Chapter 31

Evaluation of Smart Driving Advisors: Smartphone Apps or Value Added Services

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Introduction

Background

In recent years the carbon output from road transport has become a significant issue for governments, car manufactures and consumers. The most recent figures released by the European Union in 2011 showed that transport (including road, rail, air and shipping) was responsible for 19 per cent of total greenhouse gas emissions, with road transport contributing 82 per cent of this share (European Commission, 2011). However, over the past few years (since 2007), a trend has been seen whereby road transport emissions have actually reduced by 2.9 per cent (European Union, 2010). This may be due to a number of factors, including the increase in fuel prices, the proliferation of hybrid powertrain and electric vehicles coming onto the market, or a general shift in consumer trend towards more economical and ecological personal transport.

Eco-driving is a term used to describe a driving style which results in an increase in fuel economy. Reducing the unit fuel consumption for a journey not only results in a financial saving for the driver but also helps to reduce the driver's carbon footprint and the impact of other emissions. The driving techniques commonly associated with eco-driving do not necessarily advocate slower driving, but rather driving smoothly and without excessive engine speeds. Reviewing the advice presented by numerous organisations (including the AA, the RAC, the Institute of Advanced Motorists, the Energy Saving Trust, and the US Department of Energy, to name but a few; as well as the papers and reports cited within this Chapter – specifically Young et al., 2011), has identified several key factors which contribute to an economical driving style, including:

- planning ahead, anticipating traffic flow and keeping a suitable following distance to help maintain a constant speed, while avoiding sharp braking and stops;
- changing gear up as soon as possible (between 2,000 and 2,500 rpm), and considering the use of block gear changes, where appropriate;

- using smooth but positive acceleration to reach high gears and desired cruising speeds sooner;
- using engine braking (without changing down through the gears) for smooth deceleration, minimising the use of the foot brake where appropriate;
- using uniform throttle positions, with no more than half throttle used;
- obeying speed limits.

The Foot-LITE project

A UK-led project called Foot-LITE,[1] aims to bring together information on safety and fuel efficiency on a single, integrated, adaptive interface, providing driver feedback and advice on aspects of safe and green driving. The system ostensibly comprises two parts: an in-vehicle information system (IVIS), providing real-time feedback; and advice on driving style coupled with an offline (post-drive) data logging system, which can help to inform transport choices. In the Foot-LITE project, 'Smart' driving is defined as that which is both safe and fuel-efficient. A previously completed Cognitive Work Analysis (CWA; Rasmussen et al., 1994; Vicente, 1999), which defined project constraints and detailed principal information elements that could be presented to the driver, highlighted several behavioural aspects the system would hope to address. These were: correct gear change (including the appropriate use of block changes); and maintaining a consistent speed profile (facilitated by planning ahead in order to avoid unnecessary acceleration and braking events). Both relate to fuel efficiency; with respect to safety, maintaining appropriate headway, lane position and lane deviation were identified (Birrell et al., 2011).

Apps or value added service

Over the past three to four years there has been an explosion of eco-driver coaching advisory systems released onto the market. Broadly speaking, these can be grouped into two distinct categories: downloadable smartphone applications ('apps'); and eco features which are provided as an 'added value service' on already existing platforms (such as satellite navigation systems or vehicle manufacturers' in-car displays).

The increasing processing power, affordability and sensors available on modern smartphones has led to an expanding market in eco-driving applications. The complexity of the available smartphone apps differs greatly, with some utilising a Bluetooth OBD II port connector to read engine parameters, while others simply use internal accelerometers, or a combination of GPS and other sensors. The one feature that links all available apps is that visual (and often auditory) feedback is given to the driver, in the vehicle, in real time.

1 See www.foot-lite.net (accessed 31 March 2012).

Green driving applications are not only the domain of independent developers; numerous vehicle manufactures have also created their own, which not only add to the manufacturers' ethos but also give their drivers added value. An example of this is the Mini Connected 'MINIMALISM Analyser', which analyses how efficiently the driver accelerates, brakes and changes gear and presents this information to the driver in the vehicle, with a number of stars indicating how well the driver has rated in the last 10 minutes. In addition to this real-time feedback, the Fiat EcoDrive system allows driving data to be collected and stored on a USB drive for analysis on a PC post-drive, where longer-term trends and lessons for improvement can be delivered. Numerous satellite navigation system manufacturers also deliver an 'added service' of eco driving information, which can include an 'eco' route option, providing a more fuel-efficient route, as well as real-time feedback on driving efficiency and post-trip fuel and mileage reports.

The aim of this study was to evaluate the Foot-LITE system against two other eco-driving systems currently on the market, one a smartphone app, the other a satnav system, with the added value of an eco-driving advisor. Subjective views were collected from the participants via three questionnaires following a naturalistic driving scenario on public roads.

Methodology

Experimental design

A within-subjects, repeated measures design was utilised for this study, with all participants completing the same driving route, with all three eco-driving aids. Variables collected were subjective measures of driver workload, user preferences and qualitative views on the three systems.

The driving scenario

The driving scenario used for this study was established on public roads in and around the local area. This was selected to provide a variety of road types, speed limits and likely traffic situations, while avoiding known accident black spots and difficult junctions. The route was 10.5 miles long, and took between 20 and 25 minutes (mean time 22.5 minutes) to complete, depending on traffic conditions and self-selected driving speeds. Approximately half of the route was urban driving, at speed limits of 30 mph, with half classified as intra-urban, with speed limits of either 40 mph or 50 mph. No sections of motorway or duel carriageway driving were including on this route.

Data collected

Three separate questionnaires were used for the benchmarking trials. The first, the Driver Activity Load Index, or DALI, is an assessment of subjective workload during the driving task, when using eco-driving systems (Pauzie and Forzy, 1996). DALI is heavily based on the NASA-Task Load Index (TLX; Hart and Staveland, 1988), which is a widely accepted standard subjective workload measure and is considered to be very sensitive and reliable. DALI, however, is more tailored for the evaluation of IVIS, with ratings for six factors (global attention demand, visual demand, auditory demand, stress, temporal demand and interference), each scored from 0 to 5 (low to high), with a mean value calculated for all of them, resulting in the DALI rating. DALI has specific benefits over TLX, with reference to this study, as it is more driving specific, and previous research conducted for the Foot-LITE project showed DALI as being more sensitive than TLX to changes in interface design. (Birrell and Young, in press).

The second standardised questionnaire used was QUIS (Questionnaire for User Interaction Satisfaction; Chin et al., 1988). QUIS was originally developed to assess user satisfaction with a human–computer interface and is used under licence from the University of Maryland, USA. For the current study an amended version of QUIS was used, in terms of the sections included and the questions asked. The questionnaire was shortened from 12 to 7 sections, with irrelevant sections such as ‘System experience’, ‘Multimedia’ and ‘Technical Manuals and Online Help’, removed. In the sections retained, some statements were adjusted slightly to make them more driving-specific; for example, the ratings for the statement ‘The system tends to be’ were changed from ‘Noisy’ and ‘Quiet’ to ‘Distracting’ and ‘Not Distracting’ respectively. Participants record their responses to these statements on a 9-point scale, with 1 being an unfavourable response to the statement and 9 being favourable. If a specific question was deemed not applicable for that specific system, this could also be recorded on the questionnaire and no data would be inputted. Once participants had rated each statement in the questionnaire, all the scores were aggregated to give an overall QUIS rating, out of 9 (with a higher score translating to a better rating for the system). In addition to mean scores, ratings for each section could be obtained for an insight into the pros and cons of each system.

The final questionnaire administered was specifically developed for these trials. While DALI and QUIS were completed after each trial, the Benchmarking Questionnaire was only completed at the end of the study, once the participants had used each of the three systems. It addressed issues such as user preference, trust, assessment of potentially longer-term benefits, and likely costs people would be prepared to pay for the systems.

Participants

Sixteen participants volunteered for the study (11 male, 5 female), with an average age of 45.1 years (SD = 9.5), and driving experience of 26.6 years (SD = 10.5). All participants recruited had no detailed knowledge of the Foot-LITE project. They were a mix of managerial, technical and administrative personnel. No payment was made to the participants; however, the time taken to complete the study could be booked to the project.

Eco driving systems evaluated

Three eco-driving systems were evaluated in this study: two were off-the-shelf systems, freely available to purchase on the market today, plus Foot-LITE. Each system provides visual and auditory feedback, advising the driver as to greener driving behaviours. The control of the vehicle, however, always remains with the driver, the systems are only advisory and offer the driver feedback as to ways to improve their driving behaviour; the decision to accept or reject this advice always lies with the driver of the vehicle.

The first eco-driving system evaluated was the EcoGyzer smartphone application (developed by Nomadic Solutions; Figure 31.1). It is a low-cost downloadable app that needs no other sensors or equipment installed that are not already installed on the smartphone itself. EcoGyzer calculates vehicle speed from the phone's internal GPS, acceleration and braking rates from the accelerometer, and cornering speed from the gyroscope. Fuel economy and emissions are estimated according to vehicle speed and acceleration, against an internal database of vehicle makes and models, from which the current vehicle is selected. The main feature of the system is a visual representation of fuel efficiency for the entire journey, from green (good) to red (poor), with current performance marked by a blue dot (Figure 31.1). As well as the visual representation, the average fuel economy is also presented, in numerical form in l/100 km, while next to this is current driving speed in km/h. The application also gives auditory feedback on acceleration, braking and corner-taking behaviours. After the journey a trip summary can be viewed, which shows journey time and distance, average and total fuel used and CO_2 emitted, as well as a rating out of 10 for the drive (Figure 31.1). This system will be called 'Smartphone' through the rest of this chapter.

The second system was the Vexia EcoNav 480 satnav system (Figure 31.2), which, as well as providing all the functionality of a normal satnav (route guidance, speed camera locations, current speed limits, etc.), also gives eco-driving advice. For the purposes of the current study, no navigation information was given, with the visual and auditory feedback dedicated to presenting eco-driving advice only. As with the smartphone app, the vehicle being driven was selected from a database of over 3,000 vehicles, with advice presented based on the vehicle type and current driving speed (according to GPS) only. Eco-driving information presented includes suggested gear position, shown as a large number on the main

Figure 31.1 Main display of the EcoGyzer smartphone application seen during driving (left) and post trip summary (right)

display and also verbalised over the internal speakers. In addition, braking and acceleration advice is given, illustrated by the box to the top left of the gear display on Figure 31.2 (the circle will go red and fill the square when braking is deemed excessive and, conversely, with the pedal with respect to acceleration). Also shown is recommended headway (to the left of the braking/accelerating icon); actual headway is not monitored, the system presents just recommendations. Below the braking and headway icons are the current speed limit, according to the speed database, and current driving speed in mph. The final important feature is the green bar under the gear indicator, which is a visual representation of the efficiency of the driving speed related to the current speed limit. As shown in Figure 31.2, driving at 55 mph in a 70 mph zone is deemed 'Green' for efficient; however, if the speed limit was 40 mph, this bar would change to red, as the driver would be over the speed limit. Again, a post-trip summary is available, which summarises journey time and distance, number of speed cameras passed and recommendations to increase efficiency on the next drive. This system will be called 'Satnav' throughout the rest of this chapter.

The third system evaluated was Foot-LITE, and, as is stated above, this provides the driver with real-time information on both safety and eco-driving behaviours. Safety advice consists of headway monitoring and lane departure warnings; these are assessed using a lane departure camera fitted to the vehicle. Eco-driving advice offered relates to gear changes (up and down) and braking and

Figure 31.2 The Vexia EcoNav 480 satnav eco display during driving

acceleration information; this advice is calculated based on data from the vehicle's OBD II port. As well as this real-time 'operational' feedback, Foot-LITE also offers strategic advice in the form of 'pop-ups'; these are presented to the driver when a longer-term trend has been observed by the system with respect to driving behaviours: information such as good (or poor) use of the throttle pedal, or speed consistency, both of which have been shown to be beneficial (or detrimental) to fuel economy. Foot-LITE presents the safety and the eco-related information to the driver simultaneously, via a novel, integrated, interface, which was developed specifically for the Foot-LITE project and based on Ecological Interface Design (EID) principles (Figure 31.3).

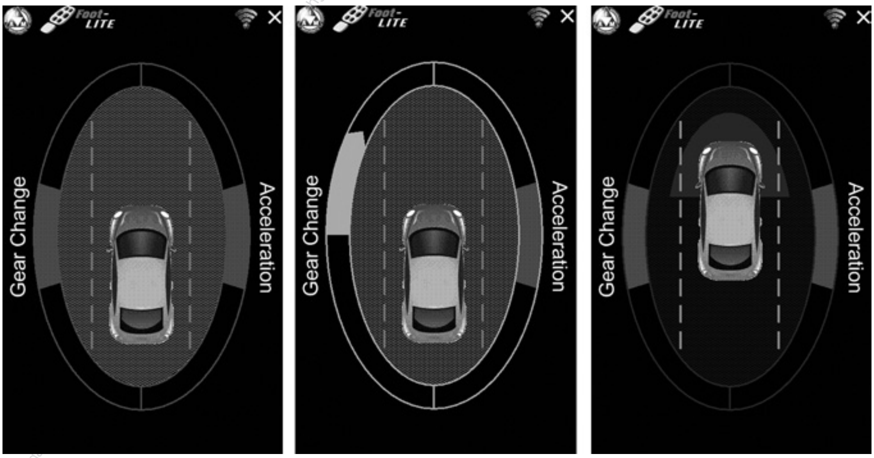

Figure 31.3 The Foot-LITE EID interface (UK Reg. Des.: 4017134-41)

Table 31.1 shows a summary of the information presented on each system and how it is presented (visual, auditory, or both). All three systems present eco-driving advice; however, each system also has aspects that it alone presents (e.g., safety with Foot-LITE, speed limits and camera with 'Satnav', cornering speed with 'Smartphone').

Table 31.1 Summary of information presented on each of the three systems tested

		Foot-LITE	Satnav	Smartphone
Eco	Gear-change advice	Yes (V&A)	Yes (V&A)	No
	Braking/acceleration advice	Yes (V&A)	Yes (V)	Yes (A)
Safety	Headway-monitoring	Yes (V&A)	No	No
	Lane departure warning	Yes (V&A)	No	No
	Inappropriate cornering speed	No	No	Yes (A)
Driver information	Speed limits and cameras	No	Yes (V&A)	No
	Current driving speed	No	Yes (V)	Yes (V)
	Overall efficiency rating	Yes (V)	Yes (V)	Yes (V)
	Post-trip summary	No	Yes (V)	Yes (V)

V Visual feedback

A Auditory feedback

Procedure

Upon arrival, participants were given a brief background to the aims of the trials, namely to assess three different eco-driving aids and gain their views on the systems tested; it was stressed that there was no evaluation of their driving performance. In an attempt to control for traffic conditions and avoid peak traffic flow, three fixed study times were established (09.15–11.15, 11.30–13.30, 14.00–16.00). Participants were informed that the three eco-driving systems would give visual and audio feedback, but would not intervene with the control of vehicle; and that their primary task was to drive safely, using the feedback where appropriate. After this initial briefing, signed informed consent was gained and participants were shown to the test vehicle.

An examiner was present with the participants at all times when they were in the vehicle; this was to give driving directions, deal with any technical issues which might arise with the systems and to answer any questions. In total, three driving conditions were completed, driving a set route on public roads, following which the DALI and QUIS questionnaires were completed. Once all three experimental conditions were completed, the participants completed the Benchmarking Questionnaire.

Data analysis

Questionnaire data were coded in Microsoft Excel then aggregated across all participants for each parameter measured, to enable comparisons of mean data. Statistical significance of the subjective measures of driver workload (DALI) and subjective preference (QUIS) were assessed, using Friedman and Wilcoxon Signed Rank tests. Data from the Benchmarking Questionnaire were processed in a similar manner, but no statistical testing was conducted. Statistical significance was accepted at $p<0.05$ and assessed using PASW 18.1 for Windows.

Results

Table 31.2 DALI factor and overall mean ratings

	Foot-LITE	Satnav	Smartphone
Global	1.94	2.31	1.13
Visual	1.81	2.13	1.50
Auditory	0.94	2.88	1.00
Stress	1.06	2.88	0.88
Temporal	1.06	2.38	0.50
Interference	1.38	2.81	0.88
DALI	**1.36**	**2.56**	**0.98**
SD	0.97	1.46	1.10

DALI

The Driver Activity Load Index (DALI) is a questionnaire specifically designed for evaluating in-vehicle information systems (IVIS), which rates factors such as visual demand and interference, as well as some more standard workload measures, such as, temporal demand and stress (Table 31.2). Results from this study show that the Satnav system was rated at a significantly higher ($x^2(2) = 20.22$, $p<0.001$) workload, compared with the Smartphone app and Foot-LITE systems (Figure 31.4).

When considering the factor analysis of the six individual sub-scales (interference, visual, etc., from which the mean DALI rating is aggregated), some interesting results were also seen. For example, there was no difference ($x^2(2) = 2.81$, $p = 0.245$) between any of the three systems tested when visual demand was assessed (Figure 31.5). The global attentional demand for Foot-LITE and Satnav were significantly higher (($Z = -2.21$, $p<0.05$) and ($Z = -2.73$, $p<0.01$) respectively) than the Smartphone (Figure 31.5). While the temporal demand of the

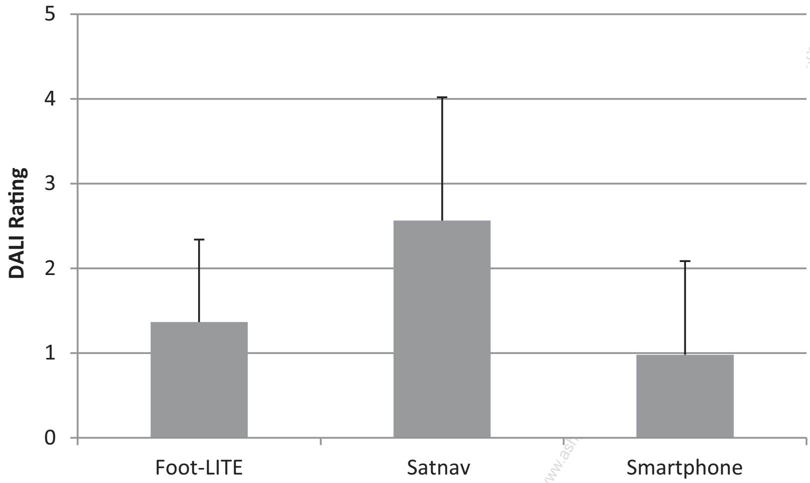

Figure 31.4 Mean DALI rating given by participants for each experimental condition

Note: Asterisk (*) indicates significant (p<0.05) difference between Foot-LITE and Smartphone conditions. Error bars represent standard deviation.

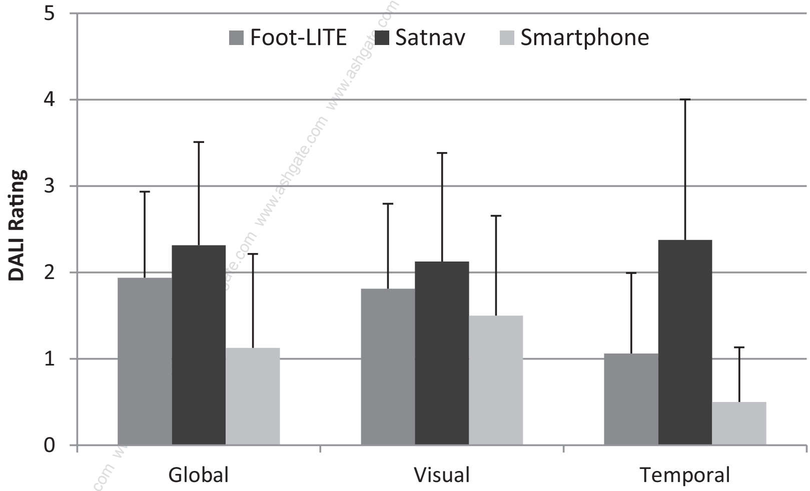

Figure 31.5 DALI Factor (Global, Visual and Temporal) rating for each experimental condition

Note: Asterisk (*) indicates significant (p<0.05) difference between Foot-LITE and Smartphone conditions, plus (+) indicates significant difference from Smartphone condition. Error bars represent standard deviation.

Satnav system was significantly greater than both the Foot-LITE and Smartphone systems (($Z = -2.44$, $p<0.05$) and ($Z = -3.40$, $p<0.001$) respectively), there was also an observable trend ($p \approx 0.1$) for the Foot-LITE system to be rated higher for temporal demand, compared with the Smartphone (Figure 31.5). The three remaining factors, which are not mentioned above (Auditory, Stress, Interference), followed the same pattern as seen with the mean DALI ratings in Figure 31.5, namely Satnav to be rated significantly higher than the Foot-LITE and Smartphone systems, with no differences noted between the latter two systems.

Table 31.3 QUIS ratings for each section of the questionnaire and overall mean ratings

	Foot-LITE	EcoNav	Smartphone
Overall	6.46	4.80	5.64
Screen	6.71	5.13	6.01
Terminology	6.82	5.70	6.12
Learning	7.37	5.88	6.52
Capabilities	6.62	5.35	5.69
Aspects	7.27	5.20	4.77
Mean	**6.76**	**5.32**	**5.72**
SD	1.74	2.31	2.21

QUIS

The Questionnaire of User Interaction Satisfaction (QUIS) was used to rate participants' views on each of the displays, feedback given, and overall effectiveness of the three systems. Statistical tests revealed a significant ($x^2(2) = 11.63$, $p<0.01$) difference in QUIS ratings between the three systems tested, with Foot-LITE being rated significantly higher (and, therefore, more favourably) than the Satnav and Smartphone systems (Figure 31.6). Individual analysis of the sections of QUIS, as presented in Table 31.3 (screen, learning, etc.), was not conducted, as the pattern born out in Figure 31.6 was repeated, i.e., Foot-LITE rated the highest and Satnav the lowest, closely followed by Smartphone. However, comments regarding these findings will be discussed in the next part of this chapter.

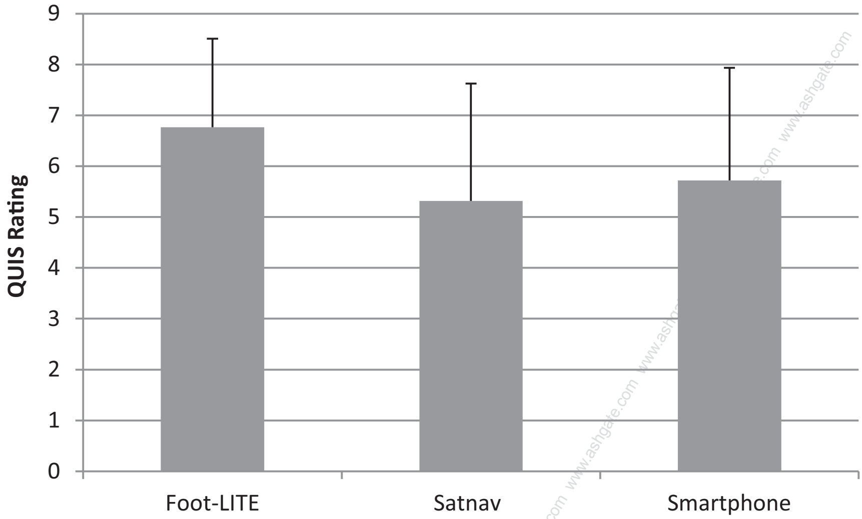

Figure 31.6 Mean QUIS rating for the three experimental conditions
Note: Asterisk (*) indicates significant (p<0.05) difference between SatNav and Smartphone conditions. Error bars represent standard deviation.

Benchmarking questionnaire

Due to the nature of the benchmarking questionnaire (i.e., not a standardised questionnaire, but designed specifically for the project and asking mainly subjective questions), no statistical analysis was conducted; however, discussions follow.

Discussion

DALI

Interestingly, results from the DALI questionnaire revealed that there was no significant difference in Visual Demand between any of the three systems (Foot-LITE, Smartphone or Satnav), with each system being rated at 1.8, 1.5, and 2.1, out of 5, respectively (Figure 31.5). This implies that visual demand during the driving task was low for the Foot-LITE and Smartphone systems, and low–moderate for Satnav. Global Attention Demand is the overall attention required during the driving condition with regard to what is usually experienced during 'normal' driving. This was rated significantly higher for the Foot-LITE and Satnav systems, compared to Smartphone. With respect to Foot-LITE, while a global rating of just under 2 is not particularly high, it does suggest that care needs to be taken, if any additional information is to be considered for addition to the Foot-LITE display, so as not to increase the perceived workload beyond its current levels.

Temporal Demand (issues such as time pressure, a feeling of being rushed during the task, or, conversely, the task being self-paced and manageable) with the Smartphone app was very low indeed (Table 31.2). This is probably reflected in the fact that no real-time advice was given, and fuel economy data presented was the average for the entire journey and not instantaneous. While temporal demand with the Foot-LITE system was also rated low, there was a trend for this to be higher than for the Smartphone (Figure 31.5), which is likely to be a result of real-time feedback given to the driver. A positive result for Foot-LITE was that despite real-time information on gear change, braking and acceleration, plus advice, headway monitoring and lane deviation warnings being given to the driver, the temporal demand did not increase above low. Further, it was not significantly greater than a system which gave no real-time feedback at all. This aim was implicit in the Foot-LITE ecological interface design, as the literature surrounding EID suggests that, by presenting environmental constraints in a graphical format for direct perception, performance is improved and workload is reduced over conventional displays, which require users to integrate information in their heads (Sanderson et al., 2003, Hajdukiewicz and Vicente, 2004, Young and Birrell, 2010).

As is stated in the results, the Satnav system was rated significantly higher in terms of perceived workload when driving, than the Foot-LITE or Smartphone systems, with a mean rating of 2.56 (SD = 1.46) out of 5, compared with 1.36 (0.97), and 0.98 (1.10), respectively. Looking at the individual factors presented in Table 31.2, we can see that the Auditory Demand, Stress, and Interference associated with using the Satnav system were the main contributors to the high mean DALI rating, with each of these factors being rated at nearly 3 (out of 5), compared to around 1 in the other systems tested (Figure 31.7).

Evidence given by participants in the final Benchmarking Questionnaire suggests that the root cause for these increases in demand was the fact that the Satnav system presented visual and auditory feedback for every gear change recommended. This could be nearing 50 times for each 25-minute drive. In addition, feedback would be given at all times, even when taking a roundabout, or during periods of heavy braking, as no workload manager or audio mitigation system was employed. Another factor, cited as increasing stress and frustration when using the Satnav, was that the gear selection was based solely on speed, according to the GPS, with no knowledge of what gear the car was actually in – as would be possible with an OBD II connection. This resulted in numerous occasions when a participant was being advised to change into a gear the car was already in, thus making the information obsolete and generally annoying.

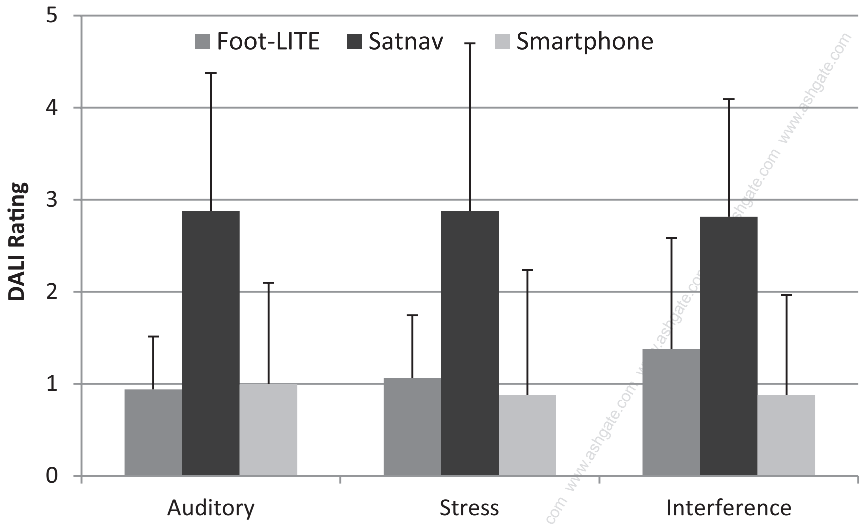

Figure 31.7 DALI Factor (Auditory, Stress and Interference) rating for each experimental condition

Note: Asterisk (*) indicates significant ($p<0.05$) difference between Foot-LITE and Smartphone conditions. Error bars represent standard deviation.

QUIS

The Foot-LITE system received a significantly higher rating ($p<0.01$) on QUIS, compared to the other two systems tested (6.76 (out of 9), verses 5.32 for Satnav and 5.72 for Smartphone). In general Foot-LITE was rated as being understandable and easy to use, as well as being flexible and stimulating. An area where the Foot-LITE system significantly outperformed the others was with respect to screen properties, characterised by the visual interface which feeds information back to the driver. The highest QUIS rating (mean for all participants) for a single question was achieved by the Foot-LITE system, for the question 'Use of colour on the screen – Unhelpful/Helpful', with a score of 8.13 (SD = 0.89). Foot-LITE was designed to give feedback by position of blocks of colour on the screen, with the skill-based components being 'semantically mapped'; that is, the relations between and constraints on behaviour and performance are directly represented on the display. Sanderson et al. suggest 'Good semantic mapping means that system states (normal and abnormal), relations and constraints can be easily perceived' (2003: 152).

The Foot-LITE system also consistently outscored the others on aspects relating to learning. This was an interesting finding, as previous research conducted on the project revealed that the interface has a steep learning curve, partly due to the novelty of the design, but also as a result of the amount of information presented (most systems are either eco- or safety advisors, so present a limited data set, whereas Foot-LITE feeds back both). Results from this current study support those from others conducted for the project, in suggesting that users become accustomed to its layout, with the use of colour and the system's intuitive nature, leading to an increased understanding of the display with use (Young and Birrell, 2010).

An interesting finding with respect to the Smartphone system was that it achieved the highest rating of all three systems for being 'clear' and 'understandable', but also rated the lowest for being 'dull' to use, and certain information was deemed 'unhelpful'. This polarises the views on the perceived usefulness of the system and, combined with the results from DALI, which showed low workload during driving, suggests that the app was easy to interpret, but that the feedback given offered little practical advice for actually changing driving behaviours.

The Satnav system received the lowest mean rating on the QUIS questionnaire, of 5.32 (SD = 2.31); however, some of the individual aspects of the system were rated highly, namely the access to the speed camera locations and the post-trip summary. The real-time driving information on the display was understandable; however, it was rated as frustrating to use, as it received the lowest single question score for all the systems across the entire QUIS questionnaire (of 3.25), when considering the question 'Overall reaction to the system – Frustrating / Satisfying'. The reasons for this low score are more than likely to be a result of the gear change audio, which was not well received.

QUIS also addressed issues such as distraction to the driver. When asked 'How often do you look at the screen – Very frequently/Not frequently' and 'System tends to be – Distracting/Not Distracting', some interesting differences were observed. All three systems were ranked similarly, with participants rating themselves as looking at the screen more frequently than not. Foot-LITE received its lowest rating on the entire questionnaire for this question, at 4.31; Satnav was rated at 3.75; Smartphone 4.93. However, when asked if the systems were distracting or not, the Smartphone and Foot-LITE systems were rated on the 'Not distracting' side of the scale, whereas the Satnav was rated as 'Distracting'. This implies that while assessing visual distraction is obviously an important aspect of IVIS assessment, it is not the only factor that should be considered. As highlighted by this study, auditory distraction is also an important consideration. Other important lessons were learned regarding audio feedback. Audio feedback for the Smartphone app was rated as unhelpful and this was mainly because it was reprimanding the driver, rather than informing him/her. On the other hand, Satnav presented audio information far too frequently, with a lack of intelligence as to actual gear position, which led to increased frustration and temporal demand.

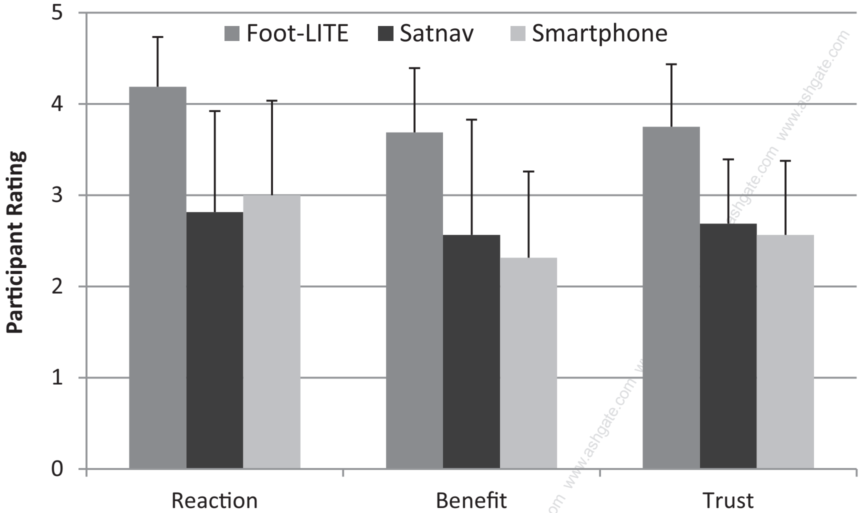

Figure 31.8 Mean participant ratings on the Benchmarking Questionnaire to the questions: Immediate 'Reactions'; potential 'Benefits'; and 'Trust' in the three systems tested

1 = Very Negative, No Benefit, Not at all; 5 = Very positive, Very large benefit, Completely. Error bars represent standard deviation.

Benchmarking questionnaire

Figure 31.8 shows that the immediate reactions to the Foot-LITE system were rated as positive by the participants, while the Satnav and Smartphone systems were rated as neutral. They also saw Foot-LITE as having a larger benefit to their driving in the longer term. This was mainly due to the additional value supplied by the safety aspect (in particular, the headway monitoring) of Foot-LITE, in addition to the eco advice. Finally, participants trusted the data presented by Foot-LITE to a large degree, compared with a moderate degree for the other systems. This is more than likely to be a result of Foot-LITE actually reading parameters from the engine and, hence, having a degree of intelligence regarding current gear selected and pedal input.

The final questions examine the amount that participants would be prepared to pay to use any of the three systems tested. Firstly, as a one-off purchase (e.g., they bought it directly from a shop or online); and, secondly, as a regular monthly payment on a service provider contract (e.g., mobile phone or broadband). When considering the Smartphone, the cost would involve downloading the app, not purchasing the mobile phone; with Satnav, it would involve purchasing the whole system, including mapping functionality. For Foot-LITE, again, the mobile phone was not included, but the lane departure camera, OBD II connector, and software were.

Results showed that participants would be prepared to pay between £50 and £100 to purchase the Foot-LITE system outright, with 4 out of 16 participants willing to pay over £100. When considering the Smartphone app, participants were prepared to pay less than £10 on average, with no one being willing to pay more than £20. For the Satnav system respondents were divided, with approximately one-third of participants being prepared to pay up to £100, another third between £11 and £50, and the remaining third not prepared to pay anything at all. This split may have been because many people already had a satnav system, so would not be prepared to pay anything for another one, or simply did not deem the addition of eco features worth paying a premium for. In general, participants did not really like the idea of paying for an eco-driving service on a monthly basis, with 12 participants (out of 16) saying they would not pay monthly to use the Smartphone, 8 saying the sane for Satnav, and 5 saying the same for Foot-LITE. Of those who would be prepared to pay monthly to use Foot-LITE, as an added service to a mobile phone or as a satnav contract, the average was between £5 and £10 a month.

Conclusions

Results from the study showed that the Satnav system was rated by the participants as increasing their workload during driving, significantly more than the Foot-LITE and Smartphone systems, and was also rated the lowest in terms of user preference. Reasons given for this were the over-presentation of gear audio information and a lack of intelligence regarding which gear the driver was actually in, resulting in increases in temporal demand, frustration and reduced user acceptance. The Smartphone app resulted in the lowest levels of perceived workload during driving of any systems, but was also ranked low when considering user preference. Findings suggest that while the app was easy to use and understand, the information given during driving offered little practical advice for changing driving behaviours. Workload during driving with Foot-LITE was slightly higher than the Smartphone, but significantly lower than Satnav. Foot-LITE was also rated the most useful and satisfying to use by the participants questioned; therefore, it can be interpreted that a trade-off between workload and usefulness was achieved with Foot-LITE.

The general consensus from participants in this study was that eco-driving functionality was something that users liked, but are not prepared to pay a premium for. This is emphasised by the fact that the most useful aspects of the Foot-LITE system were seen to be the safety features and overall visual display, rather than the eco-driving coaching features. Important findings for this and future research were that for audio feedback to be accepted by users it should be positive (or encouraging), or at the very least neutral, rather than negative (or reprimanding). Also, audio feedback should be intelligent and appropriate and not delivered at a time of increased mental workload. The Foot-LITE project has shown that complex and dynamic information can be presented to the driver without dramatic increases in workload, and that this information is generally well accepted.

A key factor to this has been the use of Ecological Interface Design for the driving interface, which the authors would recommend, when it is necessary to present differing information requirements onto a single, integrated, in-vehicle display.

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References

Birrell, S.A. and Young, M.S. (in press). The Impact of Smart Driving Aids on Driving Performance and Driver Distraction. *Transportation Research: Part F*.

Birrell, S.A. et al. (2011). Cognitive Work Analysis for safe and efficient driving. *Theoretical Issues in Ergonomics Science*. First published 21 March 2011 (iFirst). DOI: 10.1080/1463922X.2010.539285.

Chin, J.P. et al. (1988). *Development of a Tool Measuring User Satisfaction of the Human–Computer Interface. Proceedings of SIGCHI '88*. New York: ACM.

European Commission, Eurostat (2011). *Energy, Transport and Environment Indicators.* 2010 Edition. EU, 1–211.

European Union, European Environment Agency (2010). *Annual European Community Greenhouse Gas Inventory 1990–2008 and Inventory Report 2010*. EU: EEA, 148–66.

Hajdukiewicz, J.R. and Vicente, K.J. (2004). A theoretical note on the relationship between work domain analysis and task analysis. *Theoretical Issues in Ergonomics Science*, 5, 527–38.

Hart, S. and Staveland, L. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research, in *Human Mental Workload*, edited by P. Hancock and N. Meshkati. Elsevier: Amsterdam, 139–83.

Pauzie, A. and Forzy, J.-F. (1996). *Ergonomic Evaluation of Guidance and Traffic Information in the CARMINAT Program. Proceedings of the Third Annual World Congress on Intelligent Transport Systems* (Orlando, Florida, 14–18 October.)

Rasmussen, J. et al. (1994). *Cognitive Systems Engineering*. New York: Wiley.

Sanderson, P. et al. (2003). Process monitoring and configural display design: A neuroimaging study. *Theoretical Issues in Ergonomics Science*, 4, 151–74.

Vicente, K. (1999). *Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-based Work*. Mahwah, NJ: Lawrence Erlbaum Associates.

Young, M.S. and Birrell, S.A. 2010. Ecological IVIS Design: Using EID to develop a novel in-vehicle information system. *Theoretical Issues in Ergonomics Science*, First published 30 September 2010 (iFirst). DOI: 10.1080/1463922X.2010.505270.

Young M.S. et al. (2011). Safe driving in a green world: A review of driver performance benchmarks and technologies to support 'smart' driving. *Applied Ergonomics*, 42, 533–39.