Jun 25th, 12:00 AM

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Pierro Hirsch
Virage Simulation, Montréal, Canada

Francois Bellavance
HEC Montréal, Montréal, Canada

Siavash Tahari
Université de Montréal, Montréal, Canada

Jocelyn Faubert
Université de Montréal, Montréal, Canada

Hirsch, Pierro; Bellavance, Francois; Tahari, Siavash; and Faubert, Jocelyn. Towards the Validation of a Driving Simulator-Based Hazard Response Test for Novice Drivers. In: Proceedings of the Eighth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, June 22-25, 2015, Salt Lake City, Utah. Iowa City, IA: Public Policy Center, University of Iowa, 2015: 338-344.

TOWARDS THE VALIDATION OF A DRIVING SIMULATOR-BASED HAZARD RESPONSE TEST FOR NOVICE DRIVERS

Pierro Hirsch[1], Francois Bellavance[2], Siavash Tahari[3] & Jocelyn Faubert[3]
Virage Simulation[1], HEC Montréal[2], Université de Montréal[3]
Montréal, Canada
Pierro.hirsch@viragesimulation.com

Summary: Underdeveloped hazard perception skills are associated with the higher crash risk of young novice drivers. Some driver licensing authorities use hazard perception tests (HPTs) that measure reaction times or multiple-choice responses to brief driving scenes videotaped from a vehicle traveling at legal speeds. To date, evaluations of the association between HPT scores and novice driver crash rates have been mixed. Several possible explanations for this are: high-risk novice drivers may offset good HP skills by exceeding the speed limit; current HPTs do not capture behavioral responses to hazards from candidates whose attention is engaged in the driving task; there is no established typology of driving hazards that might produce a finer-grained analysis of test results, and; current measures of HP ability may lack sensitivity. To address these potential flaws, we developed a driving simulator-based Hazard Response Test (HRT) in which drivers respond to sixteen programmed hazard events derived from a proposed typology that combines visible or hidden, real or potential conflicts, while driving over three continuous routes. The study results indicate no statistically significant difference in crash rates between young novice and experienced drivers. However, a novel, composite measure called the Continuous Time to Collision (C-TTC) did discriminate between young novice and older experienced drivers. Additional research on the validation of this measure and further refinement of the hazard typology could contribute to the creation of a standardized, driving simulator-based HRT for use in the evaluation of novice, professional and aging drivers.

INTRODUCTION

Compared with experienced adult drivers, young novice drivers are overrepresented in road traffic injury in all jurisdictions world-wide, most likely due to their relative immaturity and lack of driving skill and experience (Mayhew & Simpson, 1995). Crash risk decreases, on average, with increased driving experience even after the confounding effects of age have been controlled (Maycock & Lockwood, 1993). One potential reason for the safety benefits of driving experience is the improvement in a driver's ability to perceive and to respond to hazards, defined as dangerous situations in the traffic environment (Deery, 1999). Some government licensing authorities test hazard perception ability by asking candidates to respond to brief driving scenes videotaped from a vehicle traveling at legal speeds. HPT scores are based on the time delay between the appearance of the hazard and the mouse click response of the candidate indicating when or where the hazard appeared or which one of four pre-selected actions he would select, e.g. slow down (Bellavance et al., 2005).

Evaluations by licensing authorities that matched HPT scores to actual driving records produced mixed results. Congdon (1999) compared the HPT scores of nearly 100,000 probationary drivers with their first year crash records and found that novice drivers with lower HPT scores were more likely to be in the Fatal/Serious injury group but that this likelihood varied with interacting variables such as age, sex, length of licensure and age at licensing. These interactions indicate that reaction time, the primary measure of HPTs, has different effects for different sub-populations. An evaluation by Wells et al. (2008) of HPT scores and self-reported crashes found that safety benefits were associated with decreased crash risk for only one type of crash, i.e. non-low-speed accidents where drivers accept some blame.

There are several potential explanations for these mixed results. Current government HP tests are not based on a hazard typology, e.g. visible versus hidden hazards (see Borowsky et al., 2013). A crash typology might produce a finer grained analysis of the relationship between HPT scores and crashes. Also, HPT events are videotaped at legal driving speeds. The higher speeds commonly selected by young male drivers could offset the safety benefits of good hazard perception skills. In addition, government HPTs do not capture the behavioural responses of candidates who are engaged in the complex task of driving.

This article reports the results of an experiment designed to improve hazard perception testing. First, based on a theoretical model proposed by Groeger (2000), we created a Hazard Response Test (HRT) on a realistic driving simulator. The HRT was composed of distinct types of hazards, e.g. visible or hidden, real or potential, and it focused exclusively on measuring and analyzing drivers' behavioral responses. Our hypothesis was that young novice drivers differ from experienced drivers in their responses to hazards.

METHOD

Participants

Sixty-two novice and experienced drivers were recruited in the Montreal area from personal contacts and advertisements. Participants were screened for susceptibility to simulator adaptation syndrome and offered an incentive of $50. The first group was composed of young novice drivers, 18 to 22 years old (n=29; average age 20.2 years ± 1.2 years; average years of driving experience 2.4 ± 1.3; five females). The second group was composed of experienced drivers, 25 to 55 years old with at least four years of driving, fewer than four demerit points and no collisions over the past four years (n=33; average age 36.1 ± 8.9; average years of driving experience 16.0 ± 8.0; six females).

Apparatus

Car simulator. The car simulator used in this study is the VS500 simulator from Virage Simulation. It consists of a driver seat, three-channel 55" LCD panels, 180° field of view and 1:1 graphic-to-optic ratio visual system, rear view mirror images inlayed on the panels, free-standing blind spot monitors, active pedals and steering system, and a rich audio environment. Visual rendering and graphics are delivered at 1920 x 1080 resolution with a 60-Hz frame rate.

Stimuli. Sixteen hazard events were programmed and distributed at approximately one-minute intervals over three driving routes, rural highway, expressway and city (see Table 1). Eight of the hazards represent real traffic conflicts (Types A and B hazard in Table 1). Risser (1985) defines a conflict as "an observable event which would end in an accident unless one of the involved parties slows down, changes lanes, or accelerates to avoid collision". The remaining eight hazard events (Type C) are only potential traffic conflicts that will not result in a crash unless the candidates make a driving error. Both real and potential conflicts are categorized in types and subtypes.

In Type A events the real conflicts are clearly visible and in Type B events atmospheric or environmental factors hide the real conflict from view. In sub-type A1 hazards, drivers can make predictions based on the possible behaviors of road users. Sub-type A2 involves two or more concurrent and clearly visible hazards that compete for the driver's attention. Type B hazards can surprise the driver who does not anticipate that a parked truck may hide a pedestrian or a fog bank may hide stopped vehicles. In all eight Type A and Type B events, a crash is inevitable if the driver does not respond in a correct and timely manner. The eight Type C events are visible, potential conflicts that never directly obstruct the driver's progress. In sub-type C1 events drivers have swerve space if a real conflict suddenly emerges. In sub-type C2 events, either space or visibility is restricted if a real conflict suddenly emerges.

The three driving routes, rural, expressway, and city were driven in the same sequence for all participants and required an average of 12, 5 and 4 minutes respectively to complete. Participants were asked to drive normally, as if they were in a real car on real roads with real consequences for their actions. There were two practice drives of five minutes each that did not include any HRT events. A first, straight-line practice drive preceded the rural and expressway HRT routes. A second practice drive focusing on 90-degree turns followed the rural and expressway HRT routes and preceded the city HRT route. The order of the hazard events did not differ within each route. If a crash occurred during the HRT, the driver restarted the engine and continued driving.

Table 1. Hazard event types

Hazard Type	Route	Event order	Event Description
A1: Single, visible conflict	Rural highway	3	Car exiting driveway
		5	Motorcycle running stop sign
		7	Vehicle approaching head-on
	City	14	Pedestrian crossing on red light
A2: Dual, visible conflicts	Expressway	8	Lead vehicle stopping in merge ramp and trucks blocking right lane of expressway
	City	15	Car stopped on blind curve with vehicle driving beside
B: Hidden conflict	Expressway	12	Vehicles stopped in fog bank
	City	16	Pedestrian emerging from behind truck
C1: Potential conflict with swerve space	Rural highway	1	Motorcycle stopped on shoulder
		4	Cars stopped on shoulder
	Expressway	9	Pedestrians on shoulder at tunnel entrance
		10	Motorcycle in breakdown lane in tunnel
	City	13	Pedestrian on sidewalk
C2: Potential conflict without swerve space	Rural highway	2	Pedestrians on shoulder and oncoming car
		6	Cyclists on shoulder and oncoming truck
	Expressway	11	Fog at end of tunnel

Hazard response measures

A novel measure called the Continuous Time-to-Collision (C-TTC) was computed to investigate participants' responses to each hazard event. To calculate the C-TTC, we initially defined the driver's visual search area in front of the vehicle with a visual angle and radius (Figure 1). The visual angle used in this article is 90 degrees with a radius of 400 m. (Note that angles of 60 and 120 degrees and a 600 m radius were also tested and gave similar results.) When the vehicle is in motion, the computation per event of the C-TTC starts when the hazard (hidden or visible) enters the visual search area and ends when the hazard is outside the visual area or when the vehicle is fully stopped. Technically, as the vehicle is moving in the direction of the hazard and the hazard is inside the visual area, the time needed to reach the hazard at the current speed is computed at each instant along the path of travel (i.e. every 0.1 second, a rate that corresponds to the simulator recording frequency of the speed and position of the vehicle and the hazards). The C-TTC for an event is the sum of all the instant time-to-collision measures computed when the hazard is inside the visual area of the moving vehicle. When a driver is slowing down by releasing the gas pedal or braking in response to the potential hazard, the time-to-collision increases at each instant that speed is decreasing, thereby contributing higher values for a longer period of time to the C-TTC. On the other hand, higher speed or acceleration results in lower time-to-collision values at each instant and therefore produce a smaller C-TTC. Higher C-TTC values suggest better risk management by the drivers of the real and potential conflicts ahead. For each event we also computed and analyzed the average speed during the time that the hazard was inside the visual area of the driver’s moving vehicle.

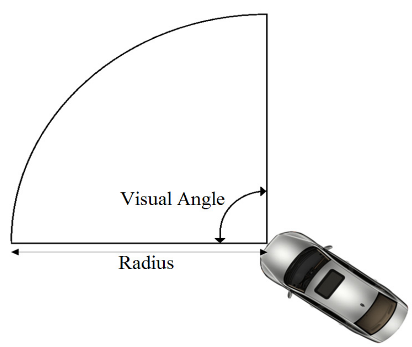

Figure 1. Visual area ahead of the vehicle for computation of C-TTC

RESULTS

Crashes per group (younger novice drivers and older experienced drivers)

Forty-four crashes occurred in total, 24 for young novice drivers and 20 for experienced drivers. The difference between groups was not statistically significant. All of the type A1 and type A2 visible conflict events produced crashes for both groups except for event 14, where no one from either group crashed. All the type B hidden conflict events produced crashes for both groups. Although type C hazards presented only potential conflicts and were not expected to produce any crashes, one novice driver crashed at event 2. Over half the total crashes occurred at two events, 5 and 12. In event 5, where a motorcyclist runs a stop sign, seven of the 13 crashes involved experienced drivers, some of whom blamed the motorcyclist. In event 12, where vehicles were stopped in the fog, young, novice drivers had 10 of the 15 crashes.

Driver response measures per hazard event

Table 2 describes measures of a driver's response for the events where the mean difference was statistically different between the young novice and experienced drivers. The means of the two groups for the C-TTC and the average speeds were compared using two-sided t-tests. For 15 of the 16 events, compared to experienced drivers, the average speed of novice drivers was higher, and their C-TTC was lower in 14 of the 16 events. Five of the 16 HRT events yielded statistically significant differences between the two groups for C-TTC and average speed. The experienced drivers recorded higher average C-TTCs and lower average speeds in all statistically significant comparisons.

Because of the exploratory nature of the experiment, we did not adjust the p-values for multiple testing. Statistically significant measures should therefore be considered here as having greater potential to identify more risky novice drivers using a simulator-based HRT. These potential discriminant measures would need further validation in subsequent studies.

Table 2. Novice and experienced drivers' responses to HRT events

Hazard type	Event	Response measures: C-TTC (seconds) Avg. speed (m/s)	Young novice drivers (n=29)					Experienced drivers (n=33)					t-test p-value[1]
			mean	std	med	min	max	mean	std	med	min	max	
A1	7	C-TTC	5492	1521	5535	3389	9399	6424	1488	6257	3161	9963	0.026
		Average speed	14.0	4.2	13.2	6.0	22.7	11.8	3.3	11.6	6.3	23.4	0.034
B	12	C-TTC	787	145	806	462	1055	940	214	936	569	1515	0.002
		Average speed	20.4	4.2	19.4	13.6	30.3	17.2	3.2	16.5	11.0	23.9	0.001
	16	C-TTC	4223	605	4239	3194	5615	4821	1024	4484	3514	7991	0.008
		Average speed	15.8	2.2	15.6	12.0	20.1	13.9	2.4	14.1	8.4	18.5	0.002
C1	10	C-TTC	607	66	622	481	702	656	103	654	508	979	0.031
		Average speed	26.1	2.9	25.5	22.3	32.6	24.2	3.4	24.1	15.9	30.9	0.021
C2	11	C-TTC	3237	408	3324	2406	4137	3710	737	3404	2540	5147	0.003
		Average speed	23.8	3.4	22.7	18.3	32.2	21.0	4.2	21.8	14.2	30.6	0.006

[1] Two-sided p-value unadjusted for multiple tests.

DISCUSSION / CONCLUSION

The results of this study on responses to driving hazards support the hypothesis that young novice drivers differ from experienced older drivers and that a composite measure of driver performance, the C-TTC, can be more sensitive in discriminating between groups than a categorical measure like crashes. In research by Mueller and Trick (2012), only novice drivers crashed in the fog. In our HRT study, both novice and experienced drivers crashed in the fog and both the real and the potential conflict events in the fog produced significantly riskier C-TTC scores for novices. Although statistically significant differences were found in only five of the hazards, the trend line of C-TTC scores and average speeds clearly favoured experienced drivers. Further research is needed to better understand the relation between hazards types and C-TTC scores. Interestingly, C-TTC scores discriminated between novice and experienced drivers across almost all hazard event types: both hidden hazards; one single, visible hazard, and one event each from the two potential hazard sub-types, with and without swerve space. Overall, the above results hint at the possibility that the C-TTC may be a robust measure of hazard response skill. Further research on the C-TTC and further refinement of the hazard typology presented in this article could contribute to the creation of a standardized, driving simulator-based HRT for use in the training and evaluation of novice drivers. A validated HRT also has potential applications in the assessment of professional and aging drivers as well as drivers in rehabilitation settings.

ACKNOWLEDGMENT

The development of the HRT and this validation study were financially supported by AUTO21 and the Société de l'assurance automobile du Québec. We are thankful to David Nguyen-Tri and Maricela Ocampo for data collection and Stéphane Desrosiers and Rémi Quimper from Virage Simulation for the elaboration and coding of the hazard events on the simulator.

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