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Indicators of Simulated Driving Skills in Adolescents with Autism Spectrum Disorder

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Indicators of Simulated Driving Skills in Adolescents with Autism Spectrum Disorder

Abstract

Adolescents are at high risk for motor vehicle crashes (MVCs). Teens with autism spectrum disorder (ASD) may have an even greater risk for MVCs due to impaired visual, cognitive, and motor skills critical for driving. This prospective two group study demonstrated the demographic, clinical, and simulated driving skill differences of seven adolescents with ASD (mean age = 15.14, *SD* ±1.22) compared to 22 healthy controls (HC) (mean age = 14.32, *SD* ±.72) through a comprehensive driving evaluation (CDE) conducted by an occupational therapist certified driving rehabilitation specialist (OT-CDRS). Adolescents with ASD performed poorer on right eye acuity (*Fischer's (F)* = 13.44, *p* = .003), cognition (*Mann-Whitney Statistic (U)* = 29.00, *p* = .01), visual motor integration (*U* = 27.50, *p* = .01), motor coordination (*U* = 5.00, *p* = .001), operational skills for managing simulator controls (*U* = 4.00, *p*U = 30.50, *p* = .02), speed regulation (*U* = 13.50, *p* = .001), lane maintenance (*U* = 34.00, *p* = .03), signaling (*U* = 38.50, *p* = .03), and adjustment to stimuli (*U* = 9.00, *p*U = 5.00, *p*Conclusion). Compared to the HC, adolescents with ASD performed worse on visual, cognitive, motor, simulator operational, and fitness to drive skills, suggesting that an OT-CDRS may play an important role in assessing teens with ASD before they pursue traditional driver's education.

Keywords

Automobile Driving, Adolescence, Autism Spectrum Disorder, Fitness to Drive, Simulator

Cover Page Footnote

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Credentials Display and Country

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Literature Review

Adolescent drivers aged 16 to 19 years are three times more likely than drivers aged 20 years and older to be involved in a motor vehicle crash (Centers for Disease Control and Prevention [CDC], 2013b). Although little is known about autism spectrum disorder (ASD) and driving, Classen and colleagues (in press) found that teens with attention deficit hyperactivity disorder (ADHD) and/or ASD are performing worse than healthy controls (HC) on a clinical test battery of visual acuity, selective attention, visual motor integration, cognition, and motor performance; and that moderate correlations exist between impaired functioning on visual motor integration and motor performance and driving errors made in the simulator. As such, this group is at risk for impaired fitness to drive, which is the ability to drive safely and smoothly while compensating for impairment (Brouwer & Ponds, 1994).

One in 50 children aged 6 to 17 years in the United States has ASD (CDC, 2013a). ASD is a spectrum disorder (autistic disorder, pervasive developmental disorder-not otherwise specified, Asperger syndrome, Rhett's syndrome, childhood disintegrative disorder) characterized by repetitive behaviors and impairment in social interactions and communication (American Psychiatric Association [APA], 2000). Those with ASD may struggle with verbal and nonverbal communication, often preoccupy themselves with specific interests, have a narrow range of focus, adhere to specific routines, and experience problems with change, all of which can further impact their fitness to drive (APA, 2000). Teens with ASD can experience difficulty with executive functions, including attention shifting, mental flexibility, planning, inhibition, initiation, and monitoring of actions (Hill, 2004); motor coordination deficits (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010); and visual processing deficits (Simmons et al., 2009). Driving requires all of these abilities to work in a coordinated manner; however, the evidence demonstrating how these unique characteristics of teens with ASD impact their driving is lacking in the literature (Classen & Monahan, 2013).

Driving

Driving is a means of community mobility that can provide a teen independent access to academia, employment, recreational and social opportunities, goods, and medical and other professional services (Monahan, 2012; Womack & Silverstein, 2012). Traditionally, a teen undergoes driving education with a licensed driving school instructor. The classroom and in-car training includes traffic laws and regulations, skills for hazard avoidance, and the responsibilities inherent in driving a vehicle (American Association of Motor Vehicle Administrators [AAMVA], n.d). For student drivers who have medical conditions, however, the services of an occupational therapist (OT) who is also a certified driving rehabilitation specialist (CDRS) can be sought to complete a comprehensive driving evaluation (CDE). The OT-CDRS assesses the functional performance components (client and contextual factors) via a clinical battery of tests (Classen, Monahan, & Wang, in press), as well as the individual's fitness to drive via a simulator (Classen et al., in press) and their on-road performance. Specifically, the OT-

CDRS examines driving errors that can happen in several areas, such as lane maintenance (lateral position of the vehicle in motion and stopped), speed regulation (obeying speed laws and managing braking and accelerating), ability to yield (giving right-of-way to other vehicles or pedestrians), use of signals (properly using turning signals), visual scan (displaying scanning of the surrounding environment while driving), adjustment to stimuli (overall ability to respond to changes in driving situations), and gap acceptance (determining safe time and distance for crossing in front of traffic) (Justiss, Mann, Stav, & Velozo, 2006). The OT-CDRS then works in a team format with the driving school instructor to provide the driver education component to the student, while modifying the curriculum to adjust to the student's specific needs (Monahan, 2012). For example, because the driving school instructor is not trained to work with individuals with medical conditions or to understand how these conditions affect driving outcomes, the OT-CDRS may address the motor coordination deficits of a student with ASD when he or she makes simple turns. The OT-CDRS may recommend that the driving school instructor control the accelerator and brake while the student controls the steering wheel. With practice, the student may show profiency of the latter upon which the OT-CDRS may recommend to the driving school instructor that the student assume control of the accelerator and brake.

Driving Simulator

The CDE, and more specifically the on-road assessment, is considered the gold standard for measuring fitness to drive (Di Stefano & Macdonald, 2005). Using a driving simulator is an acceptable alternative to test a teen without a driver's permit, because it provides a safe alternative that minimizes on-road risks and allows the OT-CDRS to evaluate reproducible driving conditions not confounded by extraneous variables often found on the roadways (e.g., a child running across the road). Evidence suggests that errors recorded during simulator evaluations relate to errors assessed during on-road testing in the same population (Shechtman, Awadzi, Classen, Lanford, & Joo, 2010; Bédard, Parkkari, Weaver, Riendeau, & Dahlquist, 2010). For example, in a group of healthy younger and older adults, the same trends were found in errors made on the road as in the errors made in the driving simulator. That is, participants had the same type of errors, yet fewer errors were made in the simulator compared to the number of errors made during the on-road evaluation. This finding suggested relative validity between the driving simulator and the on-road evaluation (Shechtman et al., 2010).

Rationale, Significance, and Purpose

Although driving is a milestone for adolescents, little is known about the fitness to drive abilities of teens with ASD who have characteristics that may impair their driving performance. The simulator is an ideal tool to assess adolescents who are not yet licensed to drive. Based on previous work (Classen et al., in press), where an OT-CDRS conducted a CDE using a clinical battery of tests and a driving simulator, the authors found that teens with ADHD and ASD had impaired fitness to drive abilities. Therefore, in the current study we are only examining group differences between teen drivers with ASD and the HC, and we expect that teens with ASD will perform worse on tests of visual, cognitive, and motor abilities, and that they will make more driving errors (by type and number) when compared to the HC.

The purpose of this study was to demonstrate the between group differences in clinical and simulated driving skills among adolescents with ASD as compared to the HC when assessed by an OT-CDRS. If teens with ASD indicate impaired clinical and driving performance issues, then our findings will help to justify the involvement of an OT-CDRS, vs a driving school instructor, in assessing and honing the fitness to drive abilities of teens with ASD, thereby positioning them to be more successful in obtaining a driver's license.

Methods

Participants

In this prospective between group study we compared seven adolescents with a physician confirmed diagnosis of ASD (mean age = 15.14, *SD* = ±1.22) to 22 HCs (mean age = 14.32, *SD* = ±.72). Participants were between the ages of 14 and 18 years, had neither a learner's permit nor a driver's license, had no seizures in the past year, were able to understand and read English, had a minimum visual acuity of 20/40 in one eye per the State of Florida's minimum requirements for driving, presented a doctor's note to participate when on a strict medication regime, were community-dwelling, had the capacity to travel to Gainesville, FL, and participated in a battery of clinical tests and driving simulator tests. Participants excluded from the study were diagnosed with severe psychiatric or physical conditions that could negatively affect driving performance, prescribed multiple psychotropic medications negatively affecting mental or physical function, and scored at below normal intelligence (<90 on the Wechsler Intelligence Scale for Children). The University of Florida's Institutional Review Board approved the study. The participants provided informed assent and their parents provided informed consent before study participation.

Instruments

While parents completed a demographic questionnaire (Table 1), the OT-CDRS assessed the following abilities of the participants: visual acuity, peripheral field, and depth perception with the Optec® 2500 Visual Analyzer Visual Tests (Stereo Optical Inc., Chicago, IL); visual attention, processing speed, and divided and selective attention with the Useful Field of View® (UFOV) and its three sub-tests with scoring recorded in milliseconds (cut-off = 500 ms) (Ball & Owsley, 1993); attention shifting, sequencing, and selective attention with the Comprehensive Trail Making Test (CTMT) with scores recorded in seconds on each of the five trails (Reynolds, 2002); visual motor integration with the Beery Visual Motor Integration (VMI) test scoring copied drawings of various complexities according to a standard score (units of measurement with a mean of 100 and a *SD* of 15) (Beery, Buktenica, & Beery, 2010); attention shifting and scanning speed with the Symbol Digit Modalities Test (SDMT) recording scores as the number of correct responses (Smith, 2002); and motor performance with the Bruininks-Oseretsky Test (BOT2) with scoring calculated from motor proficiency on all subtests (Bruininks & Bruininks, 2005). Using the STISM M500W™ (Systems Technology Inc., Hawthorne, CA), the OT-CDRS assessed seven driving errors, which were lane maintenance, speed regulation, gap acceptance, adjustment to stimuli, visual scanning, vehicle positioning, and signaling.

Procedures

Participants completed a 20 min orientation to the simulator, a 7 min acclimation drive, and a 20 min main drive. The orientation included familiarizing the participants with the simulator and car cab, specifically the primary controls, which were the steering wheel, brake, and accelerator. Before the participants proceeded to the acclimation drive, the OT-CDRS ensured that they were comfortable and confident with using the driving simulator. The acclimation drive consisted of two left turns and one right turn, all connected by straight roadways in a rural area, and without any lead or following traffic. The purpose of this drive was to ensure practice in operating the simulator. The main drive had three straight drives, nine left turns, two right turns, and five divided attention (DA) tasks. The simulator automatically recorded summary statistics and DA responses.

Data Analysis

Using PASW Statistics 20 (SPSS Inc., Chicago, IL) we analyzed data with descriptive statistics (mean, standard deviation, percentages, and frequencies), non-parametric statistics (Fischer's exact tests and Mann-Whitney U test), and Spearman's Rank Correlation Coefficient. Data were significant at the $p < .05$ two-tailed alpha level.

Results

Demographics

Even though the demographics for the two groups were similar, Table 1 demonstrates that the ASD group had more occupational therapy interventions and more parent-reported over the counter and prescription medications.

Clinical Tests

Table 2 demonstrates the between group differences for clinical tests. Compared to the HC, the group with ASD showed significantly poorer acuity of the right eye reaching 20/50 or above, took longer to complete CTMT Trail 2, and performed more poorly on the Beery VMI and the BOT2, as well as the BOT2's one-legged stationary hop.

Driving Simulator

Table 3 demonstrates that, compared to the HC, the ASD group performed worse on all of the simulator operational skills. For driving errors, the ASD group showed statistically significantly more visual scanning, speed regulation, lane maintenance, signaling, adjustment to stimuli, and total number of driving errors. They also had a statistically significantly greater number of total traffic light tickets.

Table 1

Descriptive Statistics and Between Group Differences of Demographics and Medical History for Teens with ASD and HC

		ASD (N = 7)	HC (N = 22)	Test Statistic	Statistical Significance
Age [a]		15.14 ± 1.22	14.32 ± 0.72	$t = -1.70$, $SE = .48$	$p = .13$
Gender [b]					
	Male	5 (71.4%)	13 (59.1%)		$p = .68$
	Female	2 (28.6%)	9 (40.9%)		
Ethnicity [b]					
	Hispanic	2 (28.6%)	4 (18.2%)		$p = .61$
	Non-Hispanic	5 (71.4%)	18 (81.8%)		
Race [b]					
	White	7 (100%)	19 (86.3%)	$F = 1.13$	$p = .66$
	Other	0	3 (13.6%)		
Education [b]					
	7	1 (4.5%)	0 (0.0%)	$F = 4.70$	$p = .30$
	8	6 (27.3%)	0 (0.0%)		
	9	12 (54.5%)	4 (57.1%)		
	10	2 (9.1%)	2 (28.6%)		
	11	0 (0.0%)	0 (0.0%)		
	12	1 (4.5%)	1 (14.3%)		
Intervention OT [b]					
	Yes	6 (85.7%)	0		$p < .001$
	No	1 (14.3%)	22 (100%)		
Intervention PT [b]					
	Yes	1 (14.3%)	1 (4.5%)		$p = .43$
	No	6 (85.7%)	21 (95.5%)		
Intervention SLP [b]					
	Yes	4 (57.1%)	4 (18.2%)		$p = .07$
	No	3 (42.9%)	18 (81.8%)		
# Medications [c]		3.43 ± 5.32	.41 ± .91	$U = 40.50$	$p =.07$
# Prescription Meds [c]		1.00 ± 1.41	0.32 ± 0.84	$U = 54.00$	$p = .10$
# OTC Meds [c]		2.43 ± 4.47	.09 ± 0.43	$U = 47.00$	$p = .01$
Prescription Meds During Session [b]					
	Yes	3 (42.9%)	0		$p = .01$
	No	4 (57.1%)	22 (100%)		

Note. Values are Mean ± *SD* or Frequencies (%). Significant group difference ($p < .05$). HC = Healthy Controls; ASD = Autism Spectrum Disorder; OT = Occupational Therapy; PT = Physical Therapy; SLP = Speech Language Pathology; OTC = Over the Counter. Categorical variables with zero in a cell for both populations did not undergo between group analysis; all decimals are rounded off to the second value.

[a]Independent Samples t-test. [b]Fischer's Exact Test. [c]Non-parametric Test/Mann-Whitney Test.

Table 2

Descriptive Statistics and Between Group Differences of Clinical Tests and Operational Skills for Teens with ASD and HC

	ASD (N = 7)	HC (N = 22)	Test Statistic	Statistical Significance
UFOV Risk Index [a]				
Level 1 Risk	7 (100%)	22 (100.0%)		
Level 2 Risk or above	0	0		*p-value* cannot be determined
UFOV Test 1 Score [b]	16.7 ± 0	16.7 ± .00		
UFOV Test 2 Score [b]	16.7 ± 0	18.82 ± 8.01	*U* = 70.00,	*p* = .42
UFOV Test 3 Score [b]	68.16 ± 29.57	55.13 ± 19.65	*U* = 60.50	*p* = .40
Snellen Acuity Both Eyes [a]				
20/20-20/40	5 (71.5%)	22 (100%)	*F* = 5.47	*p* = .06
20/50 & above	2 (28.6%)	0		
Snellen Acuity Right Eye [a]				
20/20-20/40	5 (71.5%)	22 (100%)	*F*= 13.44	*p* = .003
20/50 & above	2 (28.6%)	0		
Snellen Acuity Left Eye [a]				
20/20-20/40	6 (85.7%)	22 (100%)	*F* = 5.65	*p* = .10
20/50 & above	1 (14.3%)	0		
Depth Perception [a]				
Intact	4 (57.1%)	19 (86.4%)		*p* =.13
Impaired	3 (42.9%)	3 (13.6%)		
Peripheral Field Right [a]				
Field goes to 85º temporal	6 (85.7%)	22 (100.0%)		*p* = .24
Field goes to 70º temporal or less	1 (14.3%)	0 (0.0%)		
Peripheral Field Left [a]				
Field goes to 85º temporal	7 (100%)	20 (90.9%)		*p* = 1.0
Field goes to 70º temporal or less	0	2 (9.1%)		
Wear Corrective Lenses [a]				
Yes	2 (28.6%)	4 (18.2%)		*p* = .61
No	5 (71.4%)	18 (81.8%)		
CTMT Raw [b]	225.71 ± 52.80	187.55 ± 40.84	*U* = 40.50	*p* = .06
T1 Raw [b]	44.86 ± 14.36	33.23 ± 5.42	*U* = 39.50	*p* = .06
T2 Raw [b]	44.14 ± 10.00	34 ± 9.75	*U* = 29.00	*p* = .01
T3 Raw [b]	43.71 ± 8.90	38.27 ± 8.71	*U* = 51.00	*p* = .18
T4 Raw [b]	37.43 ± 12.24	31.41 ± 12.63	*U* = 43.50,	*p* = .09
T5 Raw [b]	55.57 ± 21.89	50.64 ± 18.64	*U* = 63.00	*p* = .48
VMI Standard Score [b]	88.43 ± 9.68	99.59 ± 7.49	*U* = 27.50	*p* = .01
SDMT Correct [b]	53.14 ± 7.95	60.95 ± 9.80	*U* = 45.00	*p* = .10
SDMT Total [b]	53.29 ± 7.83	61.55 ± 9.97	*U* = 43.50	*p* = .09
BOT2 Standard Score [b]	35.00 ± 8.20	52.64 ± 7.03	*U* = 5.00	*p* = .001
Transferring Pennies [b]	6.00 ± 2.31	7.77 ± 1.02	*U* = 44.00	*p* = .07
One-Legged Stationary Hop [b]	6.00 ± 2.97	7.77 ± .81	*U* = 28.50	*p* = .02

Note. Values are Mean ± *SD* or Frequencies (%). Significant group difference ($p < .05$). HC = Healthy Controls; ASD = Autism Spectrum Disorder; UFOV = Useful Field of View; CTMT = Comprehensive Trail Making Test; VMI = Visual Motor Integration; SDMT = Simple Digit Modality Test; BOT2 = Bruininks-Oseretsky Test; T1-T5 = Trails 1-5 of the CTMT. Categorical variables with zero in a cell did not undergo between group analysis; all decimals are rounded off to the second value.

[a]Fischer's Exact Test. [b]Non-parametric Test/Mann-Whitney Test.

Table 3

Descriptive Statistics and Between Group Differences of Driving Errors and Divided Attention for Teens with ASD and HC

	ASD (N = 7)	HC (N = 22)	Test Statistic	Statistical Significance
Operation Skills-Accelerator [a]	4.66 ± 1.29	7.71 ± 1.38	$U = 7.00$	$p < .001$
Operation Skills-Brake [a]	4.47 ± 1.12	8.12 ± 1.25	$U = 4.00$	$p < .001$
Operation Skills-Steering [a]	3.62 ± 1.98	7.91 ± 1.33	$U = 8.50$	$p < .001$
Operation Skills-Turn Signals [a]	6.06 ± 1.34	7.85 ± 1.33	$U = 22.00$	$p = .01$
Operation Skills-Total [a]	18.81 ± 4.53	31.60 ± 4.24	$U = 4.00$	$p < .001$
Total Visual Scanning Errors [a]	5.71 ± 5.19	2.27 ± 1.52	$U = 30.50$	$p = .02$
Total Speed Regulation Errors [a]	18.43 ± 7.19	6.50 ± 4.18	$U = 13.50$	$p = .001$
Total Lane Maintenance Errors [a]	30.43 ± 13.58	18.55 ± 7.20	$U = 34.00$	$p = .03$
Total Signaling Errors [a]	5.86 ± 5.82	1.18 ± 2.91	$U = 38.50$	$p = .03$
Total Vehicle Positioning Errors [a]	2.43 ± 1.81	1.64 ± 1.92	$U = 54.00$	$p = .23$
Total Adjustment to Stimuli Errors [a]	7.14 ± 2.85	2.23 ± 3.05	$U = 9.00$	$p < .001$
Total Gap Acceptance Errors [a]	2.71 ± 1.60	1.50 ± 1.68	$U = 45.00$	$p = .09$
Total Errors [a]	72.71 ± 17.38	33.86 ± 12.78	$U = 5.00$	$p < .001$
Total Speed Exceedances [a]	5.86 ± 3.45	5.50 ± 4.63	$U = 71.00$	$p = .76$
Total Traffic Light Tickets [a]	1.43 ± 1.27	0.32 ± 0.48	$U = 36.00$	$p = .017$
Total Road Edge Excursions [a]	17.29 ± 10.95	12.14 ± 7.51	$U = 56.50$	$p = .295$
Total Correct DA Responses [a]	2.29 ± 1.11	7.73 ± 23.11	$U = 56.00$	$p= .27$
Average DA Response Time [a]	38.04 ± 6.87	34.44 ± 12.27	$U = 55.00$	$p = .33$
Total Incorrect DA Responses [a]	0	5.05 ± 23.67	$U = 73.50$	$p = .57$
Total DAs with No Response [a]	2.71 ± 1.11	7.14 ± 23.24	$U = 63.00$	$p = .46$

Note. Values are Mean ± *SD* or Frequencies (%). Significant group difference (p < .05). DA = Divided Attention; HC = Healthy Controls; ASD = Autism Spectrum Disorder.

[a]Non-parametric Test/Mann-Whitney Test.

Discussion

The purpose of this study was to demonstrate the between group differences in clinical and simulated driving skills among adolescents with ASD as compared to the HC when assessed by an OT-CDRS. Compared to the HC, the ASD group demonstrated poorer visual acuity of the right eye. This finding was unexpected; however, it is supported by the basic visual sciences literature as Simmons et al., 2009 indicated that teens with ASD have poorer visual acuity when compared to the HC. A post hoc analysis revealed that right eye acuity was significantly and inversely correlated with lane maintenance ($r = -.778$, $p = .039$) and total driving errors ($r= -.972$, $p< .001$). These findings suggest that poorer right eye visual acuity has a relationship with lane maintenance errors as well as total driving errors. As this is a new finding, researchers may further investigate a potential cause and effect relationship in future studies.

Compared to the HC, the ASD group had a longer completion time of the CTMT Trail 2, which may be explained by Trail 2 being more complex than Trail 1. For example, Trail 2 incorporated distracters that required "adjusting" to a different pattern or routine, which is taxing for individuals with ASD (CDC, 2012). Distracters did not vary in the subsequent trails, which may indicate why no further between group differences appeared. As such, the group with ASD had more difficulty initially adjusting to the change presented by the presence of distractors, but then adapted on subsequent trials with distractors.

Consistent with findings from Verté, Geurts, Roeyers, Oosterlaan, & Sergeant (2006), the ASD group, when compared to the HC, had impaired visual motor integration as measured with the Beery VMI test. The ASD group also performed poorer on fine and gross motor coordination skills when measured with the Beery VMI (Fournier et al., 2010) and the BOT2's one-legged stationary hop (Bruininks & Bruininks, 2005).

Compared to the HC, the ASD group made more errors with all simulator operational skills, i.e., manipulating the accelerator, brake, steering wheel, and turning signals. According to Fournier et al. (2010), individuals with ASD show motor performance deficits in both the upper and lower extremities. Manipulation of basic vehicle functions involves motor movement of the extremities and these operational skills deficits may be partially attributed to the teens' decreased motor abilities.

The ASD group made more errors of visual scanning, speed regulation, lane maintenance, signaling, adjustment to stimuli, and total number of driving errors. As we did not seek to establish firm relationships in this exploratory study, we offer the following explanations to inform the reader of the conceptual ties between clinical symptoms and impaired fitness to drive skills (driving errors).

First, because individuals with ASD have difficulty in shifting attention and prioritizing visual information, two critical components of visual scanning, we are not surprised that the ASD group had a greater number of visual scanning errors compared to the HC (Wainwright-Sharp & Bryson, 1993).

Second, speed regulation involves following and maintaining speed limits and controlling the brake and accelerator. These tasks are dependent upon the ability to perceive information from the environment (visual scanning), interpret information (perception and executive functions), coordinate, pace, and sequence actions (motor functions), and then, finally, deliver the response (motor action). All of these client factors are impaired in teens with ASD (Verté et al., 2006; Fournier et al., 2010), which provides a partial explanation for the ASD groups' deficits in speed regulation.

Third, lane maintenance errors refer to the inability to maintain the lateral position of the vehicle. The ASD group had more lane maintenance errors compared to the HC. Teens with ASD have deficits in spatial awareness that may affect their position in space (Coulter, 2009) and impaired visual motor integration skills, which is a coordinated motor response based on perceived visual demands. For example, as a driver approaches a perpendicular left turn (perceived visual demands), the driver needs to rotate the steering wheel accurately and control the speed (motor response) based on the degree of the turn in a coordinated fashion with the motor visual demands of the task. It is therefore conceivable that such deficits may partially explain the inability of the group with ASD to position the vehicle appropriately, causing them to make more lane maintenance errors.

Fourth, increased signaling errors in the group with ASD may be partially related to the fact that teens with ASD have an impaired ability to understand and interpret social cues (Sheppard, Ropar, Underwood, & van Loon, 2010; APA, 2000). As such, teens with ASD may not fully comprehend the importance of on-road communication. For example, they may not recognize and communicate to other road users their intent to make a turn or a lane change. This may cause the ASD group to make more signaling errors than the HC.

Fifth, the ASD group made more errors when adjusting to stimuli, which is the ability to respond appropriately to changes in the driving environment. For example, the ability to slow down when approaching a red light and to observe the surroundings before making a left turn once the light is green. Teens with ASD characteristically fixate on routines, show limitations in prioritizing information, and demonstrate impairment in adapting to the environmental stimuli and demands (APA, 2000). These characteristics may position them to miss critical roadway and environmental information, such as observed through the ASD group's increased number of adjustments to stimuli errors.

Sixth, the ASD group had more traffic light tickets compared to the HC. It is well known that teens with ASD have deficient visual motor integration skills (Verté et al., 2006). In the driving environment, teens with ASD may have deficits in coordinating what they see (red traffic light) to the motor action of pressing the brake (Verté et al., 2006), which would explain why the group with ASD made more traffic light errors when compared to the HC.

And seventh, cumulatively, the impairments in motor skills, as well as visual motor integration skills in the group with ASD may have contributed to an increase in their total number of driving errors when compared to the HC. However, all of the assertions and conceptual ties made regarding potential explanations between clinical characteristics and driving errors require further empirical testing.

Limitations

Potential recall bias could have been infused into the study during parent responses to questionnaires (i.e., parents may over or under report a characteristic) (Raphael, 1987). Participants were recruited from a convenience sample in North Central Florida. Although our study criteria allowed for inclusion of participants with an IQ above 90, we did not use a tool to distinguish ASD severity. We also did not control for the effect of medications or other limiting factors (for the group with ASD), such as anxiety or apraxia. Because of the small sample size, findings may be subject to a Type 2 error (Portney & Watkins, 2000). As such, findings can only be generalized to participants fitting this study's profile.

This study is one of the first in the English literature to examine fitness to drive abilities in adolescents with ASD. The implications of the study suggest that adolescents with ASD may require specialized driving assessments by an OT-CDRS as well as training as a first time driver vs. receiving traditional driver's education. As such, this pilot work opens clinical practice opportunities for OT-CDRSs to evaluate the fitness to drive abilities of teens with ASD before referring them to traditional driver's education. It also opens research opportunities to determine the clinical predictors of fitness to drive and their mechanistic ties to driving errors in the ASD population, in a larger age and gender matched representative sample that is adequately powered to meet the objectives.

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References

American Association of Motor Vehicle Administrators. (n.d.). *Policy positions of the American Association of Motor Vehicle Administrators*. Retrieved from http://www.aamva.org/AAMVA-Policy-Positions/

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). doi: 10.1176/apii.books.9780890423349.15861

Ball, K. K., & Owsley, C. (1993). The useful field of view test: A new technique for evaluating age-related declines in visual function. *Journal of the American Optometric Association*, *64*(1), 71-79.

Bédard, M. B., Parkkari, M., Weaver, B., Riendeau, J., & Dahlquist, M. (2010). Assessment of driving performance using a simulator protocol: Validity and reproducibility. *The American Journal of Occupational Therapy*, *64*(2), 336-340. doi: 10.5014/ajot.64.2.336

Beery, K. E., Buktenica, N. A., & Beery, N. A. (2010). *The Beery-Buktenica Developmental Test of Visual-Motor Integration Manual* (6th ed.). Bloomington, MN: Pearson.

Brouwer, W. H., & Ponds, R. W. (1994). Driving competence in older persons. *Disability and Rehabilitation*, *16*(3), 149-161.

Bruininks, R. H., & Bruininks, B. D. (2005). *Bruininks-Oseretsky Test of Motor Proficiency Manual* (2nd ed.). Bloomington, MN: Pearson.

Centers for Disease Control and Prevention. (2012). *Autism spectrum disorders (ASDs)*. Retrieved from http://www.cdc.gov/ncbddd/autism

Centers for Disease Control and Prevention. (2013a). *Changes in prevalence of parent-reported autism spectrum disorder in school-aged children: 2007 to 2011-2012* (Report No. 65). Retrieved from http://www.cdc.gov/nchs/data/nhsr/nhsr065.pdf

Centers for Disease Control and Prevention. (2013b). *Injury prevention and control: Motor vehicle safety*. Retrieved from http://www.cdc.gov/MotorVehicleSafety/teen_drivers

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. doi: 10.1080/15389588.2012.700747

Classen, S., Monahan, M., & Wang, Y. (in press). Driving characteristics of teens with attention deficit hyperactivity and autism spectrum disorder. *American Journal of Occupational Therapy*.

Coulter, R. A. (2009). Understanding the visual symptoms of individuals with autism spectrum disorder (ASD). *Optometry & Vision Development*, *40*(3), 164-175. Retrieved from http://millvalleyoptometry.com/yahoo_site_admin/assets/docs/Article_UnderstandingVisualSymp.123162400.pdf

Di Stefano, M., & Macdonald, W. (2005). On-the-road evaluation of driving performance. In J. M. Pellerito (Ed.), *Driver rehabilitation and community mobility: Principles and practice* (pp. 255-274). St Louis, MO: Mosby.

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. doi: 10.1007/s10803-010-0981-3

Hill, E. L. (2004). Evaluating the theory of executive dysfunction in autism. *Developmental Review*, *24*(2), 189-233.

Justiss, M. D., Mann, W. C., Stav, W., & Velozo, C. (2006). Development of a behind-the-wheel driving performance assessment for older adults. *Topics in Geriatric Rehabilitation*, *22*(2), 121-128.

Monahan, M. (2012). Evaluating and treating adolescents with special needs. In M. J. McGuire & E. Schold Davis (Eds.), *Driving and community mobility: Occupational therapy strategies across the lifespan* (pp. 383–410). Bethesda, MD: AOTA.

Portney, L. G., & Watkins, M. P. (2000). *Foundations of clinical research: Applications to practice* (2nd ed.). Upper Saddle River, NJ: Prentice-Hall Inc.

Raphael, K. (1987). Recall bias: A proposal for assessment and control. *International Journal of Epidemiology*, *16*(2), 167-170. doi: 10.1093/ije/16.2.167

Reynolds, C. R. (2002). *Comprehensive Trail-Making Test*. Austin, TX: PRO-ED.

Shechtman, O., Awadzi, K., Classen, S., Lanford, D. N., & Joo, Y. (2010). Validity and critical driving errors of on-road assessment for older drivers. *American Journal of Occupational Therapy*, *64*(2), 242-251. doi: 10.5014/ajot.64.2.242

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. doi: 10.1007/s10803-009-0890-5

Simmons, D. R., Robertson, A. E., McKay, L. S., Toal, E., McAleer, P., & Pollick, F. E. (2009). Vision in autism spectrum disorders. *Vision Research*, *49*(22), 2705-2739. doi: 10.1016/j.visres.2009.08.005

Smith, A. (2002). *Symbol Digit Modalities Test Manual*. Michigan: Western Psychological Services.

Verté, S., Geurts, H. M., Roeyers, H., Oosterlaan, J., & Sergeant, J. A. (2006). Executive functioning in children with an autism spectrum disorder: Can we differentiate within the spectrum? *Journal of Autism and Developmental Disorders*, *36*(3), 351-372. doi: 10.1007/s10803-006-0074-5

Wainwright-Sharp, J. A., & Bryson, S. E. (1993). Visual orienting deficits in high-functioning people with autism. *Journal of Autism and Developmental Disorders*, *23*(1), 1-13. doi: 0162-3257/93/0300~3001507.00/0

Womack, J. L., & Silverstein, N. (2012). The big picture: Comprehensive community mobility options. In M. J. McGuire & E. Schold-Davis (Eds.), *Driving and community mobility: Occupational therapy strategies across the lifespan* (pp. 19-46). Bethesda, MD: AOTA Press.