Simulator performance differences between experienced and novice bus drivers

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Abstract

In order to combat the problem of novice bus driver risk, a bus simulator was developed to improve decision-making at hazards that are most often associated with bus crashes. If the simulator is capable of discriminating between novice and experienced bus drivers then it can be argued that it is a valid tool for bus driver training to improve road safety. The purpose of this study then is to investigate whether there are significant differences between experienced and novice bus driver performance. Twelve novice bus drivers with 2-3weeks of driver training, and twelve experienced drivers who had held their PCV (Public Commercial Vehicle) license for at least three years were asked to drive a simulated bus route. Participants drove for approximately 15 minutes encountering three major hazardous locations for bus driving, namely, layby bus stops, parallel bus stops and right hand junctions. At these locations, parameters measured were speed, acceleration, position, steering and braking. The results showed that experienced drivers demonstrated greater caution but more confident behavioural strategies at layby and parallel bus stops. At right hand junctions, experienced drivers drove slower and further away from the kerb and used the brake significantly more often than novice bus drivers did. Results are discussed with reference to the use of a driving simulator for novice bus driver training.

Keywords – bus drivers, driver training, novice drivers, experience drivers

1. Introduction

Analysis of bus accidents within Arriva has shown that bus drivers in their first year of service are over represented in at-fault accidents [4]. There is a large corpus of literature showing that lack of driving experience and not age is the greatest contributing factor to crash risk (e.g. [7, 8] given that accident risk falls by around 30% in the first year of driving, irrespective of age [6]. It appears that novice drivers are deficient in a number of driving related skills [5] and current research suggests two main areas – roadway scanning and hazard perception skills. For example, Underwood et al [10] found that after a drive, experienced drivers were able to recall more incidental events than novice drivers and on demanding dual carriageway sections experienced drivers had more extensive scanning of the road than novice drivers [11]. However, little is known about how bus drivers respond to hazardous locations, especially bus stops and junctions where most bus crashes take place [4].

Dorn and Barker [3] found driver group difference in behaviour at simulated hazardous locations amongst a sample of police drivers and a sample of non-police trained drivers. Two tasks were completed, firstly to overtake a slow-moving bus, and secondly to follow a lead vehicle travelling at 55mph in a 30mph speed limit. Results showed that in comparison with non-police trained drivers, police drivers significantly reduced their speed on approach to pedestrians at the roadside in the urban section and were significantly more likely to cross the central division of the road at safer locations during the overtaking task. Police drivers also adopted a more central lane position compared with non-police trained drivers on urban roads and at traffic lights during the following task. Dorn and Barker [3] concluded that driver group differences in simulated driving performance are likely to be due to the effects of training and experience.

This paper describes a similar approach to investigate whether Arriva's bus simulator is capable of discriminating between novice and experienced bus drivers with the expectation that experienced drivers will demonstrate safer simulated driving performance than novice drivers do. If the simulator discriminates between these driver groups, then it suggests that the simulator is valid and may be useful as a tool to improve novice bus driver performance in line with that of experienced drivers. In a sense therefore, a simulator might provide the opportunity for accelerating experience by exposing novice bus drivers to the hazards that they have yet to encounter and train learner bus drivers in how to respond appropriately without fear of crashing. The overall aim of the present study then is to validate a bus simulator for bus driver training.

2. Methodology

Twelve experienced bus drivers and twelve novice drivers volunteered to take part in this study. The experienced drivers had all held a driving licence for at least three years (mean 7.4, sd 4.04) and had not been involved in an accident in the previous three years. The mean age was 41.37 (range 30-62 years). All the novice drivers had taken part in 3 weeks training at Arriva's training school in order to gain their PCV licence. None of the novice drivers taking part in this study had yet taken their practical driving PCV test, but all had passed their driving theory test. The mean age of the group was 34.5 years (range 19 to 53 years).

2.1 *Experimental design and performance parameters*

Driving performance was measured around three hazardous locations – a parallel bus stop, a layby bus stop (see Figure 1 for differences between bus stop types) and a cross road where the participant was requested to turn right. Dorn et al [4] found that these were the three locations where a high percentage of bus accidents take place.

Approximately 100ft before the bus stops, the participants heard a bell ring to indicate that a passenger wished to alight the bus at the next bus stop.

A number of performance parameters were chosen to investigate the drivers' behaviour in response to the hazards depicted. The simulator parameters were selected for measurement based on previous research by Dorn and Barker [3]. The parameters chosen were:

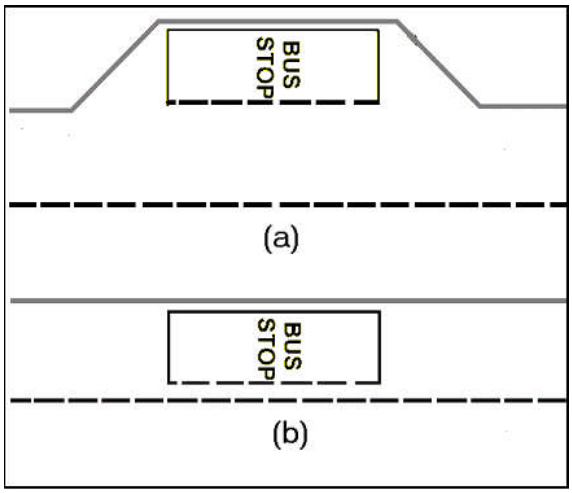

Figure 1: Diagram showing (a) Layby bus stop, and (b) parallel bus stop

Lane position – The position of the simulated bus in the road, measured from the centre of the roadway, to the centre of the bus. The centre of the roadway is described as 0ft, the left hand kerb edge as –12ft and the right hand kerb edge as +12ft, for a single carriageway road. At a layby bus stop the right hand kerb edge is described as –24ft.
Speed – The speed of the simulated vehicle (feet/second). The top speed of the simulated bus is 75feet/second.
Steering – Rate of change of the steering wheel angle (radians/second). This variable is always between 0 and 1.
Acceleration – Longitudinal acceleration due to the throttle input (feet/second^2). This variable is always positive.
Braking – Longitudinal acceleration due to the brakes (feet/second^2). This variable is always positive.
Overall acceleration – The simulated bus is subjected to a number of different accelerations – those caused by the participant using the brake and the accelerator, the friction of the road, and the effect of the hill the vehicle has to climb/descend. Combined these form the overall acceleration parameter. This variable can be positive (acceleration) or negative (deceleration).

Performance on these parameters was recorded at 100ft, 50ft and 20ft before the bus stops to investigate how drivers approached the stops after the bell rang. The same parameters were also measured at the bus stop itself and 50ft after. Performance variables were therefore measured 100ft and 50ft before the junction, and at the junction.

2.2 *Equipment*

The trials took place on the Arriva Bus Simulator (ABS). The ABS is a fixed based wide field of view simulator, which has been adapted from a STISIM PC based driving simulator. A bus cab sits in the middle of a 180° curved screen, 6m in diameter and 2.75m high from which the participant drives the simulator. The environment for the driver is therefore as realistic as possible as illustrated in Figure 2.

Figure 2: The Arriva Bus Simulator

2.3 *Procedure*

Initially the bus drivers completed a practice session on the simulator. The practice session involved driving on a straight road with low scene complexity, then on a curved road with higher scene complexity. Next they practiced pulling into two lay by bus stops and practised two right and two left turns at junctions. This was so that the driver could acclimatize to the simulated driving environment to minimize discomfort and the potential for simulator sickness (see Brock et al., [2] 2001). It was also an opportunity for the driver to ask questions and to ensure that they performed according to their normal standard of driving.

Participants were given the following instructions prior to the practice drive:

> "This first session is a practice drive so that you may get used to the feel and control of the simulator. Please drive the way you would on a real road and deal with the conditions as if they are really happening. If you hear one bell it means that you should stop at the next bus stop. You must wait at the bus stops until you think it is OK to move away. In the event of a collision the simulator will reset your position in the road and you must carry on driving. Please stop at junctions and listen for my instructions to turn left or right. Feel free to ask any questions."

After completion of the short practice trial participants then drove a simulated bus route (approximately 15minutes), and received the following instructions;

> "This next session is the main drive. Please drive the way you normally would on a real road and deal with events as if they were really happening. There will be instructions given by the simulator as to whether to turn left or right, otherwise continue along the roadway. If you hear a bell ring you must pull into the next bus stop. No one will get on or off so when you feel ready pull away again. If you have an accident the simulator will reset you in the road. Please discontinue if you begin to feel ill."
>
> Approximately 100ft before the junction the participants were given the following instruction "At the traffic lights, turn right".

The experimenter left the room and the bus drivers then drove along the simulated route. Driving performance was continually monitored and data was saved every five feet along the simulation. Distance rather than time was used as the reference point for data collection to ensure that data was collected at the same point in the simulation for each participant, so that performance around key points, such as bus stops could be monitored and compared between drivers.

3. Results and Discussion

Table 1 shows that the age distribution between the driver groups are quite different. It is therefore important to control for age using Analysis of Covariance (ANCOVA) to make sure that any significant driver group differences found are due to experience and not confounded by the effects of age.

Table 1 – Driver Group Difference in Age and Bus Driving Experience

Subject Group	n	Mean age	SD age	Mean exp	SD exp
Novice	12	34.5	9.81	0	0
Experienced	12	41.37	11.63	7.4	4.04

For some analyses, ANCOVA was unable to separate the effects of age and experience. Results for the analyses are presented in Tables 2 for the layby bus stop, Table 3 for the parallel bus stop and Table 4 for the right hand junction.

3.1 Layby Bus Stop Results

Table 2 presents the findings for the ANCOVA analyses of performance on approach to the layby bus stop hazard. Significant driver group differences 100ft from the layby bus stop for both acceleration ($F=4.99$, $p=.025$) and overall acceleration ($F=5.07$, $p=.024$) were found. Experienced drivers accelerated more assertively than novice drivers did. Additionally the overall acceleration showed that when driven by novice drivers the vehicle tended to be slowing at this point whilst

experienced drivers were gaining speed at a slow rate. There were also significant driver group differences 50ft on approach to the layby bus stop for lane position (F=3.832, p=.049) with novice drivers being closer to the kerb than experienced drivers. This difference may be due to the fact that experienced drivers have gained a better understanding of the length of the vehicle than that of novice bus drivers. As a rear wheel drive vehicle, it is more difficult to enter a lay by bus stop from close to the kerb without the back of the bus hitting or mounting the kerb. The experienced bus drivers appear to align the vehicle for a smoother manoeuvre into the bus stop with less risk of kerb collision.

Finally, analysis of measures taken 20ft from the layby bus stop show significant driver group differences for braking (F=4.23, p=.035) and overall acceleration (F=5.09, p=.020) with experienced drivers braking more assertively than novice drivers did. Experience was found to have an "approaching significant" effect on the steering wheel rate at this point (F=3.055, p=.077) with the steering rate of novice drivers being greater than that of experienced drivers. There was also an approaching significant driver group difference on steering wheel rate 20ft from the bus stop with novice drivers turning the steering wheel more rapidly than experienced drivers did. The mean speed for novice drivers was 14.28mph whereas for experienced drivers it was 8.83mph. This difference in speed may be due to experienced drivers having greater awareness of passenger hazards inside the bus, such as people standing, or sat on the edge of a seat. The novice drivers on the other hand, have not gained operational experience of this kind, which may explain why they drive faster and turn the steering wheel more sharply on approach to the bus stop. Driving the bus in this way is likely to increase the chances of passenger trips and falls.

The bell for the bus stop rang approximately 100ft from the stop – after hearing the bell the novice drivers tended to slow down in anticipation of and searching for the stop, whilst the experienced drivers maintained their speed and drove towards the bus stop more confidently. These findings support the study by Dorn and Barker [3] in which a similar affect was observed amongst police drivers. Compared with non police drivers, police drivers showed greater confidence in the performance of driving manoeuvres and had a safer response to road and traffic hazards.

Similar findings were apparent 50ft after the layby bus stop and revealed significant driver group differences for acceleration (F=3.74, p=.050) and overall acceleration (F=3.78, p=.049) with experienced drivers accelerating more assertively than novice drivers. An approaching significant effect was also found for steering wheel rate at this point (F=3.15, p=.074) with novice drivers turning the steering wheel less sharply than that of experienced drivers.

3.2 Parallel Bus Stop Results

Table 3 shows the results of the analysis of performance for the parallel bus stop. 50ft prior to the parallel bus stop significant driver group differences were found for lane position (F=4.31, p=.035) with novice drivers being closer to the kerb than experienced drivers. Analysis of measures recorded at 20ft on approach to the parallel bus stop showed significant differences for speed (F=5.01, p=.023) with novice drivers approaching the bus stop at a faster speed than experienced drivers. There was also an approaching significant effect on lane position (F=3.30, p=.067) with novice drivers being closer to the kerb than experienced drivers. Finally there were significant differences for steering rate (F=6.64, p=.011) at the parallel bus stop with novice drivers tending to have a slower steering rate than experienced drivers. There was also an

approaching significant effect on the lane position ($F=3.22$, $p=.079$) with novice drivers tending to stop the bus closer to the kerb than experienced drivers did.

Table 2 – Driver group differences in mean and standard deviations for lay by bus stop performance

Measure	Subject Group	100ft before		50ft before		20ft before		At stop		50ft after	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Lane Pos	Novice	-6.19	1.82	-6.12*	.80	-12.51	2.36	-14.41	1.54	-5.96	2.55
	Exp	-4.83	.76	-5.01*	.45	-12.36	1.40	-15.14	2.26	-3.00	.58
Speed	Novice	30.65	7.89	30.09	5.77	14.28	14.17	8.19	10.36	31.19	7.66
	Exp	26.77	1.41	27.20	2.27	8.83	2.47	5.58	2.88	26.63	3.08
Accel	Novice	.48*	.56	.89	1.28	.86	1.04	.35	.18	1.67*	1.88
	Exp	1.10*	.14	.42	.29	.52	.22	1.56	2.50	3.86*	1.65
Braking	Novice	•	•	-.73	2.42	-.36*	.90	-1.97	2.22	•	•
	Exp	•	•	-.30	.68	-2.17*	2.72	-.69	.95	•	•
Overall Accel	Novice	-.17*	.56	-.49	2.94	-.06*	1.49	-2.16	2.18	1.01*	1.89
	Exp	.46*	.15	-.53	.85	-2.20*	2.81	.30	3.01	3.22*	1.65
Steering	Novice	.023	.012	.0045	.0033	.014	.0095	.033	.019	.030	.012
	Exp	.029	.007	.0036	.0032	.013	.016	.030	.014	.038	.011

* Indicates significant results beyond .05

• Indicates where ANCOVA cannot separate the effects of age and experience

Table 3 – Driver group differences in mean and standard deviations for parallel bus stop performance

Measure	Subject Group	100ft before		50ft before		20ft before		At stop		50ft after	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Lane Pos	Novice	-6.11	.62	-6.70*	.62	-6.76	.67	-7.34	.51	-5.80	.517
	Exp	-5.29	.55	-5.85*	.44	-6.45	.75	-6.25	1.10	-5.42	.32
Speed	Novice	20.42	7.01	16.11	4.93	14.89*	5.77	6.08	4.11	22.32	3.05
	Exp	21.69	6.40	17.61	5.19	8.08*	3.87	6.28	8.30	20.97	4.09
Accel	Novice	.28	.22	.30	.12	.34	.12	5.266	3.83	3.75	2.96
	Exp	1.66	2.28	.20	.21	.40	.08	2.13	2.92	3.41	2.22
Braking	Novice	-.90	2.09	-3.05	3.50	-2.56	3.35	-1.37	3.79	•	•
	Exp	-.035	.07	-3.32	3.86	-5.69	4.96	-2.53	4.39	•	•
Overall Accel	Novice	-1.27	2.15	-3.39	3.58	-2.87	3.41	3.25	6.60	3.09	2.96
	Exp	.978	2.31	-3.77	3.93	-5.93	4.92	-1.05	6.37	2.75	2.22
Steering	Novice	.005	.007	.003	.002	.0029	.0019	.004*	.006	.005	.004
	Exp	.003	.004	.004	.005	.0023	.0028	2.25*	4.50	.003	.002

* Indicates significant results beyond .05

• Indicates where ANCOVA cannot separate the effects of age and experience

Experienced drivers tend to drive further from the kerb perhaps to reduce the risk of colliding with pedestrians and road side objects or maybe because it is a more assertive way of driving by maintaining a more central position in the lane [3]. Experienced drivers may also be maintaining their road position for longer before turning into the bus top, whilst novice drivers are preparing for the bus stop before it is necessary to do so.

At the bus stop novice drivers tended to have a slower steering rate and tended to stop closer to the kerb than experienced drivers did. Drivers are taught that the vehicle should stop between 12 inches and 18 inches from the kerb. Both sets of drivers tended to stop less than 12 inches from the kerb, with experienced drivers having a mean stopping distance from the kerb of 10.2

inches and novice drivers having a mean stopping distance of 9.1 inches from the kerb. Neither set of drivers stopped at the bus stop at a correct distance from the kerb but this may be due to lateral distances being harder to perceive on a simulator [1, 9].

3.3 Right Hand Junction Results

Table 4 gives the results for driver group differences for right hand junction performance. Analysis of performance100ft from the right hand turn junction showed a significant difference for speed (F=4.817,p=.026). Experienced drivers tended to drive more slowly on approach to the junction than novice drivers did. At 50ft from the right hand junction, results showed significant difference for lane position (F=5.56, p=.016) with novice drivers tending to drive closer to the kerb than experienced drivers did. There was also a significant difference for braking (F=8.24, p=.004) and overall acceleration (F=7.53, p=.005) between the groups showing that experienced drivers tended to brake more assertively than novice drivers did. At the right hand junction itself, there was a significant driver group difference for braking (F=4.42, p=.031) with experienced drivers tending to brake more assertively at the junction than novice drivers did.

Table 4 – Driver group differences in mean and standard deviations for right hand junction performance

Measure	Subject Group	100ft before		50ft before		At junction	
		Mean	SD	Mean	SD	Mean	SD
Lane Pos	Novice	-6.30	.724	-6.31*	.53	-6.03	.69
	Exp	-5.70	.59	-5.41*	.56	-5.19	.99
Speed	Novice	28.70*	8.74	20.51	5.99	3.90	2.56
	Exp	26.76*	4.17	18.24	1.87	5.44	4.33
Acceleration	Novice	.18	.096	.28	.22	1.74	2.80
	Exp	.17	.093	.22	.004	2.09	1.94
Braking	Novice	-2.61	2.90	-5.82*	3.24	0*	0
	Exp	-1.2	1.76	-5.94*	3.87	-.22*	.52
Overall Acceleration	Novice	-3.08	2.92	-6.19*	3.41	1.10	2.80
	Exp	-1.69	1.77	-6.38*	3.87	1.22	2.17
Steering	Novice	.0069	.0061	.0023	.0026	.020	.036
	Exp	.0045	.0058	.0039	.0020	.022	.037

* indicates significant results beyond .05

It appears that experienced drivers were slower on approach to the junction, perhaps to provide more opportunity to stop safely should the need arise. In comparison to novice drivers, experienced drivers may be more conscious of the need to avoid sudden braking to maintain safety inside the vehicle as well outside. Perhaps this behavioural strategy may be one reason why experienced drivers are less likely to be involved in bus crashes at junctions compared with novice drivers [4].

When negotiating a right hand turn in a bus (when driving on the left side of the road in the UK), it is easier to turn from closer to the left hand side of the road than the right, to avoid clipping pavements or venturing into the opposing carriageway on the turn. This is especially true

of narrow turns, yet it is the novice drivers who are turning from closer to the left than experienced drivers. In the case of experienced drivers their mean distance from the kerb (left side of bus to kerb distance) was 2.69ft, and for novice drivers it was 1.79ft. This shows that the road position of experienced drivers tended to be just to the right of the centre of the carriageway, and novice drivers just to the left.

There may be many reasons experienced drivers turn from closer to the right than novice drivers do and this may be partly explained by reference to lateral position being difficult to gauge in driving simulator. For example, recent research indicates that there are differences in lateral positioning in simulated driving compared with real driving. Blana and Golias [1] found that on a real road, drivers position their vehicle considerably closer to the centre of the road and kept a relatively constant distance from the road edge in comparison to simulated driving perhaps due to reduced environmental cues in simulated driving.

4. Conclusion

The present research suggests that the simulator is able to discriminate between experienced and novice bus drivers on a number of parameters at three key hazardous locations in the expected direction [3] confirming that experienced drivers exhibit safer safer strategies in negotiating these hazards than novice drivers do. The findings support the use of a simulator for training purposes so long as caution is exercised over the use of the lateral position measure for driver training purposes.

There are two practical reasons why a simulator may be useful for novice bus driver training then. Firstly, a simulator allows for sensitive measurements of driving performance so that weaknesses can be identified in novice bus driver decision making and performance at hazardous locations. Secondly, a simulator can provide benchmarking of acceptable driving performance and provide a set of criteria against which novice drivers can be trained prior to operational driving. Areas of weaknesses can be clearly identified and targeted using simulator feedback forms based on experienced bus driver performance benchmarks to give novice bus drivers insight about how and where they can improve their drives in line with that of more experienced drivers.

Further research is currently underway to investigate the transfer of training effectiveness of a simulator-based driver training programme to see whether the simulator is indeed capable of reducing bus crashes in the real world.

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2006
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Lisa Dorn and Jenny Stannard; Simulator performance differences between experienced and novice bus drivers. Advances in Transportation Studies: An international Journal, 2006, Special Issue pp45-52

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