A case study of a virtual reality-based drink driving educational tool

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Abstract

Road traffic accidents are of major concern and could be reduced by better education. This paper describes the development of a virtual reality (VR) app that mimics the effects of alcohol on a driver. It was developed using Unity (version 2019.3.14), smartphone and Google Cardboard™. The user experiences a car following a predetermined route that is lined with trees and objects (traffic lights, road signs and other cars) which they need to spot and react to. By using graphical filters and time delays the driver has a feeling of being under the influence of alcohol. Twenty volunteers (18–60 years old; mean age $\pm$ sd 25.5 $\pm$ 11.6) participated in its evaluation. Data were collected on concentration times, reaction speed and observation of objects in both the alcohol simulated (impaired) and non-simulated (unimpaired) runs. Data were analysed using paired t-test. The result showed that people spent longer concentrating on objects in the impaired vs unimpaired run (10.72 $\pm$ 5.07 vs 5.30 $\pm$ 4.22 s n:20; $p < 0.0001$). The average reaction speed to objects in the unimpaired run was lower than in the impaired run (1.44 $\pm$ 0.66 vs 2.66 $\pm$ 0.28 s n:20; $p < 0.001$). Seventeen out of twenty subjects spotted all the required objects in the unimpaired whereas only seven out of twenty spotted all the objects in the impaired run ($p < 0.001$). The authors have shown that an inexpensive VR app can be used to demonstrate to users the effect that alcohol can have on concentration, reaction speeds and observational skills.

Keywords Virtual reality · Drink driving · Road safety · Road accident · Driver education

1 Introduction

Road traffic accidents are a major global public threat [1]. Although accidents may be attributable to a range of factors, for example the environment or human error, those which could be avoidable, such as being alcohol related, still pose a significant problem. Driving under the influence of alcohol accounted for approximately 27,000 deaths or injuries

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to people in the United Kingdom in 2021 [2]. It is one of the main causes of death among young people between the ages of 15 and 24 with male drivers aged 17–24 being over-represented [3]. There are several contributing factors to this including younger drivers' lack of experience, increased willingness to take risks, immaturity and being less likely to perceive drink-driving as being risky or unacceptable [3, 4].

Blood alcohol levels can affect people's driving ability by reducing co-ordination, slowing down reaction times, and affects speed and distance judgement [5]. Some of which can be attributable to the affects that alcohol has on vision [6–9]. Studies have shown that alcohol causes a stepwise increase in reactions times when blood alcohol levels increase which can be exacerbated in ages 20–30 [10, 11]. It is therefore important to teach people about the dangers of driving after drinking alcohol. This is not only to protect themselves, but also the lives of other drivers and pedestrians. Drink-driving has been decreased by the use of social marketing and media advocacy campaigns, as well as with increased drunk-driving enforcement [12, 13]. At the personal level, traffic safety should be obtained from the family [14, 15] and at school [16, 17]. However, there could be the danger that parents feel that they do not need to address this subject as their teenagers are not yet drinking alcohol [18]. Changing the behaviour of drink-drivers is a challenge to professionals [19] with calls for better strategies to help reduce drink-driving behaviour [20]. The use of computer-based simulations or serious games are potential ways of achieving this.

2 Related work

Driving simulations can be used to safely collect data on driver reactions in a range of different situations. Their use in research has subsequently helped change legislation, create, or change vehicle designs and controls, help to understand how the driver uses the car's controls as well as to educate the driver on how to use the vehicle and improve their driving skills [21]. Simulations are extremely useful when investigating how users react when they are expected to engage in risky behaviour that could potentially put themselves or others in harm's way, for example drink-driving. Research using simulations has found that alcohol impairs a drivers' control of speed and direction as well as increasing reaction times that are associated with speed and lateral control of the vehicle [22]. It was found that drivers' reaction times were longer when they encountered traffic lights that were turning yellow, and the time to decelerate at stop signs and red lights was also increased. Burian et al. [23] identified increased risk-taking behaviour in the form of inappropriate lane changing habits in subjects who had consumed alcohol. Despite the obvious benefits and realism of these simulations there are issues with approaches used in these studies. They can be expensive owing to the use of sophisticated technologies, for example dedicated driving hardware, conversions of actual cars and the need for high-quality projection systems for visualisation and the integration into the vehicles [24–27].Those studies that have researched drink-driving have also required that the participants consume alcohol [22, 23, 28, 29]. This raises ethical issues as they would be unsuitable for educating young people about the dangers of drinking alcohol and driving.

Allied to simulations are serious games. These can be simulation-based but use game mechanics meaning they are not always representative of a true driving experience. As they can take the form of 2D or 3D games they may be more appealing to younger demographics. Examples of road safety games for young people are available on familylearning.org. uk. Others include 2D educational games such as learn to park: Drivers Ed Direct Parking

Game [30] through to 3D ones such as virtual driving school [31] and Ford driving skills [32].

Virtual Reality (VR) is also a promising approach because of its immersive nature. Having already been used in education, it could be expanded to road safety educational programs for example to reduce risky behaviours, such as driving intoxicated, getting distracted at crossings or speeding [33]. The Road Safety Authority (RSA) have developed several VR experiences for young people. Two examples of this include 'consequences' and 'distractions' [34]. Both VR experiences use pre-recorded video stories highlighting the issues with drink-driving and being distracted whilst driving. Research into the use of VR has shown improved observational skills for hazards after using simulations [35], with those that used videos seeing better improvements compared to static images [36]. Many of the research studies into the use of VR in driving have used headsets such as the Oculus Rift™ and HTC Vive™ [37]. These are commercially available and are argued to be affordable. However, in the case of both the Oculus Rift™ and HTC Vive™ they need high performance PCs to be connected to, and the Vive also requires room space owing to its need for its tracking base stations. Therefore, the resources and expense are probably higher than previous studies have considered. In terms of the work outlined in this section few focus on the affects that alcohol can have on a person's driving ability, or the measure of those effects.

3 Problem statement and aims

At the time of writing this article there are no inexpensive VR educational tools that can be used to provide education to young drivers about the effects of driving whilst under the influence of alcohol. In the following work the authors discuss the development and evaluation of a proof-of-concept drink-driving educational tool which is based upon the inexpensive VR technology Google Cardboard™. The research investigates how the use of visual effects that distort the users' vision, mimics the effect of consumption of alcohol, affects a range of skills (observation, concentration, and reaction times).

4 Methods

The app was developed using the Unity game engine (version 2019.3.14), 3D assets were from the Unity store, and it was programmed using the C# language. For testing and evaluation purposes it was deployed to a Oneplus 7 smartphone and Google Cardboard™ VR head mounted display (HMD). The system is compatible with other commercially available smart phone HMDs (both cardboard and plastic variants) that copy the design and functionality of Google Cardboard™.

The design uses a first-person view that mimics a driver being in the interior of a car looking through its windscreen at the road (Fig. 1).

4.1 Ethics

Ethics permission was granted by The Faculty of Computing, Engineering and the Built Environment, Birmingham City University (UK). Participants were given an information

Fig. 1 Image of user viewing the scene through a Google Cardboard™ headset

sheet outlining the study objectives. Their agreement to participate was obtained through informed consent.

4.2 Implementation

As the app runs, the driver automatically follows a predetermined route in a scene that is reflective of semi-rural roads found within regions of the UK (Fig. 2). Each run takes approximately 40 s.

There are different objects located along the route classified as important (a stop sign, a red traffic light, a moving car and a stationary one) and unimportant (scene, the trees, and the background). All are scaled appropriately. As the driver is taken around the route, they must react to the important objects by clicking the button on the HMD in order to identify them. To mimic the effect of alcohol consumption the app uses Unity's graphical filters to distortion the user's vision whilst they are driving around the 3D virtual road.

There are two scenarios in the app, one where the route is followed without any visual effects applied (unimpaired) (Fig. 3a). The other run has the graphical filter (Unity shader) applied which will simulate driving under the influence of alcohol (impaired) that is making the scene blurred and distorted (Fig. 3b). In this scenario there is also an additional 0.3 s delay added to the users' reaction speed which simulates the slowdown in a person's reactions because of alcohol. This value was derived from historical information provided by Allen et al. [29].

Whilst using the app, data are collected from the user on three skills: concentration, reaction time and observational skills. Concentration reflects the time spent focussing on important objects and less important items in the environment. The latter being used as a way of gauging general distraction of the user. Reaction times relate to seeing the objects in

Fig. 2 Road layout of the scene
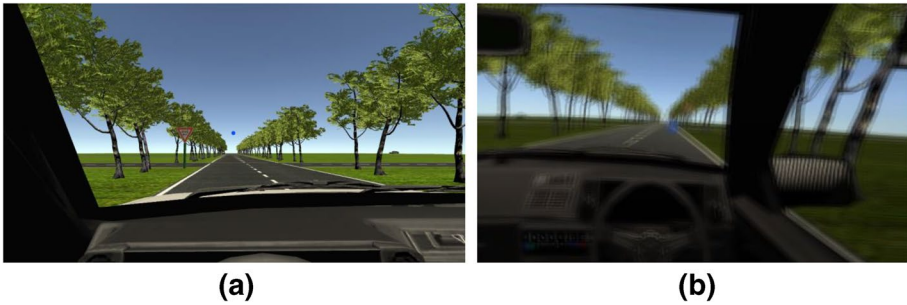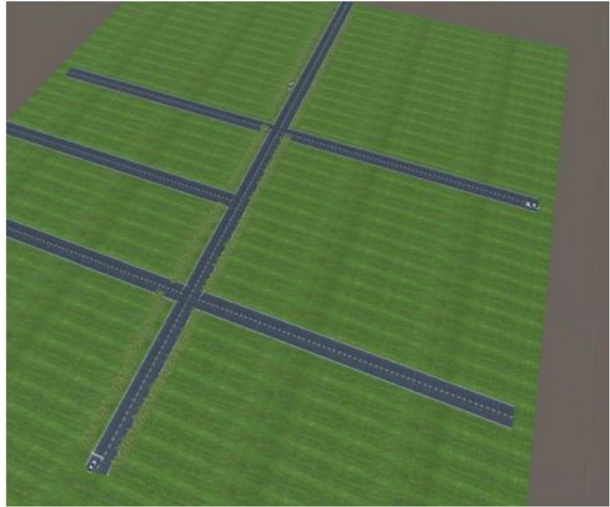
Fig. 3 **a** Image of the unimpaired (no alcohol graphic filter) driver view, **b** Impaired drivers view

the app whereas, observational skills record the number, out of the four important objects, that the driver did not detect. The reaction speed recorder starts timing when the object is visible and stop when the user taps the screen while looking at the object. If the screen is not tapped, then the object is counted as missed. The concentration timer measures how long the user 'hovers' over the object and continues until the end of the test. These data are collected during the initial drive, that is without the graphic filter (no alcohol), and then again with the shader graphic filter (with alcohol) present.

Once the prototype app was completed a reactive testing strategy was used to identify bugs and provide formative feedback. Ten people (age range 18–20; mean age 19.2 ± 0.75; 9 male and 1 female) tested the app to find any issues. Their responses identified issues relating to: they seemed too high and too far back in the driving seat, the objects were too hard to spot (blending in with the background), and the need to add a button to start the simulation. Next a methodical testing strategy was used where the testers were asked to complete a checklist of those issues that had been identified in the reactive testing. If the problems had not been resolved, they were corrected. Once the formative testing was completed the app was formally evaluated for a users' concentration, reaction time and observational skills.

5 Results

A convenience sample of twenty people (age range 18–60; mean age ± sd 25.5 ± 11.6), 17 male and 3 female) voluntarily took part in evaluating the app. Two were learner drivers with less than one year driving experience, 18 had more than three years driving experience. Of the twenty, 5 considered themselves infrequent drivers. Data were analysed in terms of:

- The time spent concentrating on important objects (e.g., signage and other vehicles)
- The time spent concentrating on less unimportant objects (the scene, the trees, and the background)
- The reaction speed to the important objects
- The number of important objects correctly identified
- Correlation between months spent driving vs concentration, reaction times and observational skills

Data were analysed using MaxStat Pro (https://maxstat.de). Descriptive statistics are presented as mean ± standard deviation. Tests for normality were conducted using Anderson–Darling test (concentration times data $p > 0.67$ and reaction times data $p > 0.15$). Comparison between impaired and unimpaired runs were conducted using two-tailed paired t-test. Correlations between months spent driving and impaired and unimpaired runs were conducted using Pearson correlation coefficient.

5.1 Concentration times

When comparing the concentration times, it was found that the participants ($n = 20$) spent significantly ($p < 0.0001$) longer looking at the important objects when they were in the impaired run (10.72 ± 5.07 s) when compared to the unimpaired run (5.30 ± 4.22 s) (Fig. 4).
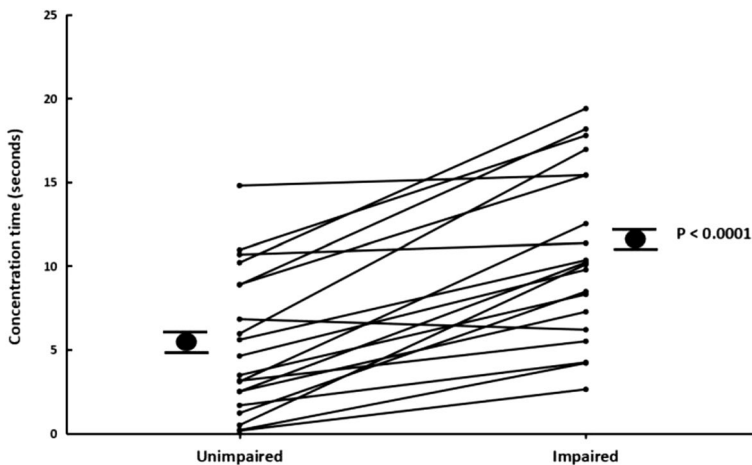

Fig. 4 Individual concentration times of unimpaired and impaired drivers for important objects. Data are presented as mean ± s.em. for twenty participants

Similarly, drivers who were in the impaired run took significantly ($p < 0.01$) longer when observing unimportant objects (1.35 ± 1.25 s) when compared to when they were in the unimpaired run (0.39 ± 0.46 s). When analysing all the participants ($n = 20$) there was no correlation between the months of driving experience and their concentration times on unimportant objects in either the impaired or unimpaired run. However, there was a significant negative correlation ($r = -0.46$: $p < 0.05$) between the months of driving experience and time spent concentrating on the important objects in the impaired run. The more months driving experience the less time they concentrated on important objects. When the infrequent drivers were removed from the analysis (sample $n = 15$) a similar pattern was observed between the months of driving experience and time spent concentrating on the important objects in the impaired run (-0.53: $p < 0.05$). When these same analyses were conducted using only on the infrequent drivers ($n = 5$) no correlations were observed.

5.2 Reaction times

The average reaction speed (*independent of the additional 0.3 s delay*) for participants ($n = 20$) detecting the four objects in the unimpaired run was significantly lower ($p < 0.001$) at 1.44 ± 0.66 s compared to the average reaction time in the impaired run which was 2.66 ± 0.28 s (Fig. 5). When analysing all the participants ($n = 20$) there were no correlations between the months of driving experience and their overall relation time to the objects either in the impaired or unimpaired run. This was also true when the infrequent drivers were removed from the analyses (sample $n = 15$) and when the same analyses were conducted using only on the infrequent drivers ($n = 5$).

5.3 Observation skills

The data showed that spotting important objects on the unimpaired run was easier for the users. Seventeen out of twenty subjects correctly spotted all the objects in the unimpaired
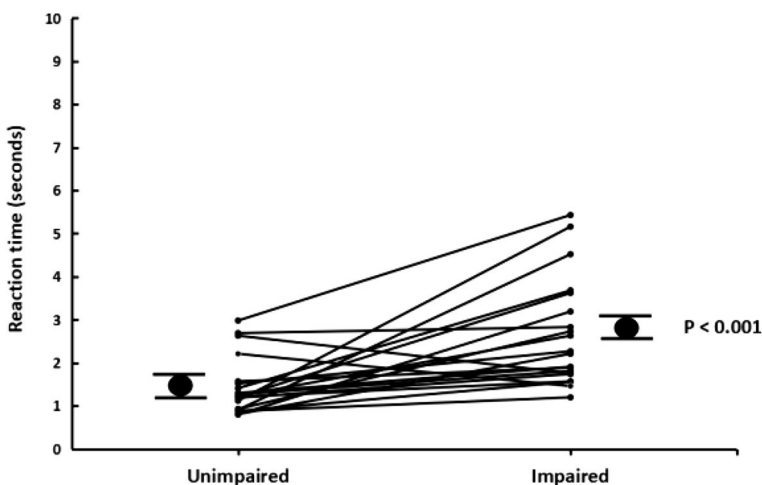

Fig. 5 Individual average reaction speed times of unimpaired and impaired drivers. Data are presented as mean $\pm$ s.em. for twenty participants

run whereas only seven out of twenty subjects correctly spotted all the objects in the impaired run ($p < 0.001$). When analysing all the participants ($n = 20$) there were no correlations between the months of driving experience and number of correctly observed objects either in the impaired or unimpaired run. This was also true when the infrequent drivers were removed from the analyses (sample $n = 15$) and when the analyses were conducted using only on the infrequent drivers ($n = 5$).

6 Discussion

Previous studies that have used driving simulations to investigate the effects of alcohol on driving skills have required the use of sophisticated simulations. These can be expensive and not readily available to the general population [38]. Other road safety simulations have used commercially available VR systems but not in the context of drink-driving education. Although their authors argue that these are relatively inexpensive [37] they may still be prohibitive to some people for example those of a low socio-economic background or that the general public are not interested in investing in such items. The sophistication of such systems is not in question, but their prevalence may not be as common as researchers have proposed. Few studies have looked at using Google Cardboard™ [37] however, as smart phones are ubiquitous and are more likely to be owned by more of the general public, than other VR systems, then Google Cardboard™ (or similar commercially available counterparts that uses its approach) was a worthy candidate for investigation given it costs a few GBP.

This initial study chose to use a rural scene as 1. there would be less variables within the scene to control and therefore allow the focus of the study to be on the whether using graphical filters could mimic alcohol-related blurred vision on the key skills that were being investigated. 2. scene selection is appropriate as data show that fatalities can be higher in rural settings than in in urban settings [39].

The results show that it is possible to mimic the effects of alcohol on vision, in VR, by using graphical manipulation of the Unity scene. This can affect the user's ability to concentrate on objects, reduce their reaction times and their ability to identify key objects. It is difficult to directly compare results to other drink-driving studies given these often involved different types of driving simulation and required participant to consume alcohol. However, looking at their general findings there are similarities to ours. These included drink-drivers stopping closer to stop signs or even after them as well as exhibiting longer reaction times to traffic lights [22]. Garrison et al. [28] identified a diminished ability for an individual to prioritize important aspects of a driving situation while neglecting less important ones. Missed observations and increased response times have been attributed to degraded visual scanning of the environment [29]. Garrison et al. [28] proposes that these negative effects are consistent with the alcohol myopia theory [40] where alcohol reduces attentional capacity.

The experimental design, whereby all drivers go through the unimpaired run first followed by the impaired one, was chosen so the users can compare normal versus impaired vision. This seems more logical when undertaking discussions as to how alcohol impacts normal driving experiences rather than undertake a cross-over study whereby the driver compares abnormal to normal vision and vice-versa. Although the study was intended to be an educational tool for younger people the authors also looked at whether the length of time someone had been driving had any influence. This is because it may have the potential

for use in educational programmes for convicted drink-drivers, given they would be potentially older and have been driving for a longer period of time. There were no trends appearing when comparing the months, a person had been driving to the different skills being assessed. The only exception was in drivers with over 500 months (40 + years). They were more likely to spend less time concentrating on important obstacles during the impaired drive-through. This could be of concern given the simulation should not give the impression that driving under the influence of alcohol is safer when the person has more years of driving experience. However, this finding may have resulted from the fact these people have more driving experience and therefore are more familiar with encountering these objects in the real-world. However, no solid conclusions can be drawn owing to the limited number of people in this age group. During the study year 2021 the UK was in COVID-19 lockdown meaning access to volunteers was restricted and therefore experiments had to be conducted using a convenience sample that were accessible to the authors.

The authors' system is intended to be an educational tool rather than an authentic simulation which could be used, for example in classroom settings. There are advantages and disadvantages to this approach. Google Cardboard™ has only one way of interacting with the Unity scene, by using a button on the headset. Therefore, it was decided that the user would need to follow a predetermined route rather than drive through it. This is because the button would have to be used to interact with the required objects within the scene. Following a fixed route also means the 'driving' requirements are the same for each participant allowing the focus of assessment to be on the key skills being investigated.

Although interaction with items such as a steering wheel, gear shifting and using the brakes are undoubtedly important, and more realistic, these would be difficult to implement in Google Cardboard™ given the limited way you can interact with the HMD. This functionality could be achieved by use of additional external controllers but would require further programming increasing complexity and cost. The focus of this initial research was primarily on the feasibility of using graphic filters to impact on driver's vision as identified as being a factor in drink-driving accidents [9]. This tool's premise was for it to have the potential for it to be a component of an educational programme which can promote discussions about issues relating to alcohol use (or other substance misuse) on driving skills. It was not intended to be an authentic drink-driving simulator.

The use of graphical filters to mimic alcohol effects is ethically preferable to previous studies that have required that the driver consumes alcohol [22, 23, 28, 29]. Although that approach is authentic it poses issues of its use as an educational tool for young people. Other simulations and VR experiences have used pre-recorded videos. These may be in the form of a story portrayed by live actors or videos of 3D created worlds. This means that altering or adapting the scenario would require re-recording. By using the Unity game engine scenes can be altered by reprogramming them, and by using 3D models scenes can be adapted and customised.

The evaluation of this system has not been exhaustive. Rather the study was aimed at assessing the feasibility that by combining inexpensive VR headsets and programmable 3D models one could create an environment that can be used to highlighting how drinking alcohol can affect driving skills. A range of metrics including reactions times, concentration and observational skills were assessed by simple algorithms incorporated into the app. These proved to be informative and demonstrated that the use of the graphical filter approach does impact on each of them. More sophisticated tools like eye tracking could provide even more information. However, its incorporation within Google Cardboard™ would be challenging given that specialised equipment and software are required. In the context of this work, it is argued that this would be an unnecessary additional cost that may

not add much to the existing experience. Using eye tracking would be more appropriate as a research tool rather than an educational one.

One item often reported as being a downside to the use of VR is cybersickness. This could impact on its effectiveness as an educational tool. As part of the ethical governance of this study, the participant information sheet and informed consent required the volunteers to report adverse events and they can elect to stop participating. No adverse events were reported. This may be in part due to the relative simplicity of the approach used (Google Cardboard™) and that that 'drive-through' usually took less than a minute to complete.

7 Conclusion

In this proof-of-concept study the authors have explored the potential of a drink-driving educational tool that could be used as a way of stimulating discussions around the subject of driving under the influence of alcohol and be experienced in a more ethical way. The tool was developed using a combination of inexpensive VR technology, software-based graphical filters, and time delays. In combination, these gave the user an experience of what it is like to be in a car when they are under the influence of alcohol. This included reducing their observational and concentration skills as well as reaction times. The tool does not represent a true driving experience, for example by addition of steering wheel, gear levers and brakes rather it is designed to be an inexpensive approach to an identified social problem. The importance of cost when developing technology-based educational tools is often overlooked but a key factor if wide-scale adoption is intended. The positive outcome from this work warrants further investigation to understand its benefit in educational settings but at this point provides interested parties with a platform for enhancement to explore other factors that can contribute to adverse effects on road safety.

8 Future work

The system described in this paper sets a basis for future expansion in terms of both being an educational tool and a platform for associated research. These include:

The addition of other scenes and scenarios. This could include different urban environments and motorways. Inclusion of elements that could impact on driving for example effects on visual acuity, colour, and light perception such as car headlights or day / night light cycles.

Apart from vision other factors that are associated with traffic accidents are noise, audio and in-vehicle distractions which could be incorporated and assessed in terms of the three skills investigated in this study. Such distractions include using mobile phones, headphones, satellite navigation (sat nav) devices, infotainment systems, noisy passengers, and poor passenger behaviours [41–43].

The success of the current system warrants formal evaluation in educational settings. This should include investigating its usability, acceptance of this type of learning experience and assessing its effect on appropriate learning outcomes.

Declarations

Conflicts of interest The authors have no conflicts or competing interests to declare that are relevant to the content of this article.

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