Driver Re-engagement with Autonomous Vehicles for

Individuals with Autism Spectrum Disorder

Senior Research Thesis

Presented in partial fulfillment of the requirements for graduation
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By

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Abstract

Autonomous driving is a new technological advance that may provide greater freedom in mobility to specific populations. Among these beneficiaries could be individuals with Autism Spectrum Disorder (ASD). ASD describes a mosaic of social communication deficits and repetitive and abnormal sensory motor-behaviors. Difficulty in shifting attention between tasks has also been identified as an issue for these individuals. In light of this difficulty, the ASD population may actually experience challenges with autonomous vehicles, particularly when situations arise in which the driver unexpectedly needs to regain control of the vehicle. Previous work has indicated that drivers with ASD restrict themselves in their driving experiences, preferring to minimize unexpected occurrences. The need to re-engage with driving in an autonomous vehicle is critical and clearly unexpected. It is important to understand the factors that might impede re-engagement. The ability to shift attention rapidly may vary substantially for all individuals, including individuals with ASD, depending on the type of alternative task in which the driver is engaged. Little is known about the effect that the type of alternative task has on driver behavior in autonomous vehicles. The present study explored the effect of different types of tasks on attention shifting for drivers with and without ASD. Twenty-four participants were required to drive a prepared autonomous driving scenario in a simulator in the Ohio State University Driving Simulation Lab. During the autonomous drive, participants performed randomly assigned tasks including a gaming task, a music listening task, a video-watching task, and no task. At selected points, an auditory alerting system notified the participant to re-engage with the vehicle. Reaction time for re-engagement was measured. Although testing is still underway, preliminary results indicate that participants with ASD had longer reaction times for all tasks. In addition, a borderline significant difference across different tasks was observed. The

results of the present study will form the basis for additional work exploring the ways in which vehicles can be adapted to maximize safety for individuals with ASD.

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Introduction and Literature Review

Autism Spectrum Disorder (ASD) describes a mosaic of social communication deficits and repetitive and abnormal sensory motor-behaviors that appear early in children and affect individuals with the disorder throughout their lifespan. The Centers for Disease Control monitors prevalence rates for autism, and in its most recent report, stated that the incidence of autism continues to increase, with a current rate of 1 in every 59 children in the U.S (CDC Newsroom, 2018). As ASD is a spectrum condition, it can range from mild to severe and display itself in varying ways among those whom it affects (Lord et al., 2018). Although individuals with ASD can benefit from emerging technology and advancements in knowledge, this population still faces daily challenges.

Autonomous vehicles are a new technological advance that will affect the lives of most people, including individuals with ASD. For a number of groups in the population, autonomous vehicles might be viewed as a technology providing greater freedom in mobility. For example, individuals with ASD may have more opportunity to use vehicles with autonomous driving technology if abnormal sensory-motor behaviors limit their use of conventional vehicles. However, individuals with ASD may actually experience difficulty with this new form of technology, particularly in the early phases of autonomous vehicle development, where situations frequently arise in which the driver unexpectedly needs to regain control of the vehicle. Previous work has indicated that drivers with ASD restrict themselves in their driving experiences, preferring to minimize unexpected occurrences (Daly et al., 2014). For example, some individuals with ASD may limit themselves by avoiding driving alone, at nighttime, on the highway, far distances, etc. Individuals with ASD are therefore restricted in their ability to be independent. Fortunately, autonomous vehicles could provide an increase in independence for this population considering the decrease in control provided by the driver in this form of technology. Though with autonomous vehicles, re-engagement is required; individuals must immediately regain control of the autonomous vehicle. The need to re-engage with driving in an autonomous vehicle is unexpected and of great significance; therefore, it is important to understand the factors that might impede re-engagement.

One major factor affecting in impeding re-engagement is the ability to shift attention between tasks. Drivers in autonomous vehicles are likely to be performing other tasks while the car is moving and need to switch attention rapidly. Visual attention shifts have been identified as an issue for individuals with ASD (Annette et al., 2015). Research has been completed revealing that adults with ASD are significantly challenged by set-shifting, which is the capacity to shift one's attention between different tasks. A 2009 study researched set-shifting in children and yielded findings that proposed the need for additional feedback to allow children with high-functioning ASD to shift successfully (Yerys et al., 2009). Typically developing (TD) children and children with ASD performed the same shift test. However, children with ASD made many more errors when compared to the control group. Research among individuals with ASD has also been completed regarding attention shifts between audition and vision (Occelli et al., 2013). A group TD participants and a group of participants with ASD were prompted to detect visual and auditory targets presented via computer at various times during the experimental session. Results indicated that in the ASD group, the type of cue did not make a difference in response time, compared to the control group in which the auditory cue produced an increased reaction time. Slower response times were observed in the ASD group overall, but the response speed differed greatly between the TD group and the ASD group for the auditory modality, whereas this difference was not observed with the visual cue. Longer reaction times could be due to issues in shifting across modalities, or to issues in processing novel stimuli (Occelli et al. 2013).

Shifting attention rapidly is a critical component in switching from disengagement to engagement in controlling an autonomous vehicle when the need arises. The ability to shift attention rapidly may not be an issue just for individuals with ASD, but may vary substantially for all individuals, depending on the type of alternative task in which the driver is engaged. For example, tasks that require only passive engagement (e.g., listening to music) may allow faster attention shift than tasks that include some sort of motor response (e.g., gaming). Task differences may be an even greater determinant of attention shift for individuals with ASD, given the difficulties described above.

The present study explored the effect of different types of tasks on attention shifting for drivers with and without ASD. Participants were asked to drive a prepared autonomous driving scenario in an immersive, realistic driving simulator. During the study, participants were randomly assigned secondary tasks to complete while disengaged from controlling the vehicle. Four different alternative tasks were chosen to assess the impact of different degrees of engagement of visual, auditory, and manual modalities on re-engagement. The tasks included a gaming task, a music-listening task, a video-watching task, and no task. At selected points, an auditory alerting system notified the participant to re-engage with the vehicle and take control of driving (safe driving was considered the primary task). An auditory alerting task was chosen because this is the prevalent means of driver notification in current vehicles. Reaction time for re-engagement was measured.

It was hypothesized that reaction time for participants with ASD would be slower than for TD group of participants for all tasks. We further anticipated that there would be greater difficulty switching attention for tasks that require more forms of attention for all participants: that reaction time will be fastest for no task, followed by a music task (auditory attention), followed by the video task (auditory and visual attention), followed by the game task (auditory, visual, and motor attention). However, it was hypothesized that the effects of the video and game tasks would create inordinately longer reaction times for the individuals with ASD.

Several studies have been completed revealing driving dangers among individuals with ASD. In a 2014 study, Daly et al. found that drivers with ASD rated their driving to be poorer than drivers without ASD rated their own driving. These self-report data indicate that drivers with ASD appear to have relatively more traffic incidents and difficulties than their non-ASD peers.

Researchers have suspected that individuals with ASD may be impaired in hazard perception due to their impairments in processing social stimuli (Shepard et al., 2010). A 2015 study found psychomotor and processing speed to be slower in individuals with ASD compared to those who are TD (Annette et al., 2015). Individuals with ASD process stimuli around them in a slower manner, which is something to carefully consider when it comes to the operation of a motor vehicle. Operating a motor vehicle requires proper processing of sensory input and a sense of caution. Certain social stimuli are cause for concern when they could potentially lead to a hazardous or life-threatening situation. Issues with a reduced ability to process social stimuli could produce reduced risk perception.

It was anticipated that the present study could face difficulty in execution due to the need to recruit a certain and specific population. There are factors that influence and hinder the research participation of adults who have ASD (Haas et al., 2016). Individuals with disabilities often have low self-esteem that results from stigma and negative attitudes towards disability.

Therefore, individuals with intellectual disabilities such as ASD have been found to be reluctant to participate in research (Thompson & Phillips, 2007). A 2013 study looked at factors affecting the research participation of individuals with an intellectual disability. The influencing factors of participant recruitment were grouped into seven themes including 1) participant attributes, 2) research process, 3) researcher's standing and style as perceived by the participant, 4) impact of participant's previous experience with research, 5) attitudes of participant's family and career, and 6) use of an active recruitment approach and 7) motivators (Nicholson et al. 2013). Such discouraging factors can differ within the group but can be expected at some level when it comes to researching this population.

While there has been minimal work done to discern driving behavior in those with ASD in semi-autonomous vehicles, some studies have been conducted with video game-like scenarios. At the Ohio State University Driving Lab, our scenario and highly immersive driving simulator impart a level of realism that is likely to produce results much more comparable to life-like driving situations. Studies performed in more realistic simulators can help us come to a conclusion as to whether or not there should be guidance to regulate what an individual should or should not do while in an autonomous vehicle. Further, such studies could lead to recommendations for enhancements in vehicle technology to limit what drivers can and cannot do behind the wheel of a self-driving car.

Method

Participants

The present study received approval from the Ohio State University Institutional Review Board (IRB Protocol 2013B0050, PI Janet Weisenberger). Twenty-four participants were tested. These participants all had valid driver's licenses and were between ages of 19 and 24. Advertisements were circulated in a weekly newsletter emailed from the Ohio State University Student Life Disability Services. The advertisement was also posted on social media as a way to reach out to our desired population. Employees of the Ohio State University Driving lab as well as members of the Nisonger Center Aspirations group dispersed the recruitment flyer throughout the university and surrounding areas. Each individual self-identified their ASD status. Of the 24 participants, 20 (14 males, 6 females) were TD individuals, and four participants (2 males, 2 females) had ASD. Individuals received $20 as compensation for their participation in the study.

Simulator Equipment and Scenario

A Realtime Technologies Inc. (RTI) simulator was used for the present study. The simulator consisted of a 2010 Honda Accord cab mounted on a 6-DOF motion-base platform. The vehicle interior was realistic and had a gas pedal, brake pedal, shifter knob, turning signal, a dashboard screen, and a steering wheel. The "Accel" cruise control button on the steering wheel controlled the autonomous driving system in the vehicle. Five projectors displayed the scenario on a cylindrical projection screen partially surrounding the vehicle, providing a 260° field of view and creating a continuous visual field. A rear projection screen was also available for the participant's rearview mirror; an LCD display is integrated for each of the side mirrors. Four cameras were mounted in the interior of the vehicle to record the participant's behavior as well as the simulated scenario. Two external audio speakers were mounted to the cylindrical screen to provide audio cues about the vehicle's motion (engine noise, wind noise, passing vehicles, etc.). SimCreator (RTI) scenario creation software was used to create the simulation. The scenario imitated a two-lane highway with some traffic. SimDriver software controlled the autonomous driving aspects of the simulation. Figure 1 shows a test participant in the simulator.

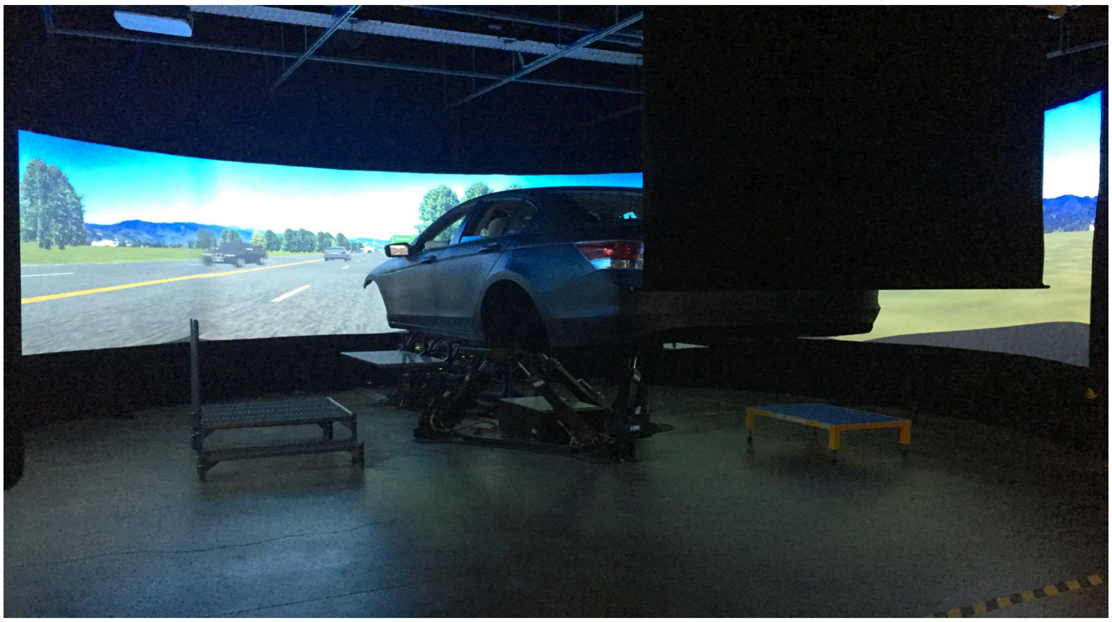

Figure 1. Test participant in the driving simulator.

Tasks

1. Game Task: The participant was instructed to open the Candy Crush app on the iPad and play the game continually (beginning with the first level) with the audio on.

2. Video Task: The participant was instructed to open the Netflix app on the iPad and continually watch the first episode of the first season of "Friends."

3. Music Task: The participant was instructed to open the YouTube app on the iPad and search for the song "Let Her Go" by Passenger. The participant would then listen to the song continually with the iPad facing down on his or her lap.

4. No Task: The participant was instructed to sit and relax in the vehicle with no other instruction.

Procedure

All 24 individuals participated in an identical driving scenario prepared by Ohio State University's Driving Simulation Lab. The participants were first given a consent form to read and sign. They then listened to an introduction to the study as well as safety precautions relating to using a driving simulator. The participants completed the study while seated alone within the vehicle. The moderator and operator stayed in the control room of the laboratory overseeing the study through camera. The moderator communicated to the participant through an intercom system. Once the simulation became active, the participants were instructed to begin a practice drive to become accustomed to the slightly different feel and responsiveness of the simulator compared to ordinary vehicles. The participants then learned more about the autonomous driving mode of the vehicle. Pressing the "Accel" cruise control button on the steering wheel turned on the car's autonomous driving capabilities.

Participants were given secondary tasks to complete while disengaged from controlling the vehicle. The tasks included a gaming task, a music-listening task, a video-watching task, and no task, as described above. Before beginning the test session, the participants practiced each task while stationary and then while driving. Once they were ready to begin, they participated in five trials of each of the four secondary tasks. The task order was randomized. At selected points during the test session, an auditory alerting system notified the participant to re-engage with the vehicle. Each trial ranged from 30-90 seconds in duration. Participants were informed that reaction time for re-engagement would be measured. During the 40-minute (approx.) study, the participants were prompted to re-engage at 20 distinct points in time (five times for each task).

Reaction Time

Re-engagement was deemed complete when the participant took hold of the vehicle's steering wheel.

Results and Discussion

The hypothesis for the present study was that reaction time for participants with ASD would be slower than for individuals in the TD group for all tasks. We further hypothesized that there would be greater difficulty for all participants in switching attention for tasks that require more forms of attention: that reaction time will be fastest for no task, followed by a music task (auditory attention), followed by the video task (auditory and visual attention), followed by the game task (auditory, visual, and motor attention). We also considered the possibility that the effects of the video and game tasks would create inordinately long reaction times for the individuals with ASD.

Figure 2 shows mean reaction time for re-engagement for each task for the TD and ASD groups. Preliminary statistical analyses (ANOVA) were performed to test the hypotheses of the study. Results should be interpreted with caution because of the very small number of participants with ASD and the big imbalance in n. Nonetheless, ANOVAs showed a statistical main effect of ASD status, $F(1,2)=6.595$, $p=0.017$, reflecting the fact that participants with ASD had longer reaction times overall than individuals without ASD. Further analysis indicated a borderline significant main effect of task, $F(1.763, 38.78)= 3.242$, $p=0.056$. No interaction effect was observed; the video task and game task were not more absorbing for participants with ASD compared to the control group.

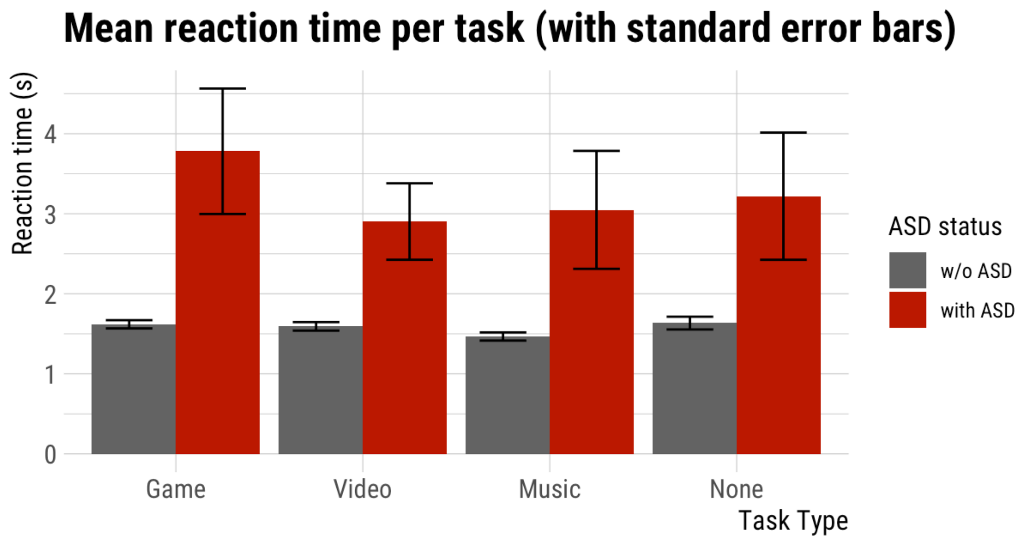

Figure 2. Mean differences in reaction times among participants with and without ASD for each of the secondary tasks.

Our data do not point to the need for specific lockouts of task while in an autonomous car. The data instead suggest the fact that participants with ASD would potentially have much longer reaction times to re-engage with driving, in comparison to those without ASD, regardless of whether another task is being performed. This difference in reaction time can be the difference between life and death. Thus, other technological improvements may be necessary to ensure the safety of drivers with ASD interacting with autonomous systems in vehicles. It should be reiterated that these results are preliminary, and more extensive testing should be completed with a larger sample of participants with ASD; results could change substantially if more data is collected.

Summary and Conclusion

The present study aimed to investigate the relationship between Autism Spectrum Disorder (ASD) and reaction times in re-engaging with autonomous vehicle technology. The hypothesis of the present study was that reaction times would be slower for participants with ASD compared to the typically developing participants, and this hypothesis was supported. It was also hypothesized that there would be longer reaction times for tasks requiring more forms of attention. We further anticipated that the effects of the video and game tasks would create inordinately long reaction times for participants with ASD. Results indicated that participants with ASD did have longer reaction times for each task compared to their TD peers. Tasks requiring more forms of attention were not more captivating for participants.

Specific tasks were also not more absorbing for individuals with ASD compared to the control group. Further, there was no interaction effect. There was no difference between the TD group and ASD group across each task, including the task where the participants' only instruction was to relax in the vehicle (no task). While our data do not suggest that individuals with ASD should refrain from specific tasks while in an autonomous vehicle, there is reason to believe that participation in any secondary task while driving an autonomous vehicle could present danger to the vehicle's occupants. The time it takes for in individual with ASD to shift from task to re-engagement may be life-threatening.

There are a several possible confounding variables in the present study. We encountered great difficulty in regards to recruiting participants. The specific population that we wished to study (available young adults with ASD and a driver's license) was a challenge to recruit in the area of Columbus, Ohio. Considering the challenge in recruiting participants, our lab asked individuals with ASD who had previously completed studies in the driving simulation lab to return for the present study. There is a possibility that this resulted in previous experience effects that could have influenced our data. Results should be carefully interpreted considering the low participant turnout, particularly for the ASD group. With continuation of this study, we hope to further extend recruiting efforts to groups outside of The Ohio State University to find more participants for the present study.

This effort supports the goal of ensuring that upcoming vehicle technology can be constructed and adapted for personal and differential use among the entire population. The overall goal of this study was to discover ways to enhance vehicle technology and create recommendations for occupants that make the autonomous driving experience as safe as possible for everyone, including individuals with ASD. The potential advantages of autonomous vehicles to expand mobility opportunities for this population are substantial, and the results of the present study will be important for end users of our data collection. Automakers would benefit from considering the results of the present study as they aim to improve their products for the use of people in all populations. Autism advocacy groups, individuals with ASD, families of those with the disorder, as well as organizations creating driver-training programs could find these results useful.

References

Annette, E. R., & Renee, L.-O. N. (August 09, 2015). *Visual attention shifting in autism spectrum disorders*. Journal of Clinical and Experimental Neuropsychology, 37, 7, 671-687.

CDC Online Newsroom. (April 26, 2018). *Autism prevalence slightly higher in CDC's ADDM Network*. Centers for Disease Control and Prevention. Centers for Disease Control and Prevention.

Daly, B. P., Nicholls, E. G., Patrick, K. E., Brinckman, D. D., & Schultheis, M. T. (December 01, 2014). *Driving Behaviors in Adults with Autism Spectrum Disorders*. Journal of Autism and Developmental Disorders, 44, 12, 3119-3128.

Haas, K., Costley, D., Falkmer, M. Richdale A, Sofronoff K, Faulkmer T. (May 2016). *Factors Influencing the Research Participation of Adults with Autism Spectrum Disorders*. Journal of Autism and Developmental Disorders, 46: 1793.

Lord, C., Elsabbagh, M., Baird, G., & Veenstra-Vanderweele, J. (August 11, 2018). *Autism spectrum disorder*. The Lancet, 392, 10146, 508-520.

Nicholson, L., Colyer, M., & Cooper, S. A. (2013). Recruitment to intellectual disability research: a qualitative study. Journal of Intellectual Disability Research, 57(7), 647 - 656.

Occelli, V., Esposito, G., Venuti, P., Arduino, G. M., Zampini, M. (April, 2013). “Attentional Shifts between Audition and Vision in Autism Spectrum Disorders.” *Research in Autism Spectrum Disorders*, vol. 7, no. 4, pp. 517–525.

Sheppard, E., Ropar, D., Underwood, G., Van Loon E. (April 2010). *Brief report: driving hazard perception in autism*. Journal of Autism and Developmental Disorders. 40: 504.

Thompson, S., & Phillips, D. (2007). Reaching and Engaging Hard-to-Reach Populations With a High Proportion of Nonassociative Members. *Qualitative Health Research*, *17*(9), 1292–1303.

Yerys, B. E., Wallace, G. L., Harrison, B., Celano, M. J., Giedd, J. N., & Kenworthy, L. E. (2009). Set-shifting in children with autism spectrum disorders: reversal shifting deficits on the Intradimensional/Extradimensional Shift Test correlate with repetitive behaviors. *Autism: the international journal of research and practice*, *13*(5), 523–538.