Journal of Transport & Health 13 (2019) 33–40

Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

The association of childhood symptoms of conduct disorder and collision risk in adulthood

Christine M. Wickens[a,b,*], Robert E. Mann[a,b], Anca R. Ialomiteanu[a], Evelyn Vingilis[c], Jane Seeley[c], Patricia Erickson[d,e], Nathan J. Kolla[e,f,g,h,i]

[a] Institute for Mental Health Policy Research, Centre for Addiction and Mental Health, Toronto, Ontario, Canada
[b] Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada
[c] Schulich School of Medicine and Dentistry, The University of Western Ontario, London, Ontario, Canada
[d] Department of Sociology, University of Toronto, Toronto, Ontario, Canada
[e] Centre for Criminology and Sociolegal Studies, University of Toronto, Toronto, Ontario, Canada
[f] Department of Psychiatry, University of Toronto, Toronto, Ontario, Canada
[g] Graduate Department of Psychological Clinical Science, University of Toronto, Toronto, Ontario, Canada
[h] Campbell Family Mental Health Research Institute, Centre for Addiction and Mental Health, Toronto, Ontario, Canada
[i] Waypoint Centre for Mental Health Care, Penetanguishene, Ontario, Canada

A B S T R A C T

Introduction: Despite limited research, existing evidence suggests that there is an association between conduct disorder (CD) and various risky driver behaviours, such as driver aggression and driving after drinking. The current study sought to estimate the association between probable CD during childhood and past-year collision risk.

Methods: Data were based on interviews with 5297 respondents who reported having driven in the past year, derived from the 2011–2013 cycles of the CAMH *Monitor*, a cross-sectional survey of adults in Ontario, Canada aged 18 years and older. A binary logistic regression was conducted of self-reported collision involvement in the previous 12 months, assessing demographic characteristics, driving exposure, demonstrated symptoms of ADHD, mild driver aggression, driving after drinking, and childhood (before age 15 years) symptoms of CD.

Results: The unadjusted odds ratio of past-year collision involvement for those reporting childhood symptoms of CD was 1.76 (*95% CI* = 1.10, 2.82). Adjusting for potential covariates, self-reporting childhood symptoms of CD was significantly associated with a 77% increase in the odds of a crash (*OR* = 1.77; *95% CI* = 1.01, 3.11).

Conclusion: These findings add to a growing literature and suggest that treatment for CD should include a focus on driver safety.

1. Introduction

Motor vehicle collisions (MVCs) are the leading cause of death among those aged 15–29 years and are the ninth leading cause of death across all age groups (World Health Organization (WHO), 2015). Safety and injury prevention researchers have explored a broad spectrum of factors thought to contribute to collision risk, seeking to identify potential interventions and countermeasures to reduce the prevalence of and toll taken by roadway crashes. The mental health of vehicle drivers is one such contributory factor.

Although empirical study has been limited, there is evidence to suggest an association between mental illness and impaired driver performance (Kujansuu et al., 2017; Wickens et al., 2014). Studies of those identified as having mental illness have found increased prevalence of driving violations, and perhaps less consistently, increased prevalence of collisions relative to control samples (Buttiglieri et al., 1969; Waller, 1965). Individuals diagnosed with mental illness have also demonstrated impaired performance on

* Corresponding author. Institute for Mental Health Policy Research, Centre for Addiction and Mental Health, 33 Russell Street, Toronto, Ontario M5S 2S1, Canada.
E-mail address: Christine.Wickens@camh.ca (C.M. Wickens).

https://doi.org/10.1016/j.jth.2019.03.007
Received 9 November 2018; Received in revised form 23 January 2019; Accepted 6 March 2019
Available online 18 March 2019
2214-1405/

simulators used to assess driver fitness (De las Cuevas et al., 2010; De las Cuevas and Sanz, 2008; de las Cuevas Castresana and Sanz Álvarez, 2009). However, assessing the potential impact of mental illness on driver performance without specifying or contrasting individual diagnoses provides only limited insight. Each disorder presents its own unique collection of potential symptoms, which may differentially affect driver performance. For this reason, and because the privilege to drive has such a profound impact on quality of life, it is important to assess independently the potential impact of each disorder on driving.

One diagnosis which has been linked to several negative driving behaviours and outcomes is conduct disorder (CD), which typically emerges early in childhood or adolescence (Moffitt, 1993). This disorder is characterized by antisocial behaviour that manifests in the violation of individuals' basic rights and societal norms or rules (American Psychiatric Association (APA), 2013). These behaviours may include aggressive conduct toward others, destruction of property, deceit, and theft. The estimated prevalence of CD has ranged from 2% to more than 10%, with median estimates set at 4% (APA, 2013; Costello et al., 2005). In the long-term, CD has been associated with: socioeconomic impacts such as lower educational attainment (Fergusson and Horwood, 1998; Fergusson et al., 2005), unemployment, and financial difficulty (Colman et al., 2009; Fergusson and Horwood, 1998; Fergusson et al., 2005); high-risk behaviour such as criminal activity (Fergusson et al., 2005) and sexual risk-taking (Bardone et al., 1998; Fergusson et al., 2005); relationship issues including separation/divorce (Colman et al., 2009; Olino et al., 2010); and reduced life satisfaction, likely affected by the demonstrated reduction in levels of peer support, coping skill, and overall global functioning (Colman et al., 2009; Olino et al., 2010).

In the roadway environment, CD has been associated with risky driving behaviours. Individuals with a history or current diagnosis of CD are more likely to receive traffic citations and to self-report roadway offences such as driving without a licence, not wearing a seatbelt, and offences related to graduated driver licensing (Barkley et al., 1993; Nada-Raja et al., 1997; Woodward et al., 2000). Conduct problems have been found to predict retaliatory aggression, thrill-seeking, and risk-taking on the roads (McDonald et al., 2014, 2018), and diagnoses of CD are more prevalent among identified high aggression drivers (Malta et al., 2005). A history of CD is significantly related to increased alcohol consumption and greater risk for the development of substance use disorders (APA, 2013; Barry et al., 1997). It should not be surprising, therefore, that individuals with CD are more likely to engage in or be arrested for alcohol- and drug-impaired driving (Karjalainen et al., 2013; McDonald et al., 2014; Thompson et al., 2007; Woodward et al., 2000). Likewise, the prevalence of lifetime CD is higher among repeat drink-drive offenders relative to the general population (LaPlante et al., 2008; Shaffer et al., 2007) and prevalence rates of CD rise with increasing numbers of drink-driving arrests (McCutcheon, 2009).

Given this association between CD and risky driving behaviours, it is important that we also understand the relationship between CD and the risk of MVCs, which are associated with property damage, injuries, and/or fatalities. Few studies have assessed this association directly. One primary exception is a population-based case-control study that used a universal health care database to compare male youth aged 16–19 years who had been hospitalized for either road trauma (cases) or appendicitis (controls) (Redelmeier et al., 2010). Results indicated that a history of disruptive behaviour disorders (i.e., CD or oppositional defiant disorder) was more prevalent among the road trauma cases than the appendicitis controls, and was associated with a 37% increase in the relative risk of serious road trauma.

A diagnosis of CD is highly comorbid with that of attention deficit hyperactivity disorder (ADHD) and is seen in as many as one quarter of children or adolescents with ADHD (Jensen et al., 1997; Willcutt et al., 2012). Moreover, although the literature has not been entirely consistent (e.g., Ferro and Leatherdale, in press; Koisaari et al., 2015; Owens et al., 2017), ADHD has been linked to risky and aggressive driving behaviour, violations, and collision involvement (Aduen et al., 2018; Barkley et al., 1993; Curry et al., 2017; Fuermaier et al., 2017; Thompson et al., 2007; Vaa, 2014; Valero et al., 2018). With this in mind, it is important that studies assessing any association between disruptive behaviour disorders and driver safety, including the current study, control for ADHD.

We have previously assessed the relationship between symptoms of CD in childhood/adolescence and driving-related outcomes in adulthood based on a population-level survey of adults in Ontario, Canada. These analyses have demonstrated that childhood symptoms of CD increase the odds of past-year driver aggression (Wickens et al., 2015) and driving after drinking (Wickens et al., 2017), even after adjusting for demographic characteristics, probable ADHD, and other potential covariates of risky driving behaviour. The purpose of the current study was to extend our analysis of this dataset to consider the association between childhood symptoms of CD and past-year involvement in a MVC.

2. Methods and materials

2.1. Sample

The Centre for Addiction and Mental Health (CAMH) *Monitor* is an ongoing cross-sectional telephone survey of adults aged 18 years and older conducted in Ontario, Canada. Questions to measure childhood symptoms of CD and to screen for current ADHD were included in the 2011–2013 cycles of the survey. Random-digit-dialing (RDD) methods via Computer Assisted Telephone Interviewing are used to administer the CAMH *Monitor*, allowing access to recently listed and unlisted telephone numbers and to individuals with cellular telephones. Each year, the sampling procedure includes four independent quarterly samples, each with approximately 750 completions. The response rate for this subset of survey cycles ranged from 48% to 51%. A sample of 5297 respondents who reported having driven a vehicle in the past year were included in the analysis. Data weights were introduced to adjust for regional representation and varying selection probabilities. An adjustment based on the most recent census figures was also conducted after stratification to correct the age by sex distribution. The final weighted sample is considered representative of Ontario's non-institutionalized adult population (see Ialomiteanu and Adlaf (2014) for more sampling design details). The CAMH *Monitor* is approved

by the CAMH research ethics committee each year.

2.2. Variables

Demographic variables included age (18–34 years, 35–54 years, 55+ years), sex (female, male), education (< high school, completed high school, some post-secondary, university degree), marital status (married or common law, previously married, never married), and region of residence (non-rural, rural based on postal code). Average distance driven per week (continuous variable) served as a control for differences in driving exposure.

Probable ADHD was assessed using the Adult ADHD Self-Report Scale-V1.1 (Kessler et al., 2005). This measure is a validated screening instrument that was developed during the revision of the WHO Composite Diagnostic Interview. Included in this screening measure are six of 18 items most predictive of an ADHD diagnosis as per the criteria listed in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; APA, 2000). Each item is rated on a 5-point Likert-type scale scored 0 to 4. Items are summed and a total score of 14 or more is considered indicative of ADHD (no, yes). It is important to distinguish between 'probable ADHD' assessed here, and cases of ADHD that would be identified by a more formal diagnostic process.

Given the already demonstrated relationship between CD and both driver aggression and driving after drinking using this dataset, these risky driver behaviours were included in the analyses to determine if any increase in the odds of a crash were above and beyond those accounted for by these specific behaviours. Mild driver aggression was measured by asking participants: ‘during the past 12 months, either as a driver or a passenger, how many times have you shouted, cursed, or made rude gestures at a driver or passenger in another vehicle?' Responses were converted to binary coding (no, yes to any of the listed aggressive driving behaviours). Driving after drinking was assessed by asking participants ‘During the past 12 months, have you driven a motor vehicle after having two or more drinks in the previous hour?’ (no, yes).

Probable CD before age 15 years was measured with five items originally developed as part of the Mini-International Neuropsychiatric Interview (MINI; Sheehan et al., 1998) and based on the DSM-IV diagnostic criteria for CD (APA, 2000). The MINI is a well-validated, short, structured psychiatric interview that can be used for epidemiological research (Karam et al., 2015; Otsubo et al., 2005; Sheehan et al., 1998; Vitola et al., 2012). Respondents were asked: 'Before you were 15 years old, did you: (1) repeatedly skip school or run away from home overnight? (2) Repeatedly lie, cheat, or steal? (3) Start fights or bully, threaten, or intimidate others? (4) Deliberately destroy things or start fires? (5) Deliberately hurt animals or people?' (no, yes). Participants who responded affirmatively to at least two items were classified as likely having had CD (i.e., probable CD) as a child (no, yes).

Past-year involvement in a MVC was the key outcome variable. Respondents were asked: 'During the past 12 months, how many times, if at all, were you involved in an accident or collision involving any kind of damage or injury to you or another person or vehicle while you were driving?' Responses were converted to binary coding, indicating any past-year collision involvement while driving (no, yes).

2.3. Analyses

All analyses conducted using Taylor Series Linearization found in STATA13 software were adjusted for the regionally stratified sampling design. Item-missing data, including refusals and 'don't know' responses, were excluded listwise. Weighted sample size was used when reporting percentages in order that these estimates could be considered representative of the population surveyed. Design-based Rao-Scott *F*-test analyses were used to assess the prevalence of past-year collision involvement by demographic factors and all risk factors including childhood symptoms of CD. Binary logistic regression analysis was used to calculate the unadjusted odds of past-year collision involvement for those reporting childhood symptoms of CD as well as those odds adjusted for demographic characteristics, driving exposure, probable ADHD, mild driver aggression, and driving after drinking.

3. Results

Probable CD before age 15 years was reported by 7.4% of the current sample. Involvement in a MVC while driving in the past year was reported by 6.4% of the sample. Table 1 presents self-reported past-year collision involvement by demographic characteristics, driving exposure, probable ADHD, mild driver aggression, driving after drinking, and probable CD before age 15 years. Based on the univariate analyses, collision involvement was more prevalent among those aged 18–34 years of age, those who were never married, those living in a non-rural region of the province, those who reported a greater number of kilometres driven weekly, those with probable ADHD, and those reporting symptoms of CD before age 15 years. There were also findings approaching significance suggesting that collision involvement was more prevalent among those with higher education ($p = 0.07$).

Binary logistic regression analysis (svy:logit) (Lee and Forhofer, 2006) of the association of probable CD before age 15 years with past-year collision involvement was conducted. The unadjusted odds ratio of 1.76 (*95% CI* = 1.10, 2.82; $p = 0.02$) indicated that drivers who reported childhood symptoms of conduct disorder were at increased odds of having experienced a MVC in the past 12 months. Multivariate analysis was then conducted, adjusting for demographic characteristics, driving exposure, probable ADHD, mild driver aggression, and driving after drinking. The *F*-adjusted mean residual goodness-of-fit test was not significant, indicating good fit of the model (presented in Table 2). Even after adjusting for demographic characteristics and other relevant risk factors, drivers with probable CD before age 15 years faced increased odds of being involved in a MVC in the past year (*OR* = 1.77; *95% CI* = 1.01, 3.11; $p = 0.048$).

The multivariate analysis also revealed that drivers aged 55+ years had lower odds of having experienced a collision relative to

Table 1
Self-reported past-year collision involvement by demographic variables, driving exposure, probable ADHD, mild driver aggression, driving after drinking, and probable CD before age 15 years.

	n	Collision Involvement[a]		
		n Yes	% Yes[b]	95% CIs[c]
Total[d]	5297	296	6.35	5.51, 7.31
Demographic variables:				
Sex				
Female	3024	173	6.19	5.12, 7.45
Male	2273	123	6.52	5.28, 8.04
Age			***	
18–34 years	647	54	8.46	6.27, 11.34
35–54 years	1968	134	7.41	6.06, 9.04
55+ years	2586	102	3.53	2.82, 4.40
Marital status			*	
Married/partner	3515	175	5.66	4.76, 6.71
Previously married	1058	62	6.30	4.42, 8.89
Never married	671	55	8.62	6.23, 11.80
Education			$p = 0.07$	
< high school	544	24	3.55	2.15, 5.80
Completed high school	1103	48	4.92	3.41, 7.04
Some post-secondary	1911	107	6.87	5.40, 8.69
University degree	1680	112	7.03	5.65, 8.72
Region of residence			*	
Non-rural	4058	241	6.79	5.81, 7.92
Rural	1239	55	4.48	3.25, 6.14
Driving exposure:				
Km driven-typical week (100s)[e]			*	
Mean (SD) Driving after drinking[a] No	4435	–	2.91	2.76, 3.06
Driving after drinking[a] Yes	255	–	3.71	2.98, 4.45
Other risk factors:				
Probable ADHD			**	
No (score ≤ 13)	4932	260	5.91	5.08, 6.87
Yes (score > 13)	151	20	12.34	7.29, 20.14
Mild driver aggression				
No	3167	161	6.02	4.93, 7.33
Yes	2062	132	6.89	5.62, 8.42
Driving after drinking				
No	5012	281	6.25	5.40, 7.22
Yes	266	12	7.06	3.67, 13.17
Probable CD before age 15 years			*	
No (< 2 symptoms)	4893	263	6.01	5.16, 6.99
Yes (2+ symptoms)	346	30	10.12	6.75, 14.90

Design-based *F* statistical significance $*p \leq 0.05$; $**p < 0.01$; $***p < 0.001$.

[a] In the last 12 months.

[b] Percentages reported are based on weighted sample size.

[c] 95% confidence intervals.

[d] Respondents who report having driven a motor vehicle in the last 12 months.

[e] Driving distance was divided by 100 so that the adjusted odds ratio presented in Table 2 reflected the change in risk for each additional 100 km of weekly driving.

those aged 18–34 years and that greater driving exposure was associated with higher odds of a crash. Marital status, region of residence, and probable ADHD were not significant predictors of MVC involvement in the multivariate model.

4. Discussion

The prevalence of CD in the current sample was estimated to be 7.4%, falling within the expected range of 2%–10% as suggested by the DSM-5 (APA, 2013). Based on this estimated prevalence and the number of licensed drivers listed in the 2013 Ontario Road Safety Annual Report (ORSAR) (Ministry of Transportation, 2013), more than 700,000 drivers in Ontario are likely to have a history of CD symptoms. The prevalence of past-year collision involvement was 6.4% in the current sample. This value is higher than the prevalence of 3.3% suggested by the number of licensed drivers and the number of drivers involved in a collision reported in the 2011 through 2013 ORSARs (Ministry of Transportation, 2011, 2012, 2013). The lower collision rate estimate provided by the ORSARs likely results from their inclusion of all licensed drivers as opposed to only those individuals who report driving in the past year. The estimate provided by the CAMH *Monitor* also includes minor collisions not reported to authorities and thus missed by the ORSARs.

Univariate analyses identified younger age, never having been married, an urban region of residence, elevated driving exposure, probable ADHD, and childhood symptoms of CD as risk factors for past-year collision involvement. The multivariate analyses

Table 2
Logistic regression model of self-reported past-year collision involvement.

	Collision Involvement [a] (n = 4341)	
	OR [b,c]	95% CIs [d]
Demographic variables:		
Sex (ref. = female)	0.96	0.69, 1.35
Age (ref. = 18–34 years)	***	
35–54 years	0.91	0.55, 1.52
55 + years	0.44**	0.25, 0.76
Marital status (ref. = married)		
Previously married	1.22	0.71, 2.09
Never married	1.14	0.66, 1.96
Education (ref. = < high school)		
Completed high school	1.26	0.55, 2.86
Some post-secondary	1.48	0.70, 3.12
University degree	1.94	0.91, 4.16
Region of residence (ref. = non-rural)	0.80	0.53, 1.22
Driving exposure:		
Km driven-typical week (100s)[e]	1.03*	1.01, 1.06
Other risk factors:		
Probable ADHD (ref. = no)	1.02	0.46, 2.27
Mild driver aggression (ref. = no)	0.89	0.62, 1.27
Driving after drinking (ref. = no)	1.10	0.52, 2.32
Probable CD before age 15 years (ref. = no)	1.77*	1.01, 3.11
Constant	0.05	0.02, .0.12
F-adjusted mean residual goodness-of-fit test	$F(9,4315) = 1.02$, $p = 0.42$	

Design-based F statistical significance * $p \leq 0.05$; ** $p < 0.01$; *** $p < 0.001$.
Ref. = reference category.
[a] In the last 12 months.
[b] Adjusted odds ratio.
[c] Based on weighted sample size.
[d] 95% confidence intervals.

revealed that probable CD before age 15 years was associated with a significant increase in the odds of a crash over the previous year. Even after adjusting for demographic characteristics and other crash-related risk factors, drivers with childhood symptoms of CD had a 77% increase in their odds of having been involved in a collision.

These results provide further evidence that neuropsychiatric and mental health is relevant to road safety (Ilie et al., 2015; Wickens et al., 2014). Previous analyses of the CAMH *Monitor* have identified an association of childhood symptoms of CD with both mild driver aggression (Wickens et al., 2015) and driving after drinking (Wickens et al., 2017). Although the current dataset did not find a relationship between driver aggression or driving after drinking and collision risk, numerous other studies have identified this association (Borkenstein et al., 1974; Mann et al., 2010; Wells-Parker et al., 2002; Wickens et al., 2016). What else might account for the increase in collision involvement among individuals with a childhood history of CD symptoms? Risk-taking on the roads or a general risky driving style including, for example, a higher preferred rate of speed, sudden lane changes without signalling, or using a cellular phone while driving could also account for the increased odds of collision involvement. A risky driving style is strongly related to personality traits such as sensation-seeking or impulsivity (Jonah, 1997; Pearson et al., 2013). Krueger et al. (1996) identified significant differences in the personality profile of individuals with CD. Among their findings, individuals with CD scored lower on social closeness, control, and harm avoidance and higher on stress reaction, alienation, and aggression than healthy controls. Furthermore, the relationship between CD and many negative outcomes in adulthood, including threats to driver safety, is partially or fully mediated by adult antisocial behaviour (Olino et al., 2010). One of the diagnostic criteria of antisocial personality disorder (APD) is evidence of CD with onset before age 15 years. The prevalence of APD is estimated to be between 0.2% and 3.3% (APA, 2013), suggesting that many childhood cases of CD progress into antisocial behaviour in adulthood. Thus, although the current study's focus was on past symptoms of CD, it is likely that current symptomatology consistent with APD is also likely to be related to risky driver behaviour and collision risk, a premise which has received support in the existing academic literature (Galovski et al., 2002; Woodall et al., 2007).

Although a statistically significant association between probable ADHD and collision involvement was identified in the univariate analyses, the relationship was not significant when probable ADHD was entered simultaneously with childhood symptoms of CD and the other covariates in the multivariate analyses. While numerous studies have cited increased collision risk associated with ADHD status (Barkley et al., 1993; Thompson et al., 2007; Vaa, 2014), more recent literature has noted a decidedly weaker association as more potential confounders are controlled (Thompson et al., 2007; Vaa, 2014; Vingilis et al., 2014). It has been suggested that CD and associated disruptive behaviours may mediate the demonstrated relationship between ADHD and negative driving outcomes (Olazagasti et al., 2013; Vaa, 2014). Future research directly examining this potential mediational relationship is warranted. If the risk of negative driving outcomes for individuals with ADHD is only increased among those with comorbid CD or APD, then intervention efforts can be targeted specifically for the most vulnerable drivers.

4.1. Limitations

It is important to acknowledge some limitations of this research. First, the data were self-reported and may be subject to certain biases. Respondents may have been inaccurate in their recall of childhood behaviours, particularly older participants who were reflecting over a longer time span. Respondents may also have underreported less socially desirable behaviours such as driver aggression or driving after drinking. The data are also correlational; thus, no causal inferences can be drawn. The measure of probable CD was a screening tool as opposed to a diagnostic measure, and cannot be used to differentiate specifiers of the diagnosis (e.g., characterized by limited prosocial emotions, age of onset). These specifiers or the severity of symptoms may play an important role in determining how CD impacts roadway safety. Finally, there was the possibility of non-response bias; it cannot be determined if eligible individuals who declined to participate would have responded to the survey in the same way as those who participated.

4.2. Implications

Recognizing that individuals with a history of CD symptoms may be at greater risk of a motor vehicle collision (Begg et al., 1999; Redelmeier et al., 2010), it is important to develop interventions designed for this more vulnerable group of drivers. Previous research suggests that individuals with past or present symptoms of CD are more likely to engage in driver aggression (Malta et al., 2005; McDonald et al., 2014; Wickens et al., 2015), to drive after use of alcohol or drugs (Karjalainen et al., 2013; LaPlante et al., 2008; Malta et al., 2005; McCutcheon et al., 2009; Shaffer et al., 2007; Thompson et al., 2007; Wickens et al., 2018; Woodward et al., 2000), and to commit and be cited for driving violations (Barkley et al., 1993; Nada-Raja et al., 1997; Woodward et al., 2000). Interventions for CD can include several different types of therapy which can be delivered in multiple settings including residential and hospital treatment or in home-, school-, and community-based programs (Kazdin, 1993). Incorporating a driver safety component into existing interventions for CD that could be delivered across diverse treatment settings could be an effective means of reducing injuries and fatalities among this population.

Parents of driving-aged adolescents who present with symptoms of CD may need to be more stringent in their training and supervision of their young drivers, particularly those who had an early onset of CD symptoms (before age 10 years). Symptoms for those with early-onset CD are more likely to persist into adulthood, thereby increasing the risk of antisocial and criminal behaviour and substance-related disorders (APA, 2013). While parents are encouraged to provide significant supervised practice time behind the wheel, to restrict their children's independent driving to lower-risk situations (e.g., daytime driving, no peer passengers), and to monitor their children's independent driving, perhaps with technologies that record speed, rapid acceleration/deceleration, and location (Simons-Morton and Ouimet, 2006), these recommendations may be particularly relevant for parents of children with a history of CD.

Remedial programming has been developed for drivers convicted of impaired driving (e.g., Flam-Zalcman et al., 2013; Stoduto et al., 2014; Wickens et al., 2018), and cognitive-behaviour therapy programs have emerged for those identified as angry or aggressive drivers (Galovski and Blanchard, 2002; Strom et al., 2013). Pre-screening participants in these programs for past or present symptoms of CD could help to identify those at greater risk to recidivate or to engage in other forms of risky driving behaviour (Malta et al., 2005; McCutcheon et al., 2009; Shaffer et al., 2007; Wickens et al., 2015). Pre-screening could allow for differential assignment to a version of the program that includes specialized curriculum targeting drivers with a history of CD symptoms. These drivers may not be aware of these patterns of behaviour, and specialized curriculum could provide these drivers with insights about their driving styles, triggers for poor choices behind the wheel, and strategies to reduce risky roadway behaviours. Specialized curriculum could also facilitate formal psychiatric assessment and possible diagnosis outside the remedial program, which may facilitate access to generalized treatment interventions beyond the driving context.

5. Conclusion

Based on data from a general population survey of adults in Ontario, Canada, symptoms of CD before age 15 years were associated with significantly increased odds of collision involvement in the past year. This finding is consistent with previous research that has identified CD as a risk factor for driver aggression, impaired driving, roadway violations, and traffic citations. These results highlight the need to consider neuropsychiatric and mental health in road safety. Further research is needed to develop theoretical models that account for the complexity of comorbid disorders and mediational relationships.

Acknowledgments

This research was funded through a grant (MOP102537) from the Canadian Institutes of Health Research (CIHR) and was also supported in part by funding from AUTO21, a member of the Networks of Centres of Excellence (NCE) program that is managed and sponsored by the Social Sciences and Humanities Research Council (SSHRC), the Natural Sciences and Engineering Research Council (NSERC), and the CIHR, in partnership with Industry Canada.

References

Aduen, P.A., Kofler, M.J., Sarver, D.E., Wells, E.L., Soto, E.F., Cox, D.J., 2018. ADHD, depression, and motor vehicle crashes: a prospective cohort study of continuously-monitored, real-world driving. J. Psychiatr. Res. 101, 42–49.

American Psychiatric Association, 2000. Diagnostic and Statistical Manual of Mental Disorders, fourth ed. American Psychiatric Association, Washington, DC.
American Psychiatric Association, 2013. Diagnostic and Statistical Manual of Mental Disorders, fifth ed. American Psychiatric Association, Arlington, VA. dsm.psychiatryonline.org, Accessed date: 1 June 2013.
Bardone, A., Moffitt, T., Caspi, A., Dickson, N., Stanton, W., Silva, P., 1998. Adult physical health outcomes of adolescent girls with conduct disorder, depression, and anxiety. J. Am. Acad. Child Adolesc. Psychiatry 37, 594–601.
Barkley, R.A., Guevremont, D.C., Anastopoulos, A.D., DuPaul, G.J., Shelton, T.L., 1993. Driving-related risks and outcomes of attention deficit hyperactivity disorder in adolescents and young adults: a 3- to 5-year follow-up survey. Pediatrics 92, 212–218.
Barry, K.L., Fleming, M.F., Manwell, L.B., Copeland, L.A., 1997. Conduct disorder and antisocial personality in adult primary care patients. J. Fam. Pract. 45, 151–158.
Begg, D.J., Langley, J.D., Williams, S.M., 1999. A longitudinal study of lifestyle factors as predictors of injuries and crashes among young adults. Accid. Anal. Prev. 31, 1–11. https://doi.org/10.1016/S0001-4575(98)00039-6.
Borkenstein, R.F., Crowther, R.F., Shumate, R.P., 1974. The role of the drinking driver in traffic accidents (the Grand Rapids study). Blutalkohol 11 (Suppl. l), 1–131.
Buttiglieri, M.W., Guennette, M., Thomson, M., 1969. Driving record of medical and surgical patients. Percept. Mot. Skills 29, 427–434.
Colman, I., Murray, J., Abbott, R.A., Maughan, B., Kuh, D., Croudace, T.J., Jones, P.B., 2009. Outcomes of conduct problems in adolescence: 40 year follow-up of national cohort. BMJ 338, a2981.
Costello, E.J., Egger, H., Angold, A., 2005. 10-year research update review: the epidemiology of child and adolescent psychiatric disorders, I: methods and public health burden. J. Am. Acad. Child Adolesc. Psychiatry 44, 972–986.
Curry, A.E., Metzger, K.B., Pfeiffer, M.R., Elliott, M.R., Winston, F.K., Power, T.J., 2017. Motor vehicle crash risk among adolescents and young adults with attention deficit/hyperactivity disorder. JAMA Pediatrics 171, 756–763.
De las Cuevas, C., Ramallo, Y., Sanz, E.J., 2010. Psychomotor performance and fitness to drive: the influence of psychiatric disease and its pharmacological treatment. Psychiatr. Res. 176, 236–241.
De las Cuevas, C., Sanz, E.J., 2008. Fitness to drive of psychiatric patients. Prim. Care Companion J. Clin. Psychiatry 10, 384–390.
de las Cuevas Castresana, C., Sanz Álvarez, E.J., 2009. Mental illness and road safety. Actas Esp. Psiquiatr. 37, 75–81.
Fergusson, D., Horwood, L., 1998. Early conduct problems and later life opportunities. JCPP (J. Child Psychol. Psychiatry) 39, 1097–1108.
Fergusson, D., Horwood, J., Ridder, E., 2005. Show me the child at seven: the consequences of conduct problems in childhood for psychosocial functioning in adulthood. JCPP (J. Child Psychol. Psychiatry) 46, 837–849.
Ferro, M. A., & Leatherdale, S. T. (in press). Traffic violations among young people with attention-deficit hyperactivity disorder. Can. J. Psychiatr.
Flam-Zalcman, R., Mann, R.E., Stoduto, G., Nochajski, T.H., Rush, B.R., Koski-Jännes, A., et al., 2013. Evidence from regression-discontinuity analyses for beneficial effects of a criterion-based increase in alcohol treatment. Int. J. Methods Psychiatr. Res. 22 (1), 59–70.
Fuermaier, A.B.M., Tucha, L., Evans, B.L., Koerts, J., de Waard, D., et al., 2017. Driving and attention deficit hyperactivity disorder. J. Neural Transm. 124 (Suppl. 1), S55–S67.
Galovski, T.E., Blanchard, E.B., 2002. The effectiveness of a brief psychological intervention on court-referred and self-referred aggressive drivers. Behav. Res. Ther. 40, 1385–1402.
Galovski, T.E., Blanchard, E.B., Veazey, C., 2002. Intermittent explosive disorder and other psychiatric co-morbidity among court-referred and self-referred aggressive drivers. Behav. Res. Ther. 40, 641–651.
Ialomiteanu, A., Adlaf, E.M., 2014. CAMH Monitor 2013: Metadata User's eGuide. Centre for Addiction and Mental Health, Toronto, Canada.
Ilie, G., Mann, R.E., Ialomiteanu, A., Adlaf, E.M., Stoduto, G., Hamilton, H., et al., 2015. Traumatic brain injury, driver aggression and motor vehicle collisions in Canadian adults. Accid. Anal. Prev. 81, 1–7. https://doi.org/10.1016/j.aap.2015.04.021.
Jensen, P.S., Martin, D., Cantwell, D.P., 1997. Comorbidity in ADHD: implications for research, practice, and DSM-V. J. Am. Acad. Child Adolesc. Psychiatry 36, 1065–1079.
Jonah, B.A., 1997. Sensation seeking and risky driving: a review and synthesis of the literature. Accid. Anal. Prev. 29, 651–665.
Karam, R.G., Breda, V., Picon, F.A., Rovaris, D.L., Victor, M.M., Salgado, C.A., et al., 2015. Persistence and remission of ADHD during adulthood: a 7-year clinical follow-up study. Psychol. Med. 45, 2045–2056.
Karjalainen, K., Lintonen, T., Joukamaa, M., Lillsunde, P., 2013. Mental disorders associated with driving under the influence of alcohol and/or drugs: a register-based study. Eur. Addict. Res. 19, 113–120.
Kazdin, A.E., 1993. Treatment of conduct disorder: progress and directions in psychotherapy research. Dev. Psychopathol. 5, 277–310.
Kessler, R.C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E., et al., 2005. The World Health Organization Adult ADHD Self-Report Scale (ASRS): a short screening scale for use in the general population. Psychol. Med. 35, 245–256.
Koisaari, T., Michelsson, K., Holopainen, J.M., Maksimainen, R., Päivänsalo, J., Rantala, K., Tervo, T., 2015. Traffic and criminal behavior of adults with attention deficit-hyperactivity with a prospective follow-up from birth to the age of 40 years. Traffic Inj. Prev. 16, 824–830.
Krueger, R.F., Caspi, A., Moffitt, T.E., Silva, P.A., McGee, R., 1996. Personality traits are differentially linked to mental disorders: a multitrait-multidiagnosis study of an adolescent birth cohort. J. Abnorm. Psychol. 105, 299–312.
Kujansuu, A., Rautiainen, S., Hakko, H., Kanamüller, J., Sihvola, N., Riipinen, P., 2017. Drivers' psychiatric disorders and fatal motor vehicle accidents in Finland. J. Psychiatr. Res. 84, 227–236.
LaPlante, D.A., Nelson, S.E., Odegaard, S.S., Labrie, R.A., Shaffer, H.J., 2008. Substance and psychiatric disorders among men and women repeat driving under the influence offenders who accept a treatment-sentencing option. J. Stud. Alcohol Drugs 69, 209–217.
Lee, E.S., Forhofer, R.N., 2006. Analyzing Complex Survey Data, second ed. Retrieved from. http://www.sagepub.com/upm-data/6428_Chapter_6_Lee_(Analyzing)_I_PDF_7.pdf.
Malta, L.S., Blanchard, E.B., Freidenberg, B.M., 2005. Psychiatric and behavioral problems in aggressive drivers. Behav. Res. Ther. 43, 1467–1484.
Mann, R.E., Stoduto, G., Vingilis, E., Asbridge, M., Wickens, C.M., Ialomiteanu, A., Sharpley, J., Smart, R.G., 2010. Alcohol and driving factors in collision risk. Accid. Anal. Prev. 42 (6), 1538–1544.
McCutcheon, V.V., Heath, A.C., Edenberg, H.J., Grucza, R.A., Hesselbrock, V.M., Kramer, J.R., et al., 2009. Alcohol criteria endorsement and psychiatric and drug use disorders among DUI offenders: greater severity among women and multiple offenders. Addict. Behav. 34, 432–439.
McDonald, C.C., Sommers, M.S., Fargo, J.D., 2014. Risky driving, mental health, and health-compromising behaviours: risk clustering in late adolescents and adults. Inj. Prev. 20, 365–372.
McDonald, C.C., Sommers, M.S., Fargo, J.D., Seacrist, T., Power, T., 2018. Simulated driving performance, self-reported driving behaviors, and mental health symptoms in adolescent novice drivers. Nurs. Res. 67, 202–211.
Ministry of Transportation, 2011. Ontario Road Safety Annual Report 2011. Ministry of Transportation, Toronto, Ontario.
Ministry of Transportation, 2012. Ontario Road Safety Annual Report 2012. Ministry of Transportation, Toronto, Ontario.
Ministry of Transportation, 2013. Ontario Road Safety Annual Report 2013. Ministry of Transportation, Toronto, Ontario.
Moffitt, T.E., 1993. Adolescence-limited and life-course-persistent antisocial behavior: a developmental taxonomy. Psychol. Rev. 100, 674–701.
Nada-Raja, S., Langley, J.D., McGee, R., Williams, S.M., Begg, D.J., Reeder, A.I., 1997. Inattentive and hyperactive behaviors and driving offenses in adolescence. J. Am. Acad. Child Adolesc. Psychiatry 36, 515–522.
Olazagasti, M.A.R., Klein, R.G., Mannuzza, S., Belsky, E.R., Hutchison, J.A., Lashua-Shriftman, E.C., Castellanos, F.X., 2013. Does childhood attention-deficit/hyperactivity disorder predict risk-taking and medical illnesses in adulthood? J. Am. Acad. Child Adolesc. Psychiatry 52 (2), 153–162.
Olino, T.M., Seeley, J.R., Lewinsohn, P.M., 2010. Conduct disorder and psychosocial outcomes at age 30: early adult psychopathology as a potential mediator. J. Abnorm. Child Psychol. 38, 1139–1149.
Otsubo, T., Tanaka, K., Koda, R., Shinoda, J., Sano, N., Tanaka, S., et al., 2005. Reliability and validity of Japanese version of the Mini-International Neuropsychiatric Interview. Psychiatr. Clin. Neurosci. 59, 517–526.
Owens, E.B., Zalecki, C., Gillette, P., Hinshaw, S.P., 2017. Girls with childhood ADHD as adults: cross-domain outcomes by diagnostic persistence. J. Consult. Clin.

Psychol. 85, 723–736.
Pearson, M.R., Murphy, E.M., Doane, A.N., 2013. Impulsivity-like traits and risky driving behaviors among college students. Accid. Anal. Prev. 53, 142–148.
Redelmeier, D.A., Chan, W.K., Lu, H., 2010. Road trauma in teenage male youth with childhood disruptive behavior disorders: a population based analysis. PLoS Med. 7, e1000369.
Shaffer, H.J., Nelson, S.E., LaPlante, D.A., Labrie, R.A., Albanese, M., Caro, G., 2007. The epidemiology of psychiatric disorders among repeat DUI offenders accepting a treatment-sentencing option. J. Consult. Clin. Psychol. 75, 795–804.
Sheehan, D.V., Lecrubier, Y., Sheehan, H., Amorim, P., Janavs, J., Weiller, E., et al., 1998. The Mini-International Neuropsychiatric Interview (M.I.N.I.): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. J. Clin. Psychiatry 59 (Suppl. 20), 22–33.
Simons-Morton, B., Ouimet, M.C., 2006. Parent involvement in novice teen driving: a review of the literature. Inj. Prev. 12 (Suppl. 1), i30–i37.
Stoduto, G., Mann, R.E., Flam-Zalcman, R., Sharpley, J., Brands, B., Butters, J., et al., 2014. Impact of Ontario's remedial program for drivers convicted of drinking and driving on substance use and problems. Can. J. Criminol. Crim. Justice 56 (2), 201–217.
Strom, T., Leskela, J., Possis, E., Thuras, P., Leuty, M.E., Doane, B.M., et al., 2013. Cognitive-behavioral group treatment for driving-related anger, aggression, and risky driving in combat veterans: a pilot study. J. Trauma. Stress 26, 405–408.
Thompson, A.L., Molina, B.S.G., Pelham Jr., W., Gnagy, E.M., 2007. Risky driving in adolescents and young adults with childhood ADHD. J. Pediatr. Psychol. 32, 745–759.
Vaa, T., 2014. ADHD and relative risk of accidents in road traffic: a meta-analysis. Accid. Anal. Prev. 62, 415–425.
Valero, S., Bosch, R., Corominas, M., Varrau, V., Ramos-Quiroga, J.A., Casas, M., 2018. Remittance or persistence of attention deficit-hyperactivity disorder (ADHD) and its impact on recidivism in risky driving behaviors. Traffic Inj. Prev. 19, 701–707.
Vingilis, E., Mann, R.E., Erickson, P., Toplak, M., Kolla, N.J., Seeley, J., Jain, U., 2014. Attention deficit hyperactivity disorder, other mental health problems, substance use, and driving: examination of a population-based, representative Canadian sample. Traffic Inj. Prev. 15, S1–S9.
Vitola, E.S., Salgado, C.A.I., Silva, K.L., Karam, R.G., Victor, M.M., Mota, N.R., et al., 2012. The role of a lifetime history of oppositional defiant and conduct disorders in adults with ADHD: implications for clinical practice. CNS Spectr. 17, 94–99.
Waller, J.A., 1965. Chronic medical conditions and traffic safety: review of the California experience. N. Engl. J. Med. 273 (26), 1413–1420.
Wells-Parker, E., Ceminsky, J., Hallberg, V., Snow, R.W., Dunaway, G., Guiling, S., Williams, M., Anderson, B., 2002. An exploratory study of the relationship between road rage and crash experience in a representative sample of US drivers. Accid. Anal. Prev. 34, 271–278.
Wickens, C.M., Flam-Zalcman, R., Stoduto, G., Docherty, C., Watson, T.M., van der Maas, M., et al., 2018. The impact of remedial program participation on convicted drinking drivers' alcohol and other drug use six months following program completion. Int. J. Ment. Health Addict. 16, 598–616.
Wickens, C.M., Mann, R.E., Ialomiteanu, A.R., Stoduto, G., 2016. Do driver anger and aggression contribute to the odds of a crash?: a population-level analysis. Transport. Res. Part F 42, 389–399.
Wickens, C.M., Mann, R.E., Vingilis, E., Ialomiteanu, A.R., Erickson, P., Kolla, N.J., Stoduto, G., van der Maas, M., 2017. The impact of childhood symptoms of conduct disorder on driving after drinking in adulthood. J. Transp. Health 6, 253–261.
Wickens, C.M., Smart, R.G., Mann, R.E., 2014. The impact of depression on driver performance. Int. J. Ment. Health Addict. 12, 524–537.
Wickens, C.M., Vingilis, E., Mann, R.E., Erickson, P., Toplak, M.E., Kolla, N.J., Seeley, J., Ialomiteanu, A.R., Stoduto, G., Ilie, G., 2015. The impact of childhood symptoms of conduct disorder on driver aggression in adulthood. Accid. Anal. Prev. 78, 87–93.
Willcutt, E.G., Nigg, J.T., Pennington, B.F., Solanto, M.V., Rohde, L.A., Tannock, R., et al., 2012. Validity of DSM – IV attention deficit/hyperactivity disorder symptom dimensions and subtypes. J. Abnorm. Psychol. 121, 991–1010.
Woodall, W.G., Delaney, H.D., Kunitz, S.J., Westerberg, V.S., Zhao, H., 2007. A randomized trial of a DWI intervention program for first offenders: intervention outcomes and interactions with antisocial personality disorder among a primarily American-Indian sample. Alcohol Clin. Exp. Res. 31, 974–987.
Woodward, L.J., Fergusson, D.M., Horwood, L.J., 2000. Driving outcomes of young people with attentional difficulties in adolescence. J. Am. Acad. Child Adolesc. Psychiatry 39, 627–634.
World Health Organization, 2015. Global Status Report on Road Safety. http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/, Accessed date: 20 October 2015.