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Driving Characteristics of Teens With Attention Deficit Hyperactivity and Autism Spectrum Disorder

Sherrilene Classen, Miriam Monahan, Yanning Wang

MeSH TERMS

- attention deficit disorder with hyperactivity
- automobile driving
- child development disorders, pervasive
- cognition
- psychomotor performance

Vehicle crashes are a leading cause of death among teens. Teens with attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), or both (ADHD–ASD) may have a greater crash risk. We examined the between-groups demographic, clinical, and predriving performance differences of 22 teens with ADHD–ASD (mean age = 15.05, standard deviation [*SD*] = 0.95) and 22 healthy control (HC) teens (mean age = 14.32, *SD* = 0.72). Compared with HC teens, the teens with ADHD–ASD performed more poorly on right-eye visual acuity, selective attention, visual–motor integration, cognition, and motor performance and made more errors on the driving simulator pertaining to visual scanning, speed regulation, lane maintenance, adjustment to stimuli, and total number of driving errors. Teens with ADHD–ASD, compared with HC teens, may have more predriving deficits and as such require the skills of a certified driving rehabilitation specialist to assess readiness to drive.

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In 2008, teen crashes in the United States accounted for 1 in 3 injury-related deaths (Centers for Disease Control and Prevention [CDC], 2012b). Specifically, in 2005 the incidence of total fatal and nonfatal injuries in teens (ages 15–19 yr) was 14% (534,911 total) and accounted for 14% (\$13.627 billion) of total costs of motor vehicles crashes (Naumann, Dellinger, Zaloshnja, Lawrence, & Miller, 2010). Reasons cited for these injuries are inexperience, risk-taking behaviors, and impulsivity. To be *fit to drive*—that is, driving safely and smoothly, while compensating for impairment (Brouwer & Ponds, 1994)—drivers must be proficient in a unique set of driving skills that comprise visual, cognitive, and motor abilities and an interaction thereof, executed in a coordinated fashion in a complex and dynamic environment (Classen, 2010). Although the CDC (2012b) has published statistics for teen crashes, it is unclear how many of those teens have special needs, such as attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), or both.

ADHD is prevalent in 5.4 million children, or 1 in 10 children, in the United States and is characterized by inattention, hyperactivity, and impulsivity (Visser, Bitsko, Danielson, Perou, & Blumberg, 2010). A meta-analysis on drivers with ADHD across the lifespan (Jerome, Segal, & Habinski, 2006) found that stimulant medication improves driving performance in younger drivers with ADHD compared with healthy control (HC) drivers and that drivers with ADHD had more self-reported motor vehicle crashes and more traffic citations, drove more without a driver's license, and drove more under the influence of alcohol. In a recent evidence-based review of teen drivers with ADHD, Classen and Monahan (2013) concluded that a multimodal intervention is possibly effective for improving on-road driving performance and that stimulants possibly do not negatively affect on-road driving. For simulated driving performance, they concluded that stimulants possibly improve driving

performance and that an ADHD diagnosis and being unmedicated possibly worsen driving performance.

ASD, prevalent in 1 of 88 children in the United States (CDC, 2012a), is characterized by social interaction deficits, verbal and nonverbal communication skill deficits, repetitive behaviors, and fixated interests (CDC, 2012a). An evidence-based review of the ASD literature revealed a paucity of driving studies among teens with this condition (Classen & Monahan, 2013). Little is known about how the severity, duration, symptoms, and medications related to ASD affect the body functions and systems. To date, in the English-language literature (2001–2013), we found only one survey (Huang, Kao, Curry, & Durbin, 2012) and one prospective study (Sheppard, Ropar, Underwood, & van Loon, 2010) on teens with ASD and driving. In the survey, 297 parents of teens (ages 15–18 yrs) with high-functioning ASD reported on their child's driving outcomes. The survey found that 63% of teens were driving or planning to drive, and 29% of the teens who were age-eligible to drive were actually driving. Of the 63% of driving teens who held a permit, 12% were reported to have been in one or more motor vehicle crashes as the driver at fault and 12% were reported to have received a citation for a moving violation in the past 12 mo (Huang et al., 2012).

The prospective study examined whether ASD impairs a person's ability to perceive roadway hazards, through video clips, as a result of deficits in processing social information (Sheppard et al., 2010) among 23 male teens with ASD (mean age = 18.55 yr, standard deviation [*SD*] = 1.79) and 21 male HC teens (mean age = 18.83 yr, *SD* = 2.25; Sheppard et al., 2010). The ASD group identified fewer social (i.e., people, such as pedestrians) hazards than the HC group. Although no between-group differences were found for nonsocial (i.e., no people) hazards, the ASD group was slower than the HC group to detect hazards under both social and nonsocial conditions.

A person who meets the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; American Psychiatric Association, 2013) criteria for both diagnostic groups may receive a dual diagnosis of ADHD and ASD (Lee & Ousley, 2006). Many of the visual, process, and motor skills required for driving may be negatively affected by ADHD, ASD, or both (ADHD–ASD; Jerome et al., 2006; Sheppard et al., 2010), but little is known about the actual type and number of errors made when assessed during a comprehensive driving evaluation.

Rationale, Significance, and Purpose

Although this growing population of potential drivers with ADHD–ASD has clear distinguishing features that

contribute uniquely to driving risk, little is known about their descriptive profiles, medical and clinical indicators, and driving errors. As such, clinicians do not have evidence-based guidelines or resources available to accurately determine fitness to drive potential in teens with ADHD–ASD. The purpose of this study was to examine the demographic, clinical, and simulated driving differences between teens with ADHD–ASD and HC teens when evaluated by an occupational therapist who was also a certified driving rehabilitation specialist (CDRS).

Method

Research Design

We used a two-group prospective study to compare teens with physician-confirmed diagnosis of ADHD–ASD with HC teens. The university's institutional review board approved the study. The teens provided informed assent, and their parents provided informed consent before participating.

Participants

The convenience sample of teens consisted of 22 with ADHD–ASD. They were recruited through newspaper advertisements, presentations, and flyers in public places (e.g., Boys and Girls Clubs, North Central Florida school districts, physicians' offices, rehabilitation centers, and the Center for Autism Related Disabilities). The inclusion criteria were (1) age ≥ 14 yr and ≤ 18 yr; (2) had not received a learner's permit or driver's license; (3) free of seizures in the previous year; (4) ability to read and understand English; (5) visual acuity of at least 20/40 in one eye (Florida's minimum requirement); (6) doctor's note to participate when a complex medication regimen existed; (7) community dwelling; (8) ability to travel to Gainesville, FL; and (9) ability to participate in a battery of clinical tests and a driving simulator test. The exclusion criteria were (1) diagnosed with severe psychiatric conditions (e.g., psychoses) or physical conditions (e.g., missing limbs) negatively affecting driving performance, (2) multiple psychotropic medications negatively affecting mental or physical functioning, and (3) below-average intelligence (<90 on the Wechsler, 2004, Intelligence Scale for Children).

Setting and Equipment

The evaluation was conducted in the University of Florida Gator Tech Smart House Simulator Laboratory in Gainesville, FL. The CDRS assessed driving performance on a 180° field of view STISM M500W™ (STI Sim, Hawthorne, CA) fixed-base high-fidelity simulator integrated into a Dodge Neon car cab.

Procedure

The participants' parents completed a demographic questionnaire, medical history, and list of medications (Table 1). The participants completed a clinical battery of tests (Table 1), an orientation to the simulator, a 7-min acclimation drive, and a 20-min main drive. The main drive included three straight drives, nine left turns, two right turns in simple traffic, and five divided attention (DA) tasks consisting of a diamond symbol located on the right side of the screen, for which the participant was asked to honk the horn when the diamond changed to a triangle. The DA task occurred at three straight drives, one left turn, and one right turn. The entire testing battery took about 2.5 hr to complete. The CDRS performed the evaluation by sitting in the passenger seat of the simulator. Teens were paid \$25.00 for study completion.

Measures

Clinical Battery of Tests. Visual tests for peripheral field, visual acuity, color discrimination, depth perception, and phorias (eye alignment on the horizontal and vertical planes) were performed using the Optec[®] 2500 Visual Analyzer (Stereo Optical Company Inc., Chicago) with visual acuity and contrast sensitivity showing moderate correlations ($r_s = .40-.70, p < .05$) with failing an on-road test (Classen et al., 2011). We categorized the binocular

visual acuity as 20/20–20/40 and $\geq 20/50$ or poorer (e.g., $\geq 20/70$). Functioning on the other visual tests was documented as impaired or nonimpaired.

Visual attention and processing speed were measured with the Useful Field of View (UFOV), a standardized test for older adults and people with neurological disorders (Ball & Owsley, 1993; Fisk, Novack, Mennemeier, & Roenker, 2002). Even though the test was not developed for teens, occupational therapy practitioners use this test as part of the standard clinical driving evaluation battery for a variety of populations, including teens. We used the three UFOV subtests, with validity to predict motor vehicle crashes and on-road outcomes (UFOV 1 = visual search and visual processing; UFOV 2 = divided attention; UFOV 3 = selective attention) and the UFOV Risk Index (RI) to assess visual–cognitive function (Ball & Owsley, 1993; Classen et al., 2011; Edwards et al., 2006).

Performance, or the threshold exposure duration at which tasks are completed correctly, is measured in milliseconds on the three UFOV subtests. UFOV 1 measures the threshold exposure duration for correct performance of identifying whether a car or truck icon was presented inside a box on a computer screen. UFOV 2 measures the threshold exposure duration for correct performance of a central identification task in conjunction with the task of localizing a varied peripheral target. UFOV 3 measures

Table 1. Descriptive Statistics and Between-Groups Differences on the Demographics of Teens With ADHD–ASD and Healthy Control Participants ($N = 44$)

	Healthy Control Participants ($n = 22$)	ADHD–ASD ($n = 22$)	Statistic ^a	p
Age, $M \pm SD$	14.32 \pm 0.716	15.05 \pm 0.950	$U = 33.5$	.004
Gender, n (%)			$\chi^2(1) = 1.68$	.195
Male	13 (59.1)	17 (77.3)		
Female	9 (40.9)	5 (22.7)		
Race, n (%)			$F(0) = 3.98$	.410
White	18 (81.8)	19 (86.4)		
Other ^b	4 (18.2)	3 (13.6)		
Education, yr, $M \pm SD$	8.86 \pm 0.990	9.55 \pm 0.912	$U = 136.5$	.008
No. of medications, $M \pm SD$	0.41 \pm 0.908	2.86 \pm 3.285	$U = 68.0$	<.001
No. of prescription medications, $M \pm SD$	0.32 \pm 0.839	1.81 \pm 1.537	$U = 79.5$	<.001
No. of OTC medications, $M \pm SD$	0.09 \pm 0.426	1.05 \pm 2.663	$U = 176.5$	.022
OT intervention, n (%)			$\chi^2(1) = 18.45$	<.001
Yes	0 (0)	13 (59.1)		
No	22 (100)	9 (40.9)		
PT intervention, n (%)			$\chi^2(1) = 3.09$	.185
Yes	1 (4.5)	5 (22.7)		
No	21 (95.5)	17 (77.3)		
SLP intervention, n (%)			$\chi^2(1) = 3.77$	.052
Yes	4 (18.2)	10 (45.5)		
No	18 (81.8)	12 (54.5)		

Note. Significant group difference ($p < .05$). ADHD–ASD = attention deficit hyperactivity disorder, autism spectrum disorder, or both; M = mean; OT = occupational therapy; OTC = over the counter; PT = physical therapy; SD = standard deviation; SLP = speech–language pathology.

^a F determined by Fisher's Exact Test; U = Mann–Whitney U test. ^bOther racial categories included African American, American Indian or First Nations, Asian, and Native Hawaiian/Pacific Islander.

the threshold exposure duration for correct performance of a central identification task and peripheral localizing task, but the peripheral target is embedded in a field of distracters. The range for performance of each of the tasks is 16–500 ms. When participants exceed 500 ms on a subtest, they do not continue to the next subtest. A five-category UFOV RI (1 = *very low risk*, 2 = *low risk*, 3 = *low–moderate risk*, 4 = *moderate–high risk*, and 5 = *high risk*; UFOV User's Guide Version 6.0.6 [Visual Awareness, Inc., 2002]), developed from a composite of the three subtests, is predictive of crashes in older drivers (Ball & Owsley, 1993). Administration of this standardized test is conducted on a touch screen and completed within 15 min.

Visual–motor integration was measured with the Beery-Buktenica Developmental Test of Visual–Motor Integration (Beery™ VMI; Beery & Beery, 2010), a test with established validity for chronological age (r_s between .80 and .95), visual–perceptual tests ($r_s = .48-.66$, $p < .05$), and academic outcomes ($r = .65$, $p \leq .05$; pp. 13–14, 116, 121). The test requires participants to copy drawings of various complexities. Standard scores, used in this study, are equal units of measurement with a mean of 100 and a SD of 15 (Beery & Beery, 2010).

Cognitive abilities were measured with the Comprehensive Trail Making Test (CTMT; Reynolds, 2002), a standardized set of five visual search and sequencing tasks that demands attention, concentration, resistance to distraction, and cognitive flexibility, in addition to visual search and sequencing demands. The CTMT has established reliability (i.e., .91 for content sampling, .84 for time sampling, and .99 for rater reliability; Reynolds, 2002, p. 29), and it has established validity in terms of the test content; internal structure, with factor loadings on the CTMT trails between 0.76 and 0.84 for men and between 0.77 and 0.86 for women; and other external variables (e.g., the Developmental Test of Visual Perception–Adolescents and Adults [DTVP–A]) with CTMT trails' correlations ranging from 0.22 to 0.76 for the General Visual Perception, Motor-Reduced Visual Perception, and Visual–Motor Integration subscales of the DTVP–A (Reynolds, 2002, pp. 33–42). The first three trails of the CTMT involve simple sequencing, and the fourth and fifth require complex sequencing. The unit of measurement is seconds, and the faster the participant completes the trails, the better the performance.

The Symbol Digit Modalities Test (SDMT; Smerbeck et al., 2011) measures the efficiency of many cerebral mechanisms in the two hemispheres (e.g., processing language symbols in the left hemisphere and special constructional functions in the right hemisphere) and in

the forebrain commissures that connect the two hemispheres to allow for integration of verbal and perceptual nonverbal mental processes in children and adults. The SDMT has demonstrated reliability (e.g., test–retest $r_s = .80$ for the written part and .76 for the oral part; Smith, 1993, p. 9). The SDMT is sensitive to discriminate among those with verbal symbolic processing difficulties. For example, in this group, four levels of severity on the SDMT oral and written performance revealed significant differences ($p < .01$) when compared with the mean scores of objective tests of speech, comprehension, reading, writing, and nonverbal cognitive functions (Smith, 1993, p. 18). The SDMT requires the participant to use a key with symbols and a corresponding number. The score sheet has 110 symbols, and the participant is given 90 s to enter as many numbers as possible. The unit of measurement is the correct number of responses (range = 0–110, with 110 indicating superior performance; Smith, 1993).

Motor performance was measured with the short form of the Bruininks–Oseretsky Test of Motor Proficiency–2 (BOT–2; Bruininks & Bruininks, 2005). The BOT–2 has internal consistency reliability, with composite coefficients ranging from .80 to .90, test–retest reliability with mean composite correlation coefficients in the mid-.80s, and interrater reliability with scores ranging in the .90s (Bruininks & Bruininks, 2005, pp. 51–56). Established validity pertains to the test content; internal structure (correlation coefficients between the composite and subscores ranging from .20 to .40); clinical groups with developmental coordination disorder, mild to moderate mental retardation, or high-functioning autism spectrum disorder; and relationships with other measures, such as the Peabody Developmental Motor Scale. Correlations among the subtests range from .51 to .75 (Bruininks & Bruininks, 2005, pp. 56–71). The unit of measurement is the standard scores, which range from 20 to 80 (mean = 50, $SD = 10$; Bruininks & Bruininks, 2005).

Driving Performance. The CDRS completed the Operational Skills Questionnaire (which can be obtained from Sherrilene Classen), using a four-question visual analog scale, after orienting the teens to the simulator and car cab. Driving errors (type and number) were recorded by the CDRS for lane maintenance, speed regulation, gap acceptance, adjustment to stimuli, visual scanning, vehicle positioning, and signaling with established validity (Justiss, Mann, Stav, & Velozo, 2006) and reliability (Posse, McCarthy, & Mann, 2006). We also recorded the simulator summary statistics, specifically the number of center line crossings, off-road crashes, collisions, pedestrians hit, and stops at traffic lights.

Data Collection

Data were entered into the database by a trained member of the research team. The database was located in a secure and password-protected data repository at the university. Data entry was monitored by the principal investigator (Classen), and quality control spot checks and corrections were made to ensure data accuracy.

Data Analysis

We used PASW Statistics 20 (IBM Corp., Armonk, NY) to perform the analyses. We provided summary statistics (frequency, mean, and standard deviations) for all data. To determine between-group differences, we used χ^2 tests or Fisher's exact tests (with $n < 5$ in any cell) for nominal variable comparisons; two-tailed independent-sample t tests for continuous data adjusted for the Levin's test of (in)equality; and Mann-Whitney U test for non-parametric data. We conducted a post hoc correlational analysis using Spearman's ρ . All comparisons (two-tailed) were considered significant at the $p < .05$ α level. Because of the exploratory nature of this study, we did not adjust for multiple comparisons.

Results

Demographic Differences Between Teens With ADHD-ASD and Healthy Control Teens

The total sample numbered 44, with 22 teens in each cohort. No teens withdrew from the study. Teens with ADHD-ASD (ADHD, $n = 9$; ASD, $n = 7$; ASD and ADHD, $n = 6$) had a mean age of 15.05 ($SD = 0.95$), and the 22 HC had a mean age of 14.32 ($SD = 0.72$). Teens with ADHD-ASD were older; had a higher level of education; used more prescription, over the counter, and total number of medications; and had more occupational therapy interventions than the HC teens.

Clinical Differences Between Teens With ADHD-ASD and Healthy Control Teens

The teens with ADHD-ASD had poorer right-eye visual acuity than the HC teens. They also performed more poorly on the UFOV 3 (selective attention), but we found no differences on the other UFOV subtests or the UFOV RI. In addition, the teens with ADHD-ASD performed more poorly on the Beery VMI, CTMT, and SDMT than the HC teens. When compared with HC teens, the teens with ADHD-ASD had poorer motor performance as evidenced by BOT-2 scores and the transferring pennies and one-legged stationary hop tasks (Table 2).

Driving Performance Differences Between Teens With ADHD-ASD and Healthy Control Teens

Compared with HC teens, teens with ADHD-ASD made more visual scanning, speed regulation, lane maintenance, and adjustment-to-stimuli errors, as well as more total driving errors (Table 3). The simulator summary data did not yield significant differences between teens with ADHD-ASD and HC teens.

Discussion

The purpose of this study was to examine the between-group differences in teens with ADHD-ASD and HC teens when evaluated by a CDRS. The teens with ADHD-ASD were older than the HC teens and were therefore further along in their education. Not surprisingly, teens with ADHD-ASD used more medications than HC teens (Dove et al., 2012; Visser & Lesesne, 2005). They also received more occupational therapy interventions than HC teens, with the literature indicating that occupational therapy is one of the most common services that these teens receive (Bitterman, Daley, Misra, Carlson, & Markowitz, 2008; Schnoes, Reid, Wagner, & Marder, 2006).

Although people with ASD have superior visual acuity (Ashwin, Ashwin, Rhydderch, Howells, & Baron-Cohen, 2009), those with ADHD have impaired visual acuity when not treated with stimulants (Martin, Aring, Landgren, Hellström, & Andersson Grönlund, 2008). We did not control for the effect of medications in this study, and as such this phenomenon requires further investigation.

For visual attention, the teens with ADHD-ASD performed more poorly on the UFOV 3 than did the HC teens. The outcome of their mean score (80.31 ms) was still, however, remarkably faster than the norms for the adult or older adult population (Ball & Owsley, 1993; Fisk et al., 2002). As such, the UFOV may not be a sensitive test for teens, but this claim needs to be examined in a larger study.

Consistent with previous findings, impaired visual-motor integration as tested with the Beery VMI is evident in teens with ADHD-ASD (Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2005; Monahan, Classen, & Helsel, 2013; Verté, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006). In post hoc analyses, we determined the correlations between the Beery VMI and driving errors and were surprised to find that the Beery VMI was significantly associated with errors of vehicle positioning ($r = .59, p \leq .01$), lane maintenance ($r = .57, p \leq .01$), and total errors ($r = .45, p \leq .04$) among teens with ADHD-ASD. These findings suggest that impaired visual-motor integration is associated with errors in basic maneuvers required for adequate vehicle control, as tested in a driving simulator.

Table 2. Descriptive Statistics and Between-Groups Differences on the Clinical Tests for Teens With ADHD-ASD and Healthy Control Participants (N = 44)

Clinical Test	Healthy Control Participants (n = 22)	ADHD-ASD (n = 22)	Statistic	p
Vision				
Snellen acuity, both eyes, n (%)			$\chi^2(3) = 7.667$	.053
20/20	16 (72.7)	8 (36.4)		
20/30	6 (27.3)	10 (45.4)		
20/40	0 (0)	2 (9.1)		
20/50	0 (0)	2 (9.1)		
Snellen acuity, right eye, n (%)			$\chi^2(4) = 14.571$	.006
20/20	18 (81.8)	6 (27.3)		
20/30	4 (18.2)	10 (45.5)		
20/40	0 (0)	4 (18.2)		
20/50	0 (0)	1 (4.5)		
20/60	0 (0)	0 (0)		
20/70	0 (0)	1 (4.5)		
Snellen acuity, left eye, n (%)			$\chi^2(3) = 5.619$	.132
20/20	17 (77.3)	11 (50.1)		
20/30	5 (22.7)	7 (31.8)		
20/40	0 (0)	3 (13.6)		
20/50	0 (0)	1 (4.5)		
Peripheral field, right, n (%)			$\chi^2(2) = 5.641$	.060
85° temporal	22 (100)	17 (77.3)		
70° temporal	0 (0)	3 (13.6)		
55° temporal	0 (0)	2 (9.1)		
35° nasal	0 (0)	0 (0)		
Peripheral field, left, n (%)			$\chi^2(2) = 1.305$	.521
85° temporal	20 (90.9)	18 (81.9)		
70° temporal	2 (9.1)	3 (13.6)		
55° temporal	0 (0)	1 (4.5)		
35° nasal	0 (0)	0 (0)		
Depth perception, n (%)			$\chi^2(2) = 3.552$	.169
Intact	19 (86.4)	15 (68.2)		
Impaired	3 (13.6)	7 (31.8)		
Lateral phoria			$\chi^2(1) = 0.358$	1.00
Impaired	1 (4.5)	2 (9.1)		
Intact	21 (95.5)	20 (90.9)		
Vertical phoria, n (%)			$\chi^2(1) = 1.100$	.607
Impaired	1 (4.5)	3 (13.6)		
Intact	21 (95.5)	19 (86.4)		
Visual cognition, M ± SD				
UFOV 1	16.7 ± 0	16.7 ± 0	$t(42) = 0.000, SE = 0.00$	1.000
UFOV 2	18.82 ± 8.01	31.09 ± 38.05	$t(22.86) = -1.48, SE = 8.29$	.15
UFOV 3	55.13 ± 19.65	80.31 ± 40.49	$t(30.37) = 2.62, SE = 9.60$	.013
UFOV risk index, n (%)			$\chi^2(1) = 2.10$	.148
Category 1: very low risk	22 (100.0)	20 (90.9)		
Category 2: low risk	0 (0)	2 (9.1)		
VMI standard score, M ± SD	99.59 ± 7.49	90.95 ± 10.56	$t(42) = 3.13, SE = 2.76$	.003
Cognition				
Cognition, M ± SD				
CTMT Raw Score Sum	187.55 ± 40.84	283.23 ± 70.43	$t(33.69) = -2.92, SE = 17.36$	.006
SDMT correct response in the written test	60.95 ± 9.8	50.82 ± 9.62	$t(42) = 3.46, SE = 2.93$	.001

(Continued)

Table 2. Descriptive Statistics and Between-Groups Differences on the Clinical Tests for Teens With ADHD-ASD and Healthy Control Participants (N = 44) (cont.)

Clinical Test	Healthy Control Participants (n = 22)	ADHD-ASD (n = 22)	Statistic	p
Motor				
BOT-2 standard score ^a , M ± SD	52.64 ± 7.03	40.43 ± 9.53	t(41) = 4.80, SE = 2.55	<.001
Transferring pennies	7.77 ± 1.02	6.86 ± 1.73	t(34.08) = 2.13, SE = 0.43	.041
One-legged stationary hop	7.77 ± 0.81	5.9 ± 2.34	t(24.55) = 3.46, SE = 0.54	.002

Note. Significant group difference ($p < .05$). ADHD-ASD = attention deficit hyperactivity disorder, autism spectrum disorder, or both; BOT-2 = Bruininks-Oseretsky Test of Motor Proficiency-2; M = mean; SD = standard deviation; CTMT = Comprehensive Trail Making Test; SDMT = Symbol Digit Modalities Test; SE = standard error; UFOV = Useful Field of View; VMI = Beery-Buktenica Developmental Test of Visual-Motor Integration.

^aBOT-2, n = 21 for ADHD-ASD.

In terms of cognition, people with a diagnosis of either ADHD or ASD may have impairments in executive functions related to planning, attention shifting, and complex sequencing (Hill, 2004; Sergeant, Geurts, & Oosterlaan, 2002). Therefore, it is not surprising that the teens with ADHD-ASD in this study performed more poorly on tests of planning, attention, set shifting, and sequencing than HC teens.

Characteristics of motor performance deficits in ADHD include lack of inhibition of non-goal-directed motor actions, sensitivity of motor response, timing of motor response (Barkley, 1997), and postural instability, which are also pervasive features of ASD (Fournier, Hass, Naik, Lodha, & Cauraug, 2010). People with a dual diagnosis may have motor skill deficits; thus, we are not surprised that these teens, when compared with HC

teens, performed more poorly on the tests of motor performance. Motor performance is a critical aspect of driving, and in a post hoc analysis conducted with teens from the diagnostic group we found correlations between the BOT-2 and errors of visual scanning ($r = .49, p \leq .03$), transferring of pennies (BOT-2 subtest), adjustment to stimuli ($r = .50, p \leq .02$), the one-legged stationary hop (BOT-2 subtest), and speed regulation ($r = .50, p = .02$) as well as total errors ($r = .45, p = .04$). Pacing, sequencing, and timing are all subcomponents of transferring pennies and the one-legged stationary hop, as well as subcomponents of the task of regulating speed in traffic. We propose, as supported by these moderate correlations, that the performance components evident in the transferring of pennies and the one-legged stationary hop are also related to speed regulation.

Table 3. Descriptive Statistics and Between-Groups Differences on the Driving Performance of Teens With ADHD-ASD and Healthy Control Participants (N = 44)

Driving Performance Variables	Healthy Control Participants (n = 22), M ± SD	ADHD-ASD (n = 22), M ± SD	t	p
Driving Errors by CDRS Evaluation				
Visual scanning	2.27 ± 1.52	4.73 ± 3.38	t(42) = -3.11, SE = -2.46	.003
Speed regulation	6.5 ± 4.18	14.23 ± 7.73	t(32.34) = -4.13, SE = 1.87	<.001
Lane maintenance	18.55 ± 7.2	26.09 ± 11.38	t(35.49) = -2.63, SE = 2.88	.013
Signaling	1.18 ± 2.91	2.95 ± 4.2	t(37.34) = -1.63, SE = 1.09	.112
Vehicle positioning	1.64 ± 1.92	2.23 ± 1.97	t(42) = -1.01, SE = -0.59	.320
Adjustment to stimuli	2.23 ± 3.05	4.82 ± 3.7	t(40.55) = -2.53, SE = 1.00	.015
Gap acceptance errors	1.5 ± 1.68	2.23 ± 1.27	t(42) = -1.62, SE = 0.45	.113
Total errors	33.86 ± 12.78	57.27 ± 20.21	t(42) = -4.59, SE = 5.10	<.001
Driving Errors by Simulator Summary Data				
Off-road crashes	0.09 ± 0.43	0.5 ± 0.86	t(30.75) = -2.00, SE = 0.20	.054
Collisions	0.27 ± 0.46	0.68 ± 1.39	t(25.44) = -1.31, SE = 0.31	.202
Pedestrians hit	0.09 ± 0.29	0.32 ± 0.57	t(31.52) = -1.67, SE = 0.14	.105
Stops at traffic lights	6.82 ± 0.66	6.82 ± 0.5	t(42) = 0, SE = 0.18	1.000
Center line crossings	2.14 ± 2.51	4.82 ± 6.22	t(27.69) = -1.88, SE = 1.43	.071
Road-edge excursions	12.14 ± 7.51	12.32 ± 8.65	t(42) = -0.07, SE = 2.44	.940
Correct DA responses	7.73 ± 23.11	2.95 ± 1.53	t(42) = 0.97, SE = 4.94	.339
Average DA response time, s	34.44 ± 12.27	32.53 ± 11.81	t(41) = 0.52, SE = 3.60	.607
Total no. of DAs with no response	7.14 ± 23.24	2.05 ± 1.53	t(42) = 1.025, SE = 2.95	.311

Note. Significant group difference ($p < .05$). M = mean; SD = standard deviation; ADHD-ASD = attention deficit hyperactivity disorder, autism spectrum disorder, or both; CDRS = certified driving rehabilitation specialist; DA = divided attention.

We observed that the teens with ADHD–ASD made more driving performance errors on the simulator as assessed by the CDRS. Consistent with findings in the literature, teens with ASD ineffectively prioritize information and show delay in attention shifting to perceive multiple stimuli on the roadway (Hill, 2004; Monahan et al., 2013). Both of these skills (prioritizing and attention shifting) are necessary for effective visual scanning and adjustment to stimuli; hence, these findings may partially explain why we observed poorer performance related to these errors.

Likewise, visual–motor integration deficits have also been documented in the ASD (Verté et al., 2006) and ADHD literature (Geurts et al., 2005). The task of driving, specifically when making a turn at an intersection, requires intact visual–motor integration skills and a coordinated motor response based on perceived visual demands. As such, this action requires staying in the lane (lane maintenance) by turning the steering wheel adequately (motor response) to match the degree of the turn (visual information) and positioning the vehicle well within the lane markings (visual and motor response), while managing appropriate speed (motor response) and negotiating sections—that is, entry, actual turn, and exit (visual information)—of the maneuver. For example, in the entry phase of the turn, speed is reduced; during the actual turn, speed is further reduced; and for exiting the turn, a gradual increase in speed is expected. We propose that because of impaired underlying visual–motor integration skills, the teens with ADHD–ASD may also experience problems in speed regulation and lane maintenance. Cumulatively, the impairments in cognition and visual–motor integration may contribute to an increase in the total number of driving errors, but such assertions require further empirical testing.

An interesting finding was that the simulator summary data did not yield any differences in aspects measured such as off-road crashes, collisions, pedestrian hits, and so forth. This finding suggests, unlike the findings of the CDRS, that simulator summary data may not be adequately sensitive to detect driving performance deficits in teens with ADHD–ASD.

Limitations and Future Research

The predominantly White sample was not representative of the general spectrum of teens with ADHD–ASD. We had a small sample size with age differences. Because it was a convenience sample, we expected selection bias (more concerned parents and teens with better insight enrolled in the study), Berkson’s bias (teens’ test-taking and driving behaviors were influenced by the evaluator’s sitting next to the client), and Hawthorne bias (teens’

test-taking and driving behaviors influenced because of the testing site and social conditions) to influence the estimates. We did not control for the effects of medications on the teens’ driving performance. We grouped teens with ASD, teens with ADHD, and teens with a dual diagnosis together, and as such intergroup variability may be evident and the correlates of driving fitness may differ between groups. We used the simulator as a mode to assess fitness to drive, and results may not be transferable to on-road driving performance. However, the simulator is an ideal instrument to test the predriving skills of teens without a driving permit or driver’s license.

Future research may determine, in a larger, representative, and age- and gender-matched sample, the predictors of simulated driving performance in teens with ASD compared with those of teens with ADHD and in both groups compared with HC teens. Doing so will mitigate the limitations of this study and make clear the fitness-to-drive deficits apparent in both groups when compared with HC teens. This step is necessary to identify underlying client issues (e.g., visual, cognitive, motor performance) before targeted intervention planning.

This descriptive article provides first-time knowledge of the demographic, clinical, and predriving-skill differences of teens with ADHD–ASD compared with HC teens, and as such lays the foundation for future research and clinical decision making.

Implications for Occupational Therapy Practice

The results of this study have the following implications for occupational therapy practice:

- Teens with ADHD–ASD perform worse than HC teens on a clinical test battery of visual acuity, selective attention, visual–motor integration, cognition, and motor performance.
- In teens with ADHD–ASD, moderate correlations exist between impaired functioning on visual–motor integration and motor performance and driving errors made in the simulator.
- Compared with HC teens, teens with ADHD–ASD make more visual scanning, speed regulation, lane maintenance, adjustment-to-stimuli, and total driving errors. These teens are a high-risk group with impaired fitness-to-drive skills, requiring a comprehensive driving evaluation by an occupational therapist CDRS. ▲

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