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Simulated Driving Performance, Self-Reported Driving Behaviors, and Mental Health Symptoms in Adolescent Novice Drivers

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Abstract

Background—Risky driving behaviors contribute to adolescent injury, disability, and death, yet little is known about how mental health factors are associated with adolescent driving behaviors.

Objectives—The purpose of the research was to determine the association of risky driving behaviors and mental health symptoms in novice adolescent drivers.

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Methods—We recruited a convenience sample ($n = 60$) of adolescents to complete an assessment of driving performance errors in a high-fidelity simulator (Simulated Driving Assessment [SDA] Error Score) and a self-report measure of risky driving (Behavior of Young Novice Drivers Survey [BYNDS]). Participants also completed a mental health assessment of self-reported symptoms of depression (Center for Epidemiologic Studies Depression Scale) and attention-deficit hyperactivity disorder (inattention and hyperactivity-impulsivity), conduct disorder and oppositional defiant disorder (Conners-3 self and parent report). We evaluated the cross-sectional relationships between SDA Error Score, BYNDS and mental health survey data with descriptive statistics, bivariate correlations, and linear regression.

Results—In linear regression models, higher self-reported ADHD-inattentive T-scores were associated with higher SDA Error Score (model adjusted $R^2 = .20$). Higher self-reported T-scores of ADHD hyperactive-impulsive and conduct disorder were associated with higher BYNDS total scores (model adjusted $R^2 = .32$). Parent-report measures were not associated with adolescent BYNDS Total Score or SDA Error Score.

Discussion—These data highlight the association of risky driving with adolescent symptoms of inattention, hyperactivity, and conduct disorder. The early stage of independent driving is an important time for addressing the relationship between driving performance and mental health conditions.

Keywords

adolescent; attention deficit hyperactivity disorder; conduct disorder; oppositional defiant disorder; risky driving behaviors

Motor vehicle crashes (MVCs) are the leading cause of death in adolescents, accounting for one out of every three adolescent fatalities (Centers for Disease Control and Prevention, 2017a, 2017b). Crash burden is measured not just in deaths, but also in over 170,000 nonfatal injuries and costs exceeding \$26 billion (Centers for Disease Control and Prevention, 2017a; National Center for Statistics and Analysis, 2016). The highest risk for an MVC in adolescents is in the first six months of licensure (Foss, Martell, Goodwin, O'Brien, & AAA Foundation for Traffic Safety, 2011; Mayhew, Simpson, & Pak, 2003) highlighting a critical time for crash prevention efforts.

Risky driving involves illegal or dangerous behind-the-wheel behaviors (decisions, actions, reactions, and performance) associated with operating a motor vehicle in a manner that may lead to harm or injury to oneself or others (Sommers & Ribak, 2008). Performance errors such as driving too fast for conditions, inadequate surveillance, and following vehicles too closely, are errors that novice drivers often make that contribute to crash risk (Braitman, Kirley, McCartt, & Chaudhary, 2008; Curry, Hafetz, Kallan, Winston, & Durbin, 2011; Peek-Asa, Britton, Young, Pawlovich, & Falb, 2010). Additional behaviors such as nighttime driving (Williams, Tefft, & Grabowski, 2012), cell phone use while driving (Carney, Mcgehee, Harland, Weiss, & Raby, 2015; Scott-Parker & Oviedo-Trespalacios, 2017), and multiple peer passengers (Tefft, Williams, & Grabowski, 2013) also increase crash risk in adolescents.

Many studies examining adolescent driver risk for MVCs have focused on age and length of licensure as crash-contributing factors (Chapman, Masten, & Browning, 2014; Curry, Pfeiffer, Durbin, & Elliott, 2015; Mayhew et al., 2003). However, there is a need to investigate mental health-related factors that might contribute to crash risk. During adolescence, mental health factors that may enhance risk include attention deficit hyperactivity disorder (ADHD), disruptive behavior disorders, and depression. ADHD is characterized by patterns of inattention and/or hyperactivity-impulsivity that interferes with functioning or development (National Institute of Mental Health, 2016), and has been identified as a critical risk factor for negative driving outcomes for adolescents and young adults (Jerome, Segal, & Habinski, 2006). In a study of licensed adolescents in New Jersey, Curry and colleagues (2017) found that the adjusted risk for an MVC for adolescents with ADHD is 1.36 times higher than adolescents without ADHD (95% CI: 1.25–1.48). Other mental health factors also have the potential to affect driving behaviors. Among adolescents and young adults, conduct behavior problems are also associated with risky driving behaviors (Thompson, Molina, Pelham, & Gnagy, 2007; Vassallo et al., 2007). Psychological distress—including depression—has also been associated with risky driving behaviors in adolescents, ages 17–25 (McDonald, Sommers, & Fargo, 2014; Scott-Parker, Watson, King, & Hyde, 2011). A recent meta-analysis—which included data from young adults—indicated that depression was associated with increased crash risk (Hill et al., 2017). More information is needed, however, on the newly licensed drivers who are at the greatest risk for an MVC.

Purpose

The purpose of this study was to examine the relationship between risky driving behaviors and mental health symptoms in a sample of newly licensed adolescents. We used Sommers and Ribak's (2008) model for risky driving behavior to guide this study, which posits that precursors and moderators influence risky driving behaviors. Precursors are factors that precede or occur before the development of risky driving behavior. Given the lack of attention to mental health factors in relationship to driving outcomes, we focused on symptoms of depression, ADHD (inattention and hyperactivity-impulsivity), conduct disorder, and oppositional defiant disorder. Moderators are factors that can affect the degree of risky driving, including driving inexperience, which we accounted for by recruiting adolescents who received their license within the previous 90 days of enrollment. Sommers and Ribak's model (2008) outlines risky driving behaviors to include behaviors such as substance use, driver inattention, drowsy driving, as well as driving performance errors. For this study, risky driving is therefore operationalized by driving performance in a high fidelity driving simulator (driving performance errors) and self-reported risky driving (behaviors such as substance use, speeding, nighttime driving, and cell phone use). We hypothesized that higher symptom scores of inattention, hyperactivity-impulsivity, conduct disorder, oppositional defiant disorder (ODD), and depression would be associated with increased risky driving behaviors in a self-report measure and as measured in a simulator.

Methods

Design and Participants

This study used a cross-sectional analysis of baseline data from a convenience sample of 16–17-year-old adolescents who were recruited to participate in a randomized clinical trial of a behavioral intervention designed to reduce adolescent driver inattention (NCT02319317). Data collection occurred from 2015–2016. The power analysis for the randomized clinical trial indicated a sample size of 60 could detect a moderate to large effect size of the intervention. At baseline, participants completed a series of questionnaires and an assessment in high-fidelity simulator, described below. Prior to the completion of the intervention to which they were randomized, participants completed the questionnaires and simulated assessment. Thus, we are carrying out the analysis here on the whole sample. Adolescents were recruited through presentations to local high schools, emails, letters and emails to families affiliated with the Children's Hospital of Philadelphia (CHOP), and word of mouth. In addition to our age requirements, inclusion criteria were having received a Pennsylvania license in the previous 90 days; access to a computer, internet, and personal email; willingness to travel to CHOP for study procedures; and the ability to read and write English. The protocol was approved by the Institutional Review Board at CHOP with a cooperative agreement with the University of Pennsylvania.

Measures

Simulated Driving Assessment (SDA)—A previously validated driving assessment in a simulator (SDA) was delivered to participants using a Realtime Technology, Inc. (RTI) fixed-based driving simulator and an Applied Science Laboratories (ASL) Mobile Eye tracking system located at the Center for Injury Research and Prevention (CIRP) Driving Simulator Core at the Children's Hospital of Philadelphia. We first describe the system the SDA was delivered on and then details of the SDA.

The driving simulator system included a driver seat, three channel 4600 liquid-crystal display (LCD) panels (160° field of view), rear view, left and right mirror inlaid images, pedals, and a steering system. Graphics were delivered at 1280×1024 resolution at 60 Hz, and raw simulator data were collected at 60 Hz. Videos of the participant's driving behavior in the simulator were also recorded by three cameras (positioned over the right shoulder, pointing at the participant's face and over the foot for view of brake and accelerator). The ASL Mobile Eye captured eye movements on the forward scene at 30 Hz. Participants wore the ASL Mobile Eye glasses (or alternative goggles worn over eyeglasses) with two video cameras (forward image and right eye of participant) to capture gaze location during the experimental drives. Video data from the two cameras were integrated into a single video with superimposed cross-hairs for eye gaze location.

The SDA comprised three experimental drives which included exposure to variations of the most common teen driver crash configurations. The total 21 potential crash scenarios included six rear-end collisions, eight left turn intersection collisions, five right side run-off-the-road events, and two hidden hazards (McDonald et al., 2012; McDonald et al., 2015). (Since the initial SDA, slight programming modifications were made: one potential rear-end

collision was removed to reduce redundancy, and excess glance duration was not evaluated in this study). The potential crash scenarios were distributed across the three experimental drives, separated by intervening straight roads, curves, and turns not intended to trigger collisions. Participants were exposed to all 21 crash scenarios across the three experimental drives. If adolescent participants drove safely, crashes were avoidable. In order to decrease the potential for a learning effect, no feedback on performance was given to participants on their performances during or after the drive (McDonald et al., 2013).

In the SDA, the following driving performance metrics were assessed for an overall SDA Error Score: lane choice, lateral acceleration during a turn, speeding, stopping behavior at a stop sign, traffic check, turn signal, yaw, braking behavior in a hazardous situation, gap selection, headway time, scanning at intersections (left and right), and scanning for hidden hazards. Supplemental Digital Content 1 (see Table) details the information on driving performance metrics, definition, calculation, source, and criterion for error in the SDA Error Score. For the eye tracking metrics of scanning at intersections (left and right), scanning for hidden hazards and traffic check, videos were coded by two study team members. The average interrater reliability of two coders with a master coder was $\kappa = 0.89$. For a minority of cases with eye tracking device calibration failure, eye-tracker-derived measures could not be calculated for scanning glances and traffic check (missing data by metric ranged from 3.7–17.2%). Missing data for scanning glances or traffic check data were imputed from available data based on percentage of errors in available data on the same metrics in the other scenarios.

The crash scenarios in which the metrics were calculated are detailed in Supplemental Digital Content 2 (see Table). Custom MATLAB (Mathworks, Natick, MA) code was used to reduce raw simulator data. The custom MATLAB code divided the simulated drives into predetermined blocks encompassing each potential crash scenario. Raw simulator data including subject vehicle position, velocity, acceleration, and yaw rate, as well as the position and velocity of surrounding vehicles, were analyzed to determine the incidence of specific driving errors as defined in Supplemental Digital Content A. Errors across all scenarios in the experimental drives were summed as a composite SDA Error Score. The SDA Error Score has demonstrated validity in a previous study with adolescent novice drivers: Adolescents had more errors than experienced adult drivers; each error committed increased the relative risk of a negative simulated driving event (construct validity); and the SDA Error Score was correlated with a driving evaluator's score of the participants simulated driving (criterion validity) (McDonald et al., 2015). Total SDA Error Score (potential range 0–113) was used in this analysis, with higher scores indicating more performance errors in the simulator.

Behavior of Young Novice Drivers Survey (BYNDS)—We assessed risky driving behaviors with the Behavior of Young Novice Drivers Scale (BYNDS), a self-report survey developed in Australian youth (Scott-Parker, Watson, King, & Hyde, 2012; Scott-Parker & Proffitt, 2015). We used the 44-item version edited to align with U.S. context (e.g., miles per hour instead of kilometers per hour). The BYNDS has five subscales (Transient Violations, Fixed Violations, Misjudgment, Risky Exposure, and Driver Mood), with items on a 5-point Likert Scale was used (1 = *never* to 5 = *nearly all the time*). Subscales can be summed for a

total score. Reliabilities were estimated using Cronbach's alpha in this sample. Transient Violations (13 items, $\alpha = .85$) included behaviors that are able to be performed multiple times during the journey (e.g., speeding); Fixed Violations (10 items, $\alpha = .72$) are behaviors more stable in nature across the journey (e.g., not wearing a seatbelt); Misjudgment (9 items, $\alpha = .76$) reflects driver errors (e.g., misjudged speed of oncoming vehicle). Risky Exposure (9 items, $\alpha = .85$) is exposure to risky driving times (e.g., carrying peer passengers at night); and Driver Mood (3 items, $\alpha = .77$) is the driver's emotive response to driving (e.g., drove faster when in a bad mood). We used the BYNDS total score in analyses ($\alpha = .92$); total possible score is 44–220.

Mental health symptom measures—Symptoms of inattention, hyperactivity-impulsivity, conduct disorder and oppositional defiant disorder (ODD) were assessed with the Conners-3 (with the DSM-5 update) using both self-report and parent report. The Conners-3 DSM-5 scales are age- and gender-standardized and have been shown to have adequate to strong reliability (range: .77–.97) and test-retest reliability (.70–.98) (Conners, 2008). We assessed self-report and parent-report of DSM-5 symptom counts, T-scores, probability for symptom criteria being met, and recommendations for follow-up for ADHD inattentive, ADHD hyperactive-impulsive, conduct disorder, and ODD. The symptom counts provide an absolute count of symptoms endorsed by a respondent which is generally used to determine whether DSM-5 criteria are met (Conners, 2008). T-scores provide a standardized score based on age and gender for participant responses. Higher scores on symptom counts and T-scores indicate increased severity of symptoms. Probability for symptom criteria being met (*yes/no*) for ADHD-Inattentive, ADHD-hyperactivity-impulsivity, conduct disorder, and ODD were based on age-specific symptom counts (in our sample for 16 year olds or 17 year olds). The Conners-3 follow up recommendations for further evaluation (*yes/no*) were based on meeting probability for symptom criteria and/or T-score ≥ 60 for each of the domains (ADHD inattentive, ADHD hyperactive-impulsive, conduct disorder, and ODD). The Conners-3 (self-report and parent-report) standardized T-scores, symptom counts, probability for symptom criteria being met and whether the participant met follow-up recommendations were evaluated for analysis.

We used the 20-item Center for Epidemiologic Studies Depression Scale (CES-D) to assess depressive symptoms in the past week (Radloff, 1977). Depressive symptoms were defined as feelings and behaviors indicative of depressed mood that may or may not meet criteria for clinical diagnosis. The CES-D has strong reliability estimated using Cronbach's alpha and has been used with adolescents (Garrison, Addy, Jackson, McKeown, & Waller, 1991; Radloff, 1977; Rutman, Shenassa, & Becker, 2008). Each item was scored on a 0–3 Likert scale for symptom occurrence in the past week (0 = *rarely or none of the time* (less than 1 day) to 3 = *all of the time* (5–7 days). Total sum score on the CES-D was used in analysis and scores could range from 0–60, with higher scores implying more distress.

Demographic information—We collected data on gender, length of licensure, race and ethnicity, parent gender, past and present history of ADHD diagnosis, and past and present use of medication for ADHD.

Procedures

After written assent and written parental/guardian consent were received, adolescent participants completed the baseline survey of self-report questionnaires. Parents/guardians were offered the opportunity to complete the parent-report measure of the Conners–3. For parents who were not present at the study visit in-person, the adolescent participants were given the questionnaire to take home to parents with instructions about how to complete it, along with an addressed/stamped envelope to mail back to the study team. After the baseline survey of self-report questionnaires was completed, the adolescent participants completed the SDA in the high-fidelity driving simulator. Participants completed three experimental drives of the SDA delivered in random order (by a random number generator). Prior to completing the experimental drives, adolescent participants completed a practice drive (~7 min) to adjust to the simulator dynamics. The SDA with all three experimental drives lasted approximately a total of 35–40 minutes.

Data Analysis

Descriptive statistics were calculated for the sample for demographic data, SDA Error Score, BYNDS Total Score, and mental health measures. Bivariate Pearson correlation coefficients were computed to determine associations between SDA Error Score, BYNDS Total Score, and mental health symptom scores (CES–D score as well as the standardized *t*-scores and symptoms counts of DSM–5 ADHD inattentive, DSM–5 ADHD hyperactive-impulsive, DSM–5 conduct disorder, and DSM–5 ODD). Data from both self-report and parent-report Conners–3 items were examined in the analysis.

We used linear regression to separately model the outcomes of SDA Error Score and BYNDS Total Score by mental health symptoms, controlling for gender and length of licensure. We used the age-standardized T-scores for the Conners–3 rather than symptom count in the linear regression models. The least significant predictors were dropped from the full, initial regression models one at a time until the most parsimonious final models were determined. Final models are reported. Given a convenience sample of adolescents where their diagnostic levels of mental health symptoms were low, we also carried out post-hoc analysis to further investigate relationships using linear regression models that included predictors of CES–D score and follow-up recommendations (*yes/no*) for the DSM–5 symptom scales of ADHD inattentive, ADHD hyperactive-impulsive, conduct disorder, and ODD. We anticipated that the proportion of the sample meeting recommendations for follow up would be low. The purpose of the post-hoc models was to investigate whether results supported the results from the T-scores. Post-hoc models included predictors that were significant in the previous linear regression models. Regression diagnostics were performed to evaluate the assumptions of normality and homoscedasticity, and to check for problems associated with collinearity and outliers; no issues were identified.

Results

Two participants did not complete the simulated assessment due to simulator sickness (3.3%) their data were used for analysis with self- and parent-report mental health and BYNDS, but not for the analysis with the SDA Error Score. One participant did not

complete the CES-D. This participant's data were used for all descriptive and bivariate analyses that did not include the CES-D, but were not included in any of the linear regression models.

Table 1 presents the demographic characteristics of the 60 adolescents. None of the adolescents reported being Hispanic/Latino. Table 2 presents the descriptive statistics for mental health symptoms by adolescent self-report ($N = 60$) and parent-report ($N = 54$ parent-report surveys were received). Table 3 presents the bivariate correlations between risky driving and mental health symptoms (self- and parent-report when available). Only adolescent report of inattention T-scores was significantly associated with SDA Error Score; higher scores of inattention were associated with more errors in the simulator ($r = .28$, $p = .04$). All self-reported mental health symptoms were significantly and positively associated with self-reported BYNDS total score (all $p < .05$) so that higher self-reported symptoms were associated with more self-reported risky driving. None of the parent-report measures were significantly associated with their adolescent's BYNDS total score or SDA Error Score. In addition, there was no significant relationship between self-reported BYNDS Total Score and SDA Error Score ($r = .24$, $p = .08$).

Table 4 presents the final linear regression models to predicting SDA Error Score and BYNDS Total Score. In initial models for the SDA Error Score, length of licensure, conduct disorder T-scores and ODD T-scores were not significant predictors, and were thus dropped from the model. In the final model, higher T-scores of ADHD-inattentive were associated with higher SDA Error Scores ($p < .01$). Adolescent girls also made significantly more errors in the simulator ($p = .01$) and depressive symptoms were inversely associated with errors in the simulator ($p < .01$).

Initial self-reported BYNDS Total Score models indicated that gender, length of licensure, ADHD-Inattentive T-scores, ODD T-scores and depressive symptoms were not significant predictors, and were thus dropped from the model. In the final model, higher T-scores of ADHD hyperactive-impulsive and conduct disorder were significantly and positively associated with higher scores on the BYNDS total scores ($p = .02$ and $p < .01$, respectively).

Table 4 also presents the final post-hoc linear regression models to predict SDA Error Score and BYNDS Total Score. In the final post-hoc model for SDA Error Score, those who met recommendations for follow-up for ADHD-inattentive had significantly more errors in the simulator ($p < .01$); depressive symptoms were still inversely associated with errors in the simulator ($p = .02$); gender was not a significant predictor ($p = .16$). In the final post-hoc model for self-reported BYNDS Total Score, those who met recommendations for follow-up for ADHD hyperactive-impulsive and conduct disorder had higher scores of self-reported risky driving ($p = .02$ and $p < .01$, respectively).

None of the predictors in the linear regression models for parent-reported symptoms (T-scores or post-hoc of follow-up recommendations) predicting SDA Error Score or BYNDS Total Score were statistically significant.

Discussion

In this sample of newly licensed adolescents, increased self-reported symptoms of inattention were uniquely associated with more performance errors in the driving simulator. This was applicable not only when examining adolescent Inattention T-scores, but also when analyzing post-hoc data related to whether adolescents met criteria for follow-up recommendations. Attention to the roadway is a critical component of safe driving behavior. Consistent with other studies, our results highlight the role of inattention in risky driving. Kingery and colleagues (2015) found that adolescents with ADHD demonstrated increased inattention in simulated distraction tasks, such as texting or phone calls, with a larger percent of their time with their eyes diverted from the roadway. Additionally, in a sample of adolescent girls, inattention was associated with their young adult driving crashes relationships (Cardoos, Loya, & Hinshaw, 2013). Our findings demonstrate that symptom severity of inattention—and not just ADHD diagnostic status—is associated with risky driving.

The analysis also highlighted that increased hyperactivity/impulsivity and conduct disorder were uniquely associated with increased self-reported risky driving. Exposure and engagement in risky driving behaviors on the road are in line with the characteristics of hyperactivity-impulsivity and conduct disorder (Brown et al., 2016; Dekkers, Popma, van Rentergem, Bexkens, & Huizenga, 2016; Turel & Bechara, 2016). With hyperactivity-impulsivity, rule violations may stem from inherent problems with self-control. With conduct disorder, rule violations may be an attempt to take advantage of a situation or express hostility. These relationships are particularly concerning given the nature of distracted driving with adolescents. Research implies that risky driving, such as texting while driving, is an impulsive choice made by young adult drivers (Hayashi, Russo, & Wirth, 2015). Likewise, in 18–19-year-old college students, impulsivity was associated with multiple types of risky driving (e.g., self-reported cell phone use while driving and traffic citations) (Pearson, Murphy, & Doane, 2013). Previous research also indicates that reports of conduct disorder behavior before age 15 is associated with risky driving behaviors in late adolescence (McDonald et al., 2014) and adulthood (Wickens et al., 2015). Our analysis suggests that conduct disorder problems and hyperactivity-impulsivity symptoms are important considerations for the development of safe driving practices among adolescents.

Overall, parent-reported symptoms of ADHD, conduct disorder, and ODD were not associated with adolescent report of their mental health measures or the adolescent reports of risky driving. Parents are a key role in the learning to drive process (Curry, Peek-Asa, Hamann, & Mirman, 2015; Mirman et al., 2014) and are important individuals in supporting positive mental health outcomes in adolescents. However, our results indicate that the adolescent report of mental health symptoms may be a better indicator of their risky driving. There was also no relationship between the adolescent simulated performance errors and self-report risky driving. These two measures may be independent in measuring different aspects of risk. Driving simulation can expose adolescents to high-risk driving scenarios in a safe manner. Self-report of driving behaviors can provide important information on their behaviors on the road. More research is needed to further understand how multiple data sources in the context of mental health and driving behaviors may inform crash risk.

There were some unanticipated results in our analyses. Increased symptoms of depression were associated with fewer performance errors in the simulator. The differences in our analysis may be due to a number of factors. This analysis was cross-sectional, which cannot account for temporal factors in relationships. Most of the adolescents were within a normal range for depressive symptoms that did not meet clinical levels; it may be the case that only when clinical levels are reached is performance negatively affected. Additionally, the sample of adolescents were licensed within 90 days of licensure and the role of depressive symptoms in newly licensed drivers may be different from that in young adult drivers. More research is needed to elucidate relationships between depression, driving behaviors, and crash risk. In addition, in the regression model, adolescent girls had more performance errors in the driving simulator. This was surprising given that adolescent boys are at a higher crash risk on the road (Centers for Disease Control and Prevention, 2017a). A better understanding of gender, skill as measured in a simulator, and risk in on-road driving is warranted.

As outlined in Sommers and Ribak's model, the compounded effects of adolescent mental health symptoms with driving inexperience presents a high-risk scenario for driving behaviors. However, interventions for adolescent driving behavior lack a focus on risk factors like mental health problems. A systematic review by Classen and Monahan (2013) pointed to the low level of evidence supporting current interventions to improve driving performance for teen drivers with ADHD. Interventions targeting adolescent drivers with ADHD have not proven to affect observable driving behaviors, though parenting behaviors may be affected (Fabiano et al., 2016). Broader preventative strategies to prevent risky driving in adolescents might include health screening prior to licensure, school-based programs to improve organization skills, and additional components of training programs that address mental health risks such as depression and ADHD (Chan, Fogler, & Hammerness, 2016; Evans et al., 2016). Nurses are well positioned in a variety of clinical settings to counsel adolescents, addressing the multidimensional nature of risks associated with mental health and risk behaviors.

Limitations

There are several limitations to this study. There are a number of precursors and moderators from Sommers and Ribak's (2008) model not measured in this study, but the unique data on mental health, self-report, and simulated driving adds important information to the literature. Given the cross-sectional nature of this study, prospective research is needed to determine the temporal relationship of adolescent mental health and risky driving changes and their effects on crash risk. We sought to recruit a convenience sample of adolescents from the community and, thus, we were not recruiting participants based on diagnosis of mental health disorders. However, the distribution of symptoms of ADHD and other disorders in this sample was reflective of normative sample of adolescents, with low percentages meeting elevated symptom counts for diagnostic status and self-report of a past or present ADHD diagnosis aligning with national estimates (National Institute of Mental Health, 2016). Although diagnostic criteria are critical for treatment and management of mental health disorders—relative to risky behavior engagement—self-reported symptom levels help to explicate the influence of mental health risk on driving behaviors. Given that the relative proportion of youth with mental health disorders in this sample was relatively small, this

limited an ability to examine the effect of clinical levels of mental health symptoms on risky driving. Although there were broad recruitment efforts through emails, letters, and presentations, no one in the sample reported being Hispanic; the sample was predominately White. Additionally, the analysis involved participants enrolled in the larger randomized controlled trial. Results should be interpreted in the context that this is not a representative sample.

Conclusion

Adolescent drivers are at a high risk for MVCs in the first year of licensure. While adolescent crash risk decreases with increased driving experience, some young drivers remain at risk even as they accumulate experience. This study used both driving simulation and self-reported driving behaviors to further our understanding of how risky driving behavior is associated with mental health symptoms. Our results indicate that increased self-reported symptoms of hyperactivity-impulsivity and conduct disorder are independently associated with increased self-reported risky driving behaviors, and inattention was uniquely associated with poorer performance in the driving simulator. There is much to learn about the relationship between driving performance and mental health conditions as adolescents are in the early stage of independent driving.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1

Participant Characteristics

Characteristic	<i>M</i>	(<i>SD</i>)
Age (years)	17.0	(0.35)
Licensure length (days)	50.8	(23.68)
Risky driving (BYNDS)		
Transient Rule Violation Scale	27.9	(7.52)
Fixed Rule Violation Scale	11.5	(2.80)
Misjudgment Scale	14.2	(3.56)
Risky exposure	24.8	(6.64)
Driver Mood Scale	4.4	(1.85)
BYNDS Total	82.8	(17.80)
SDA (errors)	23.9	(7.98)
	<i>n</i>	(%)
Gender (female)	40	(66.70)
Race		
Asian	1	(1.67)
Black/African American	9	(15.00)
White	47	(78.33)
More than 1	2	(3.33)
Other	1	(1.67)
ADHD history		
Yes	5	(8.30)
No	53	(88.30)
Don't know	2	(3.30)
ADHD present diagnosis		
Yes	5	(75.00)
No	53	(88.30)
Don't know	2	(3.30)
ADHD medication/past		
Yes	6	(10.00)
No	53	(88.30)
Don't know	1	(1.70)
ADHD medication/present		
Yes	3	(5.00)
No	57	(95.00)
Don't know	0	(0.00)
Connors-3 respondent		
Mother	45	(75.00)
Father	8	(13.30)
Grandmother	1	(1.70)

Note. $N = 60$. ADHD = Attention deficit hyperactivity disorder; BYNDS = Behavior of Young Novice Driver Survey; SDA = Simulated Driving Assessment.

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TABLE 2

Mental Health Symptoms: Self- and Parent-Report

Symptom	Respondent	M	(SD)	Min	Max
Depressive (CESD)	Self	9.2	(6.99)	0	35
	Parent	NA	NA	NA	NA
DSM5 scales (T-score)					
Inattentive	Self	50.1	(8.95)	40	76
	Parent	48.2	(8.01)	40	72
Hyperactive/impulsive	Self	49.1	(7.99)	40	73
	Parent	49	(8.14)	42	76
Conduct disorder	Self	44.6	(4.80)	40	57
	Parent	47.2	(5.29)	44	70
Oppositional defiant disorder	Self	45.6	(6.84)	40	78
	Parent	48.81	(7.58)	41	75
Symptom counts					
Inattentive	Self	2.2	(1.94)	0	8
	Parent	0.5	(1.02)	0	5
Hyperactive/impulsive	Self	1.5	(1.28)	0	6
	Parent	0.8	(1.05)	0	4
Conduct disorder	Self	0.6	(0.85)	0	3
	Parent	0.4	(0.90)	0	4
Oppositional defiant disorder	Self	0.9	(1.10)	0	6
	Parent	0.4	(0.96)	0	4
Symptom criteria probably met		<i>n</i>	(%)		
Inattentive ^a	Self	6	(10.0)		
	Parent	1	(1.9)		
Hyperactive/impulsive ^a	Self	1	(1.7)		
	Parent	0	(0.0)		
ADHD combined ^b	Self	1	(1.7)		
	Parent	0	(0.0)		

Symptom	Respondent	M	(SD)	Min	Max
Conduct disorder ^c	Self	3	(5.0)		
	Parent	3	(5.6)		
Oppositional defiant disorder ^d	Self	1	(1.7)		
	Parent	2	(3.7)		
Follow-up indicated					
Inattentive	Self	10	(16.7)		
	Parent	6	(11.1)		
Hyperactive/impulsive	Self	8	(13.3)		
	Parent	6	(11.1)		
Conduct disorder	Self	3	(5.0)		
	Parent	4	(7.4)		
Oppositional defiant disorder	Self	2	(3.3)		
	Parent	6	(11.1)		

Note. *N* = 60 (adolescent self-report; except, one participant did not complete the CES-D; their data are included in all analysis except that which includes the CES-D); *N* = 54 (parent-report; respondents included mothers, fathers, or grandmother). CES-D = Center for Epidemiologic Studies–Depression; DSM5 =; NA = not applicable; *SD* = standard deviation.

^aSymptom count 6 for 16 year olds; 5 for 17 year olds.

^bMet criteria for both Inattentive and Hyperactive/impulsive.

^cSymptom count 3.

^dSymptom count 4.

TABLE 3
Correlations Among Self- and Parent-Reported Symptoms, Simulated Driving Behaviors, and Self-Reported Risky Driving

Respondent/variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Self																			
1. DS	1.00																		
2. INATT count	.45*	1.00																	
3. INATT T-score	.51*	.90*	1.00																
4. H/I count	.28*	.44*	.51*	1.00															
5. H/I T-score	.30*	.52*	.60*	.85*	1.00														
6. CD count	.22	.42*	.45*	.19	.39*	1.00													
7. CDT-score	.19	.48*	.46*	.29*	.47*	.83*	1.00												
8. ODD count	.22	.40*	.39*	.27*	.37*	.39*	.33*	1.00											
9. ODD T-score	.23	.53*	.54*	.33*	.50*	.53*	.49*	.78*	1.00										
10. SDA Errors	-.10	.25	.28*	.19	.23	.13	.10	.20	.19	1.00									
11. BYNDS	.32*	.32*	.33*	.29*	.47*	.53*	.52*	.26*	.34*	.24	1.00								
Parent																			
12. INATT count	.36*	.33*	.33*	.04	.02	.29*	.26	.37*	.37*	-.14	.16	1.00							
13. INATT score	.27	.37*	.42*	.05	.07	.40*	.32	.36*	.43*	-.06	.14	.83*	1.00						
14. H/I count	.13	.17	.19	.04	.05	.14	.11	-.07	-.02	.11	.11	.30*	.47*	1.00					
15. H/I score	.15	.15	.17	.05	.09	.16	.22	-.02	-.02	-.10	.20	.42*	.58*	.79*	1.00				
16. CD count	.23	.24	.25	.04	.11	.03	.13	.08	.02	-.08	.24	.32*	.43*	.29*	.54*	1.00			
17. CD score	.35*	.24	.24	-.06	-.02	.03	.13	.01	-.04	-.03	.23	.46*	.48*	.30*	.48*	.88*	1.00		
18. ODD count	.39*	.33*	.29*	-.05	-.02	.16	.07	.25	.27*	-.15	.09	.53*	.56*	.23	.34*	.63*	.68*	1.00	
19. ODD score	.34*	.21	.20	-.04	.02	.22	.11	.21	.23	-.13	.20	.51*	.62*	.27*	.46*	.63*	.67*	.88*	1.00

Note. Sample sizes vary: $n = 58$ (self-report with simulated driving performance, except CES-D [$n = 57$]); $n = 60$ (self-report with BYNDS); $n = 52$ (parent report with simulated driving performance); $n = 54$ (with BYNDS). Count=symptom counts; BYNDS = Behavior of Young Novice Driver Survey (self-reported risky driving); CD = conduct disorder; DS = depressive symptoms; H/I = hyperactive/impulsive; INATT = inattentive; ODD = oppositional defiant; SDA = Simulated Driving Performance (simulated driving).

*
p < .05.

TABLE 4

Regression Models

Analysis/outcome	Predictor	n	b*	b	(SE)	95% CI	p	R ²	aR ²
Primary									
SDA	Constant	57		-0.99	(6.74)	[-14.50, 12.53]	.88	.24	.20
	Gender		0.34	5.71	(2.20)	[1.30, 10.12]	.01		
	Inattentive (T-score)		0.56	0.53	(.14)	[0.25, 0.81]	<.01		
	Depressive symptoms		-0.47	-0.54	(.17)	[-0.88, -0.19]	<.01		
BYNDS	Constant	59		-15.74	(18.97)	[-53.73, 22.25]		.34	.32
	H/I (T-score)		0.29	0.64	(.27)	[0.09, 1.19]	.02		
	Conduct disorder (T-score)		0.40	1.51	(.47)	[0.58, 2.45]	<.01		
Post hoc									
SDA	Constant	57		24.13	(2.01)	[20.10, 28.15]	<.01	.18	.14
	Gender		0.18	3.11	(2.16)	[-1.23, 7.44]	.16		
	Inattentive/met follow-up		0.43	9.35	(3.10)	[3.14, 15.56]	<.01		
	Depressive symptoms		-0.36	-0.41	(.17)	[-0.74, -0.07]	.02		
BYNDS	Constant	59		79.27	(2.28)	[74.70, 83.83]		.23	.20
	H/I met follow-up		0.29	15.02	(6.16)	[2.69, 27.35]	.02		
	Conduct disorder/met follow-up		0.34	27.73	(9.59)	[8.52, 46.94]	<.01		

Note. aR² = adjusted R²; BYNDS = Behavior of Young Novice Driver Survey (self-reported risky driving); CI = confidence interval; H/I = hyperactivity/impulsivity; SDA = Simulated Driving Assessment (simulated driving); SE = standard error.