EVS28
KINTEX, Korea, May 3-6, 2015

Gamifying the EV Driving Experience: A virtual electric vehicle to change public attitudes

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Abstract

Although significant advances have been achieved in the range and performance of battery electric vehicles (BEVs) in recent years, the rate of uptake of these vehicles is relatively slow, meaning that they will not become a significant component of national vehicle fleets for some time to come. This slow adoption can be attributed in part (price is of course a major factor) to misunderstandings, misinformation, and an absence of experience with such vehicles. This paper describes the development and evaluation of a virtual electric vehicle – effectively a game-like application on a smartphone – which mimics an individual's real use of a conventional fossil fuel powered vehicle with the equivalent experience in a BEV. The smartphone "knows" when it is in the user's conventional car, and keeps track of its travels, simulating the battery charging and usage of the virtual BEV in real time, and reporting situations such as driving range exceeded. It also provides summaries of running costs, and for long term users, indicates the need for battery replacement. In this way, it enables a user to gain some experience of what it would be like to use a BEV on a daily basis.

A preliminary evaluation of the virtual BEV concept has shown excellent results, with a significant increase in positive attitudes to BEVs after only one week's use of the smartphone app.

Keywords: virtual BEV, gamification, BEV uptake

1 Introduction

Concerns relating to greenhouse gas emissions and their contribution to global climate change, and declining fossil fuel reserves, as well as significant advances in battery technology, have led to a significant revival of interest in electric vehicles in the past 15-20 years. In many jurisdictions, in order to meet climate change commitments, policies, incentives and infrastructure are being developed or are in place, to encourage the uptake of electric vehicles as an alternative to those powered by internal combustion engines. However, in spite of these initiatives, and a growing awareness and acceptance of both climate change and peak-oil as immediate realities, in all but a small number of progressive regions, the uptake of electric vehicles has been relatively slow.

Although price is one factor in this slow adoption [1, 2], prejudice, misunderstandings, misinformation and absence of experience with such vehicles, are all significant contributors to the general low level of acceptance of this new technology. The extent of the promotion of misinformation and prejudice can be seen, for example, in a widely viewed and highly popular television motoring programme [3]. Many people misunderstand the potential benefits in running costs and performance [2], and lack of experience shows in the widespread "range-anxiety" shown by potential purchasers of electric vehicles [2, 4].

This paper describes the development and evaluation of a prototype virtual electric vehicle (VEV), conceived specifically to address these issues: the lack of experience, unwarranted prejudice, misinformation and misunderstanding. The broader research question being addressed is whether a virtual world experience, which parallels the user's real world experience, in real time, can be effective in raising awareness of difference, and bringing about changes in attitude. The techniques employed, involving the introduction of game-like virtual aspects to an otherwise real-world experience, are generally referred to as *gamification* [5]. Although a number of other researchers and developers have also exploited the virtual electric vehicle concept, these efforts have not been aimed specifically at matching the EV experience, nor has their effectiveness in addressing attitudinal issues been evaluated.

The VEV described here is an app (application for a mobile phone) running on a user's smartphone. It operates while the user is driving their conventional internal combustion engine vehicle (ICEV), mimics its movement, and tracks vital parameters such as speed, distance, (virtual) battery state-of-charge, and operating costs. Without the expense of purchasing an electric vehicle (EV), the user is able to learn of and understand the advantages and limitations that an EV has in relation to their ICEV. In this way, the VEV has the potential to inform a future purchasing decision.

A trial evaluation of the app has been carried out with a small sample group of users. Although the period of the trial was only one week, the outcome in terms of increasingly positive attitudes to EVs was quite remarkable, showing great potential for this technique of gamification, potential that might also effectively be applied to other aspects of energy and resource use.

The prototype application runs on an Android device, and is available from the Google Play store [6]. A more detailed description of its development can be found elsewhere [7, 8].

Section 2 of this paper provides a review of other relevant research, and of the technologies pertinent to the VEV project. In section 3, the design and the development of the prototype is explained. The trial evaluation and its outcome is discussed in section 4, and section 5 provides overall conclusions and recommendations, and suggestions for future research.

2 Background

This background section describes earlier work on personal choice and motivation in relation to environmental concerns, it explores the concept of gamification, and how it might be exploited in this real/virtual world application, establishes the relevant parameters for electric vehicles to be simulated, and briefly reviews other simulated vehicles.

2.1 Motivation and personal choice in relation to environmental concerns

Stern [9] has established an important distinction between environmentally significant behaviours which are undertaken because of their foreseen immediate *impact*, and a class of behaviours which are undertaken with the *intent* that they will be beneficial to the environment. For useful research in the latter case, where impact cannot be immediately assessed, it is necessary to understand people's beliefs, motives, and attitudes, and how shifts may occur in these.

Stern goes on to suggest that although private sphere behaviours such as car purchase do have a direct impact (on the environment), the impact on an individual basis is very small, and these decisions "…have environmentally significant impact only in the aggregate, when many people independently do the same things" [9]. This suggests that while environmentally motivated individuals will opt for an electric vehicle, almost regardless of the costs, either financial or to personal convenience, a large proportion will be significantly swayed in their decisions by prevailing public attitudes.

It is for these reasons that if current targets for reduction of greenhouse gas emissions are to be met in the proposed timescales without regulatory intervention, significant education, and consciousness-raising needs to be undertaken. Given the relatively high cost of car purchase, the fact that in many jurisdictions car purchase and ownership is the quintessential symbol of individual choice, and the prevailing prejudice and misinformation already alluded to, then a simple means of raising individual (potential) car purchasers' awareness of the true characteristics of EVs and their every-day and long-term personal impacts, is an important development. Areas of concern clearly include purchase cost, daily operating costs (energy), long-term operating costs (battery replacement), availability and choice, performance (in relation to ICEVs), range between charges, charge time, and availability of charging facilities [2].

2.2 Gamification vs. serious games

The research literature on computer gaming makes an important distinction between *gamification* and *serious games*. Whereas serious games are just that – games designed for a serious purpose, potentially utilising and exploiting any features of more frivolous games, gamification describes the concept of introducing some game aspects to real world applications. The distinction is most usefully represented in Figure 1, taken from Deterding *et al* [5], which provides a comprehensive definition.

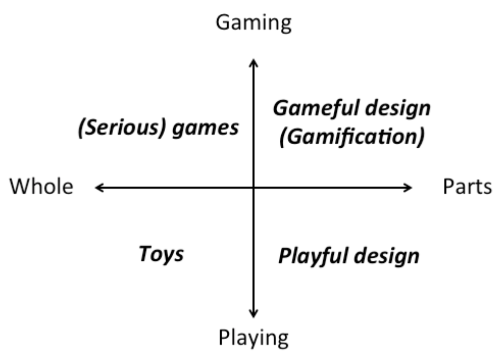

Figure 1: Gamification defined in relation to serious and other games (from Deterding *et al* [5]).

Gamification concepts are being increasingly exploited in business (marketing and staff incentives, for example) [10] and education [11]. There is general consensus that to be truly effective, gamified applications need to be engaging and compelling, and motivate users to remain involved beyond the immediate short-term [12].

One example of gamification applied to vehicle use is FuelGood [13], a mobile application which tracks vehicle use, giving a summary of distance travelled, time taken, average emissions, and the savings that could be made by driving more efficiently. Further elements of gameplay are introduced through competition between participants, and the awarding of badges and other rewards.

2.3 Electric vehicle parameters

As suggested in the introduction, apart from the cost of the initial investment, the major concerns of the general public over EV adoption relate to the battery [1, 2]: the driving range, availability of charging/swapping stations, charging time, and life-span and replacement cost. Other performance and safety concerns are relatively minor by comparison.

2.3.1 Driving range

EV technology has progressed extraordinarily rapidly in the current new dawn, after the doldrums of the 20th century, as the ICEV surged ahead following the EVs early promise [14]. There is no doubt that the highlighted issues around battery technology will continue to be a focus for research and development in the immediate future, with consequent significant advances. However, for the development of the VEV application, it is realistic present day parameters which are important. Table 1 summarises driving range figures for a small representative sample of currently available vehicles. Driving range does vary according to a variety of factors; the figures given here are considered to be typical and achievable, but are by no mean definitive.

Table 1: Driving range characteristics [15, 16]

	Driving range (km)
Ford Focus Electric	122 - 160
Nissan Leaf	117 - 135
Tesla Model S	257 - 482

2.3.2 Battery charging

Availability of charging stations, and charging times, are very dependent on jurisdiction. For example, in the USA, the Department of Energy provides a website showing the locations of accessible charging stations [17], some fast supercharger stations are available, and battery swap stations are just coming on line [18]. However, in New Zealand, there are very few charging stations presently available and most charging occurs at home, from a 15A, 230volt domestic electricity outlet [19]. Fast charging stations, however, which can achieve an 80% charge in 30 minutes, are also beginning to appear [20].

2.3.3 Battery life and replacement

Although there is considerable research on new and improved technologies for batteries and for their charging, aimed at a longer useful life-span, there is little hard information about actual life spans of batteries currently in use. Added to this are the complication that the nature of the use (patterns of charge and discharge), how charge cycle statistics ought to be measured when there are few full charge/discharge cycles, and the impact of environmental factors such as heat on battery life. However, such information as is available suggests that at the present time battery replacement might cost ~10% of the original purchase price of an EV [21], and battery life estimates vary from 70% capacity at 5years/60,000 miles, to 80% capacity at 100,000 miles [22]. It is also suggested that a battery is beyond its useful lifespan when it has lost 20% or more of its original capacity [23].

2.4 Other virtual vehicles and related applications

There are a number of existing apps for mobile phones which operate in-car, and use GPS data for a variety of purposes. These include FuelGood [13], which provides comments on overall trip characteristics, VEVCo's virtual test drive app [24], which by analysing trip data is able to recommend what kind of green car might suit the user's needs, and PlugShare [25], which assists drivers in finding nearby charging stations. There are a host of other applications which cover domains such as navigation and ride-sharing. An application which comes closer to the purpose proposed in this paper compares real ICEV performance with an equivalent virtual EV, but does this through post-analysis, and is focussed on commercial vehicles [26]. Some apps with similar behaviour to that described here are available on-line, but there is no information regarding their real purpose or effectiveness [eg 27]. Diewald *et al* [28] have commented on the promise of gamified design for in-vehicle applications, but suggest that rule definition and testing are first required, and the notion of serious games being applied to home energy management has been discussed [29].

3 Application Development

The VEV application, a simulated EV which mimics the user's driving of a real vehicle, has been implemented on the Android platform [30]. This platform was chosen for the prototype implementation because it is the most popular mobile operating system available, with more than one billion active users [31]. Program development has utilised Eclipse with ADT, which provides an integrated development environment for the Android platform [32].

3.1 Application concepts

The principal parameter of interest for the prototype application is battery state-of-charge, or driving range remaining. In order to simulate this parameter, the application needs to (i) retain a record of the battery state between trips, (ii) in real time trace the distance travelled and simulate the implied battery usage, and (iii) provide a mechanism for simulated battery charging. In addition the application should provide detailed information about the current journey, and summary history information relating to earlier journeys. An early design sketch for the driving screen is shown in Figure 2, which highlights all of these aspects.

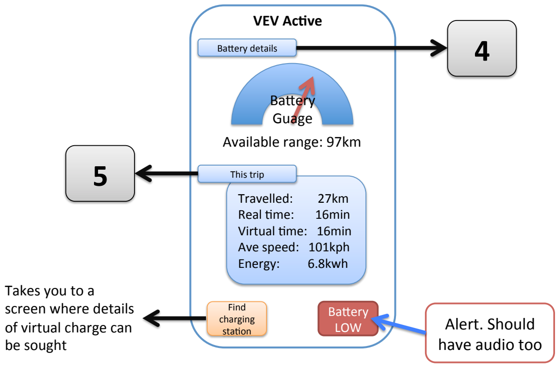

Figure 2: Part of the initial design specification of the VEV app, showing the information that needs to be available when the app is running.

It was also decided for this prototype implementation to provide the user with a choice of real vehicle models to drive, and to use representative characteristics and specifications for each of these vehicles. Only a small number of vehicles are currently offered (Nissan Leaf, Tesla Model S, and Mercedes Benz SLS), and the user must choose a model when they turn on the application. It is possible for the user to operate more than one virtual vehicle at the same time, for comparison purposes.

The following sections provide an overview of the prototype app. Section 3.2 discusses some of the issues relating to tracking the movement of the car, section 3.3 outlines the simplified battery model used for this prototype, and how it operates, and section 3.4 describes the history record and its use.

3.2 Tracking movement

Location (and hence movement) can be tracked using Google Play services. This allows for minimum thresholds to be set for position sample-time or change-distance intervals. While larger thresholds reduce battery drain (and this is an issue with an app which may be continuously monitoring position over a period of hours), they also result in reduced accuracy of calculated distance travelled, particularly in urban situations.

Google Play services operates with two different position locating options, GPS and Network. The GPS or satellite option is the more accurate of the two, but it is slower, and consumes more battery power than the Network option, which uses cell tower and WiFi information to determine location.

The normal driving screen is shown in Figure 3, with an image of the virtual vehicle currently in use (in this case the Nissan Leaf has been chosen), a battery gauge (in this case the battery is in a very low state), and data relating to the current journey.

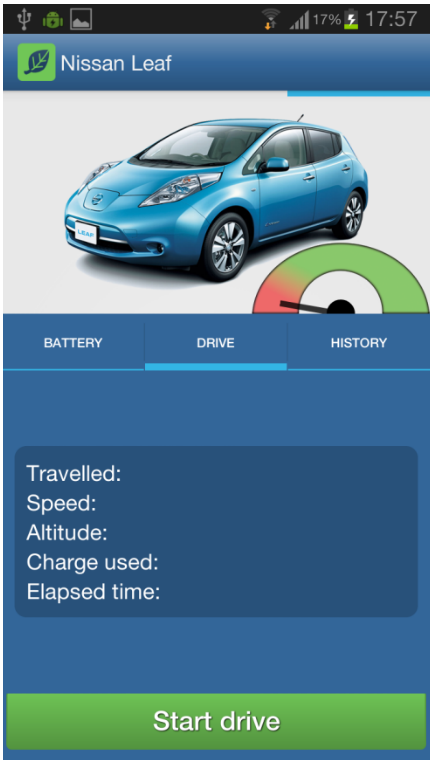

Figure 3: The VEV screen display, in-car and ready for a new journey to commence.

Because it was required that the app should start automatically, a method for detecting a new journey was required. Two approaches have been used. The first is to exploit an in-car Bluetooth connection, if available. When the mobile device pairs with the vehicle's Bluetooth, it assumes a new journey is about to commence, and initiates the app. The alternative technique triggers a new journey as soon as significant movement is detected. The user can also manually initiate a new journey, as can be seen in Figure 3.

3.3 Battery model

The prototype uses a very simple battery model for both charging and discharging. Although at a detail level this does not provide an entirely accurate representation of the virtual vehicle's battery state, for the purposes of this study, it was considered entirely adequate.

When the vehicle is moving, the battery is discharged according to distance travelled, using average energy/distance values for that vehicle model, and this calculation is performed in real-time at each position update. This information is represented on the battery gauge (all screens), and in detail on the battery screen, as can be seen in Figure 4. A more sophisticated model would take hills, speed and acceleration into account.

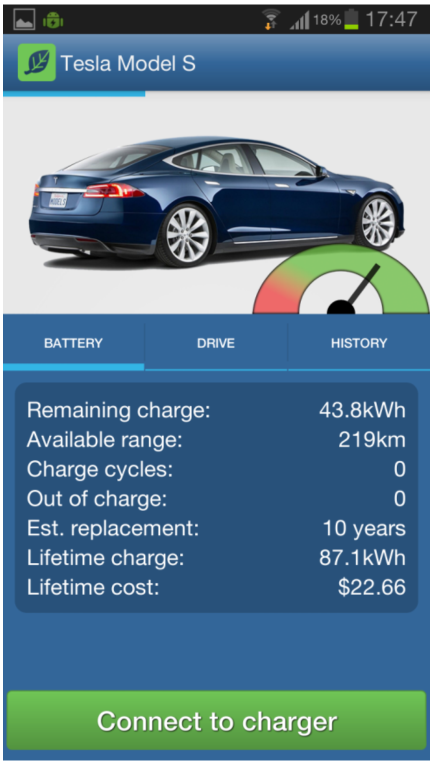

Figure 4: The VEV battery screen display, in-car with the car stationary.

Battery charging can be initiated at any time when the vehicle is stationary, using the "connect to charger" button seen in Figure 4. For battery charging in the current prototype, a linear energy/time calculation is used, and the only charging option available is based on a home charger at 230 volts, 15 amps. Future versions will use a more realistic non-linear model, with charge efficiency reducing as the battery approaches full charge, and will also provide a fast charge option. Charging, and charging type, will also be restricted to available charging locations, including home base.

3.4 History record

A record of the history of the VEV use was considered essential, so that a user could review where their virtual vehicle had taken them, and make comparisons over time of the virtual vehicle with their real ICEV. Figure 5 shows the basic history screen, which displays a list of recent trips, and provides access to summary statistics.

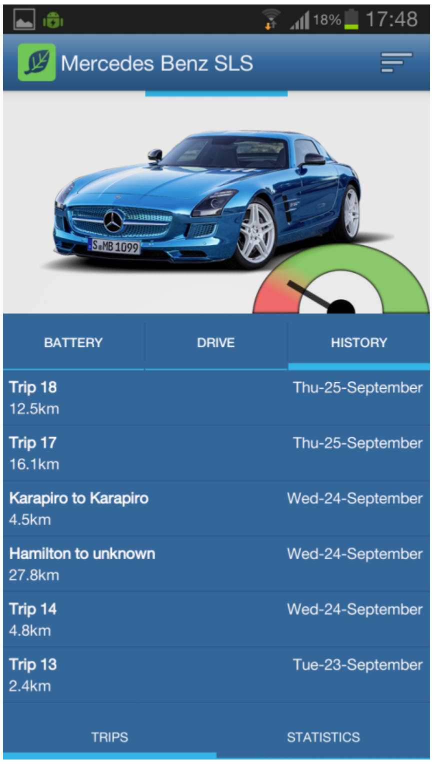

Figure 5: The VEV history screen, showing a summary of recent trips.

By selecting an individual trip from the list in Figure 5, the user can access detailed summary information for that trip. Within that summary there is a map option which shows a record of the route taken, as can be seen in Figure 6.

4 Evaluation

A small (six subject) pilot user evaluation of the application was carried out over the course of one week. Volunteer participants, once they had agreed to take part, completed a preliminary questionnaire, which explored their understanding of, and attitudes towards EVs. Questions addressed the participant's knowledge and personal opinions of EVs, and their likelihood and motivation to purchase one in the future. This questionnaire was conducted over the Internet, using SurveyMonkey [33].

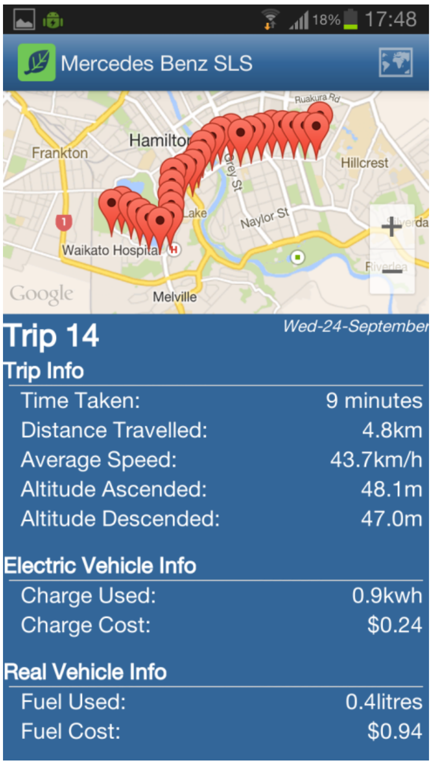

Figure 6: Individual trip details from the history record.

Participants were then instructed to download the VEV app from the Google Play store onto their own Android device and were asked to use the app for the next week, whenever they were driving their car. At the end of that week they completed a second questionnaire which repeated the preliminary questions on attitudes and knowledge, and further explored the impact of their experience with the Virtual EV.

Requiring drivers to use an in-car app does raise issues of safety. In the participant information sheet, participant's were reminded of the laws and penalties relating to mobile phone use while driving [34], and were offered the following advice:

"In order to comply with the law, and in the interests of your own safety and that of other road users, we suggest that (i) you start the app just before you commence your journey, and (ii) that you stop it after you have stopped your car. Further, (iii) there is no real need to look at the display screen while you are driving, but if you do

wish to see how the virtual vehicle is faring, you should pull over to the side of the road, as you would to deal with a phone call."

All participants drove their cars between 100 and 200 kilometres during the week-long study, and none experienced a range failure with their virtual vehicle.

When asked about their knowledge and understanding of EVs, three of the six participants indicated a better understanding after the experience, as shown in Figure 7. Further, in response to specific questions in the exit questionnaire, all six participants suggested that their understanding had improved to some extent, and that they now had a more positive attitude to EVs.

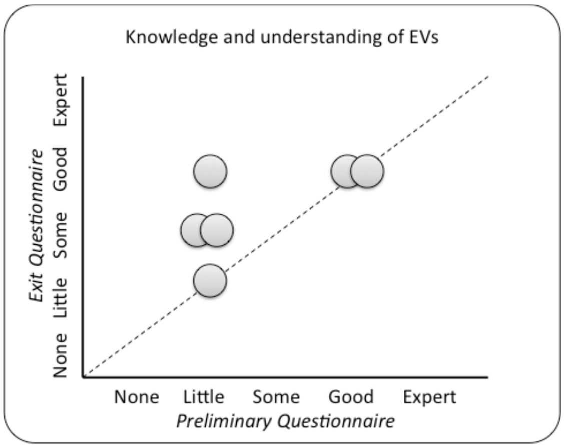

Figure 7: Participants' perceived shift in understanding as a result of their experience.

In both questionnaires, participants were also asked if their next vehicle purchase would likely be an EV. As a result of the experience, two shifted from "no" to "possibly", and one from "possibly" to "yes", as shown in Figure 8.

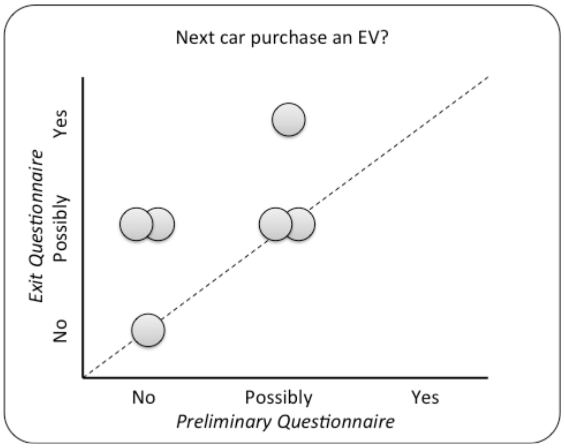

Figure 8: Study influence on likely next car purchase.

All but one participant indicated they would continue to use the app after the study was completed, and that they would recommend it to their friends. All indicated their willingness to participate in future EV studies.

These results demonstrate the real promise of this real/virtual gamification approach in providing a positive experience, informing users, and being effective in modifying attitudes. Even in the short space of one week's experience, 50% of participants recorded a positive shift in understanding and in position. The results also suggest that the technique does effectively encourage and engage participants.

In addition, participants were asked in both questionnaires to rank a number of reasons why they would not purchase an EV. Both before and after using the Virtual EV, all participants indicated that the high purchase cost of EVs was the primary reason. Participants were also asked to rank given factors in terms of *positive* motivation for purchasing an EV. In both questionnaires, EV running costs were the most important positive motivation, ranking well above any environmental concerns.

5 Discussion, Conclusions and Recommendations

Ensuring continuing growth in the uptake of EVs is increasingly important as the world strives to reduce greenhouse gas emissions and becomes increasingly aware of finite fossil fuel reserves. Although EVs are now readily available, they are significantly cheaper to operate than ICEVs, their performance cannot be slighted, charging stations are becoming more widespread, and the driving range continues to improve, many would-be purchasers are not switching to EVs. Research tends to suggest that it is financial and technical considerations which are the major impediments, and that these will not simply be overcome by growing environmental concerns (and this is born out by the questionnaire responses discussed in the preceding section).

While the purchase cost of EVs remains quite high, it is decreasing, and now that production EVs have been available for some time, a less expensive second-hand market is beginning to be established. Hence it is perceptions, often false, about the technical aspects of EVs, in particular their driving range, but also battery life and charging station availability, which create the most significant obstacles. As only a very small proportion of the population has experience with EVs, it is difficult to overcome these misconceptions, and very easy to promote them.

The research described in this paper set out to determine whether a virtual EV experience could provide sufficient understanding to dispell myths and build confidence in the technology. Applications for smartphones which track, record, and analyse driving patterns are not new, but they have not previously been used to provide a virtual EV experience in parallel with a real ICEV, with the specific aim of raising awareness and building users' confidence in their own assessment of EV technology and its impact on their lives, rather than to accept prevailing opinion.

Because of this principal aim of awareness raising and myth busting, the prototype version of the application developed here is based on a relatively simple EV model, and focuses primarily on driving range and running costs. Other features, such as charging station availability, performance and technical issues, and social interaction with other participants, will be considered in future developments, and are discussed in more detail below.

Nevertheless, by involving users in a virtual parallel experience, the VEV application has shown the significant potential of this technique, using principles of gamification, to engage, motivate, educate, raise awareness and build confidence, about this new technology.

A range of additional features are planned for the next version of the VEV app, which will then be subject to a more comprehensive and longer term evaluation. These features include:

- More precise battery charge/discharge calculations, which take into account speed, altitude variation, lights, air conditioning, regenerative braking, and non-linear charging characteristics;
- Charging station location information, and the ability to automatically add a virtual recharging detour onto the time and distance of a trip, or even recovery costs should a full range failure occur;
- Performance monitoring, which can take into account differences between the real and virtual experiences, for example if the real ICEV is driven at a higher speed than the real EV would be capable of doing;
- Future versions of the VEV are likely to provide a more comprehensive range of alternative vehicles, particularly as some of the features in this list are implemented, and individual differences between models become more significant.

In addition, in order to attract a broader user population, it is proposed that the application should be ported to other mobile platforms, specifically iOS and Windows. Although Android is widely used, the fact that VEV was available only for this platform did prove limiting in recruiting participants for the current study.

Other possible extensions to the VEV app relate to further gamifying the experience and incorporating social interaction. These include, for example, the possibility of exploiting virtual currency in initial purchase and operating costs, virtual rewards for performance achievements, competition amongst social groups for economy, driving distance, etc, and possible integration into a more comprehensive virtual world, such as Second Life [35], although this latter suggestion would compromise the real world parallel.

The concepts embodied in the VEV application, gamification and the notion of a vitual experience in parallel with an everyday real world activity, could prove useful in other areas where attitude and behaviour change might result from the experience. For example, different electricity charging regimes could be linked to smart meter information, allowing users to experiment with different usage patterns, or commuting by car could have a virtual public transport parallel, showing actual waiting/transit times and allowing users to see the real paralells for themselves.

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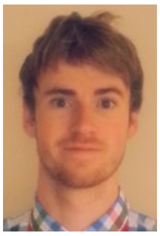
Caleb Donnelly has recently completed a BCMS(hons) degree in computer science at the University of Waikato. He designed, implemented and evaluated a version of the virtual electric vehicle for his final-year honours project.



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