mackworth, J. F. (1959). Paced memorizing in a continuous task. *Journal of experimental psychology*, *58*(3), 206. https://doi.org/https://doi.org/10.1037/h0049090

MacNeil, B. M., Lopes, V. A., & Minnes, P. M. (2009). Anxiety in children and adolescents with autism spectrum disorders. *Research in autism spectrum disorders*, *3*(1), 1-21.

Mäntylä, T., Karlsson, M. J., & Marklund, M. (2009). Executive control functions in simulated driving. *Applied neuropsychology*, *16*(1), 11-18. https://doi.org/https://doi.org/10.1080/09084280802644086

Mason, D., McConachie, H., Garland, D., Petrou, A., Rodgers, J., & Parr, J. R. (2018). Predictors of quality of life for autistic adults. *Autism Research*, *11*(8), 1138-1147. https://doi.org/https://doi.org/10.1002/aur.1965

Matson, J. L., & Adams, H. L. (2014). Characteristics of aggression among persons with autism spectrum disorders. *Research in autism spectrum disorders*, *8*(11), 1578-1584.

Mattes, S. (2003). The lane-change-task as a tool for driver distraction evaluation. *Quality of Work and Products in Enterprises of the Future*, *57*(60), 7.

Mazurek, M. O., Kanne, S. M., & Wodka, E. L. (2013). Physical aggression in children and adolescents with autism spectrum disorders. *Research in autism spectrum disorders*, *7*(3), 455-465. https://doi.org/https://doi.org/10.1016/j.rasd.2012.11.004

McKenzie, R., Evans, J. S. B., & Handley, S. J. (2010). Conditional reasoning in autism: activation and integration of knowledge and belief. *Developmental Psychology*, *46*(2), 391.

Mehler, B., Reimer, B., Coughlin, J. F., & Dusek, J. A. (2009). Impact of incremental increases in cognitive workload on physiological arousal and performance in young adult drivers. *Transportation research record*, *2138*(1), 6-12. https://doi.org/https://doi.org/10.3141/2138-02

Ming, X., Brimacombe, M., & Wagner, G. C. (2007). Prevalence of motor impairment in autism spectrum disorders. *Brain and Development*, *29*(9), 565-570.

Ministry of Public Health. (2020). *Special Needs eLearning (Autism eLearning).* Retrieved on September 28, 2022 from https://autismelearning.moph.gov.qa/Pages/Welcomeletter.aspx

Miyahara, M., Tsujii, M., Hori, M., Nakanishi, K., Kageyama, H., & Sugiyama, T. (1997). Brief report: motor incoordination in children with Asperger syndrome and learning disabilities. *Journal of autism and developmental disorders*, *27*(5), 595-603.

Monahan, M., Classen, S., & Helsel, P. V. (2013). Pre-driving evaluation of a teen with attention deficit hyperactivity disorder and autism spectrum disorder. *Canadian journal of occupational therapy*, *80*(1), 35-41. https://doi.org/https://doi.org/10.1177/0008417412474221

Morse, J. M. (1995). The significance of saturation. In (Vol. 5, pp. 147-149): Sage publications Sage CA: Thousand Oaks, CA.

Murphy, J. W., Foxe, J. J., Peters, J. B., & Molholm, S. (2014). Susceptibility to distraction in autism spectrum disorder: Probing the integrity of oscillatory alpha-band suppression mechanisms. *Autism Research*, *7*(4), 442-458. https://doi.org/https://doi.org/10.1002/aur.1374

Murray, A. L., Allison, C., Smith, P. L., Baron-Cohen, S., Booth, T., & Auyeung, B. (2017). Investigating diagnostic bias in autism spectrum conditions: an item response theory analysis of sex bias in the AQ-10. *Autism Research*, *10*(5), 790-800.

Myers, R. K., Bonsu, J. M., Carey, M. E., Yerys, B. E., Mollen, C. J., & Curry, A. E. (2019). Teaching autistic adolescents and young adults to drive: Perspectives of specialized driving instructors. *Autism in adulthood*, *1*(3), 202-209. https://doi.org/https://doi.org/10.1089/aut.2018.0054

Nazarali, N., Glazebrook, C. M., & Elliott, D. (2009). Movement planning and reprogramming in individuals with autism. *Journal of autism and developmental disorders*, *39*(10), 1401-1411.

Nicolaidis, C., Raymaker, D., McDonald, K., Dern, S., Ashkenazy, E., Boisclair, C., Robertson, S., & Baggs, A. E. (2011). Collaboration strategies in non-traditional CBPR partnerships: Lessons from an academic-community partnership with autistic self-advocates. *Research, Education, and Action*.

O'Hearn, K., Asato, M., Ordaz, S., & Luna, B. (2008). Neurodevelopment and executive function in autism. *Development and psychopathology*, *20*(4), 1103-1132. https://doi.org/https://doi.org/10.1017/S0954579408000527

OHCHR. (2021). *Committee on the Rights of Persons with Disabilities considers initial report of Qatar.* . Retrieved on September 28, 2022 from https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=16353&LangID=E

Örücü, M. Ç., & Demir, A. (2009). Psychometric evaluation of perceived stress scale for Turkish university students. *Stress and Health: Journal of the International Society for the Investigation of Stress*, *25*(1), 103-109. https://doi.org/https://doi.org/10.1002/smi.1218

Owen, A. M., McMillan, K. M., Laird, A. R., & Bullmore, E. (2005). N-back working memory paradigm: A meta-analysis of normative functional neuroimaging studies. *Human brain mapping*, *25*(1), 46-59. https://doi.org/https://doi.org/10.1002/hbm.20131

Parlement, V. (2020). *Schriftelijke vraag: Hervormd rijexamen – Slaagcijfers. Nr. 1140.* Retrieved from https://docs.vlaamsparlement.be/pfile?id=1596683

Patrick, K. E., Hurewitz, F., McCurdy, M. D., Agate, F. T., Daly, B. P., Tarazi, R. A., Chute, D. L., & Schultheis, M. T. (2018). Driving comparisons between young adults with autism spectrum disorder and typical development. *Journal of Developmental & Behavioral Pediatrics*, *39*(6), 451-460. https://doi.org/doi:10.1097/DBP.0000000000000581

Patrick, K. E., Schultheis, M. T., Agate, F. T., McCurdy, M. D., Daly, B. P., Tarazi, R. A., Chute, D. L., & Hurewitz, F. (2020). Executive function “drives” differences in simulated driving performance between young adults with and without autism spectrum disorder. *Child Neuropsychology*, *26*(5), 649-665.

Pellicano, E., Kenny, L., Brede, J., Klaric, E., Lichwa, H., & McMillin, R. (2017). Executive function predicts school readiness in autistic and typical preschool children. *Cognitive Development*, *43*, 1-13. https://doi.org/https://doi.org/10.1016/j.cogdev.2017.02.003

Pellicano, E., & Stears, M. (2011). Bridging autism, science and society: Moving toward an ethically informed approach to autism research. *Autism Research*, *4*(4), 271-282.

Pfeiffer, B., DeRita, J., Giacomucci, E., Gubler, J., Halteman, T., O’Donnell, E., Seifried, G., & Pompanio, A. (2021). Barriers and facilitators to public transportation use for individuals with intellectual and developmental disabilities. *Occupational Therapy in Mental Health*, *37*(1), 1-14.

Pijnacker, J., Geurts, B., Van Lambalgen, M., Kan, C. C., Buitelaar, J. K., & Hagoort, P. (2009). Defeasible reasoning in high-functioning adults with autism: Evidence for impaired exception-handling. *Neuropsychologia*, *47*(3), 644-651.

Poquérusse, J., Pastore, L., Dellantonio, S., & Esposito, G. (2018). Alexithymia and autism spectrum disorder: a complex relationship. *Frontiers in Psychology*, *9*, 1196.

Qoronflesh, M. W., Essa, M. M., Alharahsheh, S. T., Al-Farsi, Y. M., & Al-Adawi, S. (2019). Autism in the Gulf states: A regional overview. *Frontiers in Bioscience-Landmark*, *24*(2), 334-346.

Rao, S. M., & Gagie, B. (2006). Learning through seeing and doing: Visual supports for children with autism. *Teaching exceptional children*, *38*(6), 26-33.

Recarte, M. A., & Nunes, L. M. (2003). Mental workload while driving: effects on visual search, discrimination, and decision making. *Journal of experimental psychology: Applied*, *9*(2), 119. https://doi.org/https://doi.org/10.1037/1076-898X.9.2.119

Regan, M. A., Hallett, C., & Gordon, C. P. (2011). Driver distraction and driver inattention: Definition, relationship and taxonomy. *Accident Analysis & Prevention*, *43*(5), 1771-1781. https://doi.org/https://doi.org/10.1016/j.aap.2011.04.008

Reimer, B., Fried, R., Mehler, B., Joshi, G., Bolfek, A., Godfrey, K. M., Zhao, N., Goldin, R., & 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. https://doi.org/https://doi.org/10.1007/s10803-013-1764-4

Remington, A. M., Swettenham, J. G., & Lavie, N. (2012). Lightening the load: perceptual load impairs visual detection in typical adults but not in autism. *Journal of abnormal psychology*, *121*(2), 544.

Rinehart, N. J., Bellgrove, M. A., Tonge, B. J., Brereton, A. V., Howells-Rankin, D., & Bradshaw, J. L. (2006). An examination of movement kinematics in young people with high-functioning autism and Asperger’s disorder: further evidence for a motor planning deficit. *Journal of autism and developmental disorders*, *36*(6), 757-767.

Ross, V., Cox, D. J., Noordzij, M. L., Geryl, K., & Spooren, A. (2018). Developing a Research Protocol to Investigate Stress, Workload, and Driving Apprehension during Driving Lessons in Young Adults with an Autism Spectrum Disorder: A Feasibility Study. The International Society for Autism Research Annual Meeting 2018,

Ross, V., Cox, D. J., Reeve, R., Brown, T., Moncrief, M., Schmitt, R., & Gaffney, G. (2018). Measuring the attitudes of novice drivers with autism spectrum disorder as an indication of apprehensive driving: Going beyond basic abilities. *Autism*, *22*(1), 62-69. https://doi.org/https://doi.org/10.1177/1362361317735959

Ross, V., Jongen, E., Brijs, T., Ruiter, R., Brijs, K., & Wets, G. (2015). The relation between cognitive control and risky driving in young novice drivers. *Applied Neuropsychology: Adult*, *22*(1), 61-72. https://doi.org/https://doi.org/10.1080/23279095.2013.838958

Ross, V., Jongen, E., Van Vlierden, K., Brijs, K., Brijs, T., Hens, R., Wets, G., & Vanvuchelen, M. (2018). Process of learning to drive by young persons with autism: Experiences of the young persons themselves, parents, and driving instructors. https://doi.org/10.5507/tots.2018.012

Ross, V., JONGEN, E., Vanvuchelen, M., Brijs, T., Brijs, K., & Wets, G. (2015). Exploring the driving behavior of youth with an autism spectrum disorder: a driver instructor questionnaire.

Ross, V., Jongen, E. M., Brijs, K., Vanroelen, G., Beelen, C., Maltagliati, I., Van Beers, M., Ruiter, R. A., Brijs, T., & Alhajyaseen, W. (2019). The relation between driving errors and executive functioning in intellectually able young novice drivers with autism. *Transportation Research Part F: Traffic Psychology and Behaviour*, *63*, 38-54. https://doi.org/https://doi.org/10.1016/j.trf.2019.03.003

Ross, V., Jongen, E. M., Wang, W., Brijs, T., Brijs, K., Ruiter, R. A., & Wets, G. (2014). Investigating the influence of working memory capacity when driving behavior is combined with cognitive load: An LCT study of young novice drivers. *Accident Analysis & Prevention*, *62*, 377-387. https://doi.org/https://doi.org/10.1016/j.aap.2013.06.032

Ross, V., Jongen, E. M. M., Brijs, T., Brijs, K., Ruiter, R. A. C., & Wets, G. (2015). The relation between cognitive control and risky driving in young novice drivers. *Applied Neuropsychology: Adult*, *22*(1), 61-72.

Rowland, D. (2020). Trauma Induced Autism-An Update. *Journal of Neurology, Psychiatry and Brain Research*, *3*.

Sacrey, L.-A. R., Germani, T., Bryson, S. E., & Zwaigenbaum, L. (2014). Reaching and grasping in autism spectrum disorder: a review of recent literature. *Frontiers in neurology*, *5*, 6.

Sanders, S. J., He, X., Willsey, A. J., Ercan-Sencicek, A. G., Samocha, K. E., Cicek, A. E., Murtha, M. T., Bal, V. H., Bishop, S. L., & Dong, S. (2015). Insights into autism spectrum disorder genomic architecture and biology from 71 risk loci. *Neuron*, *87*(6), 1215-1233. https://doi.org/https://doi.org/10.1016/j.neuron.2015.09.016

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: appropriate use and interpretation. *Anesthesia & Analgesia*, *126*(5), 1763-1768.

Shechtman, O., Classen, S., Awadzi, K., & Mann, W. (2009). Comparison of driving errors between on-the-road and simulated driving assessment: a validation study. *Traffic injury prevention*, *10*(4), 379-385.

Sheppard, E., Ropar, D., Underwood, G., & van Loon, E. (2010). Brief report: Driving hazard perception in autism. *Journal of autism and developmental disorders*, *40*(4), 504-508.

Sheppard, E., van Loon, E., & Ropar, D. (2022). Dimensions of Self-Reported Driving Difficulty in Autistic and Non-Autistic Adults and their Relationship with Autistic Traits. *Journal of autism and developmental disorders*, 1-11. https://doi.org/https://doi.org/10.1007/s10803-021-05420-y

Sheppard, E., Van Loon, E., Underwood, G., & Ropar, D. (2017). Attentional differences in a driving hazard perception task in adults with autism spectrum disorders. *Journal of autism and developmental disorders*, *47*(2), 405-414. https://doi.org/https://doi.org/10.1007/s10803-016-2965-4

Shim, L., Liu, P., Politis, I., Regener, P., Brewster, S., & Pollick, F. (2015). Evaluating multimodal driver displays of varying urgency for drivers on the autistic spectrum. Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications,

Silvi, C., & Scott-Parker, B. (2018). Understanding the driving and licensing experiences of youth with autism. *Transportation Research Part F: Traffic Psychology and Behaviour*, *58*, 769-781. https://doi.org/https://doi.org/10.1016/j.trf.2018.04.021

Silvi, C., Scott-Parker, B., & Jones, C. (2018). A literature review of the likely effects of autism spectrum disorder on adolescent driving abilities. *Adolescent Research Review*, *3*(4), 449-465. https://doi.org/https://doi.org/10.1007/s40894-017-0068-x

Smigiel, S. (2020). *Students with Autism Spectrum Disorder Learning to Drive with Supplemental Curriculum: A Quantitative Study*. Robert Morris University.

Smith, L. E., Greenberg, J. S., & Mailick, M. R. (2012). Adults with autism: Outcomes, family effects, and the multi-family group psychoeducation model. *Current psychiatry reports*, *14*(6), 732-738. https://doi.org/https://doi.org/10.1007/s11920-012-0328-1

Son, J., & Park, M. (2011). Estimating cognitive load complexity using performance and physiological data in a driving simulator. Adjunct Proceedings of the Automotive User Interfaces and Interactive Vehicular Applications Conference,

Soulières, I., Hubert, B., Rouleau, N., Gagnon, L., Tremblay, P., Seron, X., & Mottron, L. (2010). Superior estimation abilities in two autistic spectrum children. *Cognitive Neuropsychology*, *27*(3), 261-276. https://doi.org/https://doi.org/10.1080/02643294.2010.519228

Stewart, M. E., Russo, N., Banks, J., Miller, L., & Burack, J. A. (2009). Sensory characteristics in ASD. *McGill Journal of Medicine: MJM*, *12*(2).

Stoit, A., van Schie, H. T., Slaats-Willemse, D. I., & Buitelaar, J. K. (2013). Grasping motor impairments in autism: not action planning but movement execution is deficient. *Journal of autism and developmental disorders*, *43*(12), 2793-2806.

Strayer, D. L., Drews, F. A., & Johnston, W. A. (2003). Cell phone-induced failures of visual attention during simulated driving. *Journal of experimental psychology: Applied*, *9*(1), 23. https://doi.org/https://doi.org/10.1037/1076-898X.9.1.23

Taylor, G. J., Bagby, R. M., & Parker, J. D. (1999). *Disorders of affect regulation: Alexithymia in medical and psychiatric illness*. Cambridge University Press.

Taylor, J. E., Stephens, A. N., & Sullman, M. J. (2021). Psychometric properties of the driving cognitions questionnaire, driving situations questionnaire, and driving behavior survey. *Transportation Research Part F: Traffic Psychology and Behaviour*, *76*, 202-214. https://doi.org/https://doi.org/10.1016/j.trf.2020.11.010

Taylor, J. M. (2015). Psychometric analysis of the ten-item perceived stress scale. *Psychological assessment*, *27*(1), 90.

Top Jr, D. N., Luke, S. G., Stephenson, K. G., & South, M. (2019). Psychophysiological arousal and auditory sensitivity in a cross-clinical sample of autistic and non-autistic anxious adults. *Frontiers in psychiatry*, *9*, 783.

Tromans, S., Chester, V., Kiani, R., Alexander, R., & Brugha, T. (2018). The prevalence of autism spectrum disorders in adult psychiatric inpatients: a systematic review. *Clinical practice and epidemiology in mental health: CP & EMH*, *14*, 177.

Tyler, S. (2013). Asperger's Syndrome: the implications for driver training methods and road safety. *Journal of the Australasian College of Road Safety*, *24*(1), 55-63.

Van Eylen, L., Boets, B., Steyaert, J., Evers, K., Wagemans, J., & Noens, I. (2016). " Cognitive flexibility in autism spectrum disorder: Explaining the inconsistencies": Corrigendum. https://doi.org/https://doi.org/10.1016/j.rasd.2016.01.008

Van Steensel, F. J., Bögels, S. M., & Perrin, S. (2011). Anxiety disorders in children and adolescents with autistic spectrum disorders: a meta-analysis. *Clinical child and family psychology review*, *14*(3), 302-317.

Vanmarcke, S. (2017). Perturbed cortical hierarchies in Autism Spectrum Disorder: The case of high-level vision.

Vanvuchelen, TANT, M., JONGEN, E., & ROSS, V. (2014a). Yes I Drive! Autorijden door adolescenten en jonge volwassenen met autisme (deel 1).

Vanvuchelen, Tant, M., Jongen, E., & Ross, V. (2014b). Yes I Drive: Autisme in het verkeer een praktische handwijzer om personen met autisme meer kansen te geven in het verkeer. In.

Vanvuchelen, M., Tant, M., Jongen, E., & Ross, V. (2014). Yes I Drive! Autorijden door adolescenten en jonge volwassenen met autisme (deel 1). *Autisme Centraal*, *4*, 9-13.

Vasa, R. A., Kalb, L., Mazurek, M., Kanne, S., Freedman, B., Keefer, A., Clemons, T., & Murray, D. (2013). Age-related differences in the prevalence and correlates of anxiety in youth with autism spectrum disorders. *Research in autism spectrum disorders*, *7*(11), 1358-1369.

Vermeulen, P. (2015). Context blindness in autism spectrum disorder: Not using the forest to see the trees as trees. *Focus on autism and other developmental disabilities*, *30*(3), 182-192.

Vermeulen, P., & Myles, B. S. (2012). *Autism as context blindness*. AAPC Publishing Shawnee Mission, KS.

Wade, J., Weitlauf, A., Broderick, N., Swanson, A., Zhang, L., Bian, D., Sarkar, M., Warren, Z., & Sarkar, N. (2017). A pilot study assessing performance and visual attention of teenagers with ASD in a novel adaptive driving simulator. *Journal of autism and developmental disorders*, *47*(11), 3405-3417. https://doi.org/https://doi.org/10.1007/s10803-017-3261-7

Wade, J., Zhang, L., Bian, D., Fan, J., Swanson, A., Weitlauf, A., Sarkar, M., Warren, Z., & Sarkar, N. (2016). A gaze-contingent adaptive virtual reality driving environment for intervention in individuals with autism spectrum disorders. *ACM Transactions on Interactive Intelligent Systems (TiiS)*, *6*(1), 1-23.

Walker, G. H., Stanton, N. A., & Chowdhury, I. (2013). Self Explaining Roads and situation awareness. *Safety science*, *56*, 18-28.

Wang, K., Gaitsch, H., Poon, H., Cox, N. J., & Rzhetsky, A. (2017). Classification of common human diseases derived from shared genetic and environmental determinants. *Nature genetics*, *49*(9), 1319-1325.

Watkins, L., Kuhn, M., Ledbetter-Cho, K., Gevarter, C., & O'Reilly, M. (2017). Evidence-based social communication interventions for children with autism spectrum disorder. *The Indian Journal of Pediatrics*, *84*(1), 68-75.

Weimer, A. K., Schatz, A. M., Lincoln, A., Ballantyne, A. O., & Trauner, D. A. (2001). " Motor" impairment in Asperger syndrome: evidence for a deficit in proprioception. *Journal of Developmental & Behavioral Pediatrics*, *22*(2), 92-101.

Wild-Wall, N., Falkenstein, M., & Gajewski, P. D. (2011). Age-related differences in working memory performance in a 2-back task. *Frontiers in Psychology*, *2*, 186. https://doi.org/https://doi.org/10.3389/fpsyg.2011.00186

Wilson, N. J., Lee, H. C., Vaz, S., Vindin, P., & Cordier, R. (2018). Scoping review of the driving behaviour of and driver training programs for people on the autism spectrum. *Behavioural neurology*, *2018*. https://doi.org/https://doi.org/10.1155/2018/6842306

Wood, R., & Happé, F. (2020). Barriers to tests and exams for autistic pupils: improving access and longer-term outcomes. *International Journal of Inclusive Education*, 1-17.

Young, K. L., Lenné, M. G., & Williamson, A. R. (2011). Sensitivity of the lane change test as a measure of in-vehicle system demand. *Applied Ergonomics*, *42*(4), 611-618. https://doi.org/https://doi.org/10.1016/j.apergo.2010.06.020

Zalla, T., Labruyère, N., & Georgieff, N. (2013). Perceiving goals and actions in individuals with autism spectrum disorders. *Journal of autism and developmental disorders*, *43*(10), 2353-2365. https://doi.org/https://doi.org/10.1007/s10803-013-1784-0

Zeidan, J., Fombonne, E., Scorah, J., Ibrahim, A., Durkin, M. S., Saxena, S., Yusuf, A., Shih, A., & Elsabbagh, M. (2022). Global prevalence of autism: a systematic review update. *Autism Research*, *15*(5), 778-790. https://doi.org/https://doi.org/10.1002/aur.2696

Zibetti, E., & Tijus, C. (2005). Understanding actions: Contextual dimensions and heuristics. International and Interdisciplinary Conference on Modeling and Using Context,

9. Nomenclatures

Alexithymia	Impaired ability to recognize and describing feeling, and identifying different types of feeling
Autism spectrum disorder	A neurodiverse pervasive developmental condition characterized by stereotyped and repetitive pattern of behavior, and restricted interests, difficulties in social communication and interaction.
E4-Wristband	A wearable technology allows the monitoring of several psychophysiological responses, like electrodermal activity in real-time and in daily life over a period of days and weeks,
Elektro Cardiogram	A record of a participants' heartbeat produced by electrocardiography to measures different Mental and physiological parameters.
Elektro EncefaloGram	A sensors-based head device to record participants' stress, drowsiness, and attention during driving.
Hazard perception	The ability to detect, understand and predict of possible hazards.
Lane change initiation	The time difference between the lane change sign appearance and participants' initiation of appropriate response to the respective sign.
Mean Deviation (MDEV)	The difference between the actual driving course of participants and the LCT baseline or normative course model, as computed based on ISO annex E-standard.
Pairwise	The statistical comparison between entities of a factor in pairs to investigate which of each entity is preferred.
Percentage of correct lane changes (PCL)	A measure of a person's ability to correctly respond to the signs by changing the lane accordingly.
Time to collision	The time remaining before a crash occur between two vehicles if the course and speed of vehicles are maintained.
Tobii eye tracking system	A low-cost binocular eye tracker that can detect the presence, attention and focus of the user.

Within-subject:	Design of study in a way that each participant confronts the same situations.

10. Appendices

This report includes 14 different appendices which will be uploaded as separate documents with the report. The list of those appendices is given below:

1. **Appendix A- Autism and driving in Qatar- A practical guide for the learning process of autistic drivers:** This is the main deliverable of the project. In this document, we presented an evidence-based practical instructional driving instructors material that has been designed for driving instructors to help them tailor their conventional driving lessons to the needs of driving trainees with autism in Qatar.
2. **Appendix B- Educational material guide for a one-day workshop:** In this document we provided a training manual to guide a workshop training to driving instructors to help them individualized their driving lessons to the needs of driving trainees with autism in Qatar.
3. **Appendix C – PowerPoints:** The PowerPoints to guid the one-day workshop were summarized in this document.
4. **Appendix D - Workshop evaluation report**: This document is a report of participants' knowledge regarding autism and driving before and after the training workshop. Moreover, it addressed the effectiveness of the workshop itself.
5. **Appendix E: Practical guide for the learning process of autistic drivers with evaluation report:** This document is a report for an evaluation of the effectiveness of the practical guide on improving the trainees' driving experiences
6. **Appendix F: Driving training Schedule**: In this Appendix, we included the driving training schedule for participants in the practical guide validation process at Karwa Driving School.
7. **Appendix G: Media Coverage to the project:** This appendix presents the collections of online newspapers that gave coverage to the valorisation of the project
8. **Appendix H: Developed questionnaires for the assessment of driving difficulties in Young adults with ASD:** This document consists of the developed questionnaire/inventory surveys that were used to assess the driving difficulties of participants with ASD.
9. **Appendix I: Psychological characteristics of the Qatari youth with ASD considering the driving tasks:**
10. **Appendix J: Norms of psychological characteristics of the Qatari youth with ASD:**
11. **Appendix K: Simulated driving scenarios:** Simulated driving scenarios to assess driving capabilities in people with an autism spectrum disorder (ASD).
12. **Appendix L: Published papers:** This document includes all the publications achieved during the project period by the research team. In total, 7 papers are already published, of which five are journal publications while two are conference proceedings.

13. **Appendix M - Under-Review & Ready for Submissions:** In this document we provide the complete drafts of the three papers which are either under-review in journals or ready for submission to the journals.
14. **Appendix N- Publications in Preparations:** The highlights (introduction, methodology and results) of papers in preparation were summarized in this document. In total 9 journal papers will be prepared and submitted to the journals in the future.
15. **Appendix O– Poster presentations:** In this document, we provided the list of poster presentations along with their abstract.