Jun 30th, 12:00 AM

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Strayer, David L; Drews, Frank A; and Burns, Stan. The Development and Evaluation of a High Fidelity Simulator Training Program for Snowplow Operators. In: Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, June 27-30, 2005, Rockport, Maine. Iowa City, IA: Public Policy Center, University of Iowa, 2005: 464-470. https://doi.org/10.17077/drivingassessment.1199

THE DEVELOPMENT AND EVALUATION OF A HIGH-FIDELITY SIMULATOR TRAINING PROGRAM FOR SNOWPLOW OPERATORS

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Summary: We report the results of a pilot training program incorporating high-fidelity simulation developed for snowplow operators. Ratings of user acceptance of the training were very high, with drivers of all levels of experience indicating that the training helped them prepare for several issues critical to the safe and efficient operation of a snowplow. In the 6-month period following training, the odds of getting in an accident were lower for the group of drivers who received training compared with a matched control group who did not receive it. In addition, the data indicate that fuel efficiency was greater for the trained drivers than for the control group.

The safe operation of a snowplow requires a high level of expertise. Drivers often operate in very stressful situations, maneuvering 30 tons of equipment in tight quarters in blizzard conditions. Drivers often work long shifts, and negotiate their vehicle in heavy traffic, on slippery roads with very limited visibility. For safe and efficient snow removal in urban settings, drivers often plow in a tight tandem formation and communicate heavily between vehicles. At the same time, the driver must manipulate the controls for the plow, the sander, the different communication devices, and maintain control of the vehicle. The driver must also have a high level of situation awareness, keeping in mind where his/her vehicle is in relation to the other vehicles on the roadway and making sure that the snow thrown by the plow does not come in contact with other vehicles, structures, or pedestrians. Drivers must develop a flexible plan for snowplow removal, and in more urban settings, must coordinate their activities with other members of their crew. Overall, the multitasking demands of a snowplow driver are very high and the skill set required to perform this task is comparable in many respects to those required of a skilled pilot flying an aircraft.

This report describes a collaborative research project between the Utah Department of Transportation (UDOT), the University of Utah, and General Electric Driver Development (GEDD). Following the lead of commercial aviation, where advanced high-fidelity simulator training has significantly improved the safety of airline travel, this research project was designed to determine the feasibility of using high-fidelity simulator training to improve the performance of snowplow operators.

The psychological literature indicates that training can be optimized by combining *part-task training* (e.g., Schneider, 1985; Wightman & Lintern, 1985) and *variable priority training* (Gopher, Weil, & Siegel, 1989; Gopher, Weil, & Bareket, 1994) techniques and both of these methods were incorporated in the current study. Part-task training is a method for taking a complex behavior, such as the safe and efficient operation of a snowplow, and decomposing it into to smaller, more manageable units that can be practiced in isolation. Part-task training has been shown to be very effective in training an appropriate response to low frequency events, such as a tire blow-out or blade catching. On the other hand, variable priority training is a technique that focuses on multitasking by encouraging the flexible allocation of attention between several concurrent operations. With variable priority training, drivers are encouraged to pay attention to all the critical components of plowing, rather than over-focusing on one element at the expense of another (thereby reducing the cognitive tunnel vision). Together, these two training techniques allow the development of skilled procedures that operate effectively in complex multitasking operations.

METHOD

Participants

Eighty maintenance workers from UDOT participated in the study. The participants' age, years with a commercial drivers license (CDL), years plowing, and years trucking are given in Table 1. An equal number of participants were selected from each of the 5 geographic regions in the state of Utah. The different regions represent urban interstate, mountain interstate, mountain 2-lane highway, and rural 2-lane highway roads, and both city and rural town driving conditions. Half of the participants were assigned to the study group and the remaining participants served in the control group. Study and control groups were matched in terms of age, years driving a snowplow, prior driving history and geographic region of the state. A requirement for participation in the study was that the participant was an employee at UDOT in their maintenance division (i.e., working as a snowplow driver).

Table 1. Participant demographic data

	Minimum	Maximum	Mean (sd)
Age	21	55	33.6 (9.3)
Years CDL	0	30	11.0 (9.0)
Years plowing	0	25	7.3 (7.1)
Years trucking	0	31	11.5 (9.8)

Apparatus

Training was conducted at GEDD facilities in Salt Lake City, UT (located at 2961 West California Avenue, Salt Lake City), and lasted 4 hours. Simulator training was performed using both the Mark II and TranSim VS high fidelity driving simulators manufactured by GEDD.

The Mark II motion-based simulator combines a fully operational truck cab with LCD projection imaging on three screens to create a 180-degree field of vision. Two LCD side mirrors simulate the rear view from the truck cab. Audio and vibration systems add accurate driving noise and feel. Closed-circuit television allows observers to watch the driver from the operator console. The TranSim VS was used to train drivers on ways to optimize shifting to maximize fuel efficiency (e.g., progressive shifting, double clutching, timing, and appropriate gear selection).

Procedure

The research project consisted of four key phases. The first phase involved performing a detailed task analysis that identified the major components to include in training. The second phase involved developing high-fidelity driving scenarios and PowerPoint slides that focused on the key components identified in the task analysis. The third phase involved the delivery of training to the 40 drivers in the study group. The fourth phase of the project involved collecting and analyzing driver performance measures for the study and control groups over a 6-month interval following the training. In the following paragraphs, we provide detail concerning the procedures used in each phase of the project.

Phase 1. The first phase of the project involved the development of a detailed task analysis of snowplow operations. We focused on critical training issues and proper procedures for plowing in winter conditions. On several occasions we met with the UDOT technical advisory committee to identify the operational issues for snowplow drivers, met with expert drivers in the field to identify major problem areas, and rode with the drivers as they performed their snowplow operations. In addition, we evaluated existing database records on sources of accidents and incidents. From the aggregated information, we identified and scripted specific driving scenarios that could be built into the driving simulations. We received ongoing feedback on the fidelity of the task analysis and driving simulations from expert UDOT drivers throughout the project.

Four key areas were identified for training: space management, speed management, crew communication, and fuel management. Space management focused on helping drivers have good situation awareness of where their vehicle was in relationship to other vehicles, structures, and pedestrians (e.g., ahead, behind, left, right, above and below the vehicle). In addition, space management issues focused on knowing where the snow was being thrown, driving in tandem in urban settings to prohibit other vehicles from coming between the plowing team, and coordinating plowing operations. Speed management focused on the speed of the snowplow, situations for altering the driving speed, discussing strategies for changing the speed of the vehicle, computing stopping distances, the distance snow was thrown (driving faster tends to throw the snow farther), and the potential damage caused by the thrown snow. Also discussed in conjunction with space and speed management was “blade catching” situations where the plow blade acts to change the direction of the vehicle. Crew communication focused on issues of communicating over the different devices in the vehicle (e.g., state radio, CB radio, cell phone) with other members of the team and neighboring stations to coordinate plowing operations. In urban settings crew communication helps to coordinate tandem plowing (e.g., in tandem plowing, the lead driver is the eyes of the team, reporting oncoming obstacles, etc.). The fuel management component of training used the TranSim VS to train drivers on ways to optimize shifting to maximize fuel efficiency (e.g., progressive shifting, double clutching, timing, and appropriate gear selection).

Phase 2. The second phase of the project took the material identified in phase 1 and developed a series of high-fidelity driving simulator scenarios and PowerPoint lecture slides. The driving scenarios consisted of 18 short plowing scenarios in urban interstate and rural mountain settings. The driving scenarios were designed to capture critical components of plowing that could be practiced in isolation (i.e., part-task training) with scenarios later in the sequence focusing on combining the lessons learned in the earlier scenarios in multitasking situations (i.e., variable priority training). Critical concepts were first introduced in lecture format, using PowerPoint slides, and then each concept was practiced in the driving simulator. As training progressed, the multi-tasking demands increased and in the final driving scenario two drivers, using different simulators, were able to plow as a team in a virtual snowplowing environment.

Phase 3. The third phase of the project involved training 40 drivers using the curriculum developed in the second phase of the project. Drivers were trained in cohorts of 4 drivers in late October and early November of 2003. When participants arrived, they completed an informed consent document. Training consisted of lecture (using PowerPoint), and practice of the concepts developed in lecture using the Mark II and TranSim VS driving simulators. The training was conducted at GEDD facilities in Salt Lake City, UT. One instructor (D.B.) was responsible for delivering the training. At the end of the training session, drivers completed a 25-item questionnaire (Table 3) designed to assess various aspects of the simulator training.

Phase 4. The fourth phase of the project involved collecting and analyzing the accident and fuel efficiency data collected over the 6-month interval following training. The experimental design was a between-subjects factorial with 40 participants assigned to the study group and 40 participants assigned to the control group. All analyses in this report used a one-tailed (directional) statistical test of the *a priori* hypothesis that simulator training improves driver efficiency. A significance level of $p<.05$ was adopted for all inferential tests.

RESULTS

Post-training survey

Immediately after the training session, participants completed a 25-item questionnaire assessing various aspects of training. The specific questionnaire items are presented in Table 2 along with the average rating and standard error for each item. Participants rated each item on a 5-point scale where a rating of 1 indicated strong disagreement, a rating of 3 was neutral, and a rating of 5 indicated strong agreement. Averaging across items (mean=4.5, sd=0.25) indicated considerable agreement, with ratings evenly centered between “agree” and “strongly agree.” Inspection of the data indicates that for each item, participant’s ratings ranged between “agree” and “strongly agree.” The standard error for each rating also indicates considerable consensus among participants.

Several items are worthy of note. First, participants found the snowplow training package very useful (average rating = 4.55), that the training should be part of UDOT training for all snowplow operators (average rating = 4.55), and that they would recommend this training for other snowplow drivers (average rating = 4.67). Second, only two correlations between the demographic variables and the rating of questionnaire items were significant, indicating that drivers of all levels of experience found the training to be useful. The first significant correlation was between age and item # 2 (“the classroom/lecture portion of the training was useful”), indicating a general trend for older drivers to rate the lecture portion of training higher than younger drivers. The second significant correlation was between years plowing and item # 24 (“the trainer understood your needs and issues”), indicating general trend for snowplow operators with less experience to rate this item higher than drivers with more plowing experience; however, in all cases ratings on this item ranged between "agree" and "strongly agree."

Overall, the ratings provide a strong indication that the drivers found the snowplow training package to be realistic, useful, well directed towards the learning objectives of speed management, space management, crew communication, and fuel management, and of sufficient quality that they recommended that this training should be part of UDOT training. Moreover, operators of all levels of experience found the course to be worthwhile.

Table 2. Questionnaire items, with mean and standard error of rating in parentheses

1) The snowplow training package was very useful. (4.6, 0.09)
2) The classroom/lecture portion of the training was very useful. (4.5, 0.09)
3) The training using the TranSim simulator for optimal shifting was very useful. (4.4, 0.11)
4) The simulations using the MARK II motion-based simulator were very useful. (4.7, 0.07)
5) This training should be part of UDOT training for all snowplow operators. (4.6, 0.11)
6) The training helped prepare me for dealing with non-routine situations. (4.3, 0.12)
7) The training helped prepare me for situations involving blade catching. (4.0, 0.16)
8) The training helped prepare me for situations involving passing cars. (4.4, 0.10)
9) The training helped prepare me for situations involving vehicles or pedestrians along the side of the road. (4.3, 0.10)
10) The training helped prepare me for situations involving plowing over structures. (4.2, 0.13)
11) This training explained why speed management is important for safe plowing. (4.7, 0.09)
12) This training explained why space management is important for safe plowing. (4.7, 0.08)
13) This training explained why good communication is important for safe plowing. (4.7, 0.07)
14) I would recommend this training for other snowplow drivers. (4.7, 0.10)
15) The course objectives satisfied my needs. (4.2, 0.14)
16) The driving simulations were realistic for the course objectives. (4.6, 0.10)
17) I practiced skills during the driving simulation part of the course that will be very useful on the road. (4.4, 0.10)
18) I practiced skills during the shifting simulation part of the course that will be very useful on the road. (4.3, 0.13)
19) The time spent in the lecture portion of the course was appropriate. (4.6, 0.08)
20) The time spent in the driving simulation portion of the course was appropriate. (4.6, 0.08)
21) The time spent in the shifting simulation portion of the course was appropriate. (4.0, 0.15)
22) The trainer had a good understanding of the course material. (4.8, 0.07)
23) The trainer worked well with the drivers. (4.9, 0.06)
24) The trainer understood your needs and issues. (4.8, 0.07)
25) The trainer gave very useful feedback. (4.8, 0.08)

Accident Rates

There were a total of 7 accidents over the 6-month interval following training. Three accidents were reported for drivers in the trained group; however, in two of the cases the trained driver was determined by the UDOT accident analysis team to be not responsible for the accident. Four accidents were reported for drivers in the control condition. This resulted in the 2 X 2 contingency table (Table 3) in which the study group had one accident and the control group had four accidents.

Table 3. Accident rates for the study and control groups

	Accident	No Accident	
Study Group	1	39	40
Control Group	4	36	40
	5	75	80

The accident data were analyzed using logistic regression. Logistic regression is a statistical procedure specifically designed to deal with cases with few events (i.e., accidents) and has the advantage of providing an estimate of the odds ratio of an accident depending on training group. The obtained odds ratio was 4.33, indicating that there were fewer accidents in the study group than the control group. At first glance, the 4.33 odds ratio appears to indicate a substantial reduction in accident rates; however, a chi squared statistical test indicated that the effect was not significant given the sample size used in the study. The statistical test of the *a priori* prediction that training should result in a reduction in accident rates was χ^2=2.05, p<.076. It is evident that there was inadequate statistical power in the experimental design to detect differences between the study and control groups. A power analysis indicated that the effect of training would become significant with 120 participants (60 in the study group and 60 in the control group).

Fuel Management and Maintenance

Based on earlier evidence on the effectiveness of simulator training in commercial trucking sector (Strayer & Drews, 2003), we expected that there would be a significant increase in fuel efficiency for those drivers who participated in training. Figure 1 presents the average monthly fuel use for drivers in the study and control groups, and Figure 2 presents the median miles per gallon for drivers in the study and control groups. It is clear that there are distinct seasonal fluctuations in fuel consumption and usage, with the greatest use in the months of December, January, and February. Unfortunately, several factors make it difficult to fully evaluate the effectiveness of simulator training on fuel management and maintenance costs in the current study. The major problem was that there was not a unique assignment of vehicles to drivers. On several occasions, more than one driver would use a vehicle during a storm and in some regions vehicles would occasionally change stations during the season, making it difficult to associate specific vehicle parameters with a unique driver.

Nevertheless, we performed a statistical analysis on the fuel efficiency data to see if there was any difference between the study and control groups. Note that due to missing data, the month of November was too noisy to include in the analysis, that the data from several drivers were lost due to missing values, and the data that were included in the analysis still have unknown levels of noise due to problems assigning fuel usage to vehicles/drivers. The analysis revealed both an effect of month, $F(4,28)=3.7$, $p<.01$, and a difference in fuel efficiency between the study (mean 4.96, sd=0.38) and the control groups (mean 4.67, sd=0.37), $F(1,31)=3.8$, $p<.05$. The difference represents a 6.2% improvement in fuel efficiency for those drivers who received simulator training. However, these data must be considered with a degree of caution, because of aforementioned problems in correctly assigning fuel usage to drivers/vehicles.

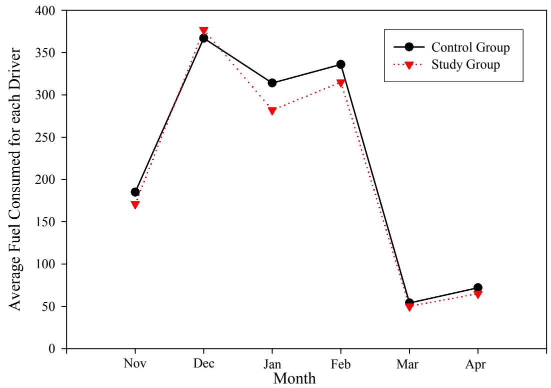

Figure 1. Fuel Usage by Month for Study and Control Groups

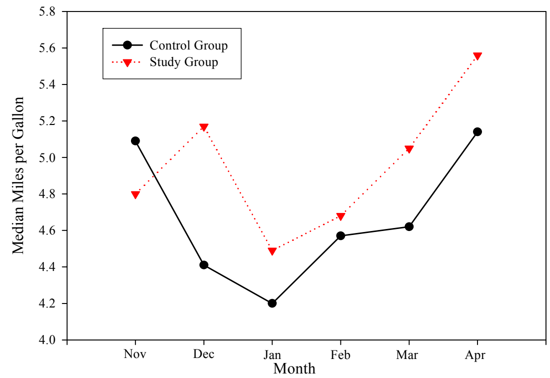

Figure 2. Fuel Efficiency by Month for Study and Control Groups

CONCLUSIONS

A customized training program incorporating high-fidelity simulation was developed for UDOT maintenance operators in a collaborative research project with the University of Utah and GEDD. Ratings of user acceptance of the training were very high, with drivers indicating that the training helped them prepare for several issues critical to the safe operation of a snowplow. Drivers of all levels of experience reported that the training was very useful and should be part of UDOT training. In the 6-month period following training, the odds of getting in an accident diminished for the group of drivers who received training compared to a matched control group who did not receive training (albeit a larger sample size would be required for this benefit to become significant). The data also indicate that fuel efficiency increases with training. Taken together, these results indicate that high fidelity simulator training holds promise for improving the safety and efficiency of snowplow operations.

REFERENCES

Gopher, D., Weil, M., & Barekt, T. (1994). Transfer of skill from a computer game trainer to flight. *Human Factors*, *36*, 387-405.

Gopher, D., Weil, M., & Siegel, D. (1989). Practice under changing priorities: An approach to training in complex skills. *Acta Psychologica*, *71*, 147-179.

Schneider, W. (1985). Training high-performance skills: Fallacies and guidelines. *Human Factors, 27*, 285-300.

Strayer, D. L., & Drews, F. A. (2003). Simulator training improves driver efficiency: Transfer from the simulator to the real world. In D. V. McGehee, J. D. Lee, & M. Rizzo (Eds.) *Driving Assessment 2003: International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design*. Published by the Public Policy Center, University of Iowa (pp. 190-193).

Wightman, D. C., & Lintern, G. (1985). Part-task training for tracking and manual control. Human Factors, 27, 267-283.