Ideation using the "Design with Intent" toolkit: A case study applying a design toolkit to support creativity in developing vehicle interfaces for fuel-efficient driving

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Abstract

Everyday driving is a significant source of greenhouse gases and pollutants within developed nations. Finding ways to combat these emissions and minimise the impact of anthropometric climate change is a growing challenge for all research disciplines. This current paper explores the use of a design toolkit “Design with Intent” to generate ideas for in-vehicle interfaces designed to reduce fuel use and emissions. A preliminary interface validation assessment is also presented in order to assess whether the ideas generated were appropriate in encouraging behavioural change and of potential value. It is suggested that whilst further evaluation of the interfaces are required, the use of the “Design with Intent” toolkit facilitated the creative process, allowing engineers to conceive initial interface designs in a creative manner.

Key Words: Design Toolkit; Fuel Efficient Driving; Interface Design; Ideation

Introduction

This paper explores the application of the Design with Intent toolkit (DwI, Lockton, Harrison & Stanton, 2010) for the creation of ideas for in-vehicle interfaces designed to support fuel-efficient driving behaviours. The process of using the DwI toolkit to generate novel ideas is discussed, with a focus on the creative process of ideation (Pannells & Claxton, 2008). This paper seeks to expand on previous research that has sought to influence pro-social behaviours through the use of design (Cash, Gram Hartlev, & Durazo, 2017; Cash, Holm-Hansen, Olsen, Christensen, & Trinh, 2017). The desire to leverage pro-social and pro-environmental behaviour is a growing concern and aim within both the ergonomics community (Thatcher, Garcia-Acosta & Morales, 2013) and the design community (Tromp & Hekkert, 2016). Rather than focusing on the physical aspects that make up a design, researchers are increasingly considering the impact that design can have on individual behaviour (Wever, Van Kuijk, & Boks, 2008). One significant global challenge faced in the first half of the twenty-first century, and requiring significant resources to address, is the impact of anthropometric climate change (Ramanathan & Feng, 2009). All disciplines have a role in exploring the steps that can be taken to limit the currently high levels of greenhouse gas emissions.

Design methods are tools that can be used to facilitate creative thinking (Tromp & Hekkert, 2016), helping users generate ideas and to structure thinking on particular topics (Daalhuizen, 2014). This paper addresses the use of one such design method, the DwI toolkit (DwI, Lockton, Harrison & Stanton, 2010) to inspire novel designs for in-vehicle interfaces intended to reduce the fuel use and emissions associated with everyday driving.

Vehicle Fuel Efficiency

Human actions have an undeniable impact on our environment and climate (Thornton & Covington, 2015). Barkenbus (2010) argues that approximately 8% of the world's total Carbon dioxide (CO_2) emissions is a direct consequence of personal transportation. Within the European Union, approximately 25% of total CO_2 emissions relate to transportation, the second highest sector after electricity generation

(Hill et al., 2012). The United States follows a similar trend with approximately 32-41% of total emissions being related to personal transportation (Vandenbergh & Steinemann, 2007; Bin & Dowlatabadi, 2005). When considering the European Union's transport emissions, 72% relate directly to road transportation, principally privately owned cars (Hill et al., 2012). Vehicle emissions include gasses such as Carbon dioxide (CO_2), Carbon Monoxide (CO), and Nitrous Oxides (NOx) as well as particulate matter, adversely impact our environment (Ramanathan & Feng, 2009) and negatively impact human health and wellbeing, with exposure to vehicle emissions being associated with an increase risk of developing a variety of respiratory based disorders, including asthma, and bronchitis (Buckeridge et al., 2002). Due to the scale of transportation and automobile related emissions, relatively small-scale actions and savings repeated across this domain can produce substantive reductions in emissions.

Although considerable technical developments within the automotive industry has led to significant improvements in vehicle fuel efficiency, further progress is still needed (Lorf, Martinez-Botas, Howley, Lytton & Cussons, 2013). Recent technical developments include the production of more energy efficient and cleaner drivetrains including the use of electric, hydrogen fuel cell and hybrid vehicles (Chan, 2007). The use of such vehicles is associated with greater efficiency and lower emissions (Gardner & Stern, 2008). The initially high investment cost of new vehicles and, in some cases, a corresponding lack of required infrastructure (Philipsen, et al., 2018), means that replacing all older vehicles with newer and more efficient vehicles is not a viable solution for addressing the current levels of vehicle pollutants, at least not in the short term. Rather than replacing older vehicles with newer, more efficient models, Barkenbus (2010) advocated that altering the way a vehicle is driven could significantly reduce fuel use and vehicle emissions. Barkenbus argued that by adopting a refined driving style, typified by modest acceleration, early gear changes, limiting the engine to approximately 2,500 revolutions per minute (RPM), anticipating traffic flow to minimise breaking, driving below the speed limit, and limiting unnecessary idling, drivers could dramatically cut their fuel usage and subsequent emissions. This driving style is commonly referred to as eco-driving (McIlroy, Stanton & Harvey, 2013), and is possible with both traditional internal combustion engines and newer hybrid vehicles (Franke, Arend, McIlroy & Stanton, 2016). Offering empirical support for the use of these strategies, within a series of simulator trials, Birrell, Young and Weldon (2013) found that the adoption of eco-driving behaviours resulted in significantly less fuel use without dramatically increasing journey time. Extending the work of Barkenbus (2010), Sivak and Schoettle (2012) suggest that the concept of eco-driving should also include strategic and tactical decisions. Strategic decisions relate to vehicle selection and on-going vehicle maintenance, for example ensuring tyres are adequately inflated. Conversely, tactical decisions, relate to routine decisions that drivers makes on a daily basis, such as navigational decisions, for example changing route in order to avoid congestion and minimising the vehicles current load. By following these guidelines drivers can benefit financially, by using less fuel, and benefit the environment, by producing less greenhouse emissions and other pollutants without compromising safety (Young, Birrell, & Stanton, 2011).

Whilst eco-driving can offer considerable benefits to both driver and the environment, previous work has shown that feedback and support are required in order to encourage the long-term adoption and maintenance of these behaviors (Allison & Stanton, 2018; McIlroy, Stanton & Harvey, 2013; McIlroy & Stanton, 2017; Tulusan, Staake & Fleisch, 2012). This feedback and driver support can most easily be achieved by the use of in-vehicle interfaces. The design of interfaces has always had an irrefutable and fundamental influence on subsequent human activities (Simon, 1969; Redstrom, 2006). Due to this influence, designers can be seen as having an explicitly intended role influencing decisions (Lockton, Harrison & Stanton, 2008). This approach is perhaps best popularised by Fabricant's (2009) phrasing that "*Designers are in the behaviour business*" (Cited in Lockton, Harrison & Stanton, 2016). Within this context, designers have a role to play in encouraging the adoption of fuel-efficient eco-driving behaviours. Acting as a form of persuasive technology, defined as *"a class of technologies that are intentionally designed to change a person's attitude or behaviour"* (IJsselsteijn, De Kort, Midden, Eggen, & Van Den Hoven, 2006), in-vehicle interfaces have the potential to change driver's relationship with their fuel efficiency and dramatically reduce their wider environmental impact (Allison & Stanton, 2018; McIlroy, Stanton & Harvey, 2013).

The design of novel interfaces to encourage a greater awareness of energy usage is not novel, and has been significantly pursued in previous research to reduce both household energy usage (Jain, Taylor, & Peschiera, 2012; Revell & Stanton, 2018) and in-vehicle energy usage whilst driving (Jamson, Hibberd, & Merat, 2013; McIlroy, Stanton, Godwin & Wood, 2017). Attari, DeKay, Davidson, and De Bruin (2010) propose that such devices can be successful at changing behaviour as users are fundamentally unaware of their energy use and how their actions contribute to overall energy use, as a consequence, users are unaware how they can modify their behaviour to be more energy efficient. Previous research has demonstrated that energy use within household environments can be significantly reduced following targeted interventions either fostering greater understanding (Revell & Stanton, 2014; 2016) or advice accounting directly for users' specific behaviours (Abrahamse, Steg, Vlek, & Rothengatter, 2007). This approach has also been documented to be a great success within previous research focused specifically within the automotive sector, primarily those targeting the uptake of eco-driving behaviours (Tulusan, Staake & Fleisch, 2012; Mensing et al., 2014). These studies have uniformly identified significant fuel savings as a result of providing in-vehicle eco-driving feedback devices that respond directly to drivers' actions. With both a need and precedent for the use of in-vehicle interfaces to address fuel usage, work is needed to design suitable interfaces which are effective at reducing fuel use and emissions, whilst also being accepted by users.

Design with Intent Toolkit

One design approach to aid in the creative development of both physical items and behaviour is the "Design with Intent" (DwI) toolkit (Lockton, Harrison & Stanton, 2010). The DwI toolkit can be viewed as a collection of design patterns that can be used to guide the development of novel systems and interfaces. From a fundamental perspective, DwI was heavily influenced by ecological psychology (Barker, 1968; Gibson, 1986), and stresses how individuals' actions can be directed and constrained, if not directly controlled, by their environment. The DwI approach is therefore predicated on the view that behaviour can be directed by design (Buchanan, 1985), both promoting potential desirable behaviours as well as constraining and reducing the potential for undesirable behaviours to occur. To encapsulate this approach, the DwI toolkit was heavily influenced by the work of Alexander (1977) within architecture and the work of Tidwell (2005) from a purer design perspective. By combining an understanding of human activities, informed by affordance theory (Gibson, 1986) with the work of established design theorists (Norman, 1999; McGrenere & Ho, 2000), DwI provides a flexible toolkit to allow designers and engineers to generate novel design ideas that can later be matured into full interfaces and systems. In this regard, DwI acts as a *"Suggestion tool"* (Lockton, Harrison & Stanton, 2010, *p383*), which seeks to inspire designers and engineers to develop novel solutions to problems. By its approach as a suggestion tool, the DwI method seeks to act as a source of inspiration, with the tools being documented to trigger innovative and creative design solutions (Eckert & Stacey, 2000).

The DwI approach is characterised by the use of 101 design cards, divided between 8 key lenses, each of which correspond to the themes of the card. Lockton, Harrison and Stanton (2010) argue that the intention of each of the lenses is to focus around a particular worldview of a problem, for example a designer with experience in safety engineering will have a focus on errorproofing, seeking to prevent deviations from safe behaviour. In contrast, an architect will have a focus on the potential of layout and use of space within an interface, applying physical design metaphors to the digital environment. Whilst Lockton, Harrison and Stanton (2010) note that many cards could fit into multiple lenses, they argue that the different lenses aim to offer alternative perspectives on a problem, and encourage individuals to think outside their immediate frame of reference. Although originally directly building on de Bono's (1987; 2017) "six thinking hats" approach and comprising of six lenses, Architectural, Errorproofing, Pervasive, Visual, Cognitive and Security (Lockton, Harrison & Stanton, 2010), the DwI approach has, through multiple iterations and testing (Lockton, Harrison, & Stanton, 2008; 2010; 2013; 2016), evolved to the 8 lenses of Architectural, Errorproofing, Interaction, Ludic, Perceptual, Cognitive, Machiavellian, and Security (Lockton, 2017). Table 1 presents the main themes of each of the lenses.

Table 1. Summary of the lenses and themes present within the DwI framework.

Lens	Theme	Example Cards	Number of Cards
Architectural Lens	Draws primarily on ideas within architecture and urban planning, seeking to apply ideas from the built environment. Largely concerns the structure and layout of items and behavior.	Angles Pave the Cowpaths	12
Errorproofing Lens	Considers any behaviour that deviates from a target behaviour as an error and seeks to reduce the likelihood of errors occurring. Seeks to design a system whereby these errors cannot occur.	Are you sure? Matched Affordances	10
Interaction Lens	Fundamentally about users interaction with the devices or displays. Based on the feedback and feedforward of information between the user and the device being considered.	Kairos Real-Time Feedback	10
Ludic Lens	Focus on the potential for gamification of a device. Popularised by the view that playful interactions can encourage the maintenance of behavior	Scores Storytelling	11
Perceptual Lens	Seeks to utilise biases in human perceptual system, for example use of heuristics, to target the design and development of objects.	Colour associations Nakedness	17
Cognitive Lens	Based on cognitive psychology and an understanding of how individuals make decisions. Seeks to bias individuals to make a desired decision.	Provoke empathy Commitment and consistency	15
Machiavellian Lens	Seeks to control the behaviour of individuals, by utilising an "Ends Justify the Means" approach.	Functional obsolescence I cut, you choose	14
Security Lens	Seek to prevent undesired behaviour through direct countermeasures. Seeks to directly control behaviour.	Peervailence Coercive atmospherics	12

The DwI method follows the design pattern approach (Lockton, Harrison & Stanton, 2013). The design pattern approach has been influential within the Human Computer Interaction community (Tidwell, 2005; Crumlish & Malone, 2009), and seeks to anchor thinking on a particular topic area or subject. The design pattern approach however has not primarily been used as tools for novel idea generation. Nevertheless, as Lockton, Harrison and Stanton, (2010; 2013) argue, such an approach can merit the consideration of multiple answers to set problem and therefore act to encourage multiple ideas. The design pattern approach as used within the DwI design cards comprises of a short title, labelling the card, colour coded to its particular lens, a question the designers can ask of their system, and a photograph of a prototypical example of the design card in action. Figures 1. and 2. present example DwI cards, Angles, from the Architecture lens and Colour Associations from the Perceptual lens. Users are required to use the information presented on each of the cards to make their own inferences regarding their products and their end users' needs, with no boundaries set in place by the tool. Previous uses of the DwI approach include proposed redesign of automated teller machines (ATMs, Lockton, Harrison & Stanton, 2010), with the authors suggesting that the use of DwI approach led to a variety of feasible design solutions. The design with intent cards were also used by Salmon et al. (2018) as part of a sociotechnical systems-based design process to create a series of new road intersection concepts. The aim was to develop new designs that would enhance interactions between drivers, cyclists, motorcyclists and pedestrians and reduce collisions. Three novel intersection concepts were produced and evaluated with end-users from each road user group (Salmon et al., 2018; Read et al., In Press).


Angles

Can you slant or angle things so some actions are easier than others?

Some cigarette bins are sold to authorities using the sloping top as a feature, discouraging people leaving litter on top

Figure 1. Example DwI Card, Angles.


Colour associations

Can you use colour to suggest associations between particular behaviours and outcomes?

This racecourse bookmaker's keyboard has a detailed language of colour-coded groups of functions, to aid rapid action-taking

Figure 2. Example DwI Card, Colour Associations.

Rationale Summary

Previous arguments have stated that greenhouse gases and other pollutants released from everyday driving have significant negative environmental and health implications. As these emissions are a leading contributor to total pollution, finding ways in which to minimise them are a key challenge for researchers across multiple domains and disciplines. One role that ergonomists and designers can take in this challenge is assisting in the development of in-vehicle interfaces designed to encourage fuel-efficient driving. One tool produced to assist designers and researchers in the development of such interfaces is the DwI toolkit (Lockton, Harrison & Stanton, 2010). The current study used a group workshop approach in order to explore the ideas that could emerge using the DwI approach when applied to developing interfaces encouraging fuel-efficient driving.

Case Study

Participants

The workshop comprised eight participants, three female participants aged 26 - 43 years (*M* = 33.67, *S.D.* = 8.62) and five male participants, aged 28 - 57 years (*M* = 38.2, *S.D.* = 13.44). Participants were from a variety of academic backgrounds including Psychology, Human Factors, Control Engineering, Automotive Engineering and Electronic Engineering. Participants within this session all had an interest in improving vehicle fuel efficiency and were invited to participate in the workshop to take advantage of their specialist knowledge of vehicle systems, including knowledge of vehicular powertrains, which could inform potential interface development. This study was approved by the Ethics committee, University of Southampton (ERGO 27172).

Procedure

This investigation utilised a case study approach, organised as a workshop event. At the start of the workshop, all participants were introduced to the goal of developing interfaces to support fuel-efficient driving. To assist this goal, participants were introduced to the concept of eco-driving, and given the opportunity to discuss with the research team any questions they had regarding this concept, interactions between eco-driving and vehicles' mechanical systems or the wider purpose of the workshop.

The workshop lasted approximately 5 hours. The first hour was devoted to the introduction and general discussion of the topic of fuel efficiency and eco-driving, and how each the participants' diverse expertise could assist in this goal. During this introduction, participants were fully introduced to the structure of the workshop, and what was expected of them. In addition, it was clarified that an interface was not limited to any specific sensory modality, but was any system which promoted fuel efficient driving. To assist with this large posters were placed at the front of the room showing the phrases "Visual (Head Up Display, HUD)", "Visual (Head Down Display, HDD)", "Auditory", "Haptic (Pedals)", "Haptic (Seat)" and "Other". These posters would be used within the workshop to categorise participants' ideas for an interface into a specific feedback modality, but also acted to remind participants that additional implementation techniques were available beyond a visual display. Three hours, consisting the majority of the workshop was dedicated to the process of ideation, and discussion of the individual DwI cards. The final hour of the workshop was dedicated to a review of the generated ideas.

Following the introduction, each workshop participant was given a unique and random selection of 12 or 13 DwI cards, so that all 101 DwI cards were distributed between the workshop attendees. Each participant was then asked to sequentially lead a group discussion on one of the DwI cards they had been assigned, generating ideas relating to the development of new in-vehicle interfaces to support fuel-efficient driving. All participants were encouraged to contribute any ideas they had related to the presented card. In this way, every DwI card had the potential to inspire multiple design ideas in the form of a round-table discussion. Once an idea was generated, it was categorised as suitable for either a singular or multiple interface modality, and placed under the relevant marker at the front of the room, using a series of post it notes. Participants were encouraged to be as creative as possible with their ideas throughout the workshop, and were told that there were no bad ideas. Due to the nature of the DwI toolkit and the workshop's stance on encouraging the free creation of ideas, it was possible for the same, or highly similar, ideas to emerge from different DwI cards. If this occurred participants were encouraged to still record the idea. Once an idea had been suggested as part of the workshop, it was written on a post-it note and attached to its relevant feedback modality, visible to the workshop attendees. This process was repeated following a round table discussion for all 101 DwI cards creating a collection of 138 generated ideas.

Once all 101 DwI cards had been discussed by the research team, participants were invited to review the produced ideas, and encouraged to present any further ideas which they had relating to the interface development. Although no new ideas emerged as part of this review, several ideas created earlier within the workshop were clarified with clearer meaning to aid future transcription.

Review of the Ideas and Final Coding

Following the workshop, the research team reviewed the ideas generated within the workshop, independent of the wider attendees. In order to make best use of the generated ideas within further research and in order to be suitable for the design of workable interfaces, the generated ideas were required to be reduced to a manageable number. Schunn, McGregor and Saner (2005) suggest that this process of refinement and reduction is a fundamental aspect of the design process. To achieve this goal, the number of ideas was culled in a two-stage process.

For the initial cull, ideas were classified as suitable or not suitable for implementation within an in-vehicle interface, the focus of the current research. This was essential in removing ideas linked to governmental policy shifts and providing greater financial incentives to eco-drivers. This initial cull removed approximate half of the ideas generated within the workshop, however these ideas were stored for future consideration.

For the second cull, each of the remaining ideas were the classified as either constraint based or demand based, following the principles of ecological interface design (Vincente & Rasmussen, 1992). Constraint based ideas sought to highlight a particular aspect of the fuel-efficient driving task to the driver in order to make the constraints that are present, but not obvious, more explicit. In contrast, demand based ideas directly imposed a specific action onto the driver, demanding an appropriate action or forcing the car to react in a certain way. It was deemed prudent to pursue ideas that were classified as constraint based for the design of vehicle interfaces in order to encourage potential user acceptance and the uptake of the developed ideas. Following this review, the remaining ideas were collected to produce initial designs.

Design Results & Discussion

From the workshop, a total of 138 ideas were generated, highlighting that each of the 101 design cards within DwI has the potential to inspire multiple ideas. Importantly, all of the eight different lenses that make up the DwI toolkit contributed to the generated ideas, suggesting the lenses are not domain specific. Figure 3 presents the relative breakdown of the ideas across the different lenses of the framework, although the total number of available cards differs in each lens, it can be seen that all lenses contributed to the process of generating novel ideas.

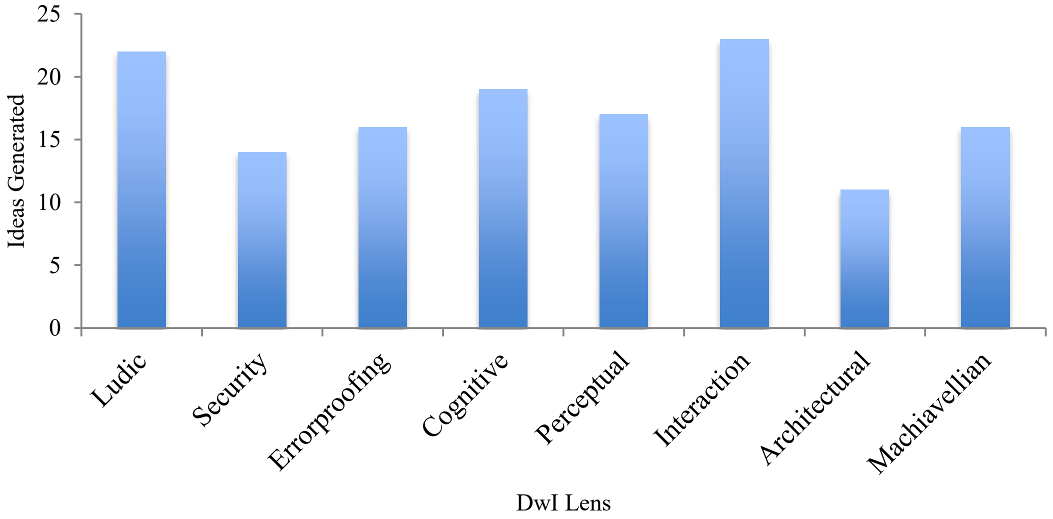

Figure 3. Number of ideas generated for each of the DwI lens.

Due to space limitations, not all 138 ideas generated within the workshop will be presented within the current paper. Table 2. presents ideas that were generated using cards from the Architectural lens. Despite this lens having a focus on the physical properties of objects and being largely inspired by ideas relating to the design of large-scale spaces, it was able to inspire 11 ideas relating to greater vehicle fuel efficiency.

Table 2. Ideas inspired by the Architectural lens, including the specific cards used.

Feedback Category	Lens	Card	Description/ Reasoning
Haptic-Pedal	Architectural	Roadblock	Limit the amount of acceleration possible via use of counterforce in pedal
Haptic-Seat	Architectural	Material Properties	Artificial bumpiness, simulating harder suspension if drivers drive in a non-eco way.
Visual - HDD	Architectural	Angles	Make it easier to select eco-friendly options and harder to select non-eco modes
Visual - HDD	Architectural	Positioning	Start stop system at traffic lights which is difficult to turn off
Visual - HDD	Architectural	Simplicity	Visual display of the financial benefits of eco-driving
OTHER	Architectural	Pave the Cowpaths	Codify eco-routes within the system
OTHER	Architectural	Converging and Diverging	Encourage greater platooning of vehicles for greater fuel economy
OTHER	Architectural	Converging and Diverging	Encourage car sharing between people with similar start/ end journeys.
OTHER	Architectural	Hiding Things	Hide sports mode to the driver so that it is harder to access
OTHER	Architectural	Hiding Things	Disable sports mode if fuel economy drops below a set of thresholds
OTHER	Architectural	Roadblock	Non-eco buttons harder to reach than eco buttons

When considering the feedback modalities of the generated ideas, that is, how each generated idea would interact with the driver of the vehicle, six key frames were considered “Visual (HUD)”, “Visual (HDD)”, “Auditory”, “Haptic (Pedals)”, “Haptic (Seat)” and “Other”. Figure 4 presents the distribution of ideas to each of the interface modalities that were considered as part of the workshop.

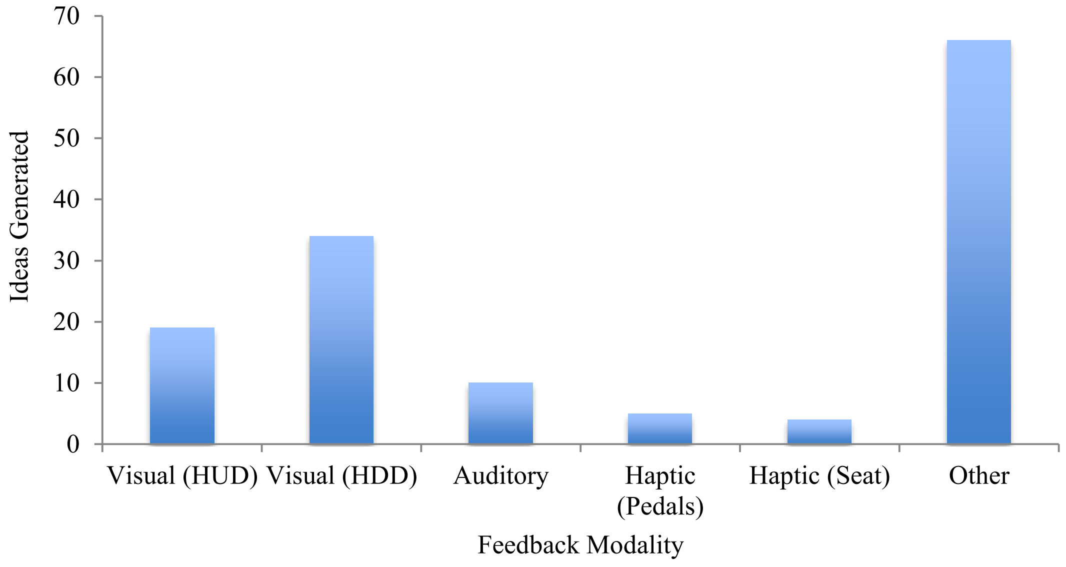

Figure 4. Number of ideas generated for each feedback modality during the workshop.

The research team did not anticipate the number of ideas that were classified as “Other”. Generated ideas within this category included “Cheaper car based services for eco-drivers, for example variable parking rates based on fuel economy” and “Greater impact of driving style/ eco-driving on insurance premiums”. Although these ideas are valuable and have the potential for discussion and dissemination, they typically operate and a higher system level than the immediate driving environment, for example governmental policy and town planning and are therefore not directly applicable to the challenge of the current paper in designing interfaces to support fuel efficiency. Despite the potential value in these ideas, they were therefore removed within the initial cull. These ideas were however recorded for future analysis and interpretation.

As discussed within the “Methods” section of the current paper, the research team was required to cull the ideas that had been generated in order to develop usable interfaces. For the first cull, all ideas that were not directly related the development of potential in-vehicle interfaces were discarded. Primarily these ideas related to changing the physical characteristics of vehicles and promoting wider societal change and environmental awareness of the emissions released when driving. Despite the potential benefits of these ideas, the research team was unable to currently test ideas such as “Make the fuel tank harder to fill, in order put barriers to refueling”. This initial cull resulted in 62 ideas being put aside, Due to the initial interface categorisation, the significant majority of these ideas were drawn from the “Other” category.

Despite this initial culling of ideas, a total of 76 ideas remained. Following the principles of ecological interface design as outlined previously, the research team completed the second cull. Following this process, it was found that 21 ideas were constraint-based and ecological, with the potential to be taken forward for the development of in-vehicle interfaces. Of the 21 ideas that were taken forward, five related to providing drivers with a visual gamification of fuel efficiency, such as a growing flower bed which flourishes or wilts based on driver performance or a polar bear sitting on a growing and shrinking iceberg which changes subject to the fuel efficiency of drivers’ actions. Although both of these ideas are unique and potentially have different implications long term, for the purpose of the current work, they were collated into a single idea, of a visual display encouraging gamification. Similarly, four generated ideas related to promoting knowledge of and encouraging the coasting behaviour, so they were also compiled into a single idea. Following this final review, 14 unique ideas were considered suitable for the development of user interfaces. The compiled interface ideas, as well as how they are intended to interact with and feedback information to the driver of the vehicle, are presented in Table 3.

Table 3. Summary of the 14 interface ideas generated within the workshop, designed to increase drivers fuel efficiency.

No.	Interface Idea	Auditory	Haptic Seat	Haptic Pedal	Visual (HUD)	Visual (HDD)
1.	Provision of a warning regarding the best moment to remove foot from accelerator to minimise required braking.	▨	▨	▨	▨	▨
2.	Tailored eco-driving suggestions based on location, e.g. notification regarding hidden bends and approaching traffic.	▨			▨	▨
3.	Colour changing lighting within the vehicle cabin based on drivers' fuel efficiency and recent actions.				▨	
4.	Provision of an eco-driving and environmental start-up notification, promoting eco-driving and highlighting the negative environmental effects of car use.				▨	▨
5.	Visual display encouraging gamification of fuel economy. Polar bear on an iceberg shrinking and growing based on drivers fuel efficiency and recent actions.				▨	▨
6.	Behavioural metaphor displays to mimic journey parameters. Challenge of keeping an item in the centre of a container based on lateral and longitudinal movements of the vehicle.				▨	▨
7.	Impose a limit on the total possible acceleration should breaking be shortly required.			▨		
8.	Provision of a warning when a stop will be required, for example as a result of traffic light or congestion.	▨	▨	▨	▨	▨
9.	Dynamic fuel tank display that grows in prominence as fuel is depleted, highlighting the limited fuel reserves to the driver.				▨	▨
10.	Dynamic band on the speedometer displaying best possible speed for the current location to minimise likelihood of stopping (traffic lights or congestion).				▨	▨
11.	Dynamic range display and estimate based upon driver's fuel efficiency and recent actions.				▨	▨
12.	Notification provided to the driver when excessive and unneeded acceleration is applied.	▨	▨	▨	▨	▨
13.	Fuel tank display based on money available rather than fuel available.				▨	▨
14.	Display the financial cost of a journey at the end of each journey, including money saved or wasted.				▨	▨

Driver Acceptance

Following the development of the DwI informed interface designs, it was deemed prudent to explore the extent to which the different proposed interfaces would likely be both accepted by drivers and perceived as effective. This would act as an initial validation activity and offer researchers an insight into the interventions that would be of most value to consider within future empirical work. Usability has been considered key in previous work when considering the acceptance of in vehicle interfaces (Harvey et al., 2011; Stanton, & Salmon, 2011). Whilst a panel of eco-driving experts might be considered an ideal sample for this activity, it was reasoned by the research team that such experts would have limited need for the proposed interfaces generated with the current research. In contrast, drivers with no eco-driving training and no particular interest in fuel-efficient driving could significantly benefit from the potential savings induced by the system (McIlroy & Stanton, 2013; 2017). Consequently, drivers with no previous eco-driving training were sought and recruited to assess the initial usability of the proposed interfaces

Validation Methodology

Participants

24 participants, (13 Male participants and 11 Female participants) completed the study validation questionnaires. Participants were recruited using opportunity sampling and not compensated for their time spent completing this research. All participants were required to have held a current full driving license for a minimum of two years to be eligible to participate in the evaluation exercise. Participants who had extensive knowledge of or had received formal training in eco-driving practices were not eligible to take part.

Measures

Participants completed two rating questionnaires as part of the validation activity. Both questionnaires utilized a five-point likert scale. For the first questionnaire, participants were presented with 14 interface ideas and asked to rate the likelihood they would be willing to use each interface on a scale of Very Unlikely (1) to Very Likely (5). For the second questionnaire, participants were asked to consider, irrespective of their previous responses, the perceived impact that each interface would have on overall fuel use, using a scale of Very Low Impact (1) to Very High Impact (5). The questionnaires used within this study are presented within Appendix 1 and 2 respectively.

Procedure

Prior to taking part in the validation activity, participants were informed that they would be asked to judge their acceptance and initial impression of a series of interfaces designed to reduce the fuel usage associated with everyday driving. Following acceptance of this, participants were presented with the questionnaires. The researcher verbally explained each concept and sought confirmation that the participant understand the functionality of the different interfaces before participants completed the questionnaires. Where appropriate, participants were asked to complete this task independently, and not to discuss their ratings with other participants. The researcher was present at all times and participants were encouraged to seek clarification from the research team if they were unclear of the meaning or functioning of any of the interface items. The questionnaires took approximately 10 minutes to complete. Ethical approval for this research was given by the University of Southampton Ethics Committee (ERGO 40131).

Validation Results & Discussion

Table 4. presents participants median and standard deviation scores regarding likelihood of use for the different interfaces developed following the DwI workshop. It can be seen that participants rated the majority of items as likely to use, at a median of 4 or in the case of “Display cost of a journey at the end of each journey, including money saved or wasted”, even higher. It was seen however that the fine detail task of “Challenge of keeping an item in the centre of a container” was rated poorly compared to the other interface displays, receiving a median rating of 2.

Table 4. Participants median and standard deviation for likelihood of use for the different interface designs developed following the DwI workshop (where 1 = Very Unlikely and 5 = Very Likely).

	Median	**Interquartile Range**
Warning on the best moment to remove foot from accelerator to minimise required braking.	4	2.75
Tailored eco-driving suggestions based on location.	4	1
Mood/ colour changing cabin based on current fuel efficiency and recent actions.	3	2.75
Eco-driving and environmental start-up notification.	4	1
Visual display encouraging gamification. Polar bear on an iceberg shrinking and growing based on drivers fuel efficiency and recent actions.	3	2
Challenge of keeping an item in the centre of a container.	2	2
Limit possible acceleration if breaking will be shortly required.	4	1
Warning when a stop will be required	4	0
Dynamic fuel tank display, highlighting limited fuel.	4	0
Dynamic band on a the speedometer displaying best possible speed for the current location to minimise likelihood of stopping (traffic lights or congestion)	4	2
Dynamic range display and estimate based upon driver's fuel efficiency and recent actions.	4	1.5
Notification when excessive acceleration is applied	4	2.75
Fuel tank display based on money available within the tank rather than fuel available	3.5	3
Display cost of a journey at the end of each journey, including money saved or wasted.	4.5	1.75

Initial data exploration was completed via the use of a box and whisker plot, presented in Figure 5. This figure supported the view that participants' ratings of likelihood to use the different interface displays differed. To explore these differences in more detail, a Friedman's test was calculated. This test revealed that there was a significant difference in participants likelihood to use the different interface displays,

χ^2 (13) = 43.82, $p = .01$. This analysis was expanded via the use of Wilcoxon signed-rank tests, with the Bonferroni correction, as post hoc tests, based upon a visual inspection of Figure 5. Five Post hoc tests were calculated, comparing lowest ranked interface display, “Challenge of keeping an item in the centre of a container” (*Mdn* = 2) to interface displays which appeared to be consistently more highly ranked. Results indicated that “Tailored eco-driving suggestions based on location” (*Mdn* = 4, $Z = 3.75$, $p < .001$, $r = .77$), “Eco-driving and environmental start-up notification” (*Mdn* = 4, $Z = 2.89$, $p = .019$, $r = .59$), “Limit possible acceleration if breaking will be shortly required” (*Mdn* = 4, $Z = 3.00$, $p = .013$, $r = .61$) “Dynamic range display and estimate based upon driver’s fuel efficiency and recent actions” (*Mdn* = 4, $Z = 3.81$, $p < .001$, $r = .77$) and “Display cost of a journey at the end of each journey, including money saved or wasted” (*Mdn* = 4.5, $Z = 3.54$, $p < .001$, $r = .72$) were all rated significantly more likely to be used.

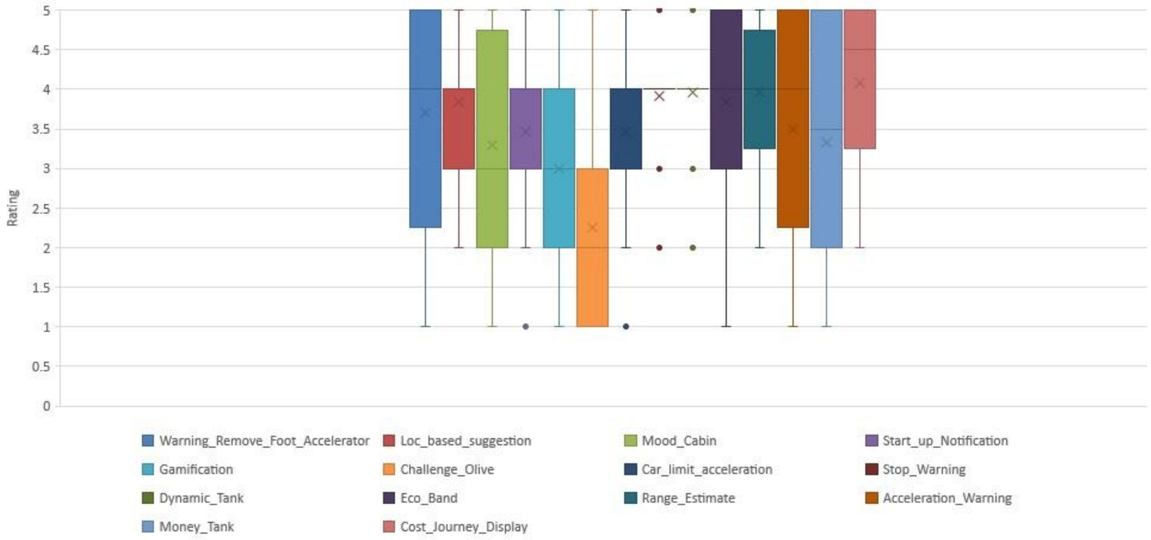

Figure 5. Box and Whisker plot for participants’ likelihood to use the proposed interfaces.

In addition to participants rating their likelihood to use the different interfaces designed within the workshop, participants were ask to rate how much of an impact the different interfaces would have on their overall fuel usage. Although no objective measures of fuel usage were taken within an empirical investigation and participants did not directly interact with the different interfaces, it was deemed important to consider the perceived benefits of each interface. Table 5 presents the median and standard deviations for these perceived effectiveness ratings. Whilst it was apparent that levels of perceived effectiveness was not as high as participant likelihood of use, numerous interface designs scored greater than 3, indicating that participants thought that such a display could make, regardless of size, a positive impact to overall fuel usage.

Table 5. Participants median and standard deviation for perceived effectiveness for the different interface designs developed following the DwI workshop (where 1 = Very Low Impact and 5 = Very High Impact).

	Median	**Interquartile Range**
Warning on the best moment to remove foot from accelerator to minimise required braking.	4	2
Tailored eco-driving suggestions based on location.	3	2
Mood/ colour changing cabin based on current fuel efficiency and recent actions.	3	1.75
Eco-driving and environmental start-up notification.	3	1.75
Visual display encouraging gamification. Polar bear on an iceberg shrinking and growing based on drivers fuel efficiency and recent actions.	3	2
Challenge of keeping an item in the centre of a container.	2	2
Limit possible acceleration if breaking will be shortly required.	4	1
Warning when a stop will be required	3	1
Dynamic fuel tank display, highlighting limited fuel.	3.5	1.75
Dynamic band on a the speedometer displaying best possible speed for the current location to minimise likelihood of stopping (traffic lights or congestion)	4	2.5
Dynamic range display and estimate based upon driver's fuel efficiency and recent actions.	3.5	2.5
Notification when excessive acceleration is applied	3.5	1.75
Fuel tank display based on money available within the tank rather than fuel available	3	2.5
Display cost of a journey at the end of each journey, including money saved or wasted.	4	2

Similar to likelihood of use, the item rated as the least effective was the "Challenge of keeping an item in the centre of a container" which received a median rating of 2. Items regarded as more effective included "Warning on the best moment to remove foot from accelerator to minimise required braking" Limit possible acceleration if breaking will be shortly required", "Dynamic band on a the speedometer displaying best possible speed for the current location to minimise likelihood of stopping (traffic lights or congestion)" and "Display cost of a journey at the end of each journey, including money saved or wasted" all of which received a median rating of 4. To explore whether there were differences in participants perceived effectiveness of the different interface displays, a Friedman's test was calculated. This test revealed that there was a significant difference in participants perceived effectiveness of the different interface displays, χ^2 (13) = 54.30, *p* = .01. Similar to likelihood ratings completed previously, a box and whisker plot was used as an initial data exploration technique, presented in Figure 6. Building on the main analysis, three post hoc tests were calculated comparing the lowest ranked interface item, again "Challenge of keeping an item in the centre of a container" (Mdn = 2) to interface items rated consistently higher. Results indicated that "Limit possible acceleration if breaking will be shortly required" (*Mdn* = 4, *Z* = 3.58, *p* = .001, *r* = .73) "Warning when a stop will be required" (*Mdn* = 3, *Z* = 3.19, *p* = .004, *r* = .65) and "Display cost of a journey at the end of each journey, including money saved or wasted" (*Mdn* = 4, *Z* = 3.59, *p* < .001, *r* = .73) were all perceived to have a significantly greater effect.

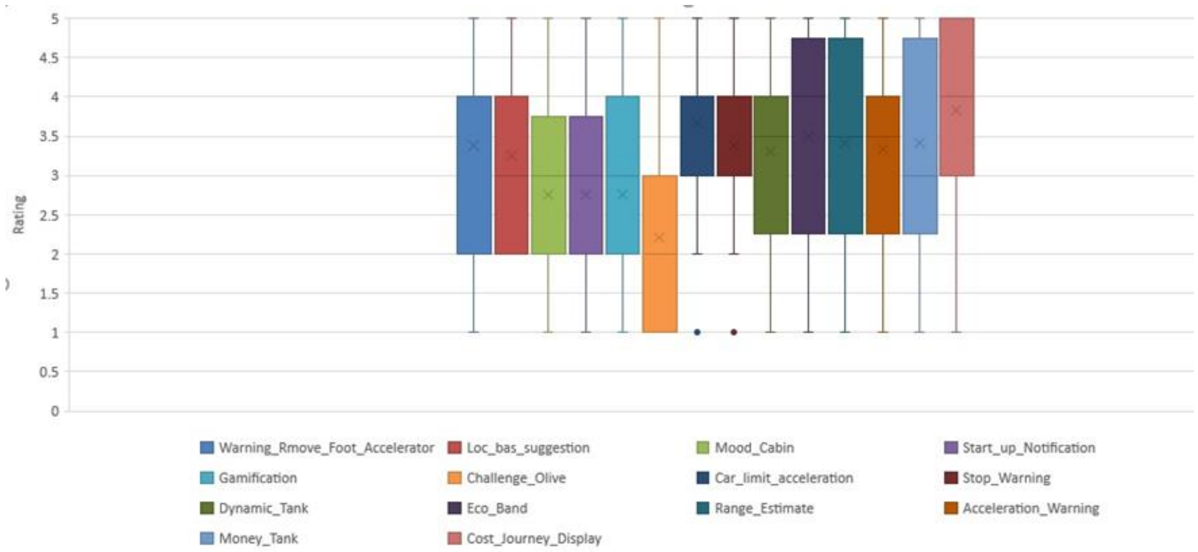

Figure 6. Box and Whisker plot for participants' perceived effectiveness of the proposed interfaces.

Overall results are supportive that participants would be willing to use the interfaces developed as part of the workshop. Despite general lower ratings for perceived effectiveness, combined these measures allow the focus of development for future laboratory studies of the proposed interventions. Upon reflection, qualitative data relating to why participants recorded the scores they did would have been beneficial for analysis. Not only would such data have yielded understanding regarding why participants left the ratings that they did, but such data would also have of value in further developing and refining the interfaces prior to empirical testing with a driving simulator.

General Discussion

The primary aim of this paper was to use the DwI toolkit (Lockton, Harrison, & Stanton, 2008; 2010; 2013; 2016) to generate ideas to facilitate fuel efficient driving, also referred to as eco-driving (Barkenbus, 2010). Furthermore, this research sought to use the generated ideas to produce a collection of initial interface designs that could be matured into future full in-vehicle interfaces to support drivers and offer feedback in achieving greater fuel efficiency (McIlroy, Stanton & Harvey, 2013; Tulusan, Staake & Fleisch, 2012). Using the DwI toolkit, 138 ideas were generated to encourage greater fuel efficiency within everyday driving. These ideas were generated using all of the available eight DwI lenses, and associated DwI cards to facilitate the generation of multiple ideas. Upon review of the ideas, it was apparent that many of the generated ideas suggested significant societal, political and financial changes to encourage this shift in driver behaviour, which were outside the scope of interface design in this case study. Of the ideas that were highly applicable to the development of interfaces, the themes of gamification and increasing awareness of coasting behaviours was repeated across multiple suggestions. Previous research has demonstrated that gamification can be highly effective at reducing fuel usage, provided it is well designed and integrated with the overall driving experience. Dahlinger et al. (2018) explored the potential of numeric, compared to symbolic eco-driving notifications at reducing fuel usage based on an extensive sample of Swiss drivers, and found that symbolic notifications such as a growing tree displayed on the vehicles dashboard reduced fuel usage by up to 3% as drivers attempted to minimize their fuel consumption. Similarly, promotion of coasting behaviours has been previously promoted within the literature to improve fuel efficiency. Beusen et al. (2009) explored the effect of an eco-driving training course and found greater coasting behaviours was associated with reduced fuel usage, and that coasting behaviours significantly increased following eco-driving training. Following consideration of the idea generated within the workshop, 14 concepts for potential interfaces were created.

Use of the DwI Toolkit

Of central interest to the current paper is considering the value that design methods (Daalhuizen, 2014; Tromp & Hekkert, 2016), and specifically the DwI toolkit (Lockton, Harrison & Stanton, 2010), can play in assisting users develop ideas and structure thinking on a particular topic. In the case of the current study, this was the encouraging the adoption of eco-driving (Barkenbus, 2010), and similar fuel-efficient driving behaviours. Due to the scale of vehicle usage, and the negative environmental impact vehicle emissions can have when considering anthropogenic climate change and global weather patterns (Karl & Trenberth, 2003; Chapman, 2007), each small saving made by individuals can have considerable positive impact on the planet as a whole.

Whilst not a formal experiment, the current work has highlighted the potential of the DwI toolkit. The number of ideas generated within the workshop can demonstrate the immediate value of the DwI toolkit. The utility of the DwI approach is further supported by the relative distribution of ideas across lenses and that each DwI lens contributed new and innovative ideas. The value of the "suggestion tool" approach is further supported by the fact that the workshop attendees were not designers, but rather experts in Automotive Engineering and Human Factors. The DwI toolkit therefore presented an efficient approach to design, whereby individuals without extensive design experience were able to generate specification, objectives and initial interface designs. Previous research has demonstrated that design is a process that is fundamentally different from science and engineering, suggesting that access to the DwI toolkit facilitated creative thinking (Lawson, 1979). This dichotomy can be further magnified by the fact that participants were given complete freedom in the ideas that could be generated. Considering that the problem of addressing vehicle emissions and fuel usage can be seen as, to use design theory language, a "wicked problem" (Buchanan, 1992). Defined by Rittel and Webber (1973), wicked problems are *"a class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing"*. Despite this difficulty, it was seen that the DwI toolkit offered a workable perspective to address the problem of improving fuel efficiency.

Realising eco-driving through design

Brown (2009) proposed that *"Design thinking relies on our ability to be intuitive, to recognize patterns, to construct ideas that have emotional meaning as well as functionality, to express ourselves in media other than words or symbols"*. Taken within these confines, developing ideas and novel interface designs to facilitate fuel efficiency can be seen as design problems. Previous research has demonstrated the value that interfaces displays can have in reducing energy usage both within the home (Jain et al., 2012; Abrahamse et al., 2007) and within vehicles (Jamson et al., 2013; McIlroy, Stanton, Godwin & Wood, 2017). By considering ideas generated within the workshop from a constraint perspective as proposed by ecological interface design (Vincente & Rasmussen, 1992), the final interface designs generated from the workshop ideas were suitable for application within a vehicle.

Of key importance within design work targeting behavioural change is the effectiveness of the intervention. Tromp and Hekkert (2016) argue that within the field of design there is a frequent lack of agreement when judging the quality of a design outcome. Indeed, within the current work, the validation activity identified significant differences in participants' responses to the different interface design ideas. Extensive testing is required to address this current lack of clarity relating to both likelihood of use and perceived effectiveness. Once completed, this work will allow a bridge to be formed between the work of the designer and the work of the scientist and engineer (Lawson, 1979). This paper has focused on the process of ideation and the initial development of interfaces to support fuel-efficient driving. The next steps of this research will be to empirically assess the different interfaces effectiveness at reducing fuel usage within a driving simulator. This research will help further validate the insights and value of the DwI approach.

Conclusion

This paper has focused on the role of a design method, specifically the DwI toolkit, in facilitating creativity in the generation of novel design ideas. Applied to the challenge of fuel-efficient driving, the DwI cards were first used to generate novel ideas designed to increase fuel efficiency, before the generated ideas were distilled to produce early designs for potential in-vehicle interfaces. Although further refinement, digitization and empirical testing is required of the proposed interfaces, it was clear that DwI offered a suitable approach to novel ideation to assist in the creative design process. Despite the fact that the DwI approach is reliant on the skills, expertise and creativity of the individuals involved in the process, the lack of prior design expertise did not limit the generation of ideas. Based on the success of this approach, it appears that all lenses within the DwI toolkit can offer scientists, engineers and designers useful insights developing prototype interfaces.

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APPENDIX

If the follow technology was available, how likely are you to use it?

	Very Unlikely	Unlikely	Neutral	Likely	Very Likely
Warning on the best moment to remove foot from accelerator to minimise required braking.					
Tailored eco-driving suggestions based on location.					
Mood/ colour changing cabin based on current fuel efficiency and recent actions.					
Eco-driving and environmental start-up notification.					
Visual display encouraging gamification. Polar bear on an iceberg shrinking and growing based on drivers fuel efficiency and recent actions.					
Challenge of keeping an item in the centre of a container.					
Limit possible acceleration if breaking will be shortly required.					
Warning when a stop will be required					
Dynamic fuel tank display, highlighting limited fuel.					
Dynamic band on a the speedometer displaying best possible speed for the current location to minimise likelihood of stopping (traffic lights or congestion)					
Dynamic range display and estimate based upon driver's fuel efficiency and recent actions.					
Notification when excessive acceleration is applied					
Fuel tank display based on money available within the tank rather than fuel available					
Display cost of a journey at the end of each journey, including money saved or wasted.					

If the following technologies were available, how much of an impact do you think they would make to your overall fuel use?

	Very Low Impact	Low Impact	Medium Impact	High Impact	Very High Impact
Warning on the best moment to remove foot from accelerator to minimise required breaking.					
Tailored eco-driving suggestions based on location.					
Mood/ colour changing cabin based on current fuel efficiency and recent actions.					
Eco-driving and environmental start-up notification.					
Visual display encouraging gamification. Polar bear on an iceberg shrinking and growing based on drivers fuel efficiency and recent actions.					
Challenge of keeping an item in the centre of a container.					
Limit possible acceleration if breaking will be shortly required.					
Warning when a stop will be required					
Dynamic fuel tank display, highlighting limited fuel.					
Dynamic band on a the speedometer displaying best possible speed for the current location to minimise likelihood of stopping (traffic lights or congestion)					
Dynamic range display and estimate based upon driver’s fuel efficiency and recent actions.					
Notification when excessive acceleration is applied					
Fuel tank display based on money available within the tank rather than fuel available					
Display cost of a journey at the end of each journey, including money saved or wasted.					