Design of a Gamified Interface to Improve Fuel Efficiency and Safe Driving

Atiyeh Vaezipour(✉), Andry Rakotonirainy, and Narelle Haworth

Centre for Accident Research and Road Safety (CARRS-Q),
Queensland University of Technology (QUT), 130 Victoria Park Road,
Queensland, 4059, Australia
{a.vaezipour,a.rakotonirainy,n.haworth}@qut.edu.au

Abstract. The increasing reliance on motor vehicles has negative effects on both human health and the environment. Improving driving style has been shown to be a particularly crucial and relatively quick step to reducing fuel consumption and vehicle emissions. In this paper, a series of conceptual designs of in-vehicle gamified interfaces were evaluated, with a particular focus on the ability to use such systems to increase driver acceptance of feedback from such interfaces in order to promote eco-safe driving. Self-determination theory (SDT) was used to inform the design of the gamified interface concepts, with a particular focus on competence, autonomy and relatedness, as well as intrinsic versus extrinsic incentives and social persuasion feedback. The study adopts a user-centered design approach, utilizing focus groups to establish user needs and motivations to aid the design of a prototype system.

Keywords: Eco-driving · Safe driving · User-centered design · User experience · Gamification · Human computer interaction

1 Introduction

An increasing reliance on motor vehicles subsequently results in an increase in gaseous and particulate pollution, which has negative effects on both human health and the environment. According to the World Health Organization [1], ambient air pollution attributes to 3.7 million deaths each year worldwide. Improving driving style has been shown to be an effective way to reduce fuel consumption and vehicle emissions [2], with the adoption of fuel-efficient driving behaviors being reported as having the potential to reduce fuel consumption amongst the existing vehicle fleet by 5–10 % [3].

Whilst there are large overlaps between eco-driving and safe driving behavior, in some traffic situations they are in conflict with one another [4, 5]. In-vehicle Human Machine Interfaces (HMI) provide an opportunity to provide real-time feedback to drivers based on the immediate traffic conditions, support of the driver and navigation. These systems are developing rapidly, having recently been used to promote fuel-efficient and safe driving.

This paper employed a user-centered design approach to inform the design of a prototype eco-safe, gamified in-vehicle system. The use of game elements in the driving

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context is becoming increasingly popular. The use of such principles as a means to influence driver behaviors has been previously explored, including a number of smartphone, app-based approaches, such as Driving Miss Daisy [6], Learner Logbook [7] and VW Smile Drive (smiledrive.vw.com), as well as more innovative approaches such as the Speed Camera Lottery (thefuntheory.com). Furthermore, Rodríguez et al. [8] sought to prevent distractions through the use of ambient devices and haptic feedback.

The objective of the gamified interface is to motivate drivers to improve their driving performance and cooperate with other drivers in order to improve fuel efficiency and traffic safety. Of particular interest, is the acceptance and effectiveness of providing driving performance feedback to drivers through this medium, both in terms of individual feedback to the driver, as well as the exchange of social persuasion feedback among other drivers. The study investigates a number of concepts, including user perceptions of the conceptual designs (e.g., how engaging the interface is, how easily it is understood, perceived usability), as well as perceived difficulties associated with the interface and ideas for improvements.

Self-determination theory (SDT) [9] was used to inform the design of the game elements and interface concepts. According to SDT, three key needs are essential for the achievement of psychological growth: competence, relatedness and autonomy. Specifically, competence refers to an individual's need to master new tasks and learn new skills, relatedness to an individual's need to experience a sense of belonging and attachment to others, and autonomy to the need to feel in control of one's own behavior and the subsequent outcomes. Not surprisingly, these factors are often targeted in order to institute behavior change, with high levels of these factors argued to be most likely to result in intrinsically motivated behavior. In addition, the theory argues that both intrinsic (e.g., beliefs, expectations, and self-identity) and extrinsic (e.g., incentives, social norms and pressure, cultural norms) motivations can influence behavior to varying degrees. Finally, social support is argued to be important to psychological growth, such that encouraging interpersonal relationships and social interactions (e.g., through group co-operation) can harness feelings of relatedness and attachment with others.

Thus, according to SDT, a number of factors need to be considered when developing in-vehicle systems for the purpose of facilitating intrinsically motivated behaviors that are less amenable to change. These include: (i) avoiding external rewards (e.g., prizes, cash incentives); (ii) providing positive feedback to drivers regarding their behavior related to relevant tasks (e.g., eco-safe driving); and, (iii) fostering social interactions (e.g., through cooperative systems).

Therefore, this research explores the proposition that the autonomy associated with an intrinsically motivated behavior may be undermined by the provision of external rewards, such that an individual's perceived control over their behavior is diminished. In addition, this study investigates whether intrinsic motivations to perform a behavior can be promoted through the provision of positive feedback regarding task performance, aimed at improving feelings of competence. Finally, this paper draws conclusions relating to user preferences for the design and development of an in-vehicle gamified interface. The main focus is on the comparative effect of individual versus social persuasion feedback in the driving context, which may be an important element for designing in-vehicle interfaces.

1.1 Conceptual Gamified Design

In the focus groups, participants were presented with a number of conceptual designs in the form of a paper prototype. These designs were displayed as images of a smartphone depicting various screens associated with a hypothetical gamified eco-safe in-vehicle interface. Participants were informed that these screens are only accessible to drivers before the commencement or after the completion of a trip, in order to minimize distraction while driving.

In Fig. 1a, screens related to *challenges and game elements* reveal how a user is able to choose between a variety of challenges, as well as view descriptions of each challenge. The design was intended to provide users with challenges based on different levels of difficulty to facilitate feelings of enhanced competence as they progressed through levels and mastered various challenges, keeping in mind that prior research has highlighted the need to balance difficulty and user skill in order to avoid boredom (when challenges are too easy) and/or frustration (when challenges are too difficult) [10]. The design also supported autonomy by providing multiple options for challenges, allowing users to feel a greater sense of control.

In Fig. 1b, the screens display *individualized performance indicators and feedback*. Specifically, these screens highlight a user's points, level progress, achievements, as well as more specific challenge and trip information (e.g., kilometers travelled, proportion of correct/incorrect performance of the challenge behavior). Focus group participants were informed that these screens are only accessible upon completion of a trip. Furthermore, they were shown additional concept screens (i.e., a 'My Profile' screen) outlining a variety of other information, such as total scores, overall eco-driving and safety scores, a list of friends who also use the system, a list of achievements earned and tips for increasing one's total score. Given that research has highlighted the importance of positive feedback to user experiences of competence and motivation [11], these screens were designed to give primarily positively-geared feedback messages.

Finally, Fig. 1c shows the social interaction features of the system. During the trip a user can choose to have scores of other drivers also using the system in proximity of their vehicle automatically projected onto the windshield (via heads-up display, using vehicle-to-vehicle technology), showing comparative scores on overall eco-driving and safety challenges. In addition, a number of screens are accessible after a trip that reveal scores in comparison to friends and/or other drivers who use the system. These components of the system were designed to provide users with the ability to socially engage with other drivers and cooperate toward a common goal of eco-safe driving.

2 Method

2.1 Participants

A total of 34 licensed drivers from the Australian state of Queensland were recruited to participate in focus group discussions. The sample was roughly evenly split on gender (16 female, 18 males), with an age range of 19–61 years ($M = 32.11$, $SD = 10.44$). A convenience sampling approach was used, with participants being university students

Fig. 1. Conceptual gamified design: (a) challenges, (b) individualized progress feedback, and (c) social persuasion feedback

or employees, their friends or associates. Focus groups were approximately 60 min, with participants offered a movie voucher as reimbursement for their time and contribution.

2.2 Procedure and Materials

Participants gave written consent to participate in an audio-recorded focus group discussion. In total, 6 focus groups of 5–6 participants were conducted. The facilitator began each focus group with a discussion about fuel-efficient and safe driving behavior, with participants encouraged to discuss their general concerns about eco-safe driving and the behaviors they perceived as being important to monitor while driving. The conceptualized gamified eco-safe in-vehicle system was than presented to participants (see Fig. 1), with the majority of the focus group devoted to facilitator-guided, semi-structured discussions regarding participant perceptions regarding issues such as usability, usefulness, and key effective features and areas for improvement, particularly in relation to device and feedback characteristics, gamified elements, and social persuasion feedback.

2.3 Data Analysis

Focus group sessions were audio-recorded, transcribed and coded using Nvivo. A thematic analysis was conducted to identify themes and patterns across responses and their association with research questions. Following that, familiarization and ongoing interpretation of the data allowed initial codes to be generated, which in turn were collated into a number of main themes. These included: (i) perceptions of gamified concepts; (ii) incentives and motivations to use the system; and (iii) social persuasion feedback.

3 Findings

The research findings are presented in regards to three main themes discussed in the previous section, namely: (i) perceptions of gamified concepts; (ii) incentives and motivations to use the system; and (iii) social persuasion feedback.

3.1 User Perceptions of Gamified Concepts

Overall, there were mixed perceptions regarding the use of game elements for an eco-safe in-vehicle system, with rather polarized perceptions regarding whether the inclusion of such elements was positive or negative. Those at the most extreme spectrum of less favorable attitudes suggested that the use of game elements would be potentially detrimental to the overall perceived legitimacy of the system as a safety intervention.

> *"I disagree with the game concept of it, it almost takes it away from safety and driving and makes it not as serious" (F, 53).*

More commonly, participants suggested that gamified elements simply didn't appeal to them. More specifically, many suggested that their preference would instead be for a

system that provided informative and personalized feedback regarding their eco-safe driving behavior, and in particular feedback designed to help them improve their eco-safe driving. However, it is worth noting that these individuals often acknowledged that some drivers may like, and benefit from, the gamified interface.

> *"I think I'd use it for feedback. I wouldn't use it for gaming. But like, if it just gave me feedback after I finished driving, then yeah, I would use it" (F, 22).*

> *"I don't think I'd use the game features. I'd be interested in it helping me drive safer and be more aware" (M, 32).*

However, some people had positive perceptions towards gamified elements. Specifically, a number of participants suggested that the system could be engaging and decrease the negative effects of driving monotony.

> *"Probably more appealing as a game feature rather than just like "here's buttons to push to tell you something". People might get a bit more into it as a game feature" (M, 29).*

> *"I think it's going to be fun, because sometimes a driver is going to get bored so if you have something fun, it makes your time pass smoothly" (M, 19).*

It was argued that young drivers in particular may benefit from the increased engagement with the driving task associated with a gamified system.

> *"The game thing could possibly be good for new, younger drivers when they're first starting to go out by themselves and hone their driving skills, once they get their license" (F, 33).*

> *"It would be good to have something a little bit fun in the car so for them [younger drivers] the game might be good for making it, sort of a little bit fun and engaging" (M, 36).*

In addition, other participants highlighted that the game elements could facilitate social persuasion among family and friends, suggesting they would be motivated to challenge their peers and family.

> *"I could see it being engaging with the family, to see how other members of the family are behaving. From that perspective, it would be beneficial" (F, 51).*

As a result, the majority of participants suggested that the gamified elements should represent more of a 'background feature' of the system, such that those users who wanted to gamify the feedback could do so, while the default was to have feedback provided in a more direct and informative manner.

> *"I think being able to turn that off would be good because I think personally I might be interested in the game aspect for like a week or something and then I'll probably get over it and just want the information." (F, 33).*

> *"It would be good to have an option. If you're into the game thing, I can compete with my friends, same as any iPhone game" (M, 30).*

Some participants questioned the likelihood of continued, long-term use of the system, suggesting that the novelty of the gamified elements may be short-lived. In addition, others suggested that frustration and discontinued use may result if the challenges became too difficult to master.

"I think for me, the problem will be the consistency of usage. How long are you going to use it for? There's always this period when people start using and then they are like super excited and after a point where they like, "oh, it's too much of a hassle"" (M, 22).

"I think it might improve my driving for a while but then, if I can't reach any other like challenges or achievements in the game, if it was a game, then I might just like forget it and go back to my old driving."(F, 20)

Finally, a number of participants highlighted the importance of positively-geared feedback in order to minimize the likelihood of misuse of the system and the inadvertent encouragement of poor eco-safe driving behaviors.

"I might try and see how I could push the system, like make it flash a lot that I'm doing things wrong and people would do that, like when you used to have the alcohol breath testers in the pub, you'd see who can get the highest reading, it would be similar thing with this" (M, 30)

"Good idea, if it doesn't get abused or misused. I can see my teenage son … use it for bad behavior, instead of improving, trying to compete in bad behavior" (F, 51).

3.2 Incentives and Motivations to Use the System

Participants reported polarized views regarding the factors that would motivate them to use the system. On the one hand, a number of participants suggested that intrinsic incentives, such as the knowledge that using the system was improving their eco-safe driving behavior and helping the environment, would be sufficient to motivate them to use the system.

"I think for me personally, an estimate of how much I saved, money and emissions, that would actually be the only thing important to me. If you give me a cinema voucher after one year, great, but I wouldn't really go for it" (M, 28).

"The value has really got to come from the saving, the personal saving, not the [external] reward" (F, 35).

"I care about the environment. That would be my motivation. And any extraneous stuff like, yeah might be good, but my interest in this is from an environmental point of view" (M, 39).

"I wouldn't need exterior rewards, you can get rewarded for just being a decent driver. I'd just use it for plain curiosity" (M, 23).

Overall, the intrinsic incentives associated with game elements, such as achievements and leaderboards, appeared to have little impact on reported motivations to use the system among the participants, even though they were typically interested in receiving feedback regarding their eco-safe driving performance.

"I don't want a trophy, but I want to know when I'm driving efficiently" (M, 28).

"I don't care if my phone's saying congratulations, you got a point and a star. I don't care" (M, 29).

Interestingly, a number of participants noted that it is important to ensure that the system was accommodating, noting that different users will be motivated by different incentives, and that the system must suit an individual's needs.

"If you had a series of what the rewards are, from the point of view of I want to save money, you want to save the planet, you want to compete with your mates then you set it up into different things. The technology underneath is the same but you've got to suit you" (M, 61).

"I'd rather reward myself … maybe you could customize it in a way that mattered to you" (M, 39).

On the other hand, a number of participants argued that intrinsic incentives would not be sufficient to motivate them to use the system. Instead, these participants suggested that extrinsic rewards would be necessary to motivate them to engage with the system.

"If you're going to use something that takes your time, and I don't feel like there's a benefit to myself or anything for using it, I don't care if I can see what kind of driver I am … I need an incentive … I need money or something for free or a discount" (M, 29).

"There's got to be some sort of a reward in it for me" (M, 61).

In particular, amongst those participants who advocated extrinsic incentives, many suggested the most effective rewards would be those related to the driving task, such as fuel vouchers or insurance and vehicle registration discounts. It was also noted that the rewards would have to outweigh the effort associated with using the system and altering one's driving.

"I think the incentive would have to be car-related, like insurance [discounts], because that's going to appeal to all audiences" (F, 22).

"If my insurance [company] said that if you used this you get a percentage off on your thing [premiums], I'd be like "yeah, why not"" (M, 29).

"It would have to be ongoing beneficial money value for me in fuel or rego … it would have to be something that would keep you driving well for the points to be able to get the reward … and the rewards need to be worth it" (M, 27).

Finally, one participant noted that the focus on extrinsic incentives may result in only short-term behavior change, particularly if there is no incentive to continue engaging in particular eco-safe driving behaviors once a challenge has been mastered. Interestingly, this individual also reported that they perceived extrinsic rewards as important to increasing their motivation to use the system, suggesting paradoxical attitudes.

"Isn't it meant to change your habits driving, not just make you try to win a game. I mean, if there's good prizes, I'm going to drive really well to get to the targets and then, that's it" (M, 27).

3.3 Social Persuasion Feedback

Participants were also divided regarding their attitudes towards the social persuasion feedback aspects of the concept system. Some drivers suggested that they would be motivated to compete with friends and family in an attempt to determine who is a better driver, while others noted that they would be curious to compare their eco-safe driving ability against other drivers. There was some evidence that having family or peers who use the system would increase the likelihood that participants would use the system themselves.

"If my friends all use it I will use it. Because I want to compete in the scores. So, I am more into the social side" (F, 25).

"I would use it to see other people's scores" (M, 29).

"People are not only trying to better themselves but they can see their friends, which more and more people are going to go see if they can out do their friends" (F, 56).

However, among these participants, some voiced concern about being judged by other drivers, highlighting that negative feedback may reduce motivation to use the system, particularly among peers and family.

"I think the social interaction part is very good. So you will see what the other person's score is, but you don't want people judging you, saying "this car is really bad and he's not a good driver"" (M, 26).

"I think if you've got an awful score, you just turn it off. You'd never do it. If you've got a great score, you'd leave it on. You don't really want all your friends to get to know you're a shit driver" (M, 61).

Other participants were less interested in the social persuasion feedback, suggesting that they were more interested in competing with themselves and focusing on improving their behavior in comparison to prior levels.

"It's only if you can beat yourself. I don't want to compare with other people" (F, 35).

4 Discussion and Design Implications

The findings from this study provide important implications for the design of future gamified eco-safe in-vehicle systems and highlight the importance of adopting a user-centered design approach from an early stage of design, through to development and implementation of any system.

Overall, participants held less than favorable attitudes regarding the gamification of an eco-safe in-vehicle system, instead reporting a preference for more informative and personalized feedback. However, the potential for such elements to increase engagement with the driving task and facilitate social persuasion feedback led many to argue that game elements should represent a 'background feature' of the system, such that those users who wanted to gamify the feedback could do so. This finding highlights that users desire a sense of autonomy and control over the system, such that they can modify the system to best suit their specific individual needs. Perhaps the most important goal is to provide feedback in an engaging manner and allowing users to choose if, and how, they want to gamify the experience for themselves. This is likely to differ dependent on user demographics and personality characteristics, such as age, gender, sociability and previous experience with games and game play. It is worth mentioning that participant responses did not show large differences between age and gender, but rather were relatively divided based on life stage (e.g., novice vs experienced drivers; parents of young children vs parents of teenagers), experience with using the technology and purpose of driving. These findings provide support for the ideas of [12] who argued that "a game element may be both intrinsically and extrinsically motivating for certain people in

certain situations at certain times" (as cited in [13], p. 20). This finding therefore suggests that it is important to design in-vehicle systems in a way that allows personalization and customization, to accommodate individual users. This finding is consistent with those of previous studies [13].

Furthermore, consistent with prior research, a number of participants highlighted the importance of balancing task difficulty and user skill. Thus, careful consideration must be given to the development of challenges in order to maintain engagement and avoid situations where users become bored, such as when challenges are too easy, or frustrated, such as when challenges are too difficult.

According to SDT, intrinsic motivation is crucial for long-term behavioral change. The results of the focus study provided some evidence that intrinsic incentives would be sufficient to motivate user engagement with the system, however many participants still reported that extrinsic rewards would be necessary. Interestingly, a paradoxical attitude was noted whereby a participant reported a need for extrinsic rewards to engage with the system while also acknowledging that a focus on extrinsic incentives may result in only short-term behavior change, particularly if there is no incentive to continue engaging in particular eco-safe driving behaviors once a challenge has been mastered. Further research is required to more comprehensively understand this issue, however participants did again note the importance of autonomy and control in deciding the incentives that are most suitable to them.

The theory also argues that social support is important to psychological growth, and that encouraging interpersonal relationships and social interactions can foster feelings of relatedness. Overall, a majority of participants expressed favorable attitudes towards the social persuasion feedback aspects of the concept system. This finding suggests that the inclusion of elements such as group messages, blogs, connectivity to social networks, and chat functions may all increase a user's motivation to engage with the system.

Finally, a number of feedback characteristics were noted as being important, and should be considered in future research and system development. These included: providing positively-geared feedback in order to minimize the likelihood of misuse of the system and the inadvertent encouragement of poor eco-safe driving behaviors.

5 Conclusion

This paper presents the findings from a user-centered design focus group study which sought to investigate user perceptions of a conceptualized gamified eco-safe in-vehicle system. Results suggest that many users hold less than favorable attitudes towards gamified elements being more than a background feature to such a system, however support the functionality for users to gamify the system if they wish. Thus, consistent with SDT's concept of autonomy, users desire the ability to customize system features depend on their specific needs. Moreover, to meet a user's competence needs, challenges must be designed such that they balance task difficulty and user skill and experience levels, while the inclusion of social persuasion feedback aspects appears to be an effective method for meeting a user's need for relatedness. More research is required to comprehensively understand the role of intrinsic versus extrinsic incentives on

motivations to engage with in-vehicle system. Future research should seek to develop a more realistic prototype for further evaluation in regards to usability, paying particular attention to the impact of system use on safety outcomes, such as driver distraction and the inadvertent promotion of unsafe or unlawful driving behaviors.

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