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Predicting Motor Vehicle Collisions in a Driving Simulator in Young Adults Using the Useful Field of View Assessment

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Abstract

Objective—Being involved in motor vehicle collisions is the leading cause of death in 1 to 34 year olds, and risk is particularly high in young adults. The Useful Field of View (UFOV) task, a cognitive measure of processing speed, divided attention, and selective attention, has been shown to be predictive of motor vehicle collisions in older adults, but its use as a predictor of driving performance in a young adult population has not been investigated. The present study examined whether UFOV was a predictive measure of motor vehicle collisions in a driving simulator in a young adult population.

Method—The 3-subtest version of UFOV (lower scores measured in milliseconds indicate better performance) was administered to 60 college students. Participants also completed an 11-mile simulated drive to provide driving performance metrics.

Results—Findings suggested that subtests 1 and 2 suffered from a ceiling effect. UFOV subtest 3 significantly predicted collisions in the simulated drive. Each 30 milliseconds slower on the subtest was associated with nearly a 10% increase in the risk of a simulated collision. Post-hoc analyses revealed a small partially mediating effect of subtest 3 on the relationship between driving experience and collisions.

Conclusion—The selective attention component of UFOV subtest 3 may be a predictive measure of crash involvement in a young adult population. Improvements in selective attention may be the underlying mechanism in how driving experience improves driving performance.

Keywords

Useful field of view; selective attention; driving experience; top-down processing; driving simulator

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INTRODUCTION

Useful Field of View

Useful Field of View (UFOV) has been empirically shown to be a viable screener for poor driving outcomes in individuals over the age of 65 (Clay et al., 2005). An important aspect of driving safety includes the specific functional measure of visual processing speed (Roenker, Cissell, Ball, Wadley, & Edwards, 2003). Speed of processing training aimed at improving UFOV also aids drivers in accurately recognizing simultaneous, peripheral objects while moving in a vehicle (Leat & Lovie-Kitchin, 2006). Consequently, performance on the UFOV has consistently been found to be the strongest predictor of motor vehicle crashes (MVCs) in older adults (Ball, Beard, Roenker, Miller, & Griggs, 1988; Clay et al., 2005). However, little research has considered the use of UFOV as a predictor of driving performance in a young adult population - an age group also overrepresented in MVCs (Evans, 2004).

Young adult MVCs

Being involved in MVCs is the leading cause of death in 1 to 34 year olds (Centers for Disease Control and Prevention [CDC], 2013), and risk is particularly high in young adults. In 2012 there were 1,875 MVC fatalities in drivers aged 15 to 20 years old and 184,000 injuries in drivers aged 15 to 20. In fact, during the same period, nearly 10% of all drivers involved in fatal MVCs were 15 to 20 years old (National Highway Traffic Safety Administration [NHTSA], 2014a) . Teen drivers (ages 16 to 19) are three times more likely than drivers aged 20 and older to be in a fatal MVC (Insurance Institute for Highway Safety [IIHS], 2012). Thus, it is important to identify risk factors in this younger population with the overarching goal of reducing injuries and fatalities due to MVCs.

Prior research has investigated the attention maintenance skills of young drivers using a driving simulator (Chan, Pradhan, Pollatsek, Knodler, & Fisher, 2010). Young drivers were compared to experienced drivers pertaining to the amount of time an individual drove while not focusing on the road. Chan et al. (2010) (Chan et al., 2010) found that young drivers lose eye contact with the road more frequently and for longer periods of time than experienced drivers. These limited attention maintenance skills appear to be a factor in why young drivers are at a higher risk for MVCs.

UFOV in Young Adults

Because UFOV performance has shown to consistently be a strong predictor of MVCs in older adults (Ball et al., 1988; Clay et al., 2005), its use in young drivers warrants investigation. There have been a few studies that have investigated UFOV in young adults. Bennett et al. (2009) collected normative data for participants aged 5-22 years old to determine UFOV's utility in the evaluation of children. Findings indicated UFOV is suitable for assessment in young adults, and adult levels of UFOV scores are reached by age 14 (Bennett, Gordon, & Dutton, 2009). Sekuler and colleagues (2000) (Sekuler, Bennett, & Mamelak, 2000) examined UFOV changes as a function of age in 15-84 year old participants and found that declines in UFOV performance begin early in life, around age

20. While both older adults and young adults may exhibit UFOV decrements, the mechanisms underlying the decrements differ.

Top-down cognitive processes (processes driven by experience and knowledge (Wickens & Hollands, 2000)) generally affect young drivers as opposed to the bottom-up processes affecting older adults (Lees & Lee, 2009). In young adults, the deterioration in UFOV performance is due to a decrease in the efficiency with which information can be extracted from a cluttered scene rather than a shrinking field of view (Sekuler et al., 2000). Teens are more likely to underestimate dangerous situations, or fail to recognize hazardous situations (Jonah & Dawson, 1987). Much work has focused on the utility of cognitive training programs theorized to improve UFOV and speed of processing in older adults (Ball, Edwards, & Ross, 2007; J. D. Edwards et al., 2005). Recently, this work has been expanded to include younger adults as well (Burge et al., 2013). Burge and colleagues (2013) (Burge et al., 2013) examined the underlying mechanisms behind speed of processing training and found that it yielded increased attentional efficiency in young adults as well. Findings are promising for the use of UFOV as a predictor of driving performance in younger drivers.

Purpose

The purpose of the present study was to determine whether UFOV was an effective tool to identify young adult drivers who are at increased risk for being involved in a MVC during a simulated drive. The present study is among the first to examine whether UFOV could also predict MVCs in young adults. It was hypothesized that poorer performance on each subtest of the UFOV would predict poorer simulated driving performance as indicated by the number of MVCs in the simulator.

METHOD

Participants

Participants included 60 college students (M_{age} = 19.70 years, *SD* = 2.34 years; 51% male, 70% Caucasian) from a large, public university in the Southeast as part of a larger study investigating personality, cardiovascular reactivity, distracted driving, and simulated driving performance. All students were enrolled in introductory psychology classes and received required research credits for their participation. Prospective participants were informed about the experiment via classroom announcement. Inclusion criteria included: participants having text messaging capability on their phone, be willing to use the phone for approximately 15 minutes during the appointment, possess a valid driver's license, and be between the ages of 17 and 30. Exclusion criteria included any significant illnesses or disabilities that would prevent them from operating a motor vehicle. Participants reported an average of 3.13 years (*SD* = 2.27) since receiving their driver's license and driving an average of 4.14 days per week (SD = 2.15).

Design and Procedure

Upon arrival to the appointment, participants drove a simulated 5-mile calibration drive, which allowed the individual to familiarize him or herself with the STISIM™ simulator and to minimize practice effects. Participants then completed an 11-mile drive. Following the simulated drive, participants were directed to a desktop computer and asked to complete a demographic questionnaire. The UFOV assessment was then administered on a separate desktop computer. Upon the completion of the experiment, participants were debriefed and provided with research course credit for compensation.

Measures

Demographic questionnaire—This self-report measure was used to gather the participants' age (date of participation – date of birth), gender, race/ethnicity, and the number of years as licensed driver (date of participation – date of receiving full licensure). These data were used to describe the sample and provide a context in which to interpret the findings.

STISIM Drive—STISIM Drive (Drive, 2007) is a PC-based driving simulator that allows participants to drive in a safe and realistic environment (Stavrinos et al., 2013; Vance, Fazeli, Ball, Slater, & Ross, 2014). Participants were asked to sit in front of three 20" LCD computer monitors. The visual perspective of the participants included a roadway view from a vehicle driver's position complemented by dashboard instruments (See Figure 1). Interactive features include a steering wheel, blinker, driver seat, horn, and acceleration/ brake pedals.

Driving Scenario—Participants engaged in a brief 5 mile calibration drive to introduce the simulator and to achieve stable driving performance (e.g., ability to maintain a particular speed). A verbal warning was presented to the driver when their speed was 7 miles per hour greater or less than the posted speed limit, for every 5 seconds that appropriate speed was not maintained. Research assistants recorded and summed the number of verbal warnings drivers received to determine whether additional practice was needed (threshold of > 4 warnings constituted a "fail" and required another drive). None of the study participants required a second practice drive.

Once the participant demonstrated stable driving performance in the calibration drive, they drove an 11 mile long scenario that featured a two-lane road with traffic flowing in a bidirectional manner. The scenario was enhanced by day-time suburban scenery and surrounding simulated vehicles, with speed limits varying between 25mph and 65mph within the scenario. Participants were required to navigate through a total of twelve unexpected events that were hypothesized to evoke a response by the participant to avoid crashing (e.g., a lead vehicle braked suddenly, a pedestrian darted into the street, a cyclist swerved into the participant's lane).

Motor vehicle collisions (MVCs) were the primary outcome measure of interest. A total number of simulated (virtual) MVCs was calculated by summing the total number of times participants hit a person on the road (pedestrian), hit another vehicle/cyclist, and ran off the road.

Useful Field of View (UFOV)—UFOV is a computerized cognitive task that measures the speed of visual processing, divided attention, and selective attention (Ball et al., 1988; Clay et al., 2005). Each UFOV subtest begins with an introductory practice session to introduce the screen set-up and choice options. The scoring process is standard for all three subtests. After two correct answers, the UFOV task will automatically shorten stimulus presentation time for the next item; if the response is incorrect, stimulus presentation time lengthens. Testing continues until 75% of the answers are correct in order to estimate the perceptual threshold. Participants were asked to detect, identify, and localize a target image that was displayed briefly on the computer screen. The entire task consists of three subtests: Processing Speed (PS), Divided Attention (DA), and Selective Attention (SA). UFOV is a 15-minute computer-administered test and provides one score, reported in milliseconds (ms), for each subtest.

During subtest 1(PS), a white box containing the target object of a truck or a car appears in the center of the screen. The participant must correctly identify the object as a car or a truck. Subtest 2 (DA) continues to measure for processing speed, but further challenges the individual by adding an attentional component. In addition to identifying the target object in the white box, the participant must also locate a simultaneously presented car displayed in the periphery. The target object can be either a car or a truck; however, the periphery object is always a car, making location of the periphery stimuli the objective and not identification of the periphery stimuli. Subtest 3 (SA) duplicates the tasks of subtest 2, but includes 47 distractor triangles that encompass the entire screen and surround the periphery car as shown in Figure 2. UFOV has been shown to be a strong predictor of MVCs in driving simulators in older adults (Clay et al., 2005). Lower scores (ms) indicate better performance. Test-retest reliabilities of the computerized UFOV are high ($r = 0.884$) (J. D. Edwards et al., 2005) and is appropriate for use in young adults (Bennett, Gordon, et al., 2009).

Data Analysis Plan

To control for within-subjects covariance, a generalized estimating equation (GEE) Poisson regression was selected to analyze the effect of all UFOV subtests on simulated MVCs. Risk Ratios (RR) and their 95% confidence intervals were calculated for all predictors. All analyses were conducted in SAS 9.3 (SAS, 2011), and p values less than 0.05 were considered significant. Descriptive statistics were obtained for participants and each of the UFOV subtests as shown in Table 1. UFOV subtest 1 suffered from a ceiling effect. A perfect score of 17 ms was achieved by 95% of participants. Subtest 2 also suffered from a ceiling effect with 80% of participants attaining a perfect score of 17 ms; however, data from subtest 3 ranged from 17 ms to 347 ms, with only 4.76% of participants obtaining a perfect score of 17 ms.

Intercorrelations were run for all predictor variables (see Table 2) in the GEE Poisson model. Each UFOV subtest were included as predictors of MVCs. Due to multicollinearity between age and years since licensure ($r = .92$, $p < .0001$), age was not included in the model. Years since licensure was included as a measure of driving experience, as previous research has found the length of licensure as a more powerful effect than age (McCartt, Mayhew, Braitman, Ferguson, & Simpson, 2009). Because men have been found to have higher crash risks than women (Elvik, 2010), gender was also included in the model. The GEE Poisson model thus included gender, years since licensure, UFOV subtest 1, UFOV subtest 2, and UFOV subtest 3.

The effects of significant UFOV subtests were further explored with post-hoc analyses to better examine the mechanisms by which they predict MVCs in the simulated drive. Because experience is a significant predictor of driving performance in young adults (McCartt et al., 2009), mediation analyses were conducted to investigate if improved attentional control as measured by UFOV is the mechanism through which increased experience improves driving outcomes. Upper and lower confidence intervals were calculated using bootstrapping methods provided by the Hayes' (2012) Process macro, using an ordinary least squares or maximum likelihood path framework to estimate direct and indirect effects (Hayes, 2012).

RESULTS

Years since licensure (M = 3.13 years, SD = 2.27) was a highly statistically significant predictor of MVCs in the simulated drive ($\chi^2(1) = 13.50$, $p = .0003$). For each additional year since receiving licensure, the risk of a MVC reduced by 11%. Only UFOV subtest 3 ($\chi^2(1) = 7.52$, $p = .01$) was a statistically significant predictor of MVCs in the simulated drive. Each 30 ms slower on UFOV subtest 3 was associated with a nearly 10% increase in the risk of a MVC in the simulated drive. See Table 3 for the rate ratios and 95% confidence intervals for all predictors.

The relationship between the number of years since licensure and MVCs was statistically significantly mediated by UFOV subtest 3, but the effect was very small. Time since licensure had a significant direct effect on MVCs in the simulated drive ($t = -3.23$, $p = .002$) and total effect (direct effect + indirect effect [$t = -3.62$, $p = .0004$]). The indirect effect was −.005, (95% CI: −0.011 - −0.001), and as the 95% CI did not include 0, suggests UFOV subtest 3 statistically significantly partially mediates the relationship of time since licensure on MVCs. However, the proportion of the indirect effect to the maximum possible indirect effect that could have occurred is small ($\kappa^2 = .03$ (SE = .02), [95% CI = .007 - .07]), indicating only a small linear indirect effect. The coefficients for each effect are displayed in Figure 3.

DISCUSSION

These data suggest that UFOV subtests 1 and 2 suffered from ceiling effects, which in this instance indicate that these subtests might not be as useful in a young adult population as in older adults to predict driving performance. Previous research has found that as children develop, their UFOV scores on all subtests improve and reach adult levels by age 14 (Bennett, Gordon, et al., 2009). The results of this study indicate that selective attention (subtest 3) appears to be the best predictor of driving performance in this population. If similar results can be replicated in a larger sample, this may suggest a real, potential benefit of targeting young adults identified as being at increased risk for MVC involvement.

UFOV varies with practice and age, and individuals of all ages can benefit from training with positive effects that will endure for a minimum of six months (Ball et al., 2007) and even up to two years (Vance et al., 2007). While deficits in bottom-up cognitive processing generally affect older adults, top-down cognitive processes (i.e., lack of experience) generally affect young drivers (Lees & Lee, 2009). Teens are more likely to underestimate dangerous situations, or fail to recognize hazardous situations (Jonah & Dawson, 1987). The results of this study further support the role that experience plays in driving performance. Furthermore, the results of this study indicate that one of the underlying mechanisms by which experience improves driving performance is through improvements in selective attention, as measured by UFOV subtest 3.

If future studies confirm these preliminary findings, it may be possible to supplement the current UFOV tasks to also include category levels and risk statements specifically for use with young adults. Category levels and risk statements exist for older adults, ranging from very low risk to very high risk. For example, the high-risk score range of 350 ms to 500 ms indicates severe central vision loss and/or very slowed processing speed in older adults. While future research may be needed to investigate poor UFOV scores due to vision loss or impairment in young adults, top-down processes affect UFOV scores in young adults. The highest score on any UFOV subtest in this study was only 380 ms. These results suggest category levels and risk statements may need to be created specifically for a young adult population, taking into consideration the processes that affect UFOV scores and the range of UFOV scores in young adults.

Because UFOV was specifically created to aid individuals over the age of 65, it is possible that a revised version of the UFOV is necessary in order to accommodate young adults. It is also a possibility to lower the threshold of time necessary to identify each object. Presently, a perfect score on UFOV is 17 ms. An adjusted perfect score (i.e., lower than 17 ms) may be used in young adults, and UFOV subtests 1 and 2 may not suffer from a ceiling effect. Future research into this population should consider utilizing UFOV subtest 4, which adds a second selective attention subtest in conjunction with same/different discriminations on two objects in the center of the screen (Edwards et al., 2006). The added difficulty of subtest 4 may provide greater sensitivity in young adults. Future research should include a larger sample size to fully investigate the possible mediating effect of selective attention on the relationship between driving experience and MVCs. While the results indicated selective attention statistically partially mediated the effect of years since receiving licensure on MVCs, the effect was very small and requires a larger sample size to be better analyzed.

No study is without limitations. A few are noted here. While driving simulators provide much needed experimental control to test hypotheses with regards to driving performance, it is difficult to truly ascertain the degree to which simulated driving performance maps on to real world driving behavior. For example, in the real-world, drivers have incentive to avoid MVCs, because MVCs may result in injury. The same incentive is likely lacking in a driving simulator scenario and could have potentially influenced the findings.

Naturalistic driving approaches have been used to overcome the limitations that may exist both driving simulators and epidemiological approaches to investigating driving performance (Dingus, Hanowski, & Klauer, 2011). Future research may consider employing naturalistic methodology to examine the effectiveness of UFOV as a predictor of driving performance.

Also, the participants were a convenience sample, but the sample was representative of young drivers in the region given the varied levels of driving experience. The youngest participants were 17 years of age, but were not typical “teen drivers” in the sense that there were college students, and thus may not be comparable to those of similar age who are still in high school. These drivers may have had different driving habits than the typical 17 year old. As a result, this reinforced the use of driving experience as a predictor of driving performance rather than age, along with previous research noting the length of licensure as having a more powerful effect (McCartt et al., 2009). However, future research should consider including additional driving experience information (e.g., days driven per week and miles driven per week) to compile a more informative measure of driving experience.

CONCLUSIONS

These data provide preliminary evidence that the third subtest of the UFOV task may be a predictive measure of crash involvement in a young adult population. If similar results can be replicated in a larger young adult sample, findings may indicate the need to target at-risk individuals in training efforts. Insurance companies could also benefit from the UFOV to measure and manage driving risk in clients. Furthermore, if future studies confirm these preliminary findings, it may be possible to modify the current UFOV task to include category levels and risk statements for use with a young adult population.

Finally, speed of processing training aimed at improving UFOV has been used in an older adult population and significantly improves driving outcomes (Roenker, Cissel, Ball, Wadley, & Edwards, 2003), most notably reducing the risk of MVC involvement and being deemed at-fault in MVCs (Ball, Edwards, Ross, & McGwin, 2010; Ball et al., 2006). These speed of processing training programs may be similarly directed for use in young adults. The use of these training programs in young adults may also improve driving outcomes in young adults and accelerate driver education.

Practical Applications

UFOV subtest 3 may be used to predict MVC involvement in young adults, and thus, identify young adults who may need additional driving training. Furthermore, training programs aimed at improving UFOV may also improve selective attention in young adults, reducing the risk of MVCs and ultimately injuries and fatalities.

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Figure 1.
Photo of STISM simulator

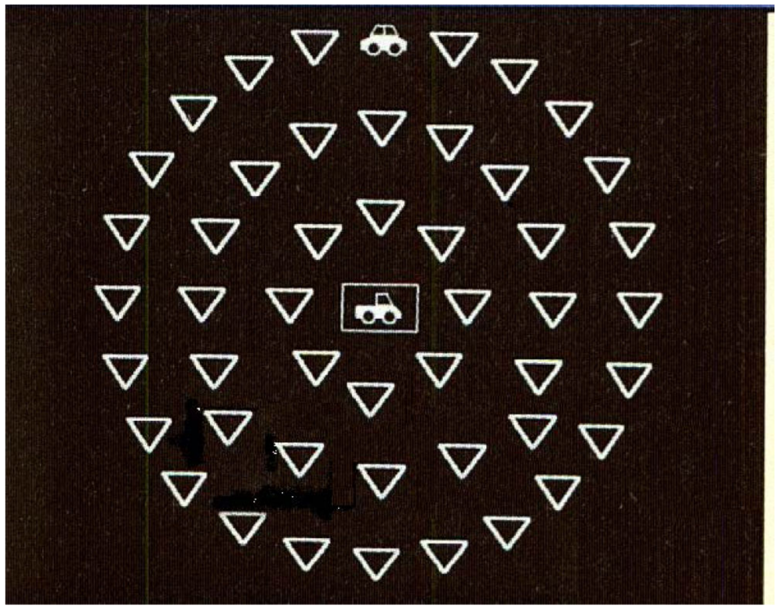

Figure 2.
Diagram of UFOV Subtest 3; central target object present, peripheral object present, and peripheral distractors present

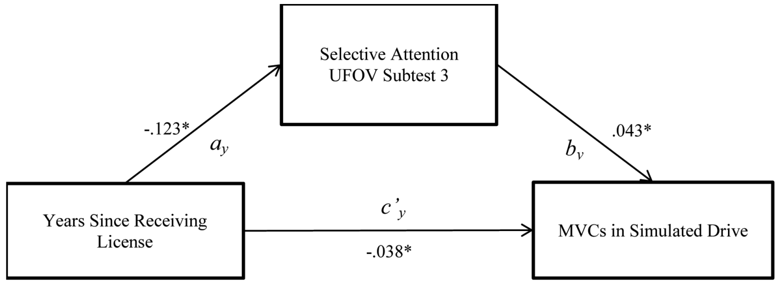

Figure 3.

The mediating effect of Selective Attention on the relationship of Years Since Receiving Full Licensure and MVCs during the Simulated Drive. * indicates p < .01, and the indirect effect = −0.05 (95% CI: −0.013 - −0.001). The proportion of the indirect effect to the maximum possible indirect effect that could have occurred is small (κ^2 = .03 (SE = .02), [95% CI = .007 - .07]), indicating this is a small linear indirect effect.

Table 1

Sample Descriptives (N = 60)

Variables	*M (SD)*	*n* (%)	Range
Demographic variables			
Age (Years)	19.70 (2.34)		17.6-30.9
Gender (number of men)		32 (50.8%)	
Ethnicity (Caucasian)		45 (70.3%)	
Years since receiving full driver's license	3.13 (2.27)		0.4-14.9
Days driven per week	4.14 (2.15)		0-6
Cognitive variables			
UFOV subtest 1: Processing Speed* (ms)	17.73 (3.40)		17-37
UFOV subtest 2: Divided Attention* (ms)	37.59 (61.65)		17-380
UFOV subtest 3: Selective Attention* (ms)	82.37 (56.94)		17-347
Driving performance variables			
MVCs	4.10 (2.41)		0-10

Note.

* = Higher scores indicated poorer performance

Table 2

Correlations for Variables Used in Model Predicting MVCs in the Simulated Drive

	Age	Years Since Licensure	UFOV 1	UFOV 2	UFOV 3
Age	1	0.92***	0.03	−0.07	−0.14*
Years Since Licensure	-	1	−0.12*	−0.05	−0.16**
UFOV 1	-	-	1	0.10	−0.09
UFOV 2	-	-	-	1	0.51***
UFOV 3	-	-	-	-	1

Note.

*$p < .10$

**$p < .05$

***$p < .0001$

Table 3

Risk Ratios, Standard Errors (SE) and 95% Confidence Intervals (CI) for Gender, Time Since Licensure, and all UFOV subtests for MVCs During the Simulated Drive

Predictor	***RR (SE)***	**95% CI**
Gender		
Female	1.17 (0.16)	0.89-1.53
Time Since Licensure		
+ 1 Year	0.89 (0.03)	0.83-0.94
UFOV Subtest 1		
+10 ms	1.12 (0.09)	0.95-1.31
UFOV Subtest 2		
+60 ms	0.97 (0.04)	0.90-1.04
UFOV Subtest 3		
+30 ms	1.09 (0.04)	1.02-1.16