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SOCIAL AND NON-SOCIAL HAZARD RESPONSE IN DRIVERS WITH AUTISM SPECTRUM DISORDER

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Abstract

Driving is a complex task that relies on manual, cognitive, visual and social skill. The social demands of driving may be challenging for individuals with Autism Spectrum Disorder (ASD) due to known social impairments. This study 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. Overall, participants responded faster to social hazards than non-social hazards. It was also found that 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. Future work should further investigate how social impairments in ASD may affect driving safety.

Keywords

Autism Spectrum Disorder; driving; developmental disabilities; hazard perception

Autism Spectrum Disorder (ASD) is one of the fastest growing developmental disabilities in the United States (Centers for Disease Control and Prevention [CDC], 2015). One of its hallmark features is impairment in social interaction and communication (Centelles, Assaiante, Etchegoyhen, Bouvard, & Schmitz, 2013). Social impairments relate to a variety of cognitive abilities and characteristics including theory of mind, social orienting and non-verbal communication (Deaner & Platt, 2003; Happe & Frith, 2006; Klin, Jones, Schultz, &

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Volkmar, 2003). These impairments have been studied extensively in the ASD population in a variety of contexts (Machalicek, O'Reilly, Beretvas, Sigafoos, & Lancioni, 2007; McConnell, 2002). Social impairments may also be evident in a slightly less obvious social environment – the network of drivers on the roadway (N. Benson, Hulac, & Kranzler, 2010; Kulp & Sortor, 2003). Although not previously studied, it stands to reason that the social impairments seen in individuals with ASD may affect social aspects of driving such as orienting to and reading the body language of pedestrians (Zalla, Labruyere, & Georgieff, 2013).

Impairments in the areas of social orienting, body language, adherence to social norms and social cues in individuals with ASD are well documented in previous literature, specifically in the context of observing and identifying conventional social and emotional situations (Centelles et al., 2013; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pierce, Glad, & Schreibman, 1997; Quimby et al., 1987). Individuals with ASD are less skilled than typically developing individuals at distinguishing motion of biological organisms from mechanical movement (Centelles et al., 2013). Previous research has shown that adults with ASD were unable to immediately recognize social oddities in an environment (V. Benson, Castelhano, Howard, Latif, & Rayner, 2015). Such delays could lead to problems in the real world driving environment.

Driving is Social

The existence of the roadway's vast and dynamic social ecosystem is contingent on the successful interactions of hundreds of drivers and other road users, including cyclists and pedestrians. The use of body language as a form of non-verbal communication is usually automatic in typically developing drivers, but can be impaired in those with ASD (Centelles et al., 2013; Klin et al., 2003; Zalla et al., 2013). The interpretation of body language comes into play for drivers most when encountering pedestrians or cyclists and is an essential skill for drivers to possess in order to maintain safety around hazards involving these road users. Guéguena and colleagues (2016) recently found that typically developing drivers were more likely to stop for and drove more slowly approaching a pedestrian who was smiling compared to one not smiling. These findings suggest that non-verbal communication - even something as subtle as a smile - can alter the relationship between drivers and pedestrians.

Hazard perception is a driver's ability to foresee potentially dangerous driving situations, and has been identified as a driving ability with serious implications for roadway safety and avoiding motor vehicle collisions (MVCs) (McKenna & Horswell, 1999). This ability may be particularly difficult for drivers with ASD, especially if the hazard is social, human or biological in nature. Failure to perceive driving hazards may result in slower reaction times and further increase risk of MVCs. Study findings of Crundall (2016) suggested that hazard prediction may be more cognitively demanding for novice drivers compared to experienced drivers as demonstrated by degradation in hazard prediction performance in novice drivers as time-on-task increased. This difference was even greater when prediction of the hazardous event was indirectly linked to the hazard (i.e., an ice cream van parked on the side of the road masking child pedestrians that might step into the street). Experienced drivers' increased attention to important areas of the real world driving environment and their ability to quickly scan the scene for hazard precursors, provides them with adequate information to react more quickly to avoid hazardous situations (Almberg et al., 2015; Borowsky et al., 2010). The ability to quickly scan the environment has been shown to be underdeveloped in novice drivers, and may also be slower in individuals with ASD (Yi et al., 2012). In the real world driving environment, the inability to rapidly scan an environment and respond to important target items (e.g., traffic lights, other cars, pedestrians, stop signs, etc.) could result in an increased risk of MVCs. Despite its importance to the driving safety of this already at-risk population of drivers, only one other study has examined the impact of the social impairments in ASD on hazard perception.

Previous ASD and Driving Research

Sheppard and colleagues (2010) sought to investigate social and non-social hazard perception by examining the ability of adults with ASD (average age = 23 years), who were regular car passengers but not licensed drivers, to identify social (e.g., a visible pedestrian or cyclist) versus non-social (e.g., car where driver was not visible) hazards which previous studies have defined as the presence or absence of a visible human element (Walker, 2005). Drivers perceive cars and other motor vehicles where the person is not visible as non-social, but become social when the source of the hazards is a visible human (Walker, 2005). Participants were asked to watch video clips taken from the perspective of a driver in a car and encouraged to imagine themselves as the driver. Participants were then instructed to press a response key as soon as something happened in the clip that would make them “need to consider taking some kind of action to avoid an accident” (Sheppard et al., 2010). This response paused the clip, at which point participants were asked to tell the experimenter the source of the hazard. Across experimental groups (ASD and controls) participants exhibited slower reaction times when presented with social hazards rather than non-social hazards (as defined by the presence or absence of a human figure respectively) (Sheppard et al., 2010). Adults with ASD had significantly longer reaction times identifying all hazards (regardless of type) than matched controls, and also identified fewer social hazards (Sheppard et al., 2010). These findings suggest that the identification of social hazards may be more difficult for drivers with ASD. However, the nature of these social impairments has not been fully explored, and few, if any, studies have examined the abilities of drivers with ASD to identify and avoid social and non-social hazards in a simulated driving environment.

The Current Study

Pedestrians and cyclists are the most common forms of social hazards in urban areas, with nearly 5,600 killed in crashes involving motor vehicles in 2014 (National Highway Traffic Safety Administration [NHTSA], 2014a, 2014b). Considering the high prevalence of social hazards on the roadway and safety risks that accompany them, it is essential to better understand the abilities of drivers with ASD to perceive and avoid these hazards. Deery (1999) postulated a model of driver risk perception when encountering driving hazards that includes two main components: (1) the driver’s perception of the hazard and (2) the driver’s self-assessment of their ability to prevent the hazard from developing into a MVC. The current study focused mainly on the first component of this model.

The overall aim of this study was to evaluate driving performance around hazardous driving situations of varying type (i.e., social or non-social) among adolescents and young adults with ASD as compared to typically developing controls in the safe environment of a driving simulator (Godley et al., 2002; Kaptein et al., 1996; Mullen et al., 2011; Underwood et al., 2011). Based on the findings of Sheppard and colleagues (2010) indicating slower reaction times to social hazards in individuals both with and without ASD, it was expected that regardless of diagnostic group, decrements in simulated driving performance (i.e., slower reaction times, a greater number of MVCs, greater speed exceedances) would occur surrounding social hazards (e.g., pedestrians) when compared to the non-social hazards (e.g., vehicles). Based on the preliminary video-based findings of Sheppard and colleagues (2010) indicating that drivers with ASD identified significantly fewer social hazards than those without ASD, it was also expected that individuals with ASD would respond significantly slower to social hazards as compared to typically developing controls in a simulated driving environment.

Although significant differences were previously found in identification of hazards while watching video clips (Sheppard et al., 2010), this method does not capture the added motor, cognitive and attention demands that the complex task of driving requires (Salvucci, 2006). A driving simulator provides a safe, and accurate means of studying how a deficit in identification of social hazards may affect the driving performance of individuals with ASD (Godley et al., 2002; Kaptein et al., 1996; Mullen et al., 2011; Underwood et al., 2011). The current study was unique in its attempt to evaluate the perception of social and non-social driving hazards in ASD drivers through the use of a driving simulator (Classen, Monahan, & Hernandez, 2013; Cox et al., 2016; Reimer et al., 2013). (Classen et al., 2013; Cox et al., 2016; Reimer et al., 2013). It was also the first to match typically developing controls to drivers with ASD on driving experience, a variable that has a significant impact on driving performance (Mayhew, Simpson, & Pak, 2003) and more specifically, hazard perception (Crundall et al., 2012). The inclusion of typically developing controls matched on driving experience allowed for isolation of the social impairments associated with ASD that may affect driving performance and hazard perception (Clark, Feehan, Tinline, & Vostanis, 1999; Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009).

Methods

Participants

The total sample consisted of 32 drivers (M_{Age}= 23.17 years, *SD* = 3.92 years): 16 with a clinical diagnosis of ASD and 16 typically developing controls. The majority of the sample was male (94%) as expected given the distribution of ASD in the general population, with ASD being five times more common in males than females (Centers for Disease Control and Prevention [CDC], 2015). As ASD occurs equally in all racial and ethnic groups, ethnic distributions were that of the general population (75% Caucasian) (Centers for Disease Control and Prevention [CDC], 2015). To ensure equality among the groups control participants were recruited according to the gender distributions of ASD participants. Typically developing controls were also matched to participants with ASD based on driving experience (as measured by months since driving permit was received) to account for its effect on driving performance (Almberg et al., 2015). Participants reported driving an average of 5.32 days per week (*SD* = 2.20) and had an average of 92.77 months (or about 7.7 years) of driving experience (*SD* = 47.47) (See Table 1). Intercorrelations among all variables used in analyses revealed no significant correlations approaching levels of concern for multicollinearity (all *r*'s < .7). There were marginally significant differences among the groups for number of comorbid diagnoses ($F(2,44) = 3.194$, $p=.051$) with the ASD group having a greater number of comorbidities (*M* = 1.44, *SD* = 2.66) as compared to typically developing controls (no reported psychological diagnoses). The most commonly reported comorbidities for ASD participants included Generalized Anxiety Disorder, Depression and Obsessive Compulsive Disorder. In addition, the ASD group reported significantly greater social skill impairment compared to the typically developing group ($t(30) = 0.934$, $p = .02$). As expected, no significant differences were found between the groups on matching variables (age, gender and driving experience). There were differences among the groups for Race, with significantly more Caucasian participants in the ASD group, $\chi^2(2) = 8.23$, $p= .02$. However, previous research has suggested no relationship between race and driving performance, therefore analyses proceeded without Race included as a covariate. The ASD group (*M* = 4.31, *SD* = 2.75) also drove significantly fewer days per week than the control group (*M* = 6.19, *SD* = 1.52), $F(2,44) = 3.25$, $p=.048$. Given the importance of driving experience to driving performance, days per week driven was included as a covariate in all analyses examining differences among diagnostic groups. See Table 1 for descriptive statistics of participant characteristics by group.

Participants with ASD were recruited from flyers, advertisements on social networks, and also from several organizations designed to address the needs of individuals with neurodevelopmental disabilities. Control participants were recruited using advertisements on social networks and flyers around the community.

General Study Inclusion/Exclusion Criteria—Exclusion criteria for the study included: (1) diagnosis of any severe psychiatric conditions (e.g., bipolar disorder) and (2) presence of severe physical disabilities (e.g., need for a wheelchair) which would prohibit full participation in the experimental protocol. Inclusion criteria included (1) age at least 16 and no older than 30 years of age; (2) acquisition of a full driver's license; (3) and the ability to read, write and comprehend English. ASD is commonly accompanied by other neurodevelopmental disabilities, with co-occurrence of one or more non-ASD neurodevelopmental diagnoses occurring in 83% of those diagnosed with ASD (Centers for Disease Control and Prevention [CDC], 2015). For this reason, participants with a co-occurring developmental disability were not excluded from the study.

ASD Group—To be assigned to the ASD group participants had to have a previous diagnosis of Autistic disorder, Asperger's syndrome, Pervasive Developmental disorder not otherwise specified or Autism Spectrum Disorder. ASD symptom counts were collected using the Autism-Spectrum Quotient (AQ) (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Volkmar, Rogers, Paul, & Pelphrey, 2014), which was administered in a pre-visit telephone screener. Participants in the group with ASD reported significantly more ASD symptoms (higher AQ scores) compared to typically developing controls.

Typically Developing Control Group—To be assigned to the typically developing control group, participants had to have no previous diagnosis of ASD. Participants in the control group also endorsed significantly fewer ASD symptoms (as measured by the AQ) than the group with ASD.

Design

A team of 12 trained graduate and undergraduate research assistants administered telephone screenings and a team of 2 trained graduate students administered tasks and questionnaires to all participants. Standardized experimental protocols were followed in all testing sessions. Participant eligibility for the study was based on information acquired during a pre-visit telephone screening process conducted by a trained research assistant. Telephone screenings for ASD participants were used to collect basic demographic information (e.g., age, gender, and years of education) as well as driving experience (e.g., months since driving permit was received). For control participants, telephone screenings were conducted to collect basic demographic information as well as match participants on age, gender and driving experience to ASD participants. Participants meeting eligibility for the study were scheduled for a study visit and mailed a packet including consent form, instructions for the visit, directions to the lab, and a series of questionnaires to complete. Prior to study participation, upon arrival, each participant provided written informed consent, and parents provided consent for participants under the age of 18.

Upon arrival, participants received instruction in the operation and use of the driving simulator during a calibration session prior to actual data collection. Preprogrammed, audible instructions provided participants information about the route to take while completing the driving task (e.g., “Turn left at the next intersection”). Participants drove a brief (1 mile), standardized simulator scenario until they achieved stable driving performance (no collisions and fewer than 2 speed warnings). Participants received verbal warnings if they drove too far below or above the posted speed limit. Participants were offered three attempts to complete the calibration drive. Participants who were unable to complete the calibration drive were deemed unfit for participation and did not proceed any further with the study. However, all participants were able to demonstrate adequate proficiency in the simulator with 64% of participants passing on the first attempt, 32% of participants passing on the second attempt and only 4% of participants needing the third attempt to meet the minimum level of proficiency. These rates were not significantly different between the ASD and non-ASD participants, with no group needing significantly more attempts to pass the calibration drive than any other group ($\chi^2(3) = 1.57$, $p = .82$). There were no incidences of simulator sickness.

Participants then engaged in the experimental driving task consisting of one five mile driving scenario with the following elements distributed throughout: (a) no hazard periods, during which participants were required to perform common driving skills (i.e., turning, stopping at stop signs); (b) social hazard events, where participants encountered driving hazards involving either a pedestrian or cyclist and, (c) non-social hazard events, where participants encountered driving hazards involving other cars. The driving scenario lasted approximately 15 minutes when driven at the posted speed limit. After completing the drive, each participant completed a series of questionnaires and tasks assessing social skills. At the conclusion of the session, participants were compensated $25.00 for their time.

Apparatus

Driving Simulator—Study participants engaged in a computerized driving simulation task to measure performance under specified conditions of interest (STISIM Drive, Systems Technology Inc., Hawthorne, CA). The simulation was displayed on three, 20” LCD computer monitors. The simulator provided a view of the roadway and dashboard instruments, including a speedometer, rpm gauge and a letter indicating the vehicle’s gear. The vehicle was controlled by moving a steering wheel in a typical driving manner while depressing the accelerator and brake pedals accordingly. An on-board stereo sound system provided naturalistic engine sounds, external road noise, and sounds of passing traffic. The driving scenario featured a two-lane, bi-directional road enhanced by daytime suburban scenery. The scenario was standardized by distance (5 miles) and varied in posted speed limit, so participants differed in the time it took them to complete the drive (on average approximately 10 to 15 minutes). During the scenarios, participants navigated through an environment containing a total of eight hazards: 4 social hazards (e.g., the presence of a clearly visible person) and 4 non-social hazards (e.g., no visible human figure present) that required an immediate evasive response (See Figure 2). Hazardous events were defined as unexpected events that required the driver to brake suddenly or make some type of evasive maneuver (i.e., swerving) to avoid a collision. Modeled after previous research efforts (Sheppard et al., 2010), the four social hazard events were as follows: an adult pedestrian walks into the driver’s path from behind a parked car, a cyclist riding on the side of the road moves into the driver’s path, a child pedestrian walks across the street into the driver’s path, and a second cyclist pulls into the driver’s path from the right side of the road. The four non-social hazards were as follows: a car following close behind a bus in the oncoming lane attempts to pass and confronts the driver head on, a car waiting in a gas station near the side of the road pulls out into the driver’s path, a truck parked in a driveway backs out into the driver’s path, and a taxi pulls out into the driver’s path from behind a tall bus on the side of the road. The simulator automatically triggered hazardous events once the driver reached a predetermined distance from the event in the scenario. If participants crashed in the simulator, a cracked windshield screen and audible crash sounds were presented to simulate a collision, the simulator screen then reloaded the roadway scene at the point of collision and participants continued to drive.

The driving simulator automatically measured driver reaction time to hazardous events, average driving speed, MVCs and speed exceedances within equidistant time blocks predetermined to begin when hazardous events were triggered until after the driver passed or collided with the hazard. (1) Reaction time reflected the amount of time in seconds that elapsed from the time the event triggered to the first of four possible reactions: a 10% increase in accelerator pressure (i.e., the driver began to depress the accelerator to speed up), a 10% decrease in accelerator pressure (i.e., the driver began to release the accelerator to slow down) (Rakauskas, Gugerty, & Ward, 2004; Stavrinos et al., 2015), an increase of at least 1 pound of pressure to the brake pedal (i.e., driver began to press the brake to slow the vehicle) (Crundall, Andrews, van Loon, & Chapman, 2010; Garrison & Williams, 2013), or a 5-degree change in steering wheel angle (i.e., the driver swerved to avoid the hazardous event) (Crundall et al., 2010; Garrison & Williams, 2013). (2) Average driving speed was collected and defined as the driver's average speed while approaching hazardous events in miles per hour (mph) (Stavrinos et al., 2013). (3) Total number of motor vehicle collisions (MVCs) was computed across each driving scenario as anytime the participant ran off the road (past a predetermined distance off of the roadway) or struck another vehicle, pedestrian, cyclist or object (Narad et al., 2013; Stavrinos et al., 2015; Stavrinos et al., 2013). (4) Speed exceedances were defined as the number of times the participant exceeded the speed limit greater than or equal to 8 miles per hour while driving through the scenario (Stavrinos et al., 2015).

Measures

Demographics—Participants were asked via telephone screening to provide basic demographic information including age, gender, race, the highest level of education completed, months since permit was received (indicator of driving experience), average days driven per week, marital status, employment status and living status (residential setting, group home or living independently).

Symptomology Variables—The Autism-Spectrum Quotient (AQ) questionnaire was used to assess the presence of symptoms consistent with ASD (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006). The AQ is a 50 item questionnaire comprised of 5 sets of 10 questions that assessed five different areas of ASD symptomology: social skill, attention switching, attention to detail, communication and imagination, with higher scores indicating a greater presence of ASD symptoms (Baron-Cohen et al., 2001). Previous research suggests that the average score for typically developing controls is approximately 16.4, and a score of 32 or greater indicates "clinically significant levels of autistic traits" (Baron-Cohen et al., 2001). Discriminative power tests of the AQ revealed a successful differentiation rate of 80% (Naito, Matsui, Maeda, & Tanaka, 2010). The Cronbach's α for the current study was .48. Previous diagnosis of an ASD was used to assign participants to the ASD group then AQ score was used to further confirm group level differences in characteristics consistent with ASD.

Social Skill Variable—The adult self-report form of the Social Responsiveness Scale - Second Edition (SRS-2) was used as a measure of social skill impairment for all participants aged 19 and older (Constantino & Gruber, 2012). The SRS-2 was a 65-item questionnaire measuring social skill impairment (e.g., "I think or talk about the same thing over and over"). It is comprised of five subscales: social awareness, social cognition, social communication, social interactions and restricted interests and repetitive behavior, with higher scores indicating greater social skill impairment. The SRS-2 has good internal consistency in the current sample (Cronbach's α = .91) and is best used to assess severity of difficulties in social interaction and behavior (Volkmar et al., 2014). As would be expected based on the review of literature above, those with ASD exhibit significant deficits in the area of social skills and, not surprisingly, SRS scores when compared to typically developing individuals (Volkmar et al., 1987). SRS-2 scores were used to quantify social skill impairments in the group with ASD.

Participants aged 16 to 18 completed the student self-report form of the Social Skills Rating System (SSRS) as a measure of social skill (Gresham & Elliott, 1990). The SSRS consists of 39 self-report social behavior items (e.g., "I make friends easily") rated on a 3-point scale (0 = Never, 1 =Sometimes, 2= Very Often), with higher scores indicating better social skills. To provide consistency, the items on the SSRS were reverse scored such that higher scores now indicted poorer social skills matching the SRS-2. By reversing the scores of the SSRS, both measures of social skill were on the same scale with higher scores indicating greater social skill impairment. The SSRS showed good internal consistency (Cronbach's $\alpha = .89$).

Statistical Analysis

The outcome variable speed exceedances had an over-dispersed distribution (i.e., the variance was larger than the mean). MVCs had a variance that was slightly smaller than the mean and violated the Shapiro Wilks test for normality ($p < .001$) for both groups (ASD and Controls). Reaction time and average driving speed were both normally distributed. All outcome variables were within the acceptable ranges for skewness and kurtosis. There was one outlier for Social Skill standard score ($Z = 3.12$); however, upon examination, this value fell within the appropriate score range of the measure and was therefore kept in analyses. Levene's Test for homogeneity of variances revealed no violations. Because there were only two levels of the within-subject independent variable (hazard type) the Levene's test was used to test homogeneity of variances and indicated no violations ($p = .643$).

For each simulated driving performance outcome, a social hazard (collapsed across the 4 social hazards) and non-social hazard (collapsed across the 4 non-social hazards) score was calculated (i.e., social hazard reaction time and non-social hazard reaction time). Repeated Measures Analyses of Covariance (RM ANCOVA) were used to analyze the effect of hazard type (social hazard or non-social hazard) on continuous measures of driving performance (reaction time and average speed). Generalized Estimating Equation (GEE) Poisson models were used to test the main effect of hazard type on driving performance measures of a count nature with non-normal distributions (MVCs and speed exceedances).

The interaction of group (ASD and Controls) and hazard type (social and non-social) was tested using RM ANCOVA with a mixed model approach (between subjects factor: group; within subjects factor: hazard type; covariate: days per week driven) for continuous driving performance outcomes measures (reaction time and average speed), and GEE Poisson models were used to test the differences among the groups in each hazard condition for driving performance measures of a count nature (MVCs and speed exceedances).

Ethics

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. Conflict of Interest: The authors declare that they have no conflict of interest.

Results

In regards to the type of initial response participants made to hazards in the simulator, the most common initial type of reaction was releasing the throttle (i.e., participant released pressure on the accelerator) for every hazard. Swerving behavior was the least commonly used initial response strategy for all hazards. Descriptive data for each of the hazards in the scenario are displayed in Table 2. Results from a RM ANCOVA examining the main effect of hazard type revealed no significant effect of hazard type for reaction time ($F(1) = 2.709$, $p = .111$) or average driving speed ($F(1) = .795$, $p = .380$). The effect of hazard type on non-normally distributed, count variables revealed hazard type to be a significant predictor of the driving performance outcome MVCs, $\chi^2(1) = 15.63$, $p < .001$. Participants had 94% fewer simulated MVCs around social hazards compared to non-social hazards (95% CI, .009 to .420).

Results from a RM ANCOVA indicated a marginally significant group by hazard type interaction for reaction time ($F(1) = 3.84$, $p = .06$) (See Figure 3). To further investigate this trend, paired samples t-tests were conducted within each group to compare reaction time to social versus non-social hazards. Significant differences emerged for reaction time to social ($M = .838$, $SD = .41$) versus non-social hazards ($M = 1.13$, $SD = .28$) in the control group, $t(15) = -3.63$, $p < .01$, with typically developing drivers reacting more quickly to social hazards. However, no significant difference was found in reaction time to social ($M = 1.05$, $SD = .36$) versus non-social hazards ($M = 1.10$, $SD = .41$) for the ASD group (See Figure 3). No significant group by hazard type interaction was found for average driving speed (See Figure 4).

GEE Poisson analyses (controlling for days per week driven) for count measures of driving performance (MVCs and speed exceedances) indicated that the Group×Hazard Type interaction was not a significant predictor of either MVCs or speed exceedances (See Figures 5 and 6).

Discussion

Effect of Hazard Type on Driving Performance

Contrary to the previous findings of Sheppard and colleagues which suggested slower reaction times to social versus non-social hazards (2010), the current findings indicated no significant effect of hazard type on reaction time or average driving speed; however overall participants had significantly fewer simulated MVCs with social hazards. Sheppard and colleagues were the first to test the effects of hazard typology (social and non-social) on hazard response time using a novel approach, but this was examined in a sample of non-drivers reacting to video clips of hazardous situations (Sheppard et al., 2010) which may have limited the external validity of the study’s findings. The current study’s methodological approach (i.e., utilization of driving simulator technology in a sample of current drivers) may provide results that are more representative of real-world driving behavior and may explain the discrepant findings. Previous literature on social orienting indicates that typically developing individuals naturally orient their visual attention to social aspects of an environment. This may explain the findings of this study suggesting that participants had fewer MVCs around social hazards (Hill et al., 2010). There is however a body of literature suggesting rather that drivers may be more likely to be involved in an MVC with pedestrians and cyclists (i.e., social hazards) as compared to other cars (i.e., non-social hazards) due to a variety of factors (Crundall, Bibby, Clarke, Ward, & Bartle, 2008; Crundall et al., 2012; Pai, 2011). These factors include the small size of social hazards, the fact that they are not easily seen and are encountered less frequently (Crundall et al., 2008; Crundall et al., 2012; Pai, 2011; Walker, 2005). The findings of these previous research studies are in contrast to the findings of the current study and highlight the need for a better understanding of the interactions between drivers and other vulnerable road users (i.e., pedestrians and cyclists).

Effect of Hazard Type and Group on Driving Performance

Contrary to expected findings, the effect of hazard type on driving performance outcomes did not vary significantly by diagnostic group. However the group by hazard interaction trended toward significance for reaction time, with typically developing controls reacting more quickly to social hazards as compared to non-social hazards. In other words, they had faster reaction times, and therefore lower likelihood of having a simulated MVC with pedestrians and cyclists compared to other vehicles (Quimby et al., 1987). This difference was however absent in drivers with ASD, who showed no difference in reaction time to pedestrians and cyclists compared to other vehicles. It is suspected that the natural tendency of typically developing controls (individuals with typical social information processing) to orient their attention to social aspects of the simulated driving environment (i.e., social orienting) (Hill et al., 2010) may explain their quickened response time to social hazards relative to non-social hazards. It is also suspected that the impairment in or lack of social orienting in individuals with ASD (Dawson et al., 1998) may explain the fact that they showed no difference in reaction to social versus non-social hazards. However, as no significant differences emerged between the groups for social hazard reaction time, this finding is provisionary and should be more thoroughly researched before firm conclusions can be determined.

Limitations

Recruiting individuals with ASD who also had a driver's license proved to be quite challenging as only 24% of individuals with ASD report being independent drivers (Feeley, 2010), which limited the sample size of the current study. However, the current study's sample size was comparable, and in some cases larger, than previous investigations of ASD and driving (Classen et al., 2013; Cox et al., 2016; Reimer et al., 2013; Sheppard et al., 2010). Future research should expound on these study findings in a larger sample of drivers with ASD.

The unexpectedly low ASD symptomology scores for some participants in the ASD group should be noted as a possible limitation of the study. A score of 32 or greater is the cutoff for clinical levels of ASD symptoms, and although the mean AQ score for the ASD group was above this cutoff ($M = 33.19$), some ASD participants scored below it (as low as 22) (Baron-Cohen, 2001). This is still elevated compared to the AQ scores noted in typically developing individuals (approximately 16), but is well below the clinical cutoff of 32 (Baron-Cohen, 2001). A full driver's license was required to participate in the study and individuals with

ASD who are able to achieve full licensure status and drive independently are typically higher functioning. Previous literature suggests that the higher functioning an individual with ASD is, the fewer number of ASD symptoms they will exhibit (Hofvander et al., 2009). The fact that obtaining a driver's license requires higher order cognitive skills more commonly noted in the high-functioning end of the Autism spectrum likely explains why some of the study participants with ASD endorsed fewer symptoms AQ than is typically seen in the general ASD population.

Although the current study's findings suggested differences in reaction time to social and non-social driving hazards, it should be noted that these various hazard types also included various other incidental aspects like complexity, size, surprise, and anticipation. The two hazard types were not balanced on these other incidental differences which may have influenced study findings. Future research should aim to more closely balance the physical (i.e., size, color) and dynamic (i.e., speed of movement and onset) characteristics of social and non-social hazards to better isolate the impact of the social nature of the hazard on driver response. In addition to hazard characteristics that may have impacted study findings, we did not collect information on whether or not participants had previously completed a hazard perception test, which could have affected hazard perception abilities. However, it is not mandatory in the country/state where the study was conducted (i.e., Birmingham, AL) so we expect that this would apply to only a few if any of our participants.

As is the challenge when conducting any research that examines the topic of injury prevention, this study was faced with the challenge of examining how people react in dangerous situations in a safe and ethical manner. The driving simulator provided a validated way to assess how vulnerable drivers react to various kinds of hazards (Godley et al., 2002; Underwood et al., 2011). Although the simulator and driving scenarios were designed to model the real world driving environment and situations, it is unclear how simulated driving behavior translates to real-world driving behavior, though several studies do show promise for use of simulators in research with at-risk groups (Godley, Triggs, & Fildes, 2002; Lew et al., 2005; Mullen et al., 2011; Underwood et al., 2011).

Future Directions

As ASD is growing increasingly more prevalent and there are now more transitioning adults with ASD than ever before, additional research on the topic of ASD and driving is expected to emerge over the next decade to meet the growing need. The findings of the current study are promising, as they suggest overall, no significant driving performance decrements among individuals with ASD as compared to typically developing drivers. However, the current study examined the driving performance and hazard perception abilities of adults with ASD who had already attained a driver's license. Taking this into consideration, it is possible that the lack of group differences may have been because only those who have successfully acquired a license took part in this study and we would naturally therefore expect them to be able to detect hazards in the environment. Future research would benefit from studying teens with ASD who are still in the learning to drive phase (i.e., are trying to or have already attained a learner's permit). Current research on teens with ASD who are learning to drive and the specific barriers they face is limited to survey data alone (Almberg et al., 2015). Incorporating individuals with ASD who are still learning to drive into driving simulator research will allow us to better understand the impact that driving experience and age play in the impairments in driving performance previously exhibited by individuals with ASD (Classen et al., 2013; Reimer et al., 2013). By more closely examining pre-drivers with ASD (i.e., those with only a learner's permit), and the cognitive, social and manual skills required for safe driving that they may be lacking, empirically-based, targeted driving training programs could be developed to aid in their learning process and improve their driving safety. Based on the findings of this study, hazard training programs may be a promising intervention for future studies to investigate in the population of individuals with ASD.

Future research should also investigate possible predictors of hazard perception and more broadly driving status in the population of drivers with ASD. It is possible that certain characteristics (i.e., ASD symptom severity, anxiety, etc.) of individuals with ASD may make them more likely/able to achieve full licensure. Identifying significant predictors of driving performance would allow us to target interventions to specific abilities or barriers to independent driving in this increasing more prevalent population of emerging adults with ASD. In addition to the identification of significant predictors of driving performance for individuals with ASD, future research should also explore possible underlying mechanisms behind the slowed response to social hazards relative to typically developing drivers among drivers with ASD. There are a variety of deficiencies associated with ASD that may be implicated in the slower reaction time such as theory of mind impairments (i.e., perspective-taking), slowed attention to social stimuli and decrements in reading and understanding body language and faces. Eye-tracking studies may be one step is parsing these underlying causes apart.

The current study findings suggested differences in the response time to social and non-social hazards for drivers with typical development, but not for drivers with ASD. The significantly faster reaction times to pedestrians and cyclists versus other cars observed in typically developing controls suggests that drivers without social skill impairment may automatically orient their attention to these social hazards more quickly than to non-social hazards (Hill et al., 2010). This quickened visual orienting in typically developing drivers may have led to the faster reaction times to social hazards relative to non-social hazards. The faster a driver is able to respond to a hazard in the environment, the less likely the driver is to collide with that hazard. These quicken reaction times to social hazards relative to non-social hazards in typically developing drivers are promising as MVCs involving pedestrians and cyclists (i.e., social hazards) are far more likely to result in an injury or fatality (Moudon et al., 2011). Why the quickened response to social hazards was not present in drivers with ASD is a question that requires further investigation. It is possible that drivers with ASD are visually attending to these hazards, but do not process social hazards as quickly as typically developing controls; however, it may also be that drivers with ASD are taking longer to orient their visual attention to these social hazards compared to typically developing controls due to impairments in social orienting (Dawson et al., 1998). Future research should utilize eye-tracking technology in the context of a driving simulator to monitor visual attention and gaze patterns of drivers with ASD compared to typically developing controls. This would provide information to help explain the differences seen in social and non-social hazard response time in drivers with ASD compared to typically developing controls. Further, if social information processing (rather than social orienting) is found to be a predictor of slower social hazard response time in individuals in ASD, social skills training programs (i.e., computerized or group-based training) should be examined as a possible intervention strategy to improve social information processing in the context of a real world driving environment. If social orienting and visual attention are found to be significant predictors of slower social hazard reaction times, driving hazard anticipation and avoidance training programs may prove to be a more effective intervention strategy for individuals with ASD.

Conclusions

This study is among the first to examine the hazard perception of individuals with ASD compared to typically developing drivers, adding to the much needed body of knowledge on ASD and driving. More research is needed to improve quality of life, ensure successful transition to adulthood and address the transportation safety needs of individuals with developmental disabilities such as ASD.

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References

Almberg M, Selander H, Falkmer M, Vaz S, Ciccarelli M, Falkmer T. Experiences of facilitators or barriers in driving education from learner and novice drivers with ADHD or ASD and their driving instructors. Developmental Neurorehabilitation. 2015:1–9.

Barnhill GP. Outcomes in Adults With Asperger Syndrome. Focus on Autism and Other Developmental Disabilities. 2007; 22(2):116–126.

Baron-Cohen S, Hoekstra RA, Knickmeyer R, Wheelwright S. The Autism-spectrum Quotient (AQ) - Adolescent version. Journal of Autism and Devlopmental Disorders. 2006; 36(3):343–350.

Baron-Cohen S, Wheelwright S, Skinner R, Martin J, Clubley E. The Autism-spectrum Quotient (AQ): Evidence from Aspergers syndrome/High-functioning Autism, males and females, scientists and mathematicians. Journal of Autism and Devlopmental Disorders. 2001; 31(1):5–17.

Beeli G, Koeneke S, Gasser K, Jancke L. Brain stimulation modulates driving behavior. Behavioral and Brain Functions. 2008; 4(34)

Benson N, Hulac DM, Kranzler JH. Independent examination of the Wechsler Adult Intelligence Scale - Fourth Edition (WAIS-IV): What does the WAIS-IV measure? Psychological Assessment. 2010; 22(1):121–130. doi: http://dx.doi.org/10.1037/a0017767. [PubMed: 20230158]

Benson V, Castelhano MS, Howard PL, Latif N, Rayner K. Looking, seeing and believing in Autism: Eye movements reveal how subtle cognitive processing differences impact in the social domain. Autism Research. 2015

Borowsky A, Shinar D, Oron-Gilad T. Age, skill, and hazard perception in driving. Accident Analysis & Prevention. 2010; 42(4):1240–1249. [PubMed: 20441838]

Broadbent J, Galic I, Stokes MA. Validation of Autism Spectrum Quotient Adult Version in an Australian sample. Autism Research and Treatment. 2013:1–7.

Brown JD. Evaluations of self and others: Self-enhancement biases in social judgements. Social Cognition. 1986; 4(4):353–376.

Centelles L, Assaiante C, Etchegoyhen K, Bouvard M, Schmitz C. From action to interaction: Exploring the contribution of body motion cues to social understanding in typical development and in Autism Spectrum Disorders. Journal of Autism and Developmental Disorders. 2013; 43(5): 1140–1150. [PubMed: 23008056]

Centers for Disease Control and Prevention [CDC]. Autism Spectrum Disroder (ASD): Facts about ASD. 2015 Feb. from http://www.cdc.gov/ncbddd/autism/data.html.

Clark T, Feehan C, Tinline C, Vostanis P. Autistic sypmtoms in children with Attention Deficit-Hyperactivity Disorder. European Child & Adolescent Psychiatry. 1999; 8:50–55. [PubMed: 10367741]

Classen S, Monahan M, Hernandez S. Indicators of simulated driving skills in adolescents with Autism Spectrum Disorder. The Open Journal of Occupational Therapy. 2013; 1(4):1–13.

Constantino, JN., Gruber, CP. Social Responsiveness Scale, Second Edition (SRS-2). Torrance, CA: Western Psychological Services; 2012.

Corbett BA, Constantine LJ, Hendren R, Rocke D, Ozonoff S. Examining executive functioning in children with Autism Spectrum Disorder, Attention Deficit Hyperactivity Disorder and typical development. Psychiatry Research. 2009; 166(2-3):210–222. [PubMed: 19285351]

Cox SM, Cox DJ, Kofler MJ, Moncrief MA, Johnson RJ, Lambert AE, Reeve RE. 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. 2016:1379–1391. [PubMed: 26676628]

Crundall D. Hazard prediction discriminates between novice and experienced drivers. Accident Analysis & Prevention. 2016; 86:47–58. [PubMed: 26513336]

Crundall D, Andrews B, van Loon E, Chapman P. Commentary training improves responsiveness to hazards in a driving simulator. Accident Analysis & Prevention. 2010; 42(6):2117–2124. [PubMed: 20728670]

Crundall D, Bibby P, Clarke D, Ward P, Bartle C. Car drivers' attitudes towards motorcyclists: A survey. Accident Analysis & Prevention. 2008; 40:983–993. [PubMed: 18460366]

Crundall D, Chapman P, Trawley S, Collins L, Van Loon E, Andrews B, Underwood G. Some hazards are more attractive than others: Drivers of varying experience respond differently to different types of hazards. Accident Analysis & Prevention. 2012; 45:600–609. [PubMed: 22269547]

Dawson G, Meltzoff AN, Osterling J, Rinaldi J, Brown E. Children with Autism fail to orient to naturally occuring social stimuli. Journal of Autism and Devlopmental Disorders. 1998; 28(6): 479–485.

Deaner RO, Platt ML. Reflexive social attention in monkeys and humans. Current Biology. 2003; 13:1609–1613. [PubMed: 13678591]

Deery HA. Hazard and risk perception among young novice drivers. Journal of Safety Research. 1999; 30(4):225–236.

Doshi A, Trivedi M. On the roles of eye gaze and head dynamics in predicting driver's intent to change lanes. IEEE Transactions on Intelligent Transportation Systems. 2009; 10(3):453–462.

Erford, BT. Disruptive Behavior Rating Scale (DBRS). East Aurora, NY: Slosson; 1993.

Feeley, C. Evaluating the transportation needs and accesibility issues for adults on the Autism Spectrum in New Jersey; Paper presented at the Transportation Research Board 89th Annual Meeting; Washington, DC. 2010 Jan.

Garrison TM, Williams CC. Impact of relevance and distraction on driving performance and visual attention in a simulated driving environment. Applied Cognitive Psychology. 2013; 27(3):396–405.

Godley ST, Triggs TJ, Fildes BN. Driving simulator validation for speed research. Accident Analysis & Prevention. 2002; 34(5):589–600. [PubMed: 12214953]

Gresham, FM., Elliott, SN. Social Skills Rating System. Circle Pines, MN: American Guidance Service; 1990.

Guéguena N, Eyssartierb C, Meineria S. A pedestrian's smile and drivers' behavior: When a smile increases careful driving. Journal of Safety Research. 2016; 56:83–88. [PubMed: 26875169]

Happe F, Frith U. The weak central coherence account: Detail-focused cognitive style in autism spectrum disorders. Journal of Autism and Developmental Disorders. 2006; 36(1):5–25. [PubMed: 16450045]

Hardiess G, Hansmann-Roth S, Mallot HA. Gaze movements and spatial working memory in collision avoidance: A traffic intersection task. Frontiers in Behavioral Neuroscience. 2013; 7(62):1–13. [PubMed: 23423702]

Hill JL, Patel S, Gu X, Seyedali NS, Bachevalier J, Sereno AB. Social orienting: Reflexive versus voluntary control. Vision Research. 2010; 50(20):2080–2092. [PubMed: 20673778]

Hofvander B, Delorme R, Chaste P, Nydén A, Wentz E, Ståhlberg O, Leboyer M. Psychiatric and psychosocial problems in adults with normal-intelligence autism spectrum disorders. BMC Psychiatry. 2009; 9(35)

Howlin P. Outcome in adult life for more able individuals with autism or Asperger syndrome. Autism. 2000; 4(1):63–83.

Kaptein N, Theeuwes J, Van Der Horst R. Driving simulator validity: Some considerations. Transportation Resesrach Record. 1996; 1550:30–36. doi: http://dx.doi.org/10.3141/1550-05.

Kleinman J, Marciano PL, Ault RL. Advanced theory of mind in high-functioning adults with Autism. Journal of Autism and Developmental Disorders. 2001; 31(1):29–36. [PubMed: 11439751]

Klin A, Jones W, Schultz R, Volkmar F. The enactive mind, or from actions to cognition: Lessons from Autism. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences. 2003; 358(1430):345–360. [PubMed: 12639332]

Klin A, Jones W, Schultz R, Volkmar F, Cohen D. Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with Autism. Archives of General Psychiatry. 2002; 59(9):809–816. [PubMed: 12215080]

Kulp MT, Sortor JM. Clinical value of the Beery Visual-Motor Intergration supplemental tests of Visual Perception and Motor Coordination. Optometry and Vision Science. 2003; 80(4):312–315. [PubMed: 12692488]

Lew HL, Poole JH, Lee EH, Jaffe DL, Huang HC, Brodd E. Predictive validity of driving-simulator assessments following traumatic brain injury: A preliminary study. Brain Injury. 2005; 19(3):177–188. [PubMed: 15832892]

Machalicek W, O'Reilly MF, Beretvas N, Sigafoos J, Lancioni. A review of interventions to reduce challenging behavior in school settings for students with autism spectrum disorders. Research in Autism Spectrum Disorders. 2007; 1(3):229–246.

Mayhew DR, Simpson HM, Pak A. Changes in collision rates among novice drivers during the first months of driving. Accident Analysis and Prevention. 2003; 35(5):683–691. [PubMed: 12850069]

McConnell SR. Intervention to facilitate social interaction for young children with Autism: Review of available research and recommendations for educational intervention and future research. Journal of Autism and Developmental Disorders. 2002; 32(5):351–372. [PubMed: 12463515]

McKenna FP, Horswell MS. Hazard perception and its relevance for driver liscensing. International Association of Traffic and Safety Sciences. 1999; 23(1):36–41.

Millstein RB, Wilens TE, Biederman J, Spencer TJ. Presenting ADHD symptoms and subtypes in clinically referred adults with ADHD. Journal of Attention Disorders. 1997; 2(3):159–166.

Moudon AV, Lin L, Jiao J, Hurvitz P, Reeves P. The risk of pedestrian injury and fatality in collisions with motor vehicles, a social ecological study of state routes and city streets in King County, Washington. Accident Analysis & Prevention. 2011; 43(1):11–24. [PubMed: 21094292]

Mullen, N., Charlton, J., Devlin, A., Bedard, M. Simulator validity: Behaviors observed on the simulator and on the road. Fisher, DL.Rizzo, M.Caird, JK., Lee, JD., editors. Boca Raton, FL: CRC Press; 2011.

Naito K, Matsui Y, Maeda K, Tanaka K. Evaluation of the validity of the Autism-spectrum Quotient (AQ) in differentiating high-functioning Autistic Spectrum Disorder from Schizophrenia. Kobe Journal of Medical Sciences. 2010; 56(3):116–124.

Narad M, Garner AA, Brassell AA, Saxby D, Antonini TN, O'Brien KM, Epstein JN. Impact of distraction on the driving performance of adolescents with and without Attention-Deficit/ Hyperactivity Disorder. The Journal of the American Medical Association Pediatrics. 2013; 167(10):1–6.

National Highway Traffic Safety Administration [NHTSA]. Traffic safety facts: Bicyclists and Other Cyclists. (DOT HS 812 282). Washington, DC: National Highway Traffic and Safety Administration's National Center for Statistics and Analysis; 2014a.

U. S. DoT.-N. H. T. a. S. Administration. , editor. National Highway Traffic Safety Administration [NHTSA]. Traffic safety facts: Pedestrians. Washington, DC: National Highway Traffic and Safety Administration's National Center for Statistics and Analysis; 2014b. p. 6

Pai C. Overtaking, rear-end, and door crashes involving bicycles: An empirical investigation. Accident Analysis & Prevention. 2011; 43(3):1228–1235. [PubMed: 21376922]

Pierce K, Glad K, Schreibman L. Social perception in children with Autism: An attentional deficit. Journal of Autism and Developmental Disorders. 1997; 27(3):265–282. [PubMed: 9229258]

Pradhan AK, Hammel KR, DeRamus R, Pollatsek A, Noyce DA, Fisher DL. Using eye movements to evaluate effects of driver age on risk perception in a driving simulator. Human Factors: The Journal of the Human Factors and Ergonomics Society. 2005; 47(4):840–852.

Quimby AR, Maycock G, Carter ID, Dixon R, Wall JG. Perceptual abilities of accident-involved drivers. Journal of Safety Research. 1987; 18(1)

Rakauskas ME, Gugerty LJ, Ward NJ. Effects of naturalistic cell phone conversations on driving performance. Journal of Safety Research. 2004; 35(4):453–464. [PubMed: 15474548]

Reimer B, Fried R, Mehler B, Joshi G, Bolfek A, Godfrey KM, Biederman J. 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. 2013; 43(9):2211–2217. [PubMed: 23338532]

Salvucci DD. Modeling driver behaior in a cognitive architechture. The Journal of Human Factors and Ergonomics Society. 2006; 48(2):362–380.

Self-driving cars need social skills. Minds on the Road: The science of what's driving behavior. 2016 Mar. Retrieved 2 March 2016, 2016, from http://www.psychologicalscience.org/index.php/news/motr/self-driving-cars-need-social-skills.html

Sheppard E, Ropar D, Underwood G, Van Loon E. Brief report: Driving hazard perception in Autism. Journal of Autism and Developmental Disorders. 2010; 40(4):504–508. [PubMed: 19890705]

Smith P, Shah M, Lobo NDV. Determining driver visual attention with one camera. IEEE Transactions on Intelligent Transportation Systems. 2003; 4(4):205–218.

Stavrinos D, Garner AA, Franklin CA, Johnson HD, Welburn SC, Griffin R, Fine PR. Distracted driving in teens with and without Attention-Deficit/Hyperactivity Disorder. Journal of Pediatric Nursing. 2015; 30(5):e183–e191. doi: http://dx.doi.org/10.1016/j.pedn.2015.04.006. [PubMed: 26049214]

Stavrinos D, Jones JL, Garner AA, Griffin R, Franklin CA, Ball D, Fine PR. Impact of distracted driving on safety and traffic flow. Accident Analysis & Prevention. 2013; 61:63–70. [PubMed: 23465745]

Underwood G, Crundall D, Chapman P. Driving simulator validation with hazard perception. Transportation Research Part F: Psychology and Behaviour. 2011; 14:435–446.

Underwood G, Phelps N, Wright C, Van Loon E, Galpin A. Eye fixation scanpaths of younger and older drivers in a hazard perception task. Ophthalmic and Physiological Optics. 2005; 25:346–356. [PubMed: 15953120]

Volkmar FR, Rogers SJ, Paul R, Pelphrey KA. Handbook of Autism and Pervasive Developmental Disorders: Fourth Edition. 2. Assesment, Interventions and Policy. 2014

Volkmar FR, Sparrow SS, Goudreau D, Cicchetti DV, Paul R, Cohen DJ. Social deficits in Autism: An operational approach using the Vineland Adaptive Behavior Scale. Journal of the American Academy of Child and Adolescent Psychiatry. 1987; 26(2):156–161. [PubMed: 3584011]

Walker I. Road users' perception of other road users: Do different transport modes invoke qualitatively different concepts in observers? Advances in Transportation Studies. 2005; 6:25–33.

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Yi L, Liu Y, Li Y, Fan Y, Huang D, Gao D. Visual scanning patterns during the dimensional change card sorting task in children with Autism Spectrum Disorder. Autism Research and Treatment. 2012; 2012:1–11.

Zalla T, Labruyere N, Georgieff N. Perceiving goals and actions in individuals with Autism Spectrum Disorders. Journal of Autism and Developmental Disorders. 2013; 43(10)

Figure 1. STISIM driving simulator

A	B

Figure 2. Social and Non-social driving hazard examples

Example A depicts one of the non-social hazards participants encountered (i.e., a vehicle approaching head on), while example B depicts one of the four social hazards encountered in the driving scenario (i.e., a pedestrian crossing the street outside of a crosswalk).

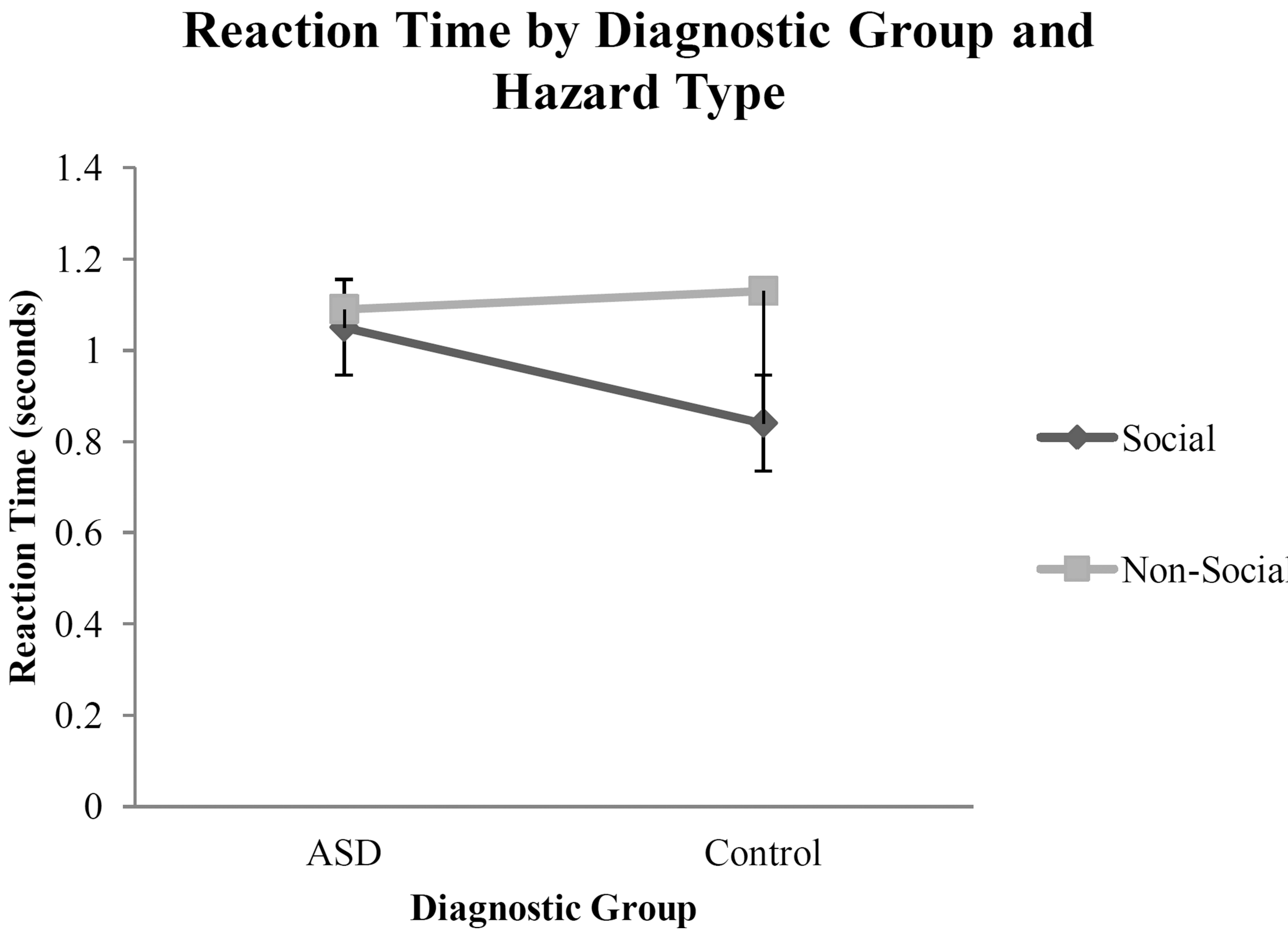

Figure 3. Interaction of diagnostic group and hazard type on reaction time

The group by hazard interaction for reaction time emerged as marginally significant ($F(1) = 3.84$, $p = .06$), control drivers reacted significantly more quickly to social as compared non non-social hazards. This difference was not found in the ASD group.

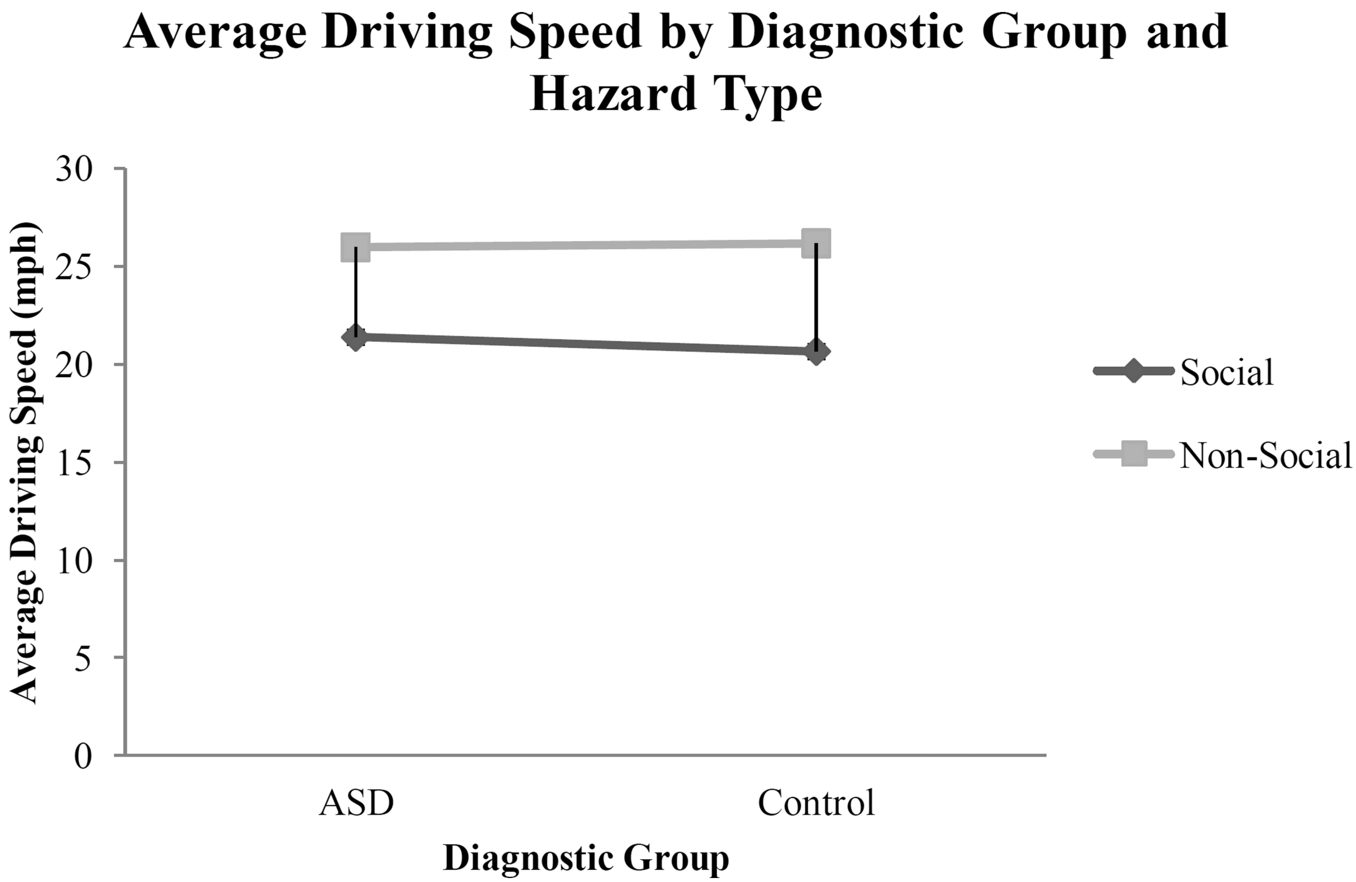

Figure 4. Interaction of diagnostic group and hazard type on average driving speed
No significant group by hazard interaction was found for average driving speed.

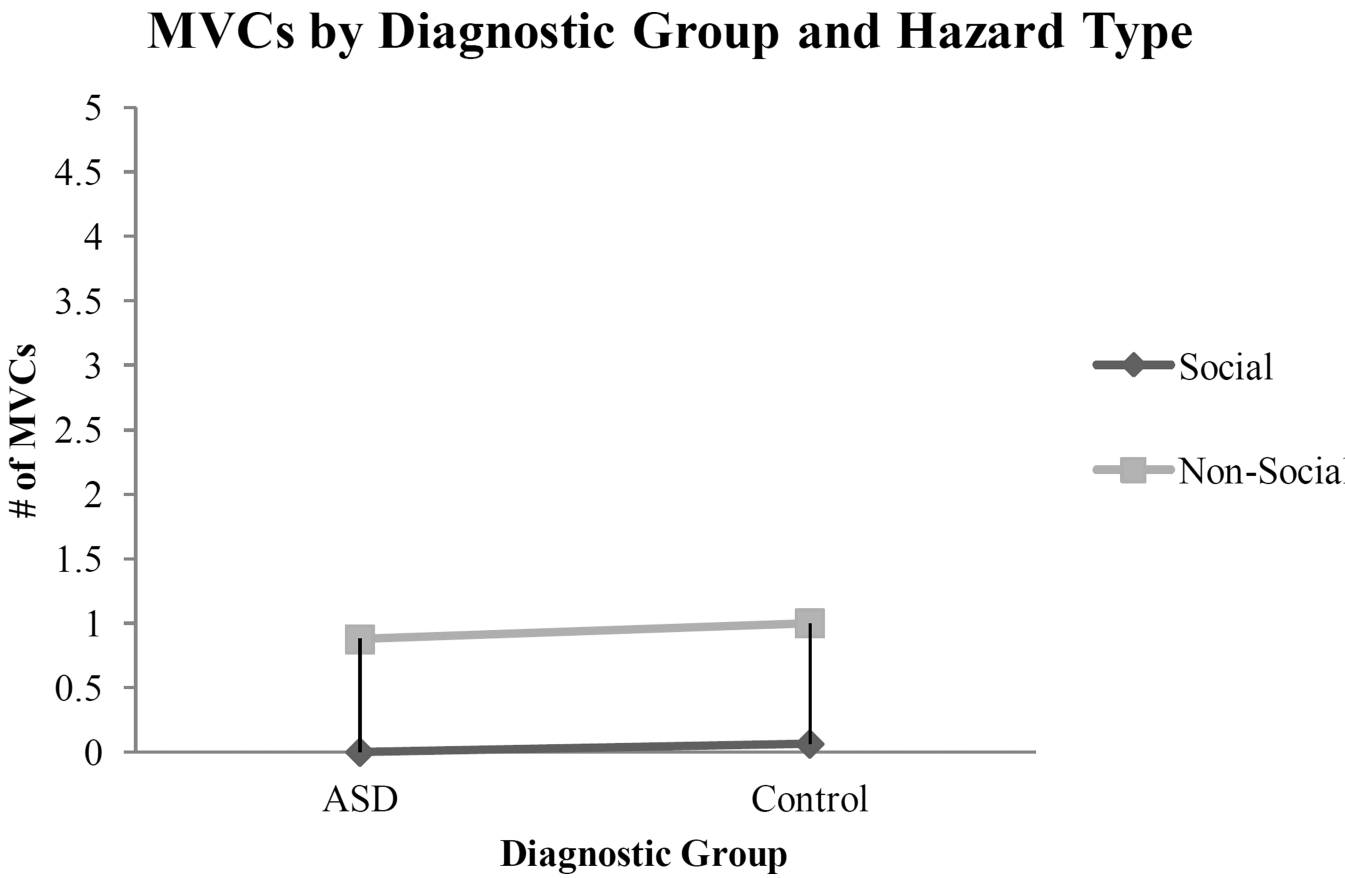

Figure 5. Interaction of diagnostic group and hazard type for Motor Vehicle Collisions (MVCs)

No significant group by hazard interaction was found for MVCs.

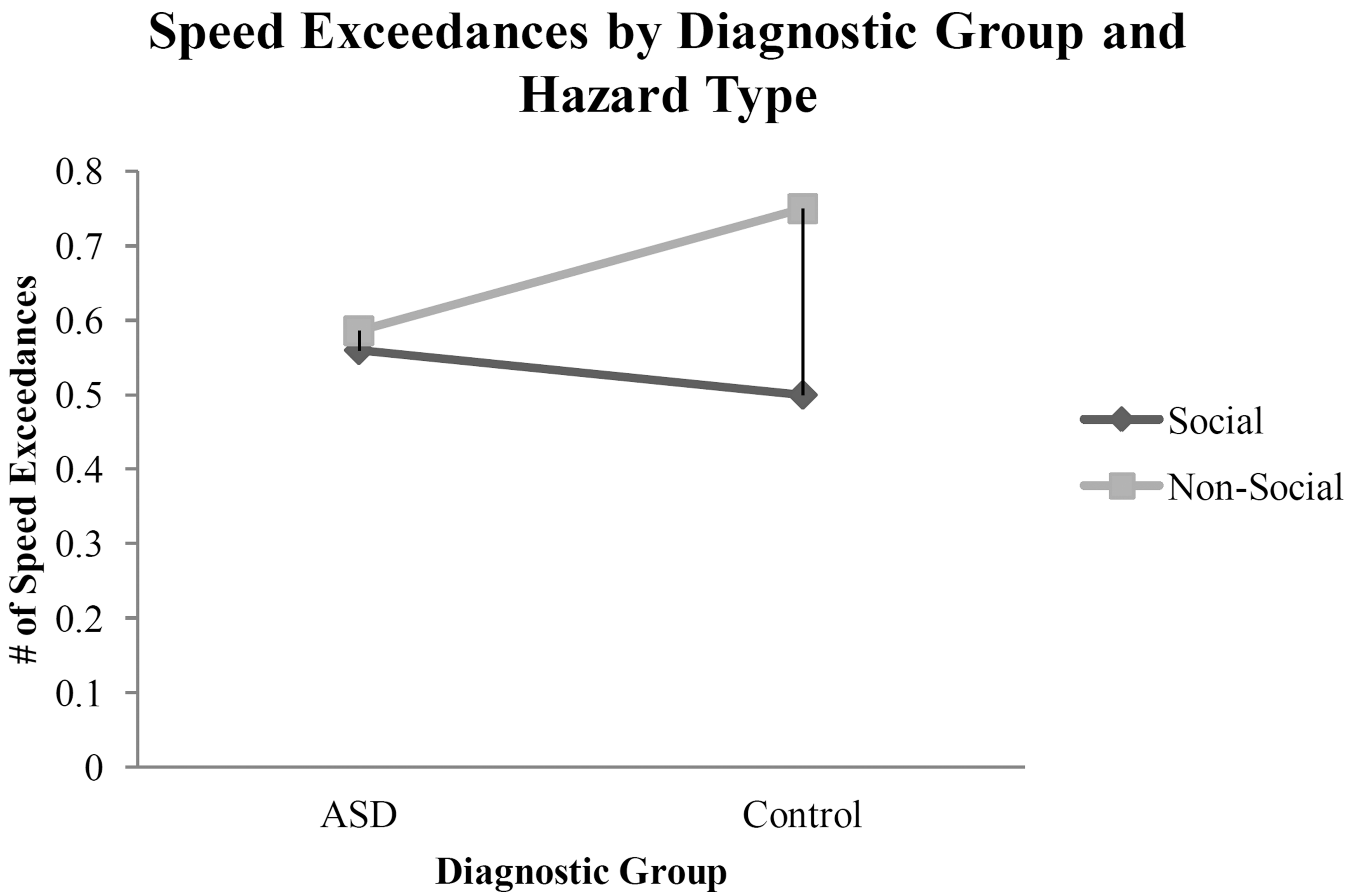

Figure 6. Interaction of diagnostic group and hazard type on speed exceedances

Although typically developing drivers had a greater number of speed exceedances approaching no-social hazards compared to social hazards, this interaction was not significant (p= .465).

Table 1

Demographic Descriptive Statistics for Participants

	ASD (n=16)			Controls (n=16)			
Variables	***M (SD)***	***n (%)***	**Range**	***M (SD)***	***n (%)***	**Range**	***t* or χ^2**
Demographic variables							
Age (Years)	23.88 (3.70)	-	17–30	22.94 (4.25)	-	16–30	$F(2,44) = 0.27$, p=.76
Gender (Male)	-	15 (94%)	-	-	15 (94%)	-	$\chi^2(1) = 0.00$, p= 1.00
Race (Caucasian)	-	13 (81%)	-	-	8 (50%)	-	$\chi^2(1) = 6.19$, p= .190
Education (Years)	13.13 (1.59)	-	10–16	13.50 (2.25)	-	9–17	$t(30) = -0.55$, p=.173
Marital Status (Single)	-	16 (100%)	-	-	13 (81%)	-	$\chi^2(1) = 3.49$, p= .175
Employed (Yes)	-	7 (44%)	-	-	13 (81%)	-	$\chi^2(1) = 4.80$, p= .069†
Months since learner's permit	95.50 (5.09)	-	11–187	91.31 (51.28)	-	14–184	$t(30) = 0.01$, p=.909
Days per week driven	4.31 (2.75)	-	0–7	6.19 (1.52)	-	2–7	**$t(30) = -2.39$, $p< .01$**
Diagnostic variables							
AQ Total Score	33.19 (5.60)	-	22–43	14.69 (3.65)	-	10–23	**$t(30) = 11.07$, $p< .001$**
Social Skill Impairment (standard score)	72.81 (12.19)	-	48–102	52.25 (6.53)	-	37–63	**$t(30) = .934$, $p = .023$**

Note: M = Mean, SD = Standard Deviation, AQ = Autism Spectrum Quotient. **Bold** = p < .05,

†Marginal significance ($p < .10$).

Table 2

Descriptive Data for Hazards

Hazard Type	Hazard	Overall Reaction Time *M (SD)*	Most Common Reaction (% of participants)
Social	Adult pedestrian from behind car	1.77 (1.03)	Release throttle (75%)
	Cyclist on roadside	.42 (.19)	Release throttle (59%)
	Child pedestrian	1.04 (1.02)	Release throttle (75%)
	Second cyclist	.54 (.41)	Release throttle (81%)
Non-social	Head on Collision	2.69 (1.13)	Release throttle (72%)
	Car at gas station	.65 (.24)	Release throttle (94%)
	Truck backing out of driveway	.64 (.29)	Release throttle (75%)
	Taxi pulling out from behind bus	.47 (.17)	Release throttle (81%)

Note: M = Mean, *SD* = Standard Deviation, Data are collapsed across groups, Reaction Time data are in seconds