Preliminary evaluation of a virtual reality-based driving assessment test

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ABSTRACT

Assessing one's own driving ability is very subjective, and there are occasions when an objective off-road assessment would be very useful, and potentially life-saving. For example, after physical or mental trauma, or approaching old age, it would be very useful for people to perform their own off-road assessment to help them to decide whether they should resume driving, or continue to drive. It is possible that people might be more likely to accept that it would be inadvisable for them to drive if they had themselves performed such an assessment. We are currently evaluating a virtual reality (VR) based driving assessment which runs on a PC and could be made easily accessible to people in these circumstances. The first stage of the evaluation was to evaluate the performance of drivers and non-drivers on the VR driving assessment and to compare the results obtained across the two groups of participants and with their performance on the Stroke Drivers Screening Assessment (SDSA). The VR driving assessment discriminated between drivers and non-drivers but the SDSA did not. In addition, two measures on the VR driving assessment correlated with drivers' scores on the SDSA.

1. INTRODUCTION

In recent years, Virtual Reality (VR) has been used to good effect in numerous training situations. Among the advantages of virtual training is that it allows individuals to work at their own speed and in situations tailored to their own specific needs. Less emphasis has been placed on the value of virtual environments in allowing people to arrive at realistic assessments of their own abilities with regard to the particular task. Sometimes, such a self assessment may inform the type of further training needed. On other occasions, it may be just as valuable in persuading the person against continuing with the activity in question. The VR application described here is primarily concerned with helping people to assess their own performance levels.

Older people often see the continuation of their ability to drive as a crucial factor in maintaining their independence (Barnes and Hoyle, 1995; Mollenkopf et al., 1997, Rabbitt et al., 1996). Similarly, drivers who have suffered physical or mental trauma often consider that being able to drive again is an important landmark in their recovery and return to normal life (Mazaux et al., 1997). Currently, however, decisions as to whether older people should continue to drive, or whether people should return to driving after physical or mental trauma, are taken on an ad hoc basis, despite potentially disastrous consequences if the wrong decision is made (British Psychological Society, 1999). Regrettably, there is no standardised method whereby older drivers or drivers who have suffered trauma can assess their own ability to continue or resume driving. VR has the potential to provide the means whereby people can test their own driving ability without exposing themselves to the potential dangers of real driving. Many skills associated with real driving can be assessed on a VR-based driving assessment test which runs on a PC. On completion of the assessment, participants could be given a print-out of their performance and a recommendation as to whether or not they should continue or resume driving. This type of driving assessment would be economical and easy to install in driving assessment centres, public libraries, Age Concern centres and rehabilitation wards, for example. Although such an assessment would not replace any safeguards that are currently in place, it would allow people more informed control over their own lives and would have the potential to save lives by making some people aware that their standard of driving is dangerous.

We have devised a VR-based driving assessment test that runs on a PC. A screen-shot from the virtual environment is shown below at Fig. 1. In the assessment, a virtual car is driven using a widely-available steering wheel, accelerator and brake set. The test requires participants to follow a sign-posted route along

major and minor roads to a particular destination (a zoo). Along the route are road junctions, traffic lights and roundabouts which the participant is required to negotiate whilst complying with road signs and speed restrictions, and interacting with other traffic.

Figure 1. *A screen-shot from the VR driving assessment test.*

We have recently begun an evaluation of our VR driving test which will be in three stages. In the first stage, the performance of drivers and non-drivers will be compared on a prototype of the test. The justification for this evaluation stage is that the VR driving test should be capable of measuring some of the driving skills that are acquired with experience. It should therefore be capable of differentiating between the performance of drivers and non-drivers. Performance measures that do not produce a difference between drivers and non-drivers will be improved and incorporated into a revised version of the test. In the second stage, the test will be performed by drivers who have suffered a stroke and older drivers to investigate whether they are able to understand the test and can use it independently. Again, any alterations required will be incorporated into a revised version. In the third stage, volunteer older drivers' performance on the test will be compared with their performance on a real DSA driving test conducted by an approved driving instructor. The VR driving assessment test will continue to be revised and evaluated until there is a high correlation between participants' performance on the test and their performance on a real world driving test. The first stage of the evaluation is described below.

2. METHOD

1.1 Participants

Forty students from the University of East London voluntarily participated in the study to earn course credits. Twenty of the students had a full driving licence and 20 had never driven a car. The two groups of participants did not differ significantly in age [Drivers - age range 18-52, mean age 28 years; Non-drivers - age range 18-54, mean age 25 years, t(38)=0.85, p=0.40]. There were 18 female and 2 male drivers and 17 female and 3 male non-drivers. Ten drivers and 7 non-drivers had previously used a driving simulator.

1.2 Equipment and Materials

The VR-based driving assessment test was constructed using World-Up software and run on a Duel Xeon PC with a 17" monitor using a *Logitech* steering wheel, accelerator and brake set. Buttons on either side of the steering wheel allow the user to look left or right. The assessment comprises a sign-posted route to the zoo with left-hand and right-hand turns, two sets of traffic lights and two roundabouts. The majority of the traffic in the simulator runs pseudo-randomly but some traffic is programmed to produce potentially hazardous traffic situations which the participant has to negotiate. A record is kept of participants' performance, including how often they crash and hit the kerb, their steering ability, their stopping times, how long they take to merge with other traffic, how well they conform to the speed limit, and the total time they take to complete the route (approximately 10 minutes, depending on the user's ability). A practise route comprising a circular road with one set of traffic lights enables users to familiarise themselves with steering the virtual car and operating the controls. A photograph of a participant using the VR driving assessment is shown at Fig. 2.

Figure 2. *A participant using the VR driving assessment test.*

The participants also performed the Stroke Driver Screening Assessment (SDSA) (Nouri & Lincoln, 1994). The SDSA comprises four cognitive tests which have been compiled to evaluate driving fitness in stroke patients and have been shown to be significantly better than other forms of driving assessment in determining individuals who were found to be unsafe to drive (Nouri & Lincoln, 1993). Three of the four tests are used in the overall assessment. The first is a measure of attention and concentration in which participants are presented with a sheet of dots in groups of three, four or five. The task is to cross out each group of four dots within a maximum time of 15 minutes. The second test is a measure of non-verbal reasoning in which participants are required to correctly place 16 cards depicting two vehicles travelling in different directions from a roundabout into a grid of compass directions so that the direction of each vehicle corresponds with one of the compass directions on the grid. In the third test, participants are presented with 12 road situations and are required to select the correct road sign for each road situation.

1.3 Procedure

Participants were initially asked about their driving experience and their previous experience of driving simulators. They were then seated in front of the VR driving simulator and the controls were explained to

them. Each participant performed the practise route until they felt confident in their ability to steer the car, stop at the traffic lights, look both ways, and avoid other traffic. They then performed the actual driving assessment test. If they accidentally deviated from the route, the experimenter pressed a button which restored the car to the road again. On completion of the driving assessment test, each participant performed the four sub-tests of the SDSA. They were then thanked for their participation and the purpose of the study was explained to them.

3. RESULTS

No participants reported any adverse effects from using the driving simulator. All were able to complete the assessment and most reported that they enjoyed the experience. (Interestingly, some participants had reported simulator sickness effects in pilot studies when the driving simulator had been used with a very large screen.)

A measure of how well participants conformed to the speed limits of 30, 40 and 50 miles per hour imposed in the VR assessment was calculated by subtracting the relevant speed limit from participants' actual speed and converting all the resulting scores to positive. Sixteen of the 60 measures of stopping time were deleted because they were over ten seconds indicating that participants had, either slowed down without actually stopping, manoeuvred the virtual car to avoid a collision, or crashed. The remaining measures were divided by the speed at which the vehicle was travelling at the time and collapsed into one measure to reduce the number of statistical comparisons. Two measures of the time taken to merge with other traffic were also collapsed into one measure. Table 1 below shows the means and standard deviations of drivers' and non-drivers' scores in the VR driving assessment and the SDSA.

Table 1. *Drivers' and non-drivers' scores in the VR driving assessment and the SDSA*

Assessment	Measure	Drivers		Non-drivers	
		Mean	SD	Mean	SD
Hit car	No. of collisions with other cars	0.95	1.19	1.40	1.60
Hit curb	No. of collisions with curb	7.95	8.50	67.40	114.01
Steering	Degrees steering wheel turned	3267	984	3540	1250
Lane positioning	Distance from centre of lane (cms)	61.83	9.95	86.27	32.56
Stopping time	Time (secs) divided by vehicle speed	0.10	0.03	0.11	0.05
Total time taken	Time (secs)	622.62	102.08	641.07	70.09
Merge into traffic	"	30.97	9.21	30.70	10.34
Speed 30 mph	Non-conformance to limit (mph)	4.01	2.56	2.88	1.21
Speed 40 mph	"	5.05	4.33	6.71	3.38
Speed 60 mph	"	20.48	5.36	23.06	4.02
SDSA Dots	Time to complete (secs)	308.15	92.68	317.29	51.64
SDSA Compass	Cars correctly positioned	24.05	10.22	28.41	5.70
SDSA Road signs	Signs correctly positioned	7.85	2.83	6.76	2.91
SDSA Total score	In accordance with SDSA calculations	3.17	2.70	3.48	2.14

It would appear from Table 1 that drivers performed better than non-drivers in the VR driving assessment by having less collisions, hitting the curb less often, over-steering less, holding a better lane position, stopping marginally quicker, and conforming better to the 40 and 60 mph speed limits, However, drivers were not better than non-drivers at merging with other traffic or conforming to the 30 mph speed limit. Conversely, in the SDSA, drivers appear to have taken longer to complete the Dots Test, positioned less cars correctly in the

Compass Test, and achieved a lower overall score than non-drivers. The only measure in which drivers predictably appear to have scored higher than non-drivers is in the Road Signs Test.

Statistical analyses were performed to investigate whether there were any significant differences between drivers and non-drivers in the above measures. In all the statistical analyses, the probability level was set at 0.05. The only significant differences revealed by independent t-tests were the numbers of times the curb was hit [t(38) = 2.33, p = 0.025] and lane positioning [t(38) = 3.21, p = 0.003], with drivers performing better than non-drivers in both measures. None of the other comparisons reached statistical significance. The drivers' SDSA total scores significantly correlated in the predicted direction with the number of times that they hit the curb [Pearsons Correlation = -0.645, p = 0.002] and their over-steering [Pearsons Correlation = -0.480, p = 0.046] in the VR driving assessment. Other correlations between the SDSA total scores and the VR driving assessment measures did not reach significance.

4. DISCUSSION

Although drivers and non-drivers differed significantly on only two of the measures from the VR driving assessment, hitting the curb and lane positioning, the trend was that their performance was better than non-drivers in all but two of the measures. In contrast, the counter-intuitive trend in the SDSA total score was that non-drivers' performance was better than drivers'. Nevertheless, drivers' SDSA total scores significantly correlated with two measures from the VR driving assessment, hitting the curb and over-steering. It would appear that the cognitive tests in the SDSA are tapping into the same navigational skills which are used in steering the virtual car.

The two measures in the VR driving assessment where drivers' performance was not better than non-drivers' were "conforming to the 30 mph speed limit" and "merging with other traffic". The reason why drivers did not perform well in "conforming to the 30 mph speed limit" was that they were inclined to exceed the limit whereas non-drivers were not [drivers' mean = 30.89, non-drivers' mean = 29.95]. This tendency probably reflects their driving speeds in the real world. Unfortunately, the "merging with other traffic" measure did not work properly as it did not take account of participants simply turning left or right without paying any attention to oncoming traffic. Even if they crashed, they might still achieve a fast score on the "merging with other traffic" measure. This measure therefore has to be revised to take account of this possibility in the next version. Another measure which should be incorporated into a revised version of the VR driving assessment is a measure of reaction time which is independent of the speed of the car and avoidance actions by the driver, e.g. a notice appearing on the screen saying "Hit the brakes now". The current method of measuring stopping time in response to a hazardous road situation is too dependent on how the participant responds, which may be to steer around the hazard without stopping.

The finding that the VR driving assessment discriminated between drivers and non-drivers but the SDSA did not, indicates that only the VR driving assessment is measuring some of the driving skills acquired through experience. Research has shown that inexperienced drivers have problems with psychomotor (Mayhew & Simpson, 1996), perceptual (Mourant & Rockwell, 1972), and cognitive skills (Groeger & Brown, 1989). For example, inexperienced drivers are more prone to steering errors and inappropriate speed choices (Mayhew & Simpson, 1996). They also lack good hazard detection skills and take longer to respond to hazards (Groeger & Brown, 1989). The role of experience in driving cannot, therefore, be overestimated and any assessment that does not take driving experience into account when considering a person's ability to drive, is not providing a realistic measure of driving ability.

5. CONCLUSIONS

To many people, the ability to drive is an important aspect of their life and a symbol of their independence. However, after brain injury, or approaching old age, although people often feel that they are able to resume or continue driving, they are not always safe to do so. We have devised a VR-based driving assessment which will allow people to test their driving ability off-road and thereby help them to come to a more informed decision as to whether they should resume driving or continue to drive.

In the first stage of an evaluation of the VR driving assessment, drivers' and non-drivers' performance was compared on the driving simulator and the SDSA. The VR driving assessment discriminated between drivers and non-drivers on two measures but the SDSA did not, indicating that only the VR assessment is measuring actual driving experience. Since the role of experience is an important element in determining an individual's driving ability, a driving assessment test should take previous driving experience into account.

The results of the evaluation indicated that some measures from the VR assessment needed to be improved, particularly "merging with other traffic", and an independent reaction time measure should be incorporated into the next version. It will be worthwhile re-examining all the measures which did not produce significant differences between drivers and non-drivers to see if they can be improved.

After these revisions, and subject to two further stages in the evaluation, testing the VR driving assessment with people who have suffered a stroke, and comparing older people's performance on the assessment with their real-life driving ability, we are confident that this VR-based driving assessment will prove to be an invaluable aid to older people and people who have suffered physical or mental trauma in allowing them to decide themselves whether or not they should continue or resume driving. At the present time, the best off-road method of testing driving ability would be to use the VR driving assessment in conjunction with the SDSA.

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