NOVICE LEARNER DRIVER PERCEPTIONS OF THE EFFICIENCY OF DRIVING SIMULATOR-BASED TRAINING IN A NATURAL SETTING IN QUEBEC

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ABSTRACT

Novice, adolescent driver overrepresentation in road crashes is a well-documented, robust phenomenon. Driver education and training are popular but controversial interventions that have rarely demonstrated safety benefits. Flight simulators have proven effective in pilot training and the decreasing costs and increasing quality of simulation technology make driving simulator-based training (DSBT) more feasible. In 2010, a long-term, naturalistic, transfer-of-training (ToT) study began to examine the effectiveness of substituting DSBT for part of the on-road training. Within the ToT study, one driving simulator hour can replace one on-road hour for up to 50% of the 15 hours of mandatory on-road lessons. The final results of the ToT study, due in 2015, will address two main questions. One, how does DSBT compare with on-road instruction in terms of performance on the government road exam? Two, does DSBT affect adolescent driver safety? This article presents questionnaire data from the first cohort of graduate learner drivers who substituted at least one hour of on-road training with one driving simulator hour. The questionnaires address learners' general perceptions of learning to drive and their specific perceptions of DBST and its comparative efficiency to on-road training as well as driving teachers' perceptions of their learners' driving competence. Results indicate that DSBT compared favorably with on-road lessons and is perceived to be either more efficient than or equally

efficient to on-road lessons for 13 of 15 specific driving skills. In addition, driving teachers gave their learners high competency ratings.

INTRODUCTION

The overrepresentation of novice adolescent drivers in crash rates is a well-documented and complex public health challenge that requires multiple interventions. Graduated licensing regulations that reduce overall exposure by prolonging the learner stage or that restrict high-risk exposure through night curfews and peer-aged passenger limits have been successful. However, evaluations show that when these exposure-based interventions expire, the crash rates of unsupervised novice adolescent drivers return to unacceptably high levels [1 - 2]. Therefore, several governments around the world are refocusing their attention on driver training.

One practical approach is to study successful training methods in other fields, e.g. aviation. Flight simulators training has reduced training costs and risks and improved training efficiency - knowledge and skills developed in flight simulators transfer very well to real aviation systems [3, 4]. Due to decreasing costs of computer hardware and software and increasing quality and fidelity of image production, driving simulator-based training (DSBT) for novice car and truck drivers has become more feasible. Several studies indicate that DSBT is an effective learning method for novice drivers [5-12].

In 2010, Quebec driving schools were invited to participate in a pilot study to validate the transfer-of-training (ToT) to on-road driving of skills learned on programmed scenarios delivered on the specially designed VS500M driving simulator (Figure 1). This simulator includes a motion-vibration platform and a 180-degree forward view, inset rear view mirrors and blind spot displays to prevent negative training due to incomplete visual representations of the driving environment. Participating driving school owners were required to respect the ToT study protocol which included obtaining signed consent forms from learner drivers allowing researchers access to future government driving records. Participating learners are permitted to substitute from one to six hours of driving simulator training for an equal number of on-road hours within the mandatory 15-hour of driving lessons for novice drivers. The two main goals of the ToT are to determine: (1) whether novice adolescents learn driving skills with equal or greater efficiency in a driving simulator as measured by their performance on the government probationary permit on-road exams, and; (2) if DBST influences crash risk during novice drivers' first years of unsupervised driving.

Sub goals of the ToT study include measuring with questionnaires the perceptions of novice drivers towards DSBT in terms of acceptability and comparative efficiency with in-car training and also to measure driving teachers' evaluations of their students' driving competencies. The final report for this ToT study is due December 2015. This article presents preliminary data on the sub goals of the ToT study.

FIGURE 1 Novice Driver Lesson on VS500M Simulator

METHOD

The Quebec Licensing System

In 2011, in Quebec a driver education program consisting of 24 hours of theory and 15 hours of on-road training lasting not less than 12 months became mandatory for all candidates for a probationary driver license. A probationary permit imposes certain restrictions on driving privileges for two years after which a Class 5 permit with full privileges is issued. Candidates can apply for a learner's permit at the age of 16.

Participants

To date, three Quebec driving schools, all located outside major urban centers, are actively participating in the ToT study. In total, 229 learner drivers, with an average age of 16.7 years and 52% female, have met the criteria of having taken at least one hour of training on the driving simulator, completed all questionnaires and graduated from the driving school. Learner drivers received no compensation for participating in the study. In addition, the 17 driving teachers who administered the final on-road driving evaluation to the 229 learners each completed a questionnaire evaluating their respective student's driving competencies.

Driving Simulator Scenarios

Vision skill training for drivers is considered essential for the achievement of basic and

advanced vehicle control and consistent safe driving outcomes [13]. Therefore, vision skill training was the primary and explicit instructional focus of all the driving simulator scenario programming. Prior to commencing the ToT study, extensive work was completed to create and test the pedagogical content and delivery methods of the training scenarios programmed into the VS500M driving simulator. Scenario programming followed proven pedagogical principles, e.g. progression from simple to complex tasks, and exploited the technological advantages of simulation, e.g. performance replays, overhead views, augmented cuing. Learning content followed the topics listed in the Quebec government novice driver curriculum [14], e.g. changing lanes, merging onto the expressway, passing, left and right turns etc…However, the instructional focus was on using simulator features to help novices learn where and when to look before and during all driving manoeuvres and to train their expectations of what to look for and how to interpret information from visible and latent hazards, e.g. visual exploration and hazard perception. Eco-driving training exercises with objective feedback were also included to help learners understand the influence of the physical forces that affect fuel consumption.

A total of 44 driving-simulator learning scenarios, each an average of seven minutes long, were organized into six one-hour sessions and distributed according the government curriculum. Each one-hour driving simulator session replaces one of six on-road hours within the 15-hours of mandatory on-road lessons. Each session is supervised by one professional driving teacher per learner except for the eco-drive session where groups of up to three students can supervised by one teacher. Simulator sessions are distinctly different from the typical on-road lesson in which the trainer sits beside the learner, controls the vehicle, when necessary, with dual brakes and verbally provides the learner with: a short list of training objectives or tasks at the start; navigational guidance to the roads where these tasks are to be practiced; instruction, coaching and feedback during these tasks, and; a general review at the end of the hour. In a typical simulator session consisting of between five and ten different training scenarios, the driving teacher sits behind the learner and outside his field of vision (see Figure 1.) in order to enhance the immersive effects of the simulator and to encourage the development of the learner's sense of autonomy[1]. At the start of each scenario, the learning objective(s) appear(s) on a PowerPoint slide that the learner is asked to read out loud. These objectives are the focus of a programmed scenario designed to create the conditions that maximize the amount and variety of experiential learning opportunities, e.g. a potential to practice forty or more consecutive lane changes during one seven-minute scenario, a frequency too difficult and too risky for real world conditions yet ideal for developing automaticity in complex manoeuvres. When appropriate, objective and precise feedback is provided to each learner during and after a scenario from within the simulation. At the end of each specific scenario and again at the end of the entire session, the teacher provides his own assessment of the learner's progress.

The study methodology took into account the fact that teachers accustomed to training novice drivers on-road in uncontrolled, dynamic environments would need to adjust their methods to train novice drivers within the programmed, safe environment of a driving simulator. To increase the probability that participating driving school teachers would adapt successfully and to maximize the pedagogical advantages of the programmed simulator scenarios, several provisions

[1] Based on the first author's observations during decades of teaching driving, it appears that many learners do not feel they are in full control of their vehicle as long as the teacher beside them is capable of applying his own brake pedal.

were made: a three-day, train-the-trainer course was provided; a teacher's guide was written and made available on the screen of the driving simulator operator station, and; annual trainer workshops were organized.

Due to the naturalistic design of this study, numerous factors that potentially influence participation in the study and the number of hours each learner took on the simulator were beyond the researchers' control. For example, signed consent forms granting access to future driving records were required for minor-aged learners. Many parents refused consent so it is possible that learners who may have wanted to participate in the study were excluded. Other learners may have decided not to participate for reasons unrelated to their openness to learning to drive on a simulator. Overall, it is difficult to estimate the extent of any self-selection bias that may exist in the study population. Among the learners who did chose to participate with the consent of a parent, access to the driving simulator in each driving school was influenced by personal scheduling conflicts and the limited availability of only one simulator per school. Therefore, the exact number of one-hour simulator sessions to be taken by each learner driver participant was not prescribed within the study design. Differences between learners in the number of driving simulator sessions taken will be accounted for in the final analysis of the study data.

Data sources

Questionnaires

A total of four questionnaires were completed, three by learners at different times during their training, and one by their respective driving teachers after the final on-road evaluation. At the time of registration at the driving school or soon thereafter, learners and their parents were informed of the details and conditions of the ToT study. If they agreed to participate, consent forms were signed and learners completed a questionnaire measuring computer use, past traffic experience on any type of motorized or non-motorized vehicle, risk perceptions, and lifestyles. After the first driving simulator lesson, the second questionnaire was completed to evaluate that learning experience. The third learner questionnaire was completed after the final on-road evaluation at the end of the mandatory twelve-month driving school program to assess the learning experiences of simulator-based and on-road lessons and to compare the efficiency of both training methods across 15 specific driving skills. At the same time, driving teachers completed the fourth questionnaire rating their respective student's driving competence.

Questionnaire items specific to driving-simulator use were developed for the ToT study and tested with actual students during the development phase of the project. The remaining questionnaire items on the learner questionnaires were taken from an extensive study of adolescent drivers by Hirsch [15]. The driving teacher questionnaire items were taken from an earlier study by Hirsch [16].

RESULTS

The responses reported in the following Tables do not always total 229 due to missing and incomplete questionnaires. Table 1 compares learner expectations and perceptions about learning

to drive and their skill achievements from at the time of registration at the driving school to the time of graduation. The most dramatic change occurred in relation to the perceived difficulty of learning how to drive. At registration, only 15.3% of the learners agreed strongly that they would find it easy to learn to drive. One year later, 51.5% of the same group agreed strongly that they had found it easy to learn to drive. The change in relation to becoming good drivers was less important and moved in the opposite direction, with 70.3% agreeing strongly that they will become good drivers and then, one year later, only 55.3% agreeing strongly that they had achieved that goal. The change in perceptions in relation to becoming safe drivers also moved in the opposite direction with 86.9% agreeing strongly that they will become safe drivers and then, one year later, only 75.3% agreeing strongly that they had achieved that goal.

TABLE 1 Comparison of Self-Assessments of Ease of Learning to Drive and Driving Skills Reported at Time of Registration in Driving School and One Year Later at Graduation

Time of report	Self-assessment	n	Agree strongly (%)	Agree moderately (%)	Disagree moderately or strongly (%)
Registration	I will find it easy to learn to drive	229	15.3	63.8	20.9
Graduation	I found it easy to learn to drive	227	51.5	41.8	6.6
Registration	I will be a good driver	229	70.3	28.0	1.8
Graduation	I am a good driver	226	55.3	43.4	1.3
Registration	I will be a safe driver	229	86.9	13.1	0
Graduation	I am a safe driver	227	75.3	24.2	0.4

Table 2 shows that learners did not take a uniform number of simulator-based training sessions and that the variation was unevenly distributed among the three participating driving schools. School A was the first to participate in the ToT study and became the site for beta testing pedagogical content, delivery methods and also the methods most suited to its own clientele for introducing and integrating simulator sessions into public expectations of traditional on-road training. School B joined later and benefited from close cooperation with School A. School C joined last and is geographically more distant from the other two schools. The administrator of School C, for multiple reasons, restricted access to the driving simulator to only one hour per student. Reasons for the distribution of the number of simulator hours taken per learner in the other two driving schools are not known and exploratory analyses using the available data did not reveal significant association between the number of training hours on the simulator and the responses to the questionnaires.

TABLE 2 Number of Self-Reported Simulator Hours per Learner at Participating Driving Schools

Simulator hours	Participating Driving Schools		
	School A	School B	School C

	(No. of learners)	(No. of learners)	(No. of learners)
1	1	9	63
2	7	24	4
3	15	27	0
4 to 6	13	59	1

Table 3 reports responses to eight items that measure the learners' appreciation of their first lesson on the driving simulator. The first set of items focuses on the learners' psychological or emotional reactions to learning to drive on the simulator. The second set asks how well the simulator session itself was structured and whether the learners appreciated the pedagogical advantages unique to simulation and to the programmed scenarios used in this study, i.e. more time to reflect on driving performance and structured scenarios focused on helping learners understand where to look while driving. The responses in the "agree completely" column of Table 3 indicate that the learning experience during the first session on the simulator was perceived by a majority of learners as enjoyable and stimulating, even if it was not completely easy or relaxing.

TABLE 3 Learner Perceptions of Driving Simulator-Based Training Reported After First Driving Simulator Session

Questionnaire items	n	Agree completely (%)	Agree moderately (%)	Disagree moderately (%)	Disagree completely (%)
Learning to drive on simulator was:					
Easy	175	27.4	60.0	12.6	0
Relaxing	174	36.8	42.0	16.1	5.2
Enjoyable	174	65.5	29.3	5.2	0
Stimulating	174	56.3	35.6	7.5	0.6
The simulator session:					
objectives were clear and concise	175	90.3	9.7	0	0
was well-organized	175	91.4	8.6	0	0
gave me time to think about my driving	174	82.2	16.7	0.6	0.6
helped me understand where I need to look when I drive	174	94.8	5.2	0	0

The responses in the "agree completely" column of Table 3 indicate that the simulator session itself received high evaluations for clarity of learning objectives, (90.3%), quality of

lesson organization, (91.4%) and appreciation of the benefits of learning in an environment that allowed more time for reflection (82.2%). Learners reported the highest level of appreciation, (94.8%), for the simulator session's contribution to helping them better understand where to look when driving.

Table 4 reports the learners' retrospective appreciation of the overall experience of learning to drive on a driving simulator. The responses in the "complete agreement" column of Table 4 present an interesting contrast to the responses reported in the "complete agreement" column immediately following the first learning experience on the driving simulator (see Table 3). For two of the questionnaire items, retrospective appreciation of learning on the simulator, compared with the initial assessments after the first simulator session, increased substantially over time, almost doubling for perceived easiness of learning (54.0% vs. 27.4%) and increasing by 38.3% for perceived relaxed quality of the learning experience (50.9% vs. 36.8%). For the study sample that took more than one lesson of one-hour on the simulator, these changes in perception regarding DBST might be attributable to their subsequent simulator experiences. For the 33% of the study sample who reported taking only one simulator session, (see Table 2), other factors are needed to explain the changes in their reported perceptions. It is interesting to note, however, that this retrospective downward adjustment in perceived difficulty of learning on the simulator is consistent with the tendency reported in Table 1 for study participants to perceive learning to drive at the end of their driving lessons to have been easier than they had anticipated at the start of the lessons. For the next two items in Table 4, compared with the initial assessments in Table 3, retrospective appreciation decreased slightly over time – the perceived enjoyableness of driving simulator-based learning decreased from the initially reported 65.5% to the retrospectively reported 53.1% and the perceived stimulating quality of DBST decreased from the initially reported 56.3% to the retrospectively reported 49.6%.

TABLE 4 Upon Graduation From Driving School, Learners' Retrospective Perceptions of the Overall Experience of Driving Simulator-Based Training

Questionnaire items	n	Agree completely (%)	Agree moderately (%)	No opinion (%)	Disagree moderately (%)	Disagree completely (%)
In general, learning to drive on simulator was						
easy	224	54.0	37.0	2.7	6.3	0
relaxing	224	50.9	28.1	11.6	7.6	1.8
enjoyable	224	53.1	26.3	12.1	6.7	1.8
stimulating	224	49.6	29.0	13.8	5.8	1.8

Table 5 presents the retrospective perceptions of participating driving school students regarding their overall experiences learning to drive on-road. The responses reported in the

"complete agreement" column in this Table present an interesting contrast to those reported in the "complete agreement" column of Table 4 (retrospective perceptions of learning to drive in a driving simulator). On-road driving lessons, compared with simulator-based training, were perceived by fewer learners as easy, (31.1% vs. 54.0%) and relaxing, (24.8% vs. 50.9%), and by nearly the same percentage of learners as enjoyable (52.6% vs. 53.1%) and stimulating (48.7% vs. 49.6%).

TABLE 5 Upon Graduation From Driving School, Learners' Retrospective Perceptions of the Overall Experience of On-Road Practical Driver Training

Questionnaire items	N	Agree completely (%)	Agree moderately (%)	No opinion (%)	Disagree moderately (%)	Disagree completely (%)
In general, learning to drive on the road was						
easy	225	31.1	60.0	5.8	3.1	0
relaxing	226	24.8	37.2	19.5	17.7	0.9
enjoyable	226	52.6	32.3	10.2	4.0	0.9
stimulating	226	48.7	38.5	11.1	1.3	0.4

An efficient method of learning is generally understood as one that achieves maximum productivity with minimum wasted effort or expense. Table 6 reports, in descending order, learners' perceptions of the comparative efficiency of learning 15 specific driving skills on the driving simulator vs. learning the same skills during on-road driving lessons. This question attempts to go beyond the typical adolescent experience of simulators as gaming platforms and to determine if and to what extent learners perceived the simulator as an effective learning platform in comparison to traditional on-road lessons.

For every skill except speed control and parking, the percentages of learners that rated the simulator as more efficient than on-road lessons were higher than the percentages that rated it as less efficient. Furthermore, the percentages of learners that rated the simulator lessons as more efficient to on-road training was greater than the percentages that rated simulators as equally efficient to on-road training for four of the 15 skills. It is interesting to note that three of these four driving skills, understanding mirrors and blind spots, risk perception and visual exploration, are among the core vision skills that were the primary focus of the ToT driving simulator scenario development. Driving in city traffic is the last of the four driving skills rated as more efficiently taught on the simulator than on-road – this rating may be influenced by the location of the participating driving schools outside large cities. For only two of the 15 driving skills, speed control and parking, the ratings for on-road lessons exceeded those for the simulator, 34.8 vs. 30.3

and 43.7 vs. 23.5 respectively. Note that speed control is not a specific lesson in the government curriculum and is also not identical to the perceptual skill of speed judgment. Driving on-road vehicles provides dynamic, vestibular feedback that would be prohibitively expensive to reproduce in simulators intended for commercial driving schools. Learning to park is a specific lesson in the government curriculum but not on the simulator – however, other simulator-based scenarios cover spatial judgments helpful for parking, e.g. the session on blind spots and mirrors.

The fourth and last questionnaire in the ToT study collects the impressions of the 17 driving teachers who administered the final on-road driving evaluation at the 15th and final hour of the Quebec mandatory driving course. For 164 learners, (72% of the sample), the driving teachers had taught their respective learners at least one lesson on the driving simulator in addition to the final on-road evaluation. Within this subgroup of learners, 30.1% had only one simulator lesson, 12.9% had two, 33.7% had three and 23.3% had four or more simulator lessons with the driving teachers who conducted their on-road evaluation. Totalling all the lessons given in the driving simulator and on-road, 77.3% of the learners had been taught by their teachers for six or more hours. After the final on-road evaluation, the teachers predicted that 89.3% of their learners would pass the Quebec government road exam on the first attempt.

TABLE 6 Upon Graduation from Driving School, Comparisons by Learners of the Efficiency of One Hour of Simulator-based Instruction and One Hour of On-road Instruction Across 15 Driving Skills

	Compared to a one-hour lesson on the road, a one-hour lesson on the driving simulator was:			
Learning content	n	More efficient (%)	Equally efficient (%)	Less efficient (%)
Understanding the mirrors and blind-spots	224	49.1	29.0	21.9
Risk perception	224	46.9	33.5	19.6
Visual exploration	224	40.6	35.7	23.7
Driving in city traffic	224	38.8	29.0	32.1
Expressways, merging and exiting	222	38.3	43.7	18.0
Respecting other road users	224	36.2	48.6	15.2
Pre-driving habits	224	36.1	35.3	28.6
Lane changes	224	35.7	44.2	20.1
Safe distances around the vehicle	224	32.6	40.2	27.2
Speed control	221	30.3	34.8	34.8
Driving in a straight line	224	29.0	43.8	27.2
Left turns	223	28.2	54.3	17.5
Right turns	224	27.2	55.4	17.4

Rural highways	221	26.2	52.5	21.3
Parking	213	23.5	32.9	43.7

DISCUSSION AND CONCLUSION

The questionnaire responses from this ToT study indicate that after one year and a total of 15 hours of combined driving simulator and on-road lessons, driving school students tend to give higher ratings for the ease and relaxation of learning on the simulator than they give for the ease and relaxation of learning on-road. When asked to directly compare the efficiency of learning 15 specific driving skills on the driving simulator to the on-road lessons, the learners reported that they found the simulator to be more efficient than or equivalently efficient to on-road lessons for all skills except parking and speed control. For three skills specifically related to vision training, i.e. understanding mirrors and blind spots, visual exploration and risk perception, the learners' rankings of the simulator as more efficient than on-road training exceeded their rankings for the simulator as equal to on-road training. This result is consistent with the learners' high evaluations, collected after their first driving simulator session, of the simulator scenarios' explicit focus on helping them to understand where they need to look while driving.

The naturalistic design of this study can be considered a strength and a limitation. The strength is the ability to measure how professional driving teachers use driving simulator-based training in a natural setting with actual learners preparing for their driving permit road exams. In fact, an implicit aim of this ToT study is to discover, with the aid of empirical data, best practices and methods for implementing DSBT. The limitation is the number of uncontrolled variables that potentially influence how the driving simulator is actually used. However, this limitation applies at least equally to the delivery of traditional on-road lessons in driving schools. Another potential limitation is that the unique combination of specially designed learning scenarios focused on vision skill development and the specific configuration of driving simulator hardware and software, e.g. with blind spot displays, plus the initial and recurrent training for the driver trainers may produce results that are not generalizable to other applications of DSBT.

The questionnaire results presented in this article may also be influenced by a self-selection bias, i.e. learner drivers who were already favorably pre-disposed towards DBST may have chosen to enroll in driving schools equipped with driving simulators. This potential bias would be problematic if the crash risk of these learner novice drivers is increased by DSBT. Before we can determine what effect, if any, DSBT has on novice driver crash risk, we must wait until 2015 after all the ToT study data, including driving records, will have been collected, analyzed and compared with the driving records of an age- and sex-matched control group.

The process of learning to drive is a complex area of study that is arguably underdeveloped in relation to its potential impact on adolescent novice driver safety. A multitude of variables related to the learner driver, the teacher, the vehicle and the driving environment, i.e. road, traffic and weather, interact in ways that make programmed instruction and the achievement of consistent learning outcomes highly challenging. The introduction of programmed learning scenarios delivered on realistic driving simulators into novice driver training holds promise for trainers, program developers and researchers. Trainers can now exercise more control over environmental variables during a lesson. Researchers and program developers can access reliable

data from the simulator that may lead to improvements in the training process and safer outcomes on the road.

Overall, preliminary questionnaire data from this ToT study indicate that the experience of learning to drive on the driving simulator using specially programmed scenarios focused on training visual skills compared favorably with on-road lessons, that DSBT is perceived by learners to be more efficient than on-road lessons for 13 out of 15 specific driving skills and that these learners earned high ratings of competency from their driving teachers.

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