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Risky bicycling behavior among youth with and without attention-deficit hyperactivity disorder

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Abstract

Background: Injury risk from car–bicycle collisions is particularly high among youth with attention-deficit hyperactivity disorder (ADHD). Here, we capitalized on advances in virtual environment technology to safely and systematically examine road-crossing behavior among child cyclists with and without ADHD.

Methods: Sixty-three youth (26 with ADHD, 37 non-ADHD controls) ages 10–14 years crossed 12 intersections with continuous cross-traffic while riding a high-fidelity bicycling simulator. Traffic density (i.e., temporal gaps between vehicles) was manipulated to examine the impact of varying traffic density on behavioral indices of road crossing, including gap selection, timing of entry into the roadway, time to spare when exiting the roadway, and close calls with oncoming cars. In addition, parents filled out questionnaires assessing their child’s ADHD symptomatology, temperamental characteristics, bicycling experience, and injury history.

Results: ADHD youth largely chose the same size gaps as non-ADHD youth, although ADHD youth were more likely to select smaller gap sizes following exposure to high-density traffic. In addition, youth with ADHD demonstrated poorer movement timing when entering the intersection, resulting in less time to spare when exiting the roadway. Hyperactivity–impulsivity symptoms were specifically associated with selection of smaller gaps, whereas timing deficits were specifically associated with inattention and inhibitory control.

Conclusion: Findings highlight two related yet potentially dissociable mechanisms that may influence injury risk among youth with ADHD and provide a foundation for development of injury prevention strategies.

Keywords

Injury risk; attention-deficit hyperactivity disorder; bicycling; road crossing

Introduction

Attention-deficit hyperactivity disorder (ADHD) is a common, developmentally persistent neurodevelopmental disorder. In addition to associated academic and social difficulties,

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youth with ADHD are at particularly high risk for unintentional injury (DiScala, Lescohier, Barthel, & Li, 1998; Hurtig, Ebeling, Jokelainen, Koivumaa-Honkanen, & Taanila, 2016; Silva, Colvin, Hagemann, Stanley, & Bower, 2014). Meta-analytic work has documented a significant association between ADHD and mild traumatic brain injury (Adeyemo et al., 2014), and ADHD is a significant predictor of accident claims among children, teens, and adults (Swensen et al., 2004). Recent work estimates that injury risk is two to five times greater among individuals with ADHD compared to population-typical rates, even after controlling for other physical and psychiatric problems (Tai, Gau, & Gau, 2013). Injury-related medical costs are also significantly higher for families of ADHD children (Swensen et al., 2003). In fact, ADHD has been implicated in unintentional childhood injury to such an extent that recent work suggests screening for ADHD may be a beneficial component of routine trauma services for children (Maxson, Lawson, Pop, Yuma-Guerrero, & Johnson, 2009).

Bicycle crashes are among the most common causes of severe injuries in childhood. Nearly 400,000 children are treated at emergency rooms yearly for bicycle-related injuries in the U.S. (Mehan, Gardner, Smith, & McKenzie, 2009). A significant number of these injuries are due to collisions with motor vehicles, and approximately one-third of all bicyclist fatalities involving collisions with motor vehicles occur at intersections (National Highway Traffic Safety Administration, 2012). Importantly, youth with ADHD are twice as likely as non-ADHD youth to be involved in bicycle crashes (Pastor & Reuben, 2006).

Crossing roads safely involves two key components: choosing a gap between vehicles that affords safe crossing and accurately timing movement through the gap. A gap affords crossing if the time available for crossing (i.e., the temporal size of the gap) is greater than the time needed to cross through the gap (Lee, Young, & McLaughlin, 1984). Given the dynamic nature of traffic, gap decisions and crossing movements must be tightly linked, as youth must choose a gap that affords safe crossing and then time their actions in relation to the gap (Plumert & Kearney, 2014a,b). Errors in gap selection or movement timing (or both) can increase injury risk.

Prior research has used a high-fidelity, immersive bicycling simulator to safely and systematically examine the behavioral processes that contribute to injury risk (see Plumert & Kearney, 2014b for a review). A robust finding is that 10- and 12-year-old typically developing children select the same temporal gap sizes as adults when crossing, but have less time to spare when exiting the roadway (Plumert, Kearney, & Cremer, 2004). Largely, this is due to the fact that children time their entry into the gap less precisely than adults (i.e., children cut in less closely behind the lead vehicle in the gap), implicating immature movement timing skills in youth cyclists' risky road-crossing behavior.

Additional work has examined how youth respond to challenging scenarios, such as high-density traffic, that may pose significant risk for car-bicycle collisions (Plumert, Kearney, Cremer, Recker, & Strutt, 2011). This work revealed that youth selected very tight gaps at intersections with high-density traffic, and continued to select smaller gaps at later intersections, even when presented with larger gaps (Plumert et al., 2011). Furthermore, although youth timed their entry into the gap more tightly when crossing high-density

intersections, they were hit 20% of the time. These results suggest high-density traffic presents substantial risks to young riders, and risky behavior in higher density traffic situations carries over to lower density traffic situations.

Importantly, maturation of brain networks underlying inhibitory control processes may impact road-crossing behavior. Past work has indicated that typically developing youth with lower levels of inhibitory control timed their entry into the roadway less precisely, and consequently had less time to spare when crossing (Stevens, Plumert, Cremer, & Kearney, 2013). The ability to tightly coordinate gap decisions and crossing movements requires high self-regulation and prospective movement control (i.e., rider must select a safe gap for crossing and begin to move at the right time). Children who have difficulty regulating and planning motor actions may be at particularly high risk for car–bicycle collisions.

Despite these advances in understanding how immature perceptual-motor skills lead to risky road crossing in typically developing children, no prior research has examined cycling behavior among ADHD youth. Risk for injury among youth with ADHD may be elevated due to a combination of factors, including signaling differences in reward processing networks leading to increased risky decisions (Beauchaine & McNulty, 2013), which are commonly associated with hyperactive–impulsive symptoms (Thompson, Molina, Pelham, & Gnagy, 2007). In support of this hypothesis, research on pedestrian road-crossing behavior revealed that ADHD youth selected riskier gaps when crossing roadways compared to their non-ADHD counterparts, and deficits in executive functioning contributed to these differences (Stavrinou et al., 2011). Further, several lines of work have indicated that ADHD youth exhibit deficits in inhibitory and effortful control relative to non-ADHD youth (Martel, 2013), which may contribute to difficulties in timing motor movements when crossing intersections, resulting in increased injury risk. Finally, ADHD commonly cooccurs with other behavioral problems (e.g., aggression) which may also contribute to injury risk (Keyes et al., 2014). However, the degree to which ADHD symptom severity and/or individual differences in inhibitory control and aggressive behavior contribute to cycling behavior and injury risk remains unknown.

The purpose of this study was to examine (a) group differences in risky road-crossing behavior among youth cyclists with and without ADHD, and (b) whether dimensional scores of ADHD symptom severity as well as parent-reported inhibitory control and aggression predict risky road-crossing behavior. Participating youth crossed four intersections with high-density traffic, sandwiched between two sets of four intersections with less dense traffic. At the high-density intersections, crossable gaps were interspersed with several small, uncrossable gaps, requiring longer waiting before crossable gaps appeared (see Plumert et al., 2011). We specifically chose to expose ADHD youth to a high-density traffic scenario as even typically developing children respond to high-density traffic with riskier road-crossing behavior (Plumert et al., 2011). We hypothesized that ADHD youth would (a) select smaller temporal gaps for crossing and (b) time their entry into the roadway less precisely, resulting in less time to spare when exiting the roadway. Finally, we expected individual differences in ADHD symptom severity, inhibitory control, and aggression would predict riskier road-crossing behavior.

Methods

Participants

Participants were 63 youth ($n = 26$ with ADHD, $n = 37$ non-ADHD comparisons) aged 10–14 years old ($M = 12.0$ years, $SD = 1.5$, 81% male). Participants were recruited via newspaper advertisements, email list-serve postings, and letters sent to families of youth enrolled in the Department of Psychology Child Research Participant Registry and to patients from the Department of Child and Adolescent Psychiatry at the University of Iowa. Parents provided informed consent and youth provided written assent. All procedures were approved by the Institutional Review Board (IRB) at the University of Iowa.

To be included in the ADHD group, youth must have (a) received a previous diagnosis of ADHD according to parent report and exhibited current ADHD symptoms based upon initial screening questions (Kessler et al., 2010), (b) met current symptom thresholds for DSM-5 ADHD according to parent report on the ADHD Rating Scale (DuPaul, Power, Anastopoulos, & Reid, 1998), and (c) had a T-score >65 based on parent-report on the inattention or hyperactivity-impulsivity subscales of the Conners' 3 (Conners, 2008). All ADHD youth were included regardless of subtype/presentation. Youth taking stimulant medications (54% of the ADHD group) completed a 24- to 48-hr medication wash-out prior to participation (M wash-out time = 43.6 hr, $SD = 19.6$).

To be included in the non-ADHD group, youth had to have (a) no parent reported prior psychiatric diagnoses, (b) symptom counts below DSM-5 diagnostic thresholds on the ADHD Rating Scale, (c) T-scores <65 on the inattention and hyperactivity subscales of the Conners' 3, and (d) no history of stimulant medication treatment. Demographic and descriptive statistics are presented in Table 1.

Measures

ADHD symptomatology.—The visiting parent (98% mothers) completed the ADHD Rating Scale (DuPaul et al., 1998) and the Conners' 3 Parent Rating Scale, Short Form (Conners, 2008) to assess current ADHD symptomatology. On the ADHD Rating Scale, parents rated the frequency of their child's ADHD symptoms over the past 6 months (never or rarely, sometimes, often, very often). Both total sum scores and symptom counts (symptom rated as occurring often or very often) were computed (α -inattention = .91, α -hyperactivity-impulsivity = .91).

The Conners' 3 (43 items) assesses current inattention, hyperactivity-impulsivity, learning, executive function, defiance, and peer relationship problems. Total sum scores for each domain and age- and sex-based T-scores were computed. Internal consistency estimates were adequate for the ADHD symptom scales (α -inattention score = .94, α -hyperactivity score = .92) and for the Conners' 3 (α -inattention = .94, α -hyperactivity-impulsivity = .93).

Child temperament and behavior.—Parents completed the Early Adolescent Temperament Questionnaire-Revised (Ellis & Rothbart, 2001), a 62-item measure that yields eight temperamental dimensions and two behavioral dimensions. Parents rated each statement on a 5-point Likert scale (always untrue to almost always true). Given previous

work implicating inhibitory control ($\alpha = .68$) and aggression ($\alpha = .70$) in bicycling performance (Stevens et al., 2013), these two scales were retained for analyses.

Bicycling experience and injury history.—Parents completed a survey to assess their child's prior bicycling experience (i.e., frequency of riding, bicycling skill, cautiousness), and a questionnaire assessing the number of accidental injuries requiring medical attention their child had sustained. Each child received a total sum score for bicycling experience ($\alpha = .81$), and for number of accidental injuries.

Apparatus.—The study was conducted using a high-fidelity, real-time bicycling simulator. The simulator consisted of a bicycle mounted on a stationary frame positioned in the middle of three 10-ft wide \times 8-ft high screens, placed at right angles relative to one another (see Figure 1). Two F1 + projectors and one Canon LV 7215 projector were used to rear-project high-resolution textured graphics onto the screens (1,280 \times 1,024 pixels on each screen), providing participants with over 270 degrees of non-stereoscopic immersive visual imagery. A ceiling projector was used to front-project graphics onto the floor. The viewpoint of the scene was adjusted to each participant's eye height. Four speakers and a subwoofer provided spatialized traffic sounds.

The handlebars, pedals, and right hand brake on the bicycle were all functional. A friction-drive flywheel connected to the rear wheel, which also connected to a torque motor that generated a dynamic force, taking into consideration ground friction, wind resistance, and the mass and inertia of the rider and bicycle. The wheel speed and steering angle were combined with virtual terrain information to render in real time the graphics corresponding to the bicyclist's trajectory through the virtual environment (see Figure 1).

Participants rode on a 12-m wide straight, residential roadway through a virtual neighborhood populated with buildings and features typical of a small town. Cross streets contained continuous traffic intersecting the primary roadway at 150-m intervals. Cars traveled at 25 or 35 mph on alternating intersections. There was a stop sign at each intersection.

Procedure

The session started with a brief practice period, during which youth rode the bicycle through two intersections without traffic to familiarize themselves with pedaling, steering, and stopping. Past work with youth in this age range has indicated that the practice period is sufficient for allowing youth to grow accustomed to riding the bicycle. Following the practice, youth completed the test session (approximately 15–20 min), during which they crossed 12 intersections with continuous traffic. Youth were instructed to stop at all intersections and to cross each intersection without being struck by a car. Cross traffic approached from the left and was constrained to the near lane. As in Plumert et al. (2011), intersections 5 through 8 were populated with high-density traffic (i.e., higher proportion of smaller gap sizes ranging from 1.5 to 4.5 s). These high-density intersections were sandwiched between two sets of four control intersections (intersections 1–4 and intersections 9–12, in which gaps randomly varied in size from 1.5 to 6.5 s). While youth

were riding, the visiting parent completed questionnaires. Parents and youths were debriefed at the end of the session.

Bicycling variables

All bicycling measures were calculated for each intersection ($n = 12$ intersections) and then averaged into three intersection sets (set 1: intersections 1–4; set 2: intersections 5–8, ‘high density’ intersections; set 3: intersections 9–12). The following measures were automatically computed from recorded positional data for each intersection:

Gap size was defined as the temporal size of the gap youth crossed ($\alpha = .92$). Larger gap sizes indicate safer gap selection.

Timing of entry was defined as the time between the rider and the lead car in the gap upon entering the intersection ($\alpha = .91$). Cutting in closely behind the lead car is safer, as this leaves more space between the rider and the tail car; thus, lower scores reflect more precise timing of entry. In addition, for each participant, we calculated the standard deviation of timing of entry across all intersections to examine consistency in timing of entry.

Crossing time was defined as the time between when the rider entered the roadway and cleared the path of the cars. Higher scores indicate slower crossing times.

Time to spare was defined as the time between the rider and the tail car in the gap when the rider cleared the path of the tail car ($\alpha = .93$). Higher scores indicate more time between the child and the oncoming car and represent safer bicycling behavior.

Hits were defined as contact with a car in the intersection and *close calls* were defined as a time to spare of <1 s ($\alpha = .80$).

Data analytic strategy

Group differences in bicycling performance were examined using separate repeated-measures analysis of covariance (ANCOVA) for each bicycling measure. ADHD diagnostic status was included as the between-subjects variable, and the three intersection sets for each bicycling measure (e.g., average gap size for intersections sets 1, 2 and 3) were included as repeated measures variables. Sphericity assumptions were met for all repeated-measures ANCOVAs, with the exception of close calls; in that case, the Greenhouse–Geisser degrees of freedom and estimates of the F -statistic were used. Further, as a complement to ANCOVA analyses, mixed-effect logistic regression analyses were conducted to evaluate gap size, intersection set, and diagnostic group as predictors of youth crossing decisions. Last, the association between ADHD symptom dimensions, temperament traits, and bicycling outcomes were examined using hierarchical linear regression analyses. Importantly, due to the high correlation between ADHD symptoms and between inhibitory control and aggression, only their residual variances were included as predictors to evaluate potential specificity of effects. Age, sex, bicycling experience, and number of previous accidental injuries were included as covariates in all models.

Results

Group differences in gap choices and crossing performance

Gap choices.—Means for the bicycling performance indices are presented in Table 2. Analyses of gap size revealed a significant effect of intersection set [$F(2, 116) = 16.66, p < .001, \eta^2 = .223$] and a significant Intersection Set \times Diagnosis interaction [$F(2, 116) = 5.80, p = .004, \eta^2 = .09$]. As expected, all youth selected significantly smaller gap sizes when crossing high-density intersections (intersection set 2) relative to intersection sets 1 and 3. However, ADHD youth took significantly smaller gaps in intersection set 3 ($M = 5.3, SD = .64$) when compared to non-ADHD youth ($M = 5.6, SD = .46$). Thus, experience with high-density traffic appeared to differentially impact ADHD youth, as they continued to select riskier gaps (i.e., smaller temporal gaps) relative to their non-ADHD counterparts after exposure to high-density traffic (see Table S1 for cycling performance means by diagnostic group and intersection set).

Mixed-effects logistic regression analyses of crossing decisions during the first and last intersection sets revealed that both gap size and intersection set influenced youth crossing decisions, such that the likelihood of taking a gap was greater in the third intersection set relative to the first ($z = 3.19, p = .001$) and the likelihood of taking a gap increased as gap size increased ($z = 10.30, p < .001$). These results are similar to past work indicating that both experience with crossing and features of the traffic (i.e., size of gaps available for crossing) influence crossing decisions (see Figure 2). However, there was no effect of diagnostic group ($z = -1.65, ns$). Analyses of gap decisions during the high-density intersections also revealed an effect of gap size ($z = 9.08, p < .001$), but no effect of diagnostic group ($z = -1.32, ns$), suggesting that ADHD and non-ADHD youth responded similarly when crossing high-density traffic.

Crossing performance.—Analyses of crossing performance revealed that timing of entry was tighter for all youth when crossing high-density intersections relative to the other intersection sets [$F(2, 116) = 6.52, p = .002, \eta^2 = .10$]. Importantly, ADHD youth timed their entry into the gap less precisely than non-ADHD youth [$F(1, 58) = 7.76, p = .007, \eta^2 = .118$] and exhibited significantly greater variability in their timing of entry than non-ADHD youth [$F(1, 62) = 3.94, p = .043, \eta^2 = .065$].

Analyses of road-crossing time revealed no significant group differences between ADHD and non-ADHD groups ($p = .88; \eta^2 = .001$). When exiting the roadway, however, ADHD youth had significantly less time to spare than non-ADHD youth [$F(1, 58) = 18.92, p < .001, \eta^2 = .246$]. As expected, there was also a main effect of intersection set [$F(2, 116) = 18.86, p < .001, \eta^2 = .25$], such that all youth had less time to spare when crossing high-density intersections relative to normal-density intersections.

Overall, ADHD youth also had more close calls compared to non-ADHD youth [$F(1, 58) = 4.79, p = .033, \eta^2 = .079$], and all youth experienced significantly more close calls when crossing high-density intersections relative to the other intersections [$F(1.4, 116) = 8.18, p < .001, \eta^2 = .13$]. There was also a significant Intersection Set \times Diagnosis interaction [$F(2, 116) = 3.41, p = .036, \eta^2 = .06$], such that ADHD youth experienced significantly

more close calls when crossing high-density intersections ($M = .72$, $SD = .36$) compared to non-ADHD youth ($M = .53$, $SD = .38$). Last, all youth were more likely to be hit when crossing high-density intersections [$F(2, 116) = 4.51$, $p = .015$, $\eta^2 = .14$]. Similar to past work, youth were hit 16.2% of the time when crossing high-density intersections.

Individual differences as predictors of road crossing.—Hierarchical linear regression analyses examined the impact of individual differences in ADHD symptom severity, inhibitory control, and aggression on primary indices of bicycling behavior. Residual variances (i.e., the unique variance in inattention apart from hyperactivity-impulsivity and vice versa; the unique variance in inhibitory control apart from aggression and vice versa) were used for each symptom dimension and temperament trait to examine specificity of associations and to reduce multicollinearity. For the first set of models, ADHD symptom dimension residual scores were entered at step 2; for the second set of models, residual scores for inhibitory control and aggression were entered at step 2. Outcomes included mean bicycling indices averaged across all intersections.

Standardized beta weights from the regression analyses are presented in Table 3. Hyperactivity-impulsivity scores negatively predicted gap size, such that youth with higher scores on hyperactivity-impulsivity selected significantly smaller gaps. Inattention scores specifically predicted timing of entry and time to spare such that higher inattention scores resulted in poorer precision in timing of entry into the roadway and less time to spare when clearing the path of the car. Neither inattention nor hyperactivity-impulsivity significantly predicted close calls.

Inhibitory control significantly predicted both timing of entry and time to spare, such that lower ratings were related to less precise timing of entry and less time to spare when crossing. Ratings of aggression only significantly predicted close calls, such that those with higher scores were also more likely to have a near miss with an oncoming car when crossing.

Discussion

This study is the first to use immersive, virtual environment technology to create an ecologically valid behavioral assay of risk-taking in child cyclists with and without ADHD. The findings revealed several differences in road-crossing behavior. First, ADHD youth largely chose the same size gaps as non-ADHD youth, although ADHD youth were more likely to select smaller gap sizes following exposure to high-density traffic relative to non-ADHD youth, suggesting that ADHD youth may have more difficulty modulating their behavior in response to changing environmental circumstances. Second, ADHD youth were consistently worse at timing their entry into the roadway and exhibited greater variability in the timing of their entry compared to non-ADHD youth. Consequently, they also had significantly less time to spare and more close calls than non-ADHD youth. Third, some specificity emerged when examining associations between ADHD symptom dimensions and bicycling outcomes. Hyperactive-impulsive symptoms specifically predicted selection of smaller gap sizes, whereas both inattention symptoms and poorer inhibitory control among all youth predicted poorer timing of entry and less time to spare when crossing.

The specificity of these associations mirror previous findings regarding two related but potentially dissociable mechanisms that may account for increased road-crossing injury risk among ADHD youth; namely, risky decision-making and impaired movement timing. First, hyperactivity–impulsivity appears to be specifically related to risky decision-making among youth with ADHD (Toplak, Jain, & Tannock, 2005). This highlights potential associations between impulsive decision-making and deficient neural signaling in reward processing networks, which has been hypothesized to contribute to increased injury risk (Wilbertz et al., 2012). Second, inattention symptoms and inhibitory control may play a role in the timing deficits that constitute one causal pathway of ADHD (Sonuga-Barke, Bitsakou, & Thompson, 2010; Zelaznik et al., 2012). Sensorimotor synchronization, underpinned by both corticostriatal and corticocerebellar neural networks (Valera et al., 2010), appears to be especially impaired among ADHD youth (Noreika, Falter, & Rubia, 2013). The current findings extend this work, suggesting that inattention may negatively impact timing of motor movements thereby increasing injury risk among ADHD youth. Thus, our findings indicate that both risky gap choices and impaired movement timing represent significant risk factors for injury among ADHD youth cyclists.

The current findings also have clear clinical and public health implications. First, it appears that both decisions (e.g., gap selection) and actions (e.g., motor timing) likely play a role in increased injury risk for child cyclists, particularly those with ADHD. These findings of dual deficits align with studies of driving behavior, which have indicated that adults with ADHD exhibit increased difficulties with vehicle control and poor decision-making (e.g., changing lanes), which, in turn, increased their risk for crashes (Groom, van Loon, Daley, Chapman, & Hollis, 2015). Prior work has also demonstrated that timing-related deficits tend to persist into adulthood among individuals with ADHD (Valera et al., 2010). Given this, prevention strategies focused on teaching ADHD youth to take larger gaps to compensate for their poorer movement timing (rather than attempting to improve their poorer movement timing) may be especially helpful. Moreover, given that youth with ADHD continued to take smaller gaps after exposure to high-density traffic (and prior work has shown this same phenomenon among younger children; Plumert et al., 2011), prevention paradigms targeting improved gap selection (i.e., waiting longer for a large gap to appear) while navigating dense traffic may be particularly beneficial.

This study has several strengths, including being the first to examine cycling injury risk among youth with ADHD using precise, real-time measurements of decision-making and motor timing using a safe yet ecologically valid format for studying injury risk. However, this work is not without limitations. We did not differentiate youth based on ADHD presentation type, nor did we obtain teacher-reported ADHD symptoms. In addition, our sample included a high proportion of males. Future work should aim to include a broader ADHD group and more females to explore heterogeneity in risk among ADHD youth. Our recruitment strategies, while broad, included use of clinic-referred and community children with ADHD. Our small sample size may have also limited our ability to detect significant interaction effects. ADHD youth were also studied off-medication, which may limit generalizability of our findings to youth who are unmedicated. Future work examining the impact of stimulant medications on injury risk remains important.

Overall, these findings add to the growing literature that motor timing deficits may be a hallmark of neurodevelopmental disorders (van der Meer et al., 2015) and provide a novel paradigm for measuring such deficits in relation to real-world impairments.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key points

- Attention-deficit hyperactivity disorder has been linked to a substantial increase in unintentional injury.
- Collisions between child cyclists and motor vehicles remain one of the most common sources of unintentional injury and youth with ADHD appear to be at particularly high risk.
- Using virtual environment technology, we demonstrate that youth with ADHD exhibit significant deficits in both the selection of gaps for crossing as well as in the timing of their movements while crossing intersections in comparison to non-ADHD youth.
- Findings indicate that both decision-making and motor timing difficulties may account for the increased risk of bicycle-related injuries among ADHD youth.



Figure 1. Photograph of a child riding the bicycling simulator. Note that visual angles are correct from the rider's viewpoint

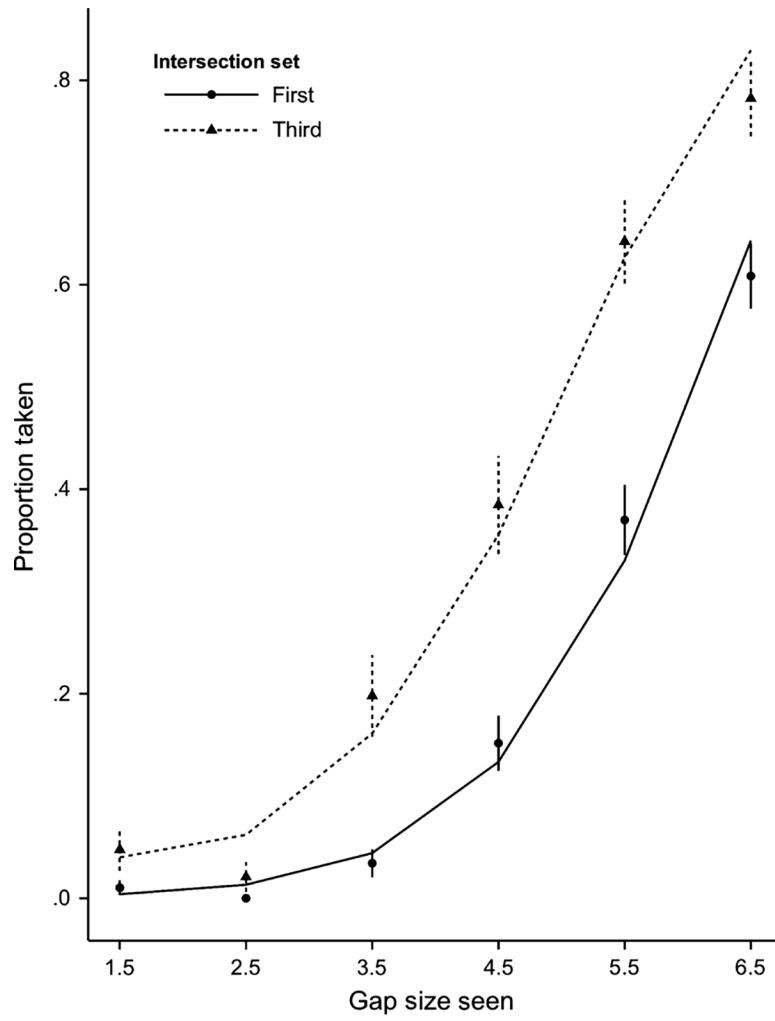


Figure 2.
Gap acceptance during the first and third intersection sets

Table 1

Demographic and descriptive statistics for ADHD and non-ADHD comparison youth

	Control	ADHD	<i>p</i> -value
<i>N</i>	37	26	
% Male	86.5	80.8	.541
Age (<i>SD</i>)	12.1 (1.4)	11.9 (1.5)	.442
Inattention symptoms (<i>SD</i>)	1.0 (1.9)	6.1 (2.7)	<.001
Hyperactivity–impulsivity symptoms (<i>SD</i>)	.83 (1.5)	2.9 (3.0)	.002
Oppositional defiant disorder symptoms (<i>SD</i>)	.52 (1.0)	1.8 (2.2)	.005
Conduct disorder symptoms (<i>SD</i>)	.03 (.19)	.28 (.54)	.039
Conners inattention T score (<i>SD</i>)	47.6 (9.3)	73.5 (10.1)	<.001
Conners hyperactivity–impulsivity T score (<i>SD</i>)	50.1 (11.1)	68.4 (15.7)	<.001
EATQ-R inhibitory control (<i>SD</i>)	3.9 (.59)	3.1 (.66)	<.001
EATQ-R aggression (<i>SD</i>)	2.2 (.66)	2.7 (.74)	.009
Bicycling experience (<i>SD</i>)	13.3 (2.7)	13.0 (2.0)	.560
Number of prior accidental injuries (<i>SD</i>)	1.5 (1.7)	2.7 (1.8)	.010

All measures based on parent-report scales. *SD*, standard deviation; ADHD, attention-deficit hyperactivity disorder.

Table 2

Mean road-crossing performance: Main effects of intersection set and diagnostic group

Road crossing performance – intersection set			
	Set 1	Set 2	Set 3
Gap size (s)	6.0 (.42)	2.9 (.96)	5.4 (.63)
Timing of entry (s)	1.6 (.61)	.90 (.48)	1.2 (.45)
Time to spare (s)	2.9 (.65)	.76 (.62)	2.8 (.37)
Road-crossing time (s)	1.5 (.22)	1.6 (.75)	1.5 (.29)
Close calls (s)	.03 (.18)	.62 (.37)	.05 (.13)
Hits	.00 (.03)	.16 (.23)	.02 (.10)
Road crossing performance – diagnostic group			
	Control	ADHD	
Gap size (s)	4.8 (.43)	4.7 (.22)	
Timing of entry (s)	1.1 (.22)	1.4 (.40)	
Time to spare (s)	2.4 (.38)	2.0 (.38)	
Road-crossing time (s)	1.5 (.34)	1.6 (.34)	
Close calls	.19 (.13)	.27 (.14)	
Hits	.05 (.10)	.07 (.11)	

Risky bicycling behavior indexed by lower gap size and time to spare and by higher scores on timing of entry, close calls, and hits. Means presented are adjusted marginal means from ANCOVA analyses following adjustment for covariates. ADHD, attention-deficit hyperactivity disorder; s, seconds.

Table 3

Summary of linear regression analyses for symptom and temperament variables predicting bicycling performance

	Gap size β	Timing of entry β	Time to spare β	Close calls β
Age	.14	-.09	-.08	-.03
Sex	.03	-.02	.19 [†]	-.01
# Injuries	.04	.07	-.02	-.04
Bicycling experience	.10	-.08	-.08	-.06
Inattention	-.05	.27 **	-.40 **	-.17
Hyperactivity–impulsivity	-.32 **	.01	.02	.19
Age	.11	-.10	-.08	-.07
Sex	.06	-.01	.20 [†]	-.01
# Injuries	.02	.05	-.03	-.01
Bicycling experience	.07	-.05	-.09	-.02
Inhibitory control	.16	-.19 [†]	.26 **	-.19
Aggression	.08	.02	-.02	.25 **

β s are standardized beta weights from step 2 of hierarchical linear regression analyses predicting bicycling performance. Residuals scores were created for inattention and hyperactivity–impulsivity (and inhibitory control and aggression) by regressing one measure on the other to examine specificity of effects.

Bold values are significant at $p < .05$.

[†] $p < .10$

** $p < .01$.