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"What Were They Thinking?": Metacognition and Impulsivity Play a Role in Young Driver Risk-Taking

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Abstract

Background: Young drivers are disproportionately at-risk for motor vehicle crashes, which are often the result of risky decision-making on-road. Lapses in higher order cognition (e.g. metacognition and impulsivity) are associated with later development of the frontal lobes in teens and young adults; however, little research has examined the impact of these factors on risky driving behavior.

Objective: The current study investigated relationships between metacognitive ability, impulsive tendencies (i.e. acting without thinking and sensation seeking), and reported and objective simulated risky driving in a sample of young adult drivers (n= 65) aged 18 to 24 years (Mage= 21.2 years; 52.3% female) from a larger analysis of executive functions and driving. Metacognitive ability was measured via the self-report Behavior Rating Inventory of Executive Function (BRIEF) Metacognition Index (MI), Acting without Thinking (AWT) was measured via items from the Eysenck Junior Impulsivity Scale, and Sensation Seeking (SS) was measured *via* the Brief Sensation Seeking Scale-4 (BSSS-4). A modified Driving Behavior Questionnaire (mDBQ) was used to assess risky driving behaviors. In addition, the Virtual Driving Test (VDT) measured ecologically valid driving performance.

Results: Worse metacognitive ability scores were associated with greater self-reported risky driving (r= 0.40, p= 0.001) and making more stop sign errors in the VDT. (r= 0.27, p= 0.030). Regression models showed that metacognitive ability alone was a predictor of crashes (p= 0.049) and accounted for variance in reported risky driving above and beyond AWT and SS (p= 0.002).

Conclusions: Findings support the BRIEF-MI as a useful and ecologically valid tool for identifying risky drivers. Future research should build off of the framework proposed by the current study to further understand how metacognitive ability influences young driver decision-making, and how individual characteristics play a role.

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Introduction

When compared with adult drivers, young drivers are 3 times more likely to be involved in a motor vehicle crash (per total miles traveled: [1]). Among young drivers, impulsive personality traits associated with the continued development of Executive Functions (EF) play an important role in risky decision-making, which may help to explain age differences in crash risk [2-6]. Two manifestations of impulsivity – sensation seeking (i.e., the desire to experience potentially dangerous, thrilling experiences) and acting without thinking (i.e., actions without due deliberation) have been associated with risky decision-making [4,7]. In addition, our previous work suggests that among young drivers, sensation-seeking is directly associated with self-reported crashes while acting without thinking is associated with risky driving behavior and can mediate the relationship between risky driving and crashes [8]. However, the way in which these distinct types of impulsivity impact driving behavior is not known.

Unsafe driving in adolescents and young adults has been linked to lapses in Executive Functions (EF) associated with later developing frontal lobes [6,8-12]. Both objective and subjective measures of EF have been used to investigate relationships with driving behavior. Some studies utilizing objective, performance-based measures of EF (e.g., computerized stimulus-response tasks) found that worse EF ability (e.g. working memory) is associated with crashes, risky driving behavior and poor performance in simulated driving [5,13-15]; however, inconsistent and some contradictory findings cloud our understanding. Performance-based EF often does not always show an association with driver behavior and, at times, better EF is associated with unsafe on-road behavior [16,17]: suggesting that drivers with higher working memory took more risks while driving However, these mixed findings may be attributed to inconsistencies in EF terminology (operational definitions) and performance-based measurements [18]. In addition, associations between objective and self-reported measures of EF are not always observed, which may be attributed to ecological validity issues in laboratory performance-based assessments [19]. Some studies have utilized self-reported EF measures such as the Behavior Rating Inventory of Executive Function (BRIEF): a clinically valid, practical-to-administer assessment of EF capacity via real-world hypothetical situations [5,19]. Prior literature has shown that the global EF composite score on the BRIEF is associated with distracted driving (e.g. texting while driving, inattention) and crash outcomes [5,18,20]. However, relationships between reported EF and intentional risky driving behavior remain unclear in young drivers [19]. One potential reason for this may be that risky decisions while driving are not fully captured by reported or performance-based EF measures. An important question then arises, if EF (as defined in prior work) does not adequately explain the manifestation of risky driving, then what other cognitive abilities may account for this behavior? Previous research on driver behavior in adults has found that although EF capacities are necessary for driving, metacognitive self-monitoring ability (or the coordination of EF) is hypothesized to play a direct role in decision-making; especially while driving [21].

Metacognition refers to one's ability to self-monitor (be aware of and regulate) cognitive processes in accordance with task-related goals [20,22]. It is believed to play a critical role in applying learning strategies in new or unfamiliar situations, which may be particularly important for young drivers who are still gaining experience [19,20,22]. Previous research on acquired brain injury suggests metacognition may be particularly important for tactical decision-making while driving, including maneuvering for obstacle avoidance, gap acceptance, turning, and overtaking [23,24]. How is metacognition helpful for drivers? One study on metacognitive strategy interventions evaluated the use of driving strategies based on foundational cognitive processes rooted in "mentalizing" or comparing others' perspectives with one's own [25,26]. The intervention, which was associated with improved driving performance, involved participants recognizing driving-specific tasks and goals, observing the performance of other drivers in order to develop strategies, and evaluating self-performance after strategy usage [25]. Specifically, both novice (i.e. young drivers) and experienced drivers in the metacognitive strategy experimental condition exhibited significant increases in Situational Awareness (SA) and decreases in all virtual driving infringements reported in the study (i.e. motor vehicle crashes, pedestrians hit, speeding violations, stop sign errors, centerline breaking, road-edge departures) with novice drivers showing greater post-intervention improvements [25]. These findings provide evidence that metacognitive ability plays a role in reflection (thought monitoring) of behavioral performance, and improvement of driving strategy based on lessons learned. But how does "thought monitoring" influence behavior? Evidence suggests this process is rooted in a driver's interpretation of behavior.

A study of young drivers found that worse metacognition may be responsible for anger-related driving behavior and aggressive intentions while driving [27,28]. Given that interpretation of one's own thoughts was related to driving behavior, Blankenship and colleagues suggested lapses in metacognitive ability may be attributed to the relationships observed between greater thought confidence and dangerous on-road decisions [27,28]. For example, metacognition is hypothesized to play a role in how a driver interprets other driver behavior (e.g., cutting him off) and choosing the behavioral reaction. In this situation, lapses in a driver's metacognitive ability may lead to risky decisions (i.e. yelling at or tailgating the offending driver) that could put the driver and others in danger or negatively impact the driver's ability to accomplish their situation-specific goal such as arriving at a destination safely [28]. However, important questions persist: is the manifestation of risky driving behaviors the product of uncontrollable urges - impulsivity? Or is this the result of weakness in metacognitive self-monitoring ability? Despite the role metacognition is evidenced to play in driving, and the potential for this ability to be measured objectively in driving simulation, little research has explicitly examined metacognition in relation to observed driving behavior among young drivers [23].

The current study addresses gaps in the literature by simultaneously measuring metacognition, impulsivity and risky driving behavior (self-reported and in ecologically valid simulated driving scenarios) and examining their relationships. We hypothesized that individuals who report higher levels of impulsivity and worse metacognitive ability will be more likely to (1) engage in more self-reported risky driving behaviors and (2) and commit more objective risk-related driving errors on a simulated driving test. We also hypothesized that metacognitive ability will explain the relationship between impulsivity and risky driving behavior.

Methods

Study design and subsample

This subsample analysis included 65 young adult drivers between the ages of 18 and 24 years from a larger study of young drivers, executive functions and driving. The larger study recruited individuals between the ages of 16 and 24 via word-of-mouth, email advertisements, and fliers posted in the greater Philadelphia, Pennsylvania area. Inclusion criteria required holding a valid driver's license or learner's permit, having normal or corrected-to-normal vision and hearing, and being able to speak English fluently. The sub-sample of 65 drivers was limited to those participants who completed the Behavior Rating Inventory of Executive Function-Adult Version (BRIEF-A) includes the Metacognitive Index (MI) but is only valid for those 19 to 24 years of age and 18-year-olds who were no longer enrolled in high school. Participants younger than age 18 and 18 year-olds who were still in high school were excluded from this subgroup analysis because they were administered the BRIEF 2 which does not include the MI subscale index.

Measures

Metacognition

Metacognition was assessed using the 75-item BRIEF-A, a standardized, reliable and valid measure of executive functions in a daily life context [29,30]. It is composed of items pertaining to difficulties in executive function-related behaviors such as, "Gets upset quickly or easily over little things" or "I forget my name," of which, respondents rate how frequently they experience the behavior on a 3-point scale: (1) never, (2) sometimes, or (3) often [29]. The BRIEF-A includes the Global Executive Composite (GEC) summary and consists of two summary scales: the Behavioral Regulation Index (BRI) and the Metacognition Index (MI) [29]. The MI used in the current study includes five subscales: Initiate, working memory, plan/organize, task monitor, and organization of materials [29]. This scale measures metacognition as the ability to organize resources, environmental factors, and strategies for problem solving, and to monitor success [29]. MI *T-scores* were used to represent participants' metacognitive ability, where higher scores indicate worse metacognitive ability.

Driving surveys

Participants reported information regarding their driving history (e.g. years driving, hours driven per week, crashes, and citations), then completed a modified Driver Behavior Questionnaire (mDBQ). The mDBQ included eight items from the original DBQ questionnaire [31] related to engagement in intentional violations and driving errors (e.g., "ignored speed limits late at night or early in the morning," "drove close to a car ahead of you", or "misjudged the speed of an oncoming vehicle when passing a car"). Two additional items asked about engagement in cell-phone use while driving (as previously described by [8,32]. Participants rated how often they engaged in a total of 10 driving behaviors on a 6-point scale from "Never" to "Nearly all the time" with higher scores indicating more unsafe driving behavior (Table 2).

Driving simulation

The Virtual Driving Test (VDT) performance measure used in this study was developed by Diagnostic Driving Inc. (www.diagnosticdriving.com, Philadelphia, PA). This software adapted and extended a previously validated lab-based simulated driving assessment by creating a compact portable assessment that runs on with conventional hardware, is completely self-guided and commercial grade, and has been validated to predict on-road driving performance in a large sample of driver license applicants [33]. The VDT assesses driver error and skills critical to safe driving in real-world driving scenarios which include features of both rural and urban settings (such as trucks, buses, stop signs, crosswalks, and work zones) in uneventful situations as well as those that represent the most common potential crash scenarios identified by the National Highway Traffic Safety Administration [34,35]. The VDT was administered to participants utilizing an ASUS Gaming PC laptop with built-in monitor (one screen), external headphones, external mouse, and a USB-compatible, off-the-shelf steering wheel and foot pedals (Logitech G29) intended for gaming console use (Figure 1).

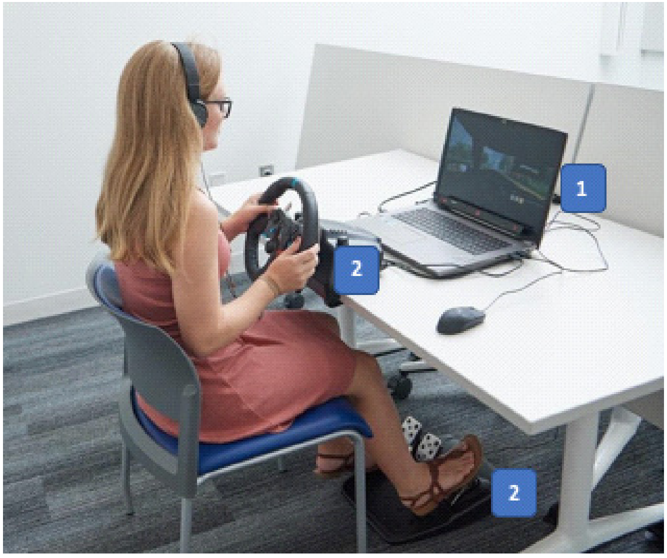

Figure 1: Workstation Set-up: 1) Laptop with built-in monitor, 2) off-the-shelf steering wheel and foot pedals.

This tool employs automated algorithms used to calculate a wide range of unsafe driving performance metrics that have previously been validated [33,35]. The metrics of risky driving used in this analysis consisted of unsafe following time, driving too fast (excessive speeding), stop sign running frequency and lane deviation (standard deviation). Unsafe following time was calculated via the frequency in which drivers followed others with less than 3 seconds of headway time between vehicles. Driving too fast was measured by the frequency in which drivers exceeded more than 120% of the posted speed limit.

Impulsivity

Impulsive personality factors were measured and included in the analysis as covariates of crashes and risky driving behavior, and of metacognition. Six items from the Eysenck Junior Impulsivity Scale were used to measure Acting Without Thinking (AWT) based upon how often respondents engage in items such as "I do and say things without stopping to think" on a 3-point likert scale [4,36,37]. Higher scores indicated more acting without thinking.

The 4-item Brief Sensation Seeking Scale-4 (BSSS-4), composed of items from Zuckerman's Sensation Seeking Scale, was used to measure the extent to which exciting or new experiences are sought despite associated risks such as "I like new and exciting experiences, even if I have to break the rules". Responses were recorded on a 4-point likert scale from strongly agree to strongly disagree [38,39]. BSSS-4 scores were recoded so that higher scores indicated greater sensation seeking tendencies.

Procedure

All study procedures were approved by the Children's Hospital of Philadelphia (CHOP) Institutional Review Board: 17-014330 and were performed in-person during a single study visit. After obtaining informed consent, participants completed a computer-administered survey that included demographics, driver's license information, impulsivity scales, and self-reported Measures of Driving Behavior (mDBQ) and Executive Functions (BRIEF-A). Shortly after, participants completed the 15-minute VDT for an objective assessment of driving performance in ecologically relevant on-road scenarios.

Statistical analyses

A Principal Component Analysis (PCA) with promax rotation was run to reduce the mDBQ items to a key risky driving factor (as in a previous study: [32]). PCAs were also conducted on BSSS-4 and acting without thinking items to generate factor component scores. Internal consistency reliability was calculated for DBQ, BSSS-4, and acting without thinking scores using coefficient "Cronbach's" Alpha. Any item loadings coefficients less than 0.4 were excluded from factors. Two-tailed Pearson correlations were conducted to identify relationships between metacognitive ability, impulsivity factor scores, risky behavior factor scores, and simulated driving performance metrics (those that showed sufficient variability). Linear and logistic regression models, where appropriate, were used to test the effect of metacognition and impulsivity on driving outcomes (risky driving and crashes, respectively). Factors that did not correlate with the variables of interest were dropped from subsequent models. Of note, crash history data were missing for 4 participants due to a survey technical error that could not be recovered (i.e., the study has accurate reported crash history data for 61 of 65 participants).

Results

Table 1 presents the demographic profile of the analytical sample. Of the 61 participants with crash history data, 33% (N= 20) reported a history of at least one motor vehicle crash. Of the total 65 participants, 34% (N= 22) reported a history of at least one citation. A positive correlation was observed between individuals reporting at least one crash and those who reported at least one citation ($r= 0.30$, $p= 0.018$)

Risky driving

The principal component analysis of the mDBQ (10 items) revealed a single component (as in a previous study: [32]). This factor consisted of 8 items, reflecting a "risky driving" component (explaining 35.98% of variance, Cronbach $\alpha= 0.81$) where intentional risky driving behaviors loaded highest (such as ignoring speed limits and unsafe overtaking as well as cell phone use). Items 6 and 7 (which were skills failures) weakly loaded to the risky driving factor (coefficients <0.4) and were excluded from the risky driving factor. See Table 2 for item loadings. Risky driving was positively associated with self-reported crashes ($r= 0.38$, $p= 0.003$) and citations ($r= 0.42$, $p= 0.001$).

Metacognition and driving

The mean of BRIEF-A MI *T-scores* was 54.15 (SD: 11.84), which fell within normal limits of the general population within this age group (<1 standard deviation). MI scores were significantly higher for males ($r= 0.36$, $p= 0.003$) indicating worse metacognitive ability, but not related to age within the narrow age range of this subsample ($r= -0.05$, $p= .726$), typical hours driven per week ($r= -0.05$, $p= .699$), or total years driving ($r= -0.09$, $p= .459$) (Table 3).

Self-reported driving outcomes

Higher MI scores (indicating worse metacognitive ability) were positively related to risky driving ($r= 0.40$, $p= .001$) as well as self-reported crashes ($r= 0.25$, $p= .049$). However, MI scores were not related to reported citations ($r= -0.01$, $p= .924$).

Virtual Driving Test-derived risky driving behaviors

Eleven percent of the subsample (N= 7) committed stop sign errors; 26% crashed into another vehicle during simulation at least once; while 28% crashed into a pedestrian at least once. In terms of speed, 94% (N= 61) drove more than 120% of the posted speed limit at least once, while 55% (N= 36) engaged in this behavior at least 3 times. Ninety-three percent of the sample (N= 60) had an unsafe following time of <3 seconds at least once, while 48% of the sample (N= 31) engaged in this behavior at least 3 times during simulation. The average lane deviation (standard deviation) from the center of the road was .69 meters (SD: 0.11 meters).

Higher MI scores were positively associated with making virtual stop sign errors ($r= 0.27$, $p= .030$); however, no other direct relationships were observed between metacognitive ability and simulated driving performance variables. Self-reported risky driving was positively related to instances of driving too fast (M= 3.75, SD= 3.23; $r= 0.28$, $p= .026$) during simulation.

Impulsivity

The principal component analysis indicated that all 4 items of the BSSS-4 loaded onto one sensation seeking component (explaining 57.91% of variance, Cronbach $\alpha= 0.78$). All 6 AWT items loaded onto one factor analysis component (explaining 54.45% of variance, Cronbach $\alpha= 0.83$). The analysis showed a moderate positive correlation ($r= 0.53$, $p<.001$) between factor scores of the two measures, meaning that drivers high in one form of impulsivity were also high in the other. The AWT factor was positively associated with worse metacognitive ability ($r= 0.39$, $p=.002$) while no significant relationship was observed between the sensation seeking factor and metacognitive ability ($r= -0.17$, $p= .189$). AWT and SS were significantly related to reported risky driving (AWT: $r= .31$, $p=.013$; SS: $r= 0.28$, $p= .027$); however, no significant associations were observed between these constructs and simulated driving performance metrics.

Regression models

Linear regressions revealed that AWT and SS were significant predictors of reported risky driving behavior (AWT: $F(1, 63)= 6.57$, $p=.013$; SS: $F(1, 63)= 5.16$, $p= .027$), Greater AWT ($\beta= 0.307$, $p= .013$) and SS ($\beta= 0.275$, $p= .027$) were associated with more risky driving. Multiple hierarchical regression showed metacognition, AWT, and SS together significantly predicted reported risky behavior: $F(3, 61)= 5.469$, $p= .002$. However, metacognition ($\beta= 0.343$, $p= .007$) showed a significant association with risky driving above and beyond AWT and SS, with worse ability related to more risky behaviors. A logistic regression with history of crashes as the outcome showed that metacognition alone was a significant indicator [$F(1, 59)= 4.049$, $p= .049$], with worse ability ($\beta= 0.253$, $p= .049$) related to crashes. Multiple hierarchical logistic regression showed metacognition, AWT, and SS did not significantly predict crashes together: $F(3, 57)= 1.448$, $p= .238$. Metacognition was not a significant indicator of crashes ($\beta= 0.265$, $p= .056$) with AWT and SS in the model.

Table 1: Demographic Profile of Young Driver Sample (N = 65).

Variable Name	Mean (SD) / %
Age in Years	21.2 (1.9)
Female	52.3%
Ethnicity	
Non-Hispanic White	52.3%
Non-Hispanic African-American	15.4%
Non-Hispanic Asian	13.9%
Multiple/Mixed	9.2%
Hispanic	7.7%
Other	1.5%
Years Driving	4.8 (12.2)
Typical Hours Driven per Week	5.3 (5.7)

Note: SD = standard deviation

Table 2: Principle Component Single Factor Analysis loadings per survey item on "risky driving" factor score.

Item	Modified Driver Behavior Questionnaire (mDBQ) Item	Risky Driving Factor
1	Ignored speed limits late at night or early in the morning?	0.82
2	Drove close to a car ahead of you or flashed your lights as a signal to go faster or get out of your way?	0.63
3	Became impatient with a slow driver in the left passing lane and passed on the right?	0.78
4	Drove with only "half an eye" on the road while looking at a map or using the controls in the car?	0.61
5	Took a chance on going through an intersection when the light turned red?	0.47
*6	Misjudged the speed of an oncoming vehicle when passing a car?	0.25
*7	Failed to check your mirrors before pulling out of a parking spot or changing lanes?	0.39
8	Failed to notice someone stepping out from behind a bus or parked vehicle?	0.50
9	Talked on a cell phone while driving?	0.67
10	Answered a text message while driving?	0.66

Note: "*" = Removed from factor due to weak item-factor loadings (correlation coefficient < .4).

Table 3: Pearson correlation coefficients between variables.

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Age	-												
2	Sex	0.06	-											
3	Years Driving	0.91***	0.08	-										
4	Mean Hours Driven/Week	-0.03	0.16	0.02	-									
5	MI (Metacognitive Ability)	-0.04	0.36**	-0.09	-0.05	-								
6	AWT Factor	0.01	0.24	0.03	0.03	0.39**	-							
7	Sensation Seeking Factor	0.06	0.15	0.08	0.05	0.17	0.53***	-						
8	Risky Driving Factor	0.03	0.19	0.11	0.22	0.40**	0.31*	0.28*	-					
9	At least one crash	0.08	0.03	0.06	0.14	0.25*	0.06	0.09	0.38**	-				
10	At least one citation	0.20	-0.03	0.24	0.27*	-0.01	0.11	0.25*	0.42**	0.30*	-			
11	Driving Too Fast (Sim)	-0.12	0.26*	0.00	0.27*	0.13	0.02	0.09	0.28*	0.17	0.19	-		
12	Lane Deviation (SD) (Sim)	-0.17	-0.04	-0.11	0.02	0.11	-0.05	-0.11	-0.11	0.00	-0.01	0.05	-	
13	Unsafe Following Time (Sim)	-0.07	0.15	-0.07	-0.03	0.10	-0.09	0.03	-0.07	0.08	-0.19	0.12	0.27*	-
14	Stop Sign Error (Sim)	-0.21	0.05	-0.17	-0.01	0.27*	0.19	-0.01	0.07	-0.05	0.00	0.31*	0.15	0.05

Note: MI: Metacognition Index summary scale; BRIEF-A, * p < .05., ** p < .01, *** p<.001, AWT: Acting without thinking; Sim: Simulated driving variable; SD: Standard Deviation.

Discussion

This paper examined the relationships between metacognitive self-monitoring ability, impulsivity, risky driving behavior, and simulated driving performance in young adult drivers. Greater impulsive tendencies in acting without thinking and sensation seeking were related to more reported risky driving, suggesting that risky decision-making may be a result of poor judgment from either acting without thinking (e.g., spur of the moment impulses temporarily take over such as yelling or honking after being cut off) or sensation seeking (i.e., having risky intentions, such as driving at high speeds for the thrill). However, this study found that only metacognitive ability was independently associated with risky driving when examined in a model with acting without thinking and sensation seeking. Specifically, individuals with worse metacognitive ability were more likely to have a history of motor vehicle crashes, engaged in more reported risky driving, and failed to stop at stop signs more often during the simulated assessment. Self-reported risky driving was also associated with driving too fast in the VDT, which suggests metacognition could be indirectly related to objective risky driving performance in excessive speeding as well (and should be studied in future work).

Metacognition – a cognitive process known to be important for learning and reacting to the environment – may be especially important when it comes to driving safely [20,22-24]. Findings from this study connecting this self-monitoring ability to risky driving and crashes supports the hypothesis that metacognition is relevant to driver decision-making. This builds on prior work [27] to suggest that metacognition may play a role in not only reacting appropriately to on-road situations but also monitoring how decisions impact the driver's goal (arriving to destination safely or a timely work arrival). For example, metacognition may be important for reacting and learning to adapt to dangerous on-road situations such as a car suddenly pulling out in front of a driver's vehicle. In this situation, metacognition may help the driver evaluate which possible behavioral reactions (i.e., slowing down, honking horn, or yelling) might best be used to respond with respects to overarching driving goals.

However, the question still remains: how does metacognition relate to impulsivity? Findings from this study suggest lapses in metacognitive self-monitoring ability may be related to risky behaviors attributed to impulsive, lack of well-thought-out actions exhibited by young drivers. Metacognitive ability may control for in-the-moment impulsive actions. The finding that metacognitive ability was related to acting without thinking but not sensation seeking supports prior research findings that greater sensation seeking impulsivity does not reflect weakness in higher-level cognitive ability. This suggests factors other than higher level cognition may play a role in sensation seeking tendencies. Moreover, if sensation seeking relates to flawed overarching goals (e.g. the desire to experience the thrill of high speeds) where metacognition does not, this suggests metacognition may be responsible for monitoring and careful planning of isolated behaviors while less reflective of the overarching driving goal itself. However, this needs to be examined in future studies.

The finding that metacognition was related to greater risky driving behavior and MVCs in the current study also supports prior research [25], which suggests that these self-reported assessments of metacognition and impulsivity may be useful for identifying individuals who engage in risky driving practices. Particularly, using the BRIEF to identify at-risk drivers may pose an advantage over lengthy neuropsychological test batteries given that it is a quick and easy-to-administer survey that can be used in various settings where on-site interventions may be deployed (e.g. clinics: [6]).

Future research should elucidate which types of driving behaviors are influenced by metacognitive ability. Moreover, is worse metacognitive ability responsible for impulsive decisions made without due deliberation? Or is it reflective of flawed overarching goals rooted in poor judgement? In the context of driving, more evidence on metacognition's relationship to risky behavior and impulsivity may provide answers to these questions. Research on the factors that affect sensation-seeking and discriminate this construct from acting without thinking in driving may be particularly helpful for understanding what causes risky driving. It is also recommended that metacognition, impulsivity and risky driving should be examined in more robust models with larger more generalizable samples to investigate causal relationships and objective assessments of cognitive ability in relation to driving capacity. Further research on higher-level cognition and its impact on driving may allow for effective intervention targeting of at-risk young adults to improve cognitive ability or compensate for developmental weaknesses.

It is important to note that this study is not without limitations. First, this study recruited a sample of drivers from the Philadelphia area. This research should be replicated with a larger and more nationally representative sample to confirm the generalizability of these findings. Second, this study included self-report measures of metacognition, impulsivity, and driving behaviors, which comes with well-known limitations in the field. In an attempt to tackle these limitations, this study included an objective simulated driving assessment in addition to the self-reported driving surveys. With regard to simulated driving, driving variables such as count of crashes were limited in variability due to a low occurrence, and therefore, were not fit for use in analysis. This may explain why metacognition and impulsivity were not related to simulated crashes.

Conclusion

This study extends initial evidence of metacognitive self-monitoring's impact on risky decision-making in young drivers. Worse metacognitive ability was related to reported crashes and both reported and simulated risky driving. Greater acting without thinking and sensation seeking forms of impulsivity were also associated with reported risky driving. However, metacognitive ability significantly predicted risky driving above and beyond acting without thinking and sensation seeking. Measuring metacognitive ability via the Behavior Rating Inventory of Executive Function (BRIEF) is a useful, ecologically valid method for identifying risky drivers. The findings from this study set a framework for understanding the role metacognition plays in the manifestation of risky driving behavior in young adults.

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Conflict of Interest

Dr. Flaura K. Winston and CHOP own part of Diagnostic Driving, Inc., the company whose driving simulation software was utilized for this study. The results of this study were externally reviewed by Dr. Sean Commins of Maynooth University who does not have reporting obligations to CHOP or Dr. Winston.

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