
Evaluation of a gamified intervention for eco-driving: A pilot study

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✎ **ABSTRACT.** L'eco-driving è uno stile di guida del veicolo che riduce il consumo di energia, mentre la gamification si riferisce all'uso di tecniche di gioco in contesti non di gioco per motivare il coinvolgimento dell'utente. In questo studio è stato valutato un intervento di eco-guida gamificato basato su un'app per smartphone. Gli effetti dell'utilizzo dell'app sui punteggi dei parametri di guida ecologica nell'arco di 3 settimane di guida sono stati confrontati in quattro condizioni: Controllo (C1); Educazione (C2), Gamification (E1); Gamification + Educazione (E2). Le esperienze degli utenti suggeriscono che il sistema di punteggio dell'app è stato percepito come affidabile ed equo e i dati emersi suggeriscono che un approccio gamificato che utilizza un'app per smartphone può incoraggiare efficacemente la guida ecologica, con benefici statisticamente significativi. Un intervento di questo tipo ha il vantaggio di essere relativamente economico, dato che si basa sulla tecnologia degli smartphone esistente e ampiamente disponibile ma si rendono necessarie ulteriori ricerche con un campione più ampio per verificare che gli effetti mostrati siano effettivamente affidabili.

✎ **SUMMARY.** Eco-driving is a style of vehicle driving that reduces energy consumption, while gamification refers to use of game techniques in non-game contexts to motivate user engagement. A gamified eco-driving intervention based on a smartphone app was evaluated. In a mixed methods approach, effects of using the app on eco-driving parameter scores over 3 weeks of driving were compared across four conditions: Control (C1), Education (C2), Gamification (E1), Gamification + Education (E2). Users were also invited to share their experiences in a focus group. Comparing across the four conditions, effect were null. However, combining the control and user groups showed a benefit of using the app for overall score, harsh braking score, speeding score and leaderboard position. User experiences suggest the app scoring system was perceived as reliable and fair. Suggestions for improvements included redesigning the leaderboard and balancing intrinsic with extrinsic rewards for longer term engagement. These data suggest a gamified approach using a smartphone app may effectively encourage eco-driving, with statistically significant benefits of regular reflection on eco-driving scores. Such an intervention has the advantage of being relatively economical, given that it is based on existing, widely available smartphone technology. Nevertheless, further research with a larger sample is required to verify that the effects shown are reliable, and to improve psychological understanding of gamification applied to eco-driving.

Keywords: Driving, Eco-driving, Gamification, User-experience, Speeding

INTRODUCTION

Background

Eco-driving is a style of vehicle driving that reduces energy consumption, maximizing mileage per unit of energy consumed (Stillwater & Kurani, 2013). Elements include adherence to speed limits, accelerating and braking smoothly and avoiding over revving (Magaña & Muñoz-Organero, 2015) as well as vehicle maintenance, trip planning and vehicle choice (Stillwater & Kurani, 2013). Eco-driving may save up to 25% of fuel (Kamal, Mukai, Murata & Kawabe, 2011).

Literature review

Gamification refers to use of game techniques in non-game contexts to motivate user engagement and participation (Deterding, Dixon, Khaled & Nacke, 2011). Gamification introduces intrinsically motivating elements such as target scores, as opposed to extrinsic rewards like cash. There is a rich literature showing that gamification can benefit driving in general (e.g. Diewald, Möller, Roalter, Stockinger & Kranz, 2013). Gamification applied to eco-driving was recently reviewed by Stephens (2022). The review identified 39 separate studies, of which 13 comprised evaluation studies employing quantitative indices of eco-driving. These studies comprised both lab-based (simulator) and real-world driving scenarios. However, only three of these were found to be of acceptable quality for drawing meaningful conclusions. Recurring methodological problems included conflation of intrinsic rewards of gamification with extrinsic rewards and absence of inferential statistical analysis.

The evaluation studies reviewed and found to be of acceptable quality included Magaña and Muñoz-Organero (2015), who evaluated a smartphone app-based system in 36 drivers over 2,160 road trips in Spain. They found lowered fuel consumption in participants who used the app, which provided instant feedback on eco-driving scores, in-game achievements and social comparisons, compared with controls. Steinberger and colleagues (Steinberger, Schroeter, Foth & Johnson, 2017; Steinberger, Schroeter & Watling, 2017) evaluated their coastmaster system which encouraged minimal braking during transitions from higher to lower speeds. Within-subjects simulator studies with 32 and 24 male drivers showed that using the system reduced overall

speed, driving over the speed limit, improved anticipation. The review concluded that gamification offers promise as a method of encouraging eco-driving but its efficacy in that domain remains largely unsubstantiated (Stephens, 2022).

The present study

In the present study a smartphone app-based gamification system relevant to eco-driving was evaluated. The *Safest Driver* smartphone app (Cambridge Mobile Telematics) was chosen as it had the most functionality relevant to gamifying eco-driving compared with similar widely available apps, while having extensive compatibility and free availability on the iOS (Apple) and Android operating systems. This choice recognized that safe/eco-driving overlap, with both driving styles sharing goals including reducing average speed and avoiding harsh acceleration and braking (Vaezipour, Rakotonirainy, Haworth & Delhomme, 2019).

Based on GPS and other data, the *Safest Driver App* compiles daily scores out of 100 for: distraction (mobile phone usage), speeding (exceeding posted speed limits), braking (braking harshly), acceleration (accelerating harshly), cornering (excessive G-force). An overall Safe Driving score combining these was used as a surrogate indicator of eco-driving. A leaderboard also updates daily. As this app runs in the background it presented no driving safety hazard due to mobile phone distraction.

As mentioned already, one aim of gamification is to generate intrinsic motivation. Certain elements of intrinsic motivation, specifically, satisfying work with clear goals and tasks, and hopes/experiences of success (McGonigal, 2011) overlap with psychological flow theory (Csikszentmihalyi & LeFevre, 1989; Šimleša, Guegan, Blanchard, Tarpin-Bernard & Buisine, 2018). Psychological flow is experienced when there is a good match between the challenges presented by a situation and the skills a person possesses to meet such challenges. In the context of eco-driving, gamification may generate flow and consequent intrinsic motivation and enjoyment by increasing the level of challenge of the otherwise mundane task of driving. Therefore, flow, or relatedly enjoyment, may mediate effects of gamification on eco-driving. As this has not been investigated previously in the context of gamification applied to eco-driving, measures of flow and enjoyment were included.

Sensation seeking, defined as “the seeking of varied, novel, complex, and intense sensations and experiences and the willingness to take physical, social, legal, and financial risks for the sake of such experiences” (Zuckerman, 1994, as cited by Jonah, 1997), was assessed as a possible moderating variable. Fewer indications of eco-driving were predicted for individuals with higher sensation seeking scores. Acceptance of technology was also assessed as a possible moderator, predicting fewer indications of eco-driving for individuals less accepting of technology. Finally, eco-driving knowledge was assessed as a further moderator, predicting fewer indications of eco-driving for more knowledgeable individuals already performing eco-driving behaviours ahead of the intervention.

A mixed methods approach was applied. A quantitative phase lasted three weeks with four conditions: Control: asked to drive normally (C1); Education: reviewed an eco-driving information package and challenged to adopt an eco-driving style (C2); Gamification: used the Safest Driver app checking scores daily and challenged to adopt an eco-driving style (E1); Gamification + Education: used the *Safest Driver App* checking scores daily and challenged to adopt an eco-driving style, plus reviewed an eco-driving information package (E2). These conditions were in place over weeks 1 and 2, but in week 3 all participants used the *Safest Driver App* checking scores daily and were challenged to adopt an eco-driving style. This meant all participants could share experiences of using the app in user-experience focus groups.

Hypotheses

(i) Eco-driving parameters (overall score; speeding score; braking score; acceleration score; leaderboard position) will be higher in condition E2 vs E1, in condition C2 vs C1, and in the combined experimental groups (E1 and E2) compared with the combined control groups (C1 and C2).

(ii) Flow and enjoyment will be higher for E2 vs E1, for C2 vs C1, and for combined experimental groups v combined control groups.

(iii) Changes in eco-driving parameters will be mediated by psychological flow and/ or enjoyment.

(iv) Effects assessed under hypotheses (i) and (ii) will be moderated by sensation seeking, acceptance of technology, and eco-driving knowledge.

METHOD

Participants

Recruitment adverts were placed physically around a university campus and on Twitter. Prerequisites were: verified informed consent, UK based, aged 18+, full UK driving licence, drive regularly (over two hours weekly), access to an insured, road-legal vehicle. The final sample ($N = 24$) comprised 15 females, 8 males and 1 non-binary individual of mean age 33.5 years ($SD = 13.3$). Compensation was £8 Amazon vouchers per hour for up to 9-hours (total £72.00). This sample size was chosen based on affordability within the available resources for carrying out the study. The study protocol was reviewed favourably by the Keele University Research Ethics Committee.

Design

Quantitative data were analysed in a 3×4 mixed design with participants randomly allocated to one of 4 conditions: Control (C1), Education (C2), Gamification (E1), Gamification + Education (E2). The within-subjects variable was week (1, 2, 3). Dependent variables were relevant app scores (overall score, speeding score, braking score, acceleration score, leaderboard position), Engeser and Ulrich flow scale scores, enjoyment ratings. Questionnaire scores were employed as possible mediator or moderator variables. A qualitative phase gathered user experiences via a series of focus groups guided by a question script.

Materials

- *Safest Driver App* (Cambridge Mobile Telematics). This outputs daily 0-100 scores for distraction, speeding, braking, acceleration and cornering. These are combined into an overall score; a higher value is consistent with eco-driving. Distraction and cornering scores, irrelevant to eco-driving, were discarded.
- *Safest Driver User Guide*. A five-page illustrated guide to the functionality of the *Safest Driver App* was created.
- *Eco-driving Education Package*. This was assembled based on eco-driving advice published by the UK Energy Saving Trust (<https://energysavingtrust.org.uk/advice/efficient-driving/>).

- *Driving context.* Participants estimated the proportion of driving (a) built-up areas with 20/30 mph limits; (b) A or B-roads with 40-60 mph limits; (c) dual carriageways/motorways. They also provided make, model, year, fuel type, engine size (where applicable) of their car, and whether anyone else had driven it.
- *Enjoyment Visual Analogue Scale (VAS).* Driving enjoyment (“I enjoyed driving over the last week”) was rated on a horizontal line anchored left, “Not at all” and right, “Very much” using a graphic slider scored 0-100, as used by Stephens and Smith (2022).
- *Questionnaires.* These were the *Engeser Short Flow Scale* (10-items; Engeser & Baumann, 2016); the *Flow Index* (3-items; Ulrich, Keller, Hoening, Waller & Grön, 2014); the *Brief Sensation Seeking Scale* (8-items; Hoyle, Stephenson, Palmgreen, Lorch & Donohew, 2002); the *Acceptance of Technology Scale* (9-items; Van der Laan, Heino & De Waard, 1997); the *Eco-driving Knowledge Scale* (5-items; Günther, Kacperski & Krems, 2020).

Procedure

Participants attended an induction meeting via video call. After providing informed consent, a baseline survey collected demographic information (age in whole years; gender with the options: female, male, non-binary, prefer not to say); years of holding a full driving licence; usual weekly driving time; understanding of eco-driving (open text response); understanding of strategies to achieve eco-driving (open text response); extent of practicing eco-driving (open text response). Participants next completed the questionnaires.

After installing the *Safest Driver* smartphone app on their phone, participants were randomised to one of the four conditions: Control (C1); Education (C2); Gamification (E1); Gamification + Education (E2). The E1 and E2 groups were briefed on app functionality. The C2 and E2 Education groups were given several minutes to study the *Eco-driving Education Package*. The C1 group was instructed: “When you are out in the car, please drive the way you would normally”. Alternatively, C2, E1 and E2 were instructed: “We challenge you to try and become more of an eco-driver, that is, to reduce how much energy you use during driving”. C1 and C2 were further directed not to open the *Safest Driver App* for the first 2 weeks of driving. Participants received copies of all instructions and information. E1 and E2 were prompted

each evening to enter app scores into an online survey. The instructions changed for C1 and C2 at week 3. They were sent the *Safest Driver User Guide*, challenged to try and become an eco-driver, and prompted daily to check and enter their app scores into a survey.

Weekly online surveys asked participants to complete the flow scales, the enjoyment VAS and driving context information for driving over the last week. Current average mpg (or miles per KWh) from their car’s computer display was also requested where available.

User experiences were shared by 23 participants in one of four, 1-hour, online focus groups. A question script guided discussion for the topics: knowledge about eco-driving; general usability of the app; specific app features; gamification; extrinsic rewards; suggested additional features; study procedures; open comments. Discussions were transcribed for thematic analysis, which aimed to detect pertinent patterns in the data. These themes were then developed based on how users talked about their experiences of using the gamified app, with the aim being interpretation and sense-making of the data.

RESULTS

Quantitative data analysis

Due to the small sample size, no effort was made to manage outliers. Skewness and Kurtosis coefficients were within an acceptable range except overall score in week 2 (Skewness = -1.530 , Kurtosis = 3.600), and speeding scores across weeks 1-3 (Skewness -2.456 to -2.244 , Kurtosis 4.488 to 6.239). Therefore, a mixture of parametric and non-parametric analyses were applied. Descriptive data are shown in Table 1.

Hypothesis (i) was assessed in a series of 3×4 mixed ANOVAs (week: 1, 2, 3 \times condition: C1, C2, E1, E2) for the dependent variables: overall score; braking score; acceleration score; and leaderboard position. All main and interaction effects were null ($p < .05$), apart from the main effect of week on leaderboard position, $F_{(2,40)} = 9.951$, $p < .001$, $\eta^2 p = .332$. Holm-corrected contrasts showed lower (i.e. superior) leaderboard position in week 2 vs 1, $p < .001$, and in week 3 vs 1, $p = .002$. The main effect of condition (C1, C2, E1, E2) on Speed was assessed using a Kruskal-Wallis test, which found no effect ($p > .05$). The main effect of week (1,2,3) on speed was

Table 1 – Descriptive data of a combination of parametric and non-parametric analyses

	Control (C1)	Education (C2)	Gamification (E1)	Gamification + Education (E2)
Age	38.2 (13.4)	26.8 (12.4)	35.7 (11.8)	33.3 (16.0)
Gender ¹	3/3/0	3/2/1	5/1/0	4/2/0
Sensation seeking	2.50 (.60)	3.50 (.65)	2.88 (1.11)	2.46 (.48)
AOT (usefulness)	2.30 (.17)	2.60 (.61)	2.90 (.72)	2.23 (.32)
AOT (satisfaction)	3.67 (.20)	3.13 (.21)	3.13 (.26)	3.00 (.32)
Eco-driving knowledge	4.90 (1.67)	4.90 (1.37)	3.97 (1.69)	4.80 (1.50)
Licence years	19.00 (13.19)	7.21 (12.32)	14.17 (8.95)	14.83 (14.28)
Engine cc of main car ²	1,652 (321)	1,187 (135)	1,200 (236)	1,567 (234)
Number of scored trips ³	81.0 (23.0)	91.5 (26.1)	77.8 (55.3)	56.7 (19.4)
Number of scored km ³	1,006 (386)	1,135 (449)	590 (389)	824 (543)
Fuel type ^{2,4}	2/3/0/1	6/0/0/0	4/2/0/0	4/2/0/0
Ratio of road types ^{2,5}	52/38/10	50/38/12	66/26/8	40/34/26
Passenger ^{2,6}	4	2	5	5

Note. ¹ Frequencies for female/male/non-binary; ² Recorded after week one of driving; ³ Recorded across all three weeks of driving; ⁴ Frequencies for petrol/diesel/hybrid/BEV; ⁵ Mean percentage for 20-30mph/40-60mph/70mph road types; ⁶ Frequencies for passengers in another car at least once.

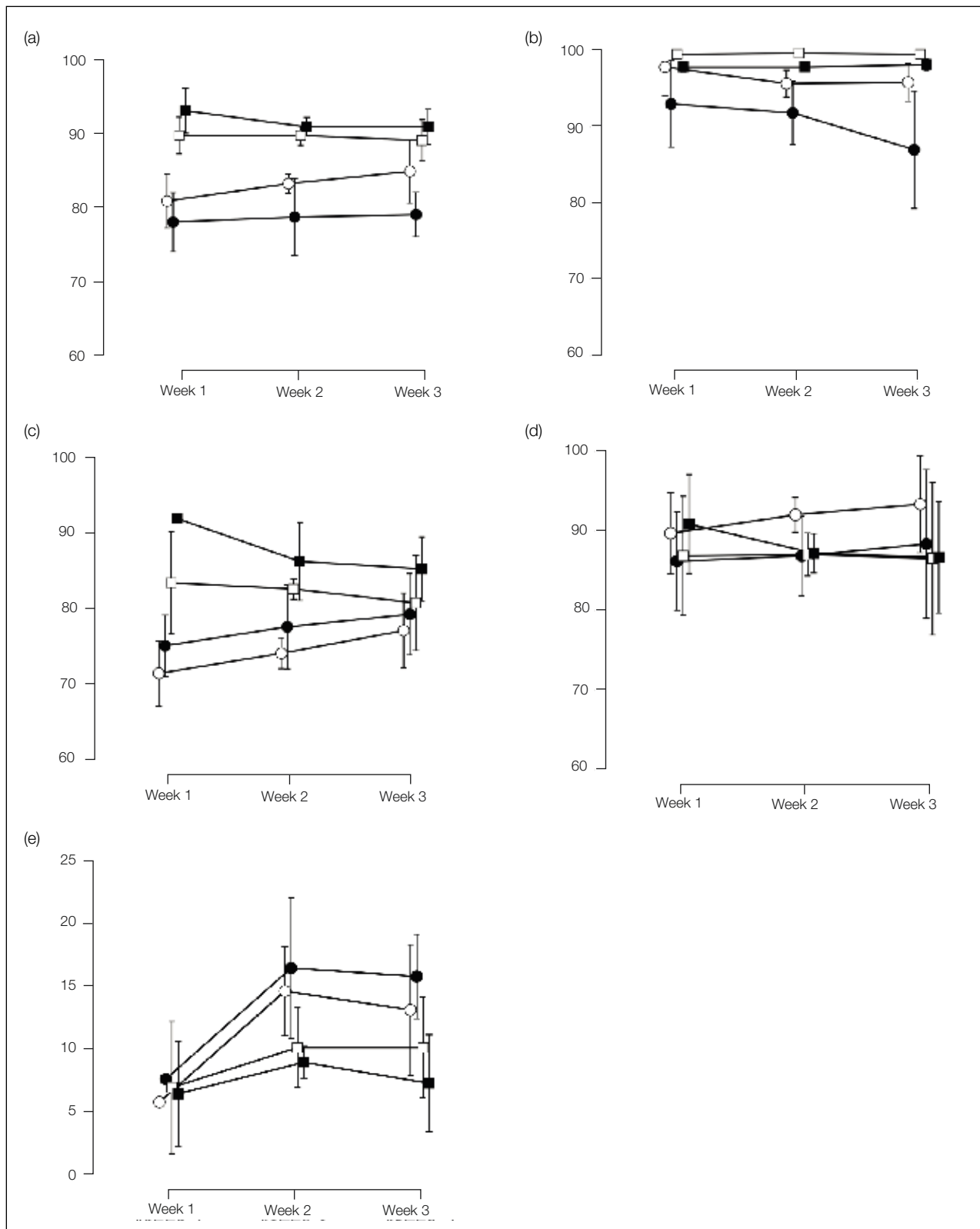
assessed using a Friedman test, which also found no effect ($p > .05$). These data are illustrated in Figure 1.

Acknowledging the low power afforded by the small sample, the two experimental groups were combined into a single group (E1 and E2), as were the two control groups (C1 and C2). A 3×2 ANOVA showed a main effect of condition

for overall score, $F_{(1,22)} = 6.631$, $p = .017$, $\eta^2 p = .232$. As the interaction was close to significant, $F_{(2,44)} = 2.778$, $p = .073$, $\eta^2 p = .112$, contrasts were computed. These showed higher overall scores in the experimental vs the control group in week 1, $p = .005$ and week 2, $p = .025$, but not week 3, $p = .051$.

The condition × week interaction was significant for

Figure 1 – Overall score (a), speeding score (b), braking score (c), acceleration score (d), and leaderboard rank (e) across the three weeks of driving (weeks 1, 2 and 3), by experimental group



Legenda. White circle = C1; dark circle = C2; white square = E1; dark square = E2.

braking, $F_{(2,44)} = 5.912, p = .005, \eta^2 p = .212$. Contrasts showed higher braking scores in the experimental vs the control group in week 1, $p = .003$, but not week 2, $p = .065$, or week 3, $p = .289$. Main and interaction effects were null for acceleration score ($p > .05$). For leaderboard position, the interaction was close to significant, $F_{(2,44)} = 3.188, p = .051, \eta^2 p = .127$, and contrasts were computed. These showed lower (i.e. superior) leaderboard position in the experimental group in week 2, $p = .026$, and week 3, $p = .032$, but not week 1, $p = .999$.

Speeding was assessed using non-parametric tests, showing a main effect of condition, $F_{(1,22)} = 5.607, p = .027, \eta^2 p = .203$. Mann-Whitney tests showed higher scores in the experimental group in week 2, $p = .009$, and week 3, $p = .033$, but not week 1, $p = .115$. Overall, these analyses support hypothesis 1, with evidence that overall score, speeding score, braking score and leaderboard position differed across the experimental and control groups in a direction consistent with increased eco-driving. These data are illustrated in Figure 2.

Hypothesis (ii) analyses first compared across conditions C1, C2, E1, E2, and then across the combined experimental (E1 and E2) and control (C1 and C2) groups. Across four conditions all main and interaction effects were null ($p > .05$), apart from the main effect of week on enjoyment rating, $F_{(2,28)} = 3.476, p = .045, \eta^2 p = .199$. Holm-corrected contrasts showed higher enjoyment ratings for week 3 vs 2, $p = .044$, but no effect for week 2 vs 1, $p = .204$, or week 3 vs 1, $p = .372$. For the combined experimental and control groups all main and interaction effects were also null ($p > .05$). Overall, this hypothesis was not supported. Descriptive data are shown in Table 2.

Hypothesis (iii) analyses began with checking correlations between the overall eco-driving scores, the two flow scale scores and the enjoyment rating scores across the three driving weeks. As none of these correlations were significant ($p > .05$) this hypothesis was not supported.

Hypothesis (iv) was assessed in analyses of covariance including condition, combined experimental groups (E1 and E2) compared with combined control groups (C1 and C2), week (1, 2, 3) and one of the covariates: sensation seeking, acceptance of technology (usefulness), acceptance of technology (satisfaction) or eco-driving knowledge. The dependent variables were: overall score, braking, speeding, leaderboard position. As none of the three-way interactions were significant, $F_{(2,40)} < 1.65, p > .205$, this hypothesis also was not supported.

Qualitative data analysis

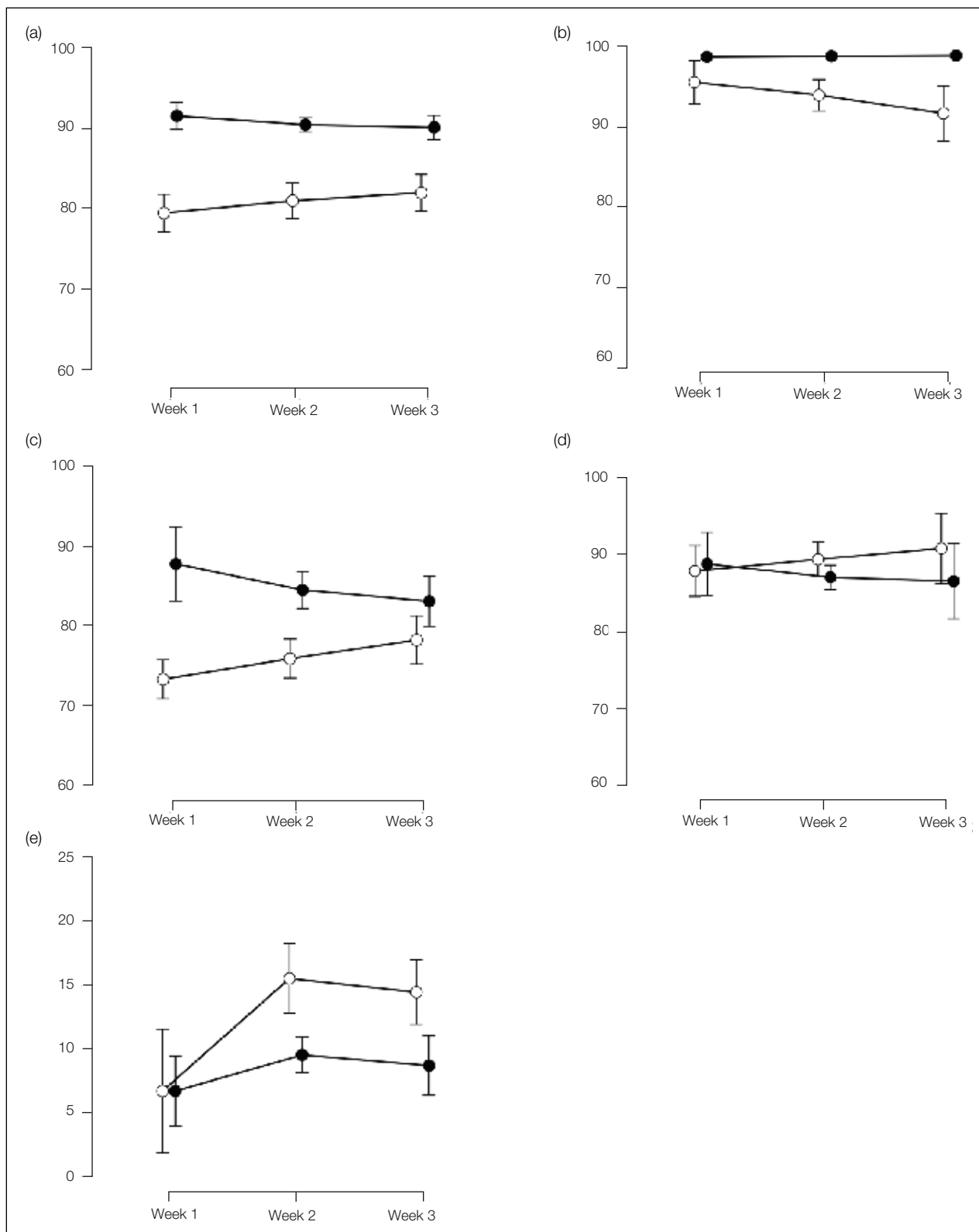
Thematic analysis (Braun & Clarke, 2006) of focus group transcripts was carried out solely by the author. The decision to employ one coder was taken in view of the limited scope of this pilot study. Limitations of not asking a second person to code a sample of the data are discussed in the limitations section of the Discussion. The coding process comprised several stages. First, the author reviewed the transcripts and noted initial codes. Then, initial codes were refined to identify overarching elements and sub-themes. A third stage involved selecting quotes that aligned with these themes, followed by a review and naming of the themes. Once finalized, the report writing commenced. The codebook is included as supplementary material in Appendix. The analysis identified seven themes: Intrinsic motivation, Eco-driving, App positives, App niggles, Real world context, Wider concerns, It's just not for me. These are described below.

Intrinsic motivation. Gamification harnesses intrinsic motivation towards promoting desirable behaviours such that any scoring system must be perceived as fair. This was indeed the perception of participants, e.g. "I think the metrics on the whole were pretty good. And they, certainly from an eco-perspective, acceleration and braking, were probably pretty important aspects of that (08)"; "When I was in the car with other people who aren't quite as safe drivers. The score was going down. So yeah, I think it was really accurate (26)". Participants enjoyed using the app, e.g. "I did find it fun and I was telling my family about it (26)"; "It made me think about things I hadn't really thought about, but in a way that made it quite fun (12)".

Eco-driving. Participants discussed specific improvements in eco-driving technique, including accelerating more gently, e.g. "I didn't realize how harsh I accelerate until I started using the app (21)"; "I definitely watch like my rev counter more now (19)", avoiding sudden braking, e.g. "I think my braking score went up once I was seeing the app and I was kind of more aware of that (26)"; "So, then, that would say to me, yeah, probably I'm too close to the ones in front (23)", and speeding less, e.g. "I think it encouraged me to think like, ohh, I am actually sticking to the speed limit and doing pretty well (12)".

App positives. Participants experienced the app as user-friendly, e.g. "It was very straightforward and it was very appealing to look at (24)". Some liked the mapping feature, e.g. "It was quite nice to see where I'd been (17)"; "I'm used

Figure 2 – Overall score (a), speeding score (b), braking score (c), acceleration score (d), and leaderboard rank (e) across the three weeks of driving (weeks 1, 2 and 3), by experimental group



Legenda. White circle = combined control group; dark circle = combined experimental group.

Table 2 – Means (SDs) for the Engeser and Ulrich flow scales, and enjoyment rating across weeks 1-3 of driving, by condition

		Control (C1)	Education (C2)	Gamification (E1)	Gamification + Information (E2)
Engeser flow	Week 1	5.37 (.55)	5.05 (.50)	4.68 (.45)	5.13 (.63)
	Week 2	5.47 (.55)	4.10 (1.13)	5.03 (.77)	5.13 (.54)
	Week 3	5.33 (.67)	5.10 (.71)	5.08 (.83)	5.32 (.52)
Ulrich flow	Week 1	15.33 (3.08)	15.67 (2.94)	18.00 (3.16)	16.00 (2.53)
	Week 2	15.33 (3.20)	14.50 (3.02)	16.00 (3.10)	14.50 (1.76)
	Week 3	14.50 (7.45)	11.17 (8.73)	13.67 (7.45)	14.17 (7.28)
Enjoyment	Week 1	73.00 (28.41)	80.67 (15.63)	80.67 (16.37)	83.00 (12.19)
	Week 2	71.00 (28.73)	61.00 (40.04)	78.50 (21.55)	80.50 (17.92)
	Week 3	81.20 (26.86)	87.00 (16.09)	80.50 (23.56)	82.75 (4.92)

to... running apps and stuff like that... so it felt like the most visually, like familiar in terms of the app (12)". Participants described the leaderboard enhancing motivation, e.g. "I wanted to win and beat other people's scores. So yeah, I think it did encourage me slightly (14)"; "I think the competition element was quite healthy (16)". The driving tips feature was also welcomed, e.g. "I got tips and yeah, I did take them on board and I think it did increase sort of the scores (26)".

App niggles. Numerous participants expressed frustration when emergency braking impacted their score, e.g. "It was either that or mow down the pedestrian in front of me (11)". Some found the driving tips menus repetitive, e.g. "It was just the same thing every time... and it was just constantly - Ohh try not to accelerate. Ohh try not to brake so hard (11)"; "They didn't tell you, like, how to improve it (14)". Discussing absent features several would have welcomed specific challenges, like improving braking score: "Having short term challenges to, especially if there's a reward or something for it, then yeah, definitely (08)". One participant wished for more integration

with social media: "If you could post your scoreboards straight to your socials or something like that might be a way of competing with friends (08)". Suggestions for extrinsic rewards were numerous, including reduced insurance costs, charitable donations, shopping vouchers and fuel discounts, e.g. "For every 10,000 points you get will donate even if it's 10p, you know, to some kind of you know, sustainability or whatever (17)". Another suggestion was tangible feedback on fuel savings, e.g. "If the 'overall score' had a 'you've saved xxx amount on petrol this week compared to the average driver' (12)". Introducing live feedback received a mixed evaluation. Participants balanced benefits, e.g. "Accelerating or, like, going over the speed limit, I think that's fair enough for it to ping, just for your own safety and others (06)", with potential for annoyance or distraction, e.g. "I think I find a distraction. I just wanna swear at it (17)".

Real world context. Tension was expressed between eco-driving at the speed limit and other road users speeding, e.g. "I would be irritating the person behind me who was trying

to get home faster than me (09)”. Tension was also expressed between scores and genuine eco-driving, e.g. “You’ve got to put your foot down a little bit to actually stay within eco driving, otherwise you’re sitting there for 15-20 minutes, wasting all that fuel just sitting there (05)”; “If you were driving, which... shouldn’t be driving 50 in a 30, it would actually probably be more eco but it wouldn’t be safe (08)”. Several participants found their enthusiasm for using the app plateaued, e.g. “It became quite a chore sort of looking at it every day because I come home, got to get the tea on and it’s, it’s another thing I’ve got to do (09)”.

Wider concerns. One privacy concern equated the app with insurance tracking devices, e.g. “I know personally if, if I saw an offer to have a black box I would 100% not choose that (16)”. Another was concern over traffic infringements being reported: “How fast could you go without them notifying the authorities? (08)”. There was concern over the limits of gamification for behaviour change, e.g. “If people wanted to treat it like a game, so they have to find some way to manipulate the data to make them seem like they’re driving better than they actually are (16)”. A further concern was the bigger picture around pro-eco behaviours beyond eco-driving: “We’ve recently moved house and positioned ourselves so that I can walk to work. I can walk my kids to nursery, I can walk them to school (11)”.

It’s just not for me. Finally, several drivers did not like the app, e.g. “For me personally, I don’t think I really changed how I drove throughout it (24)”; “It didn’t really make me alter my ways (04)”. One issue was perceived interference with the sense of freedom that driving can provide, e.g. “It took away, it made it harder for me to drive (05)”.

DISCUSSION

Results in context

This pilot study evaluated a gamified approach to encouraging eco-driving based on a smartphone app. A quantitative data analysis comparing users and non-users of an eco-driving app was followed by a qualitative analysis of user experiences.

The configuration of the study with four conditions (C1, C2, E1, E2) lacked the statistical power to detect any differences across conditions. However, comparing the combined experimental groups (E1 and E2) with the

combined control groups (C1 and C2) enabled, over two weeks of driving, comparisons between an experimental group of individuals reflecting daily on their Safest Driver app scores and trying to improve them ($n = 12$), with a control group of individuals driving with the app running in the background without reviewing their scores ($n = 12$). Hypothesis (i) that the eco-driving parameters assessed by the Safest Driver app would show improvement in the experimental conditions (E1 and E2) over the control conditions (C1 and C2), was supported with evidence of increased overall score, braking score, speeding score and higher leader board position in the experimental group. In demonstrating reduced incidences of harsh braking and speeding, these data suggest tangible benefits of gamified approaches to eco driving, at least in the short-term. This finding is in line with the findings of a recent review of gamification applied to eco-driving (Stephens, 2022). However, a larger-scale study with consequent increased statistical power is required to verify these effects.

The psychological mechanism underlying these gamification effects remains unclear.

While hypothesis (ii) was unsupported, with no effects for psychological flow or enjoyment, there was insufficient data to eliminate these mechanisms. Further research should assess this hypothesis with greater statistical power. Hypotheses (iii-iv) predicting mediation and moderation effects could also not be adequately tested due to low statistical power. This limitation should be addressed in a higher powered study.

The qualitative data indicate that, in delivering a trustworthy scoring system, the Safest Driver app was fit for purpose. Users were able to identify and reflect upon specific eco-driving techniques, including accelerating and braking more gently and avoiding speeding. They liked both the trips menu which displayed their prior journeys as a trace on a map with key incidents flagged and the driving tips, although more sophisticated and detailed tips would have been desirable. The leaderboard aspect received mixed reviews, consistent with previous studies (e.g. Stephens, 2022; Vaezipour, Rakotonirainy & Haworth, 2016). There was an appetite for personalised leader boards enabling competition against known other people such as family, friends or work colleagues, perhaps via social media.

There was, however, a plateauing of enthusiasm for using the app, suggesting a solely gamified approach to eco driving via intrinsic motivation may be time-limited, as has been suggested by Rapp and Boldi (2023) in their

study assessing the lived and meaning-laden experience of behaviour change. One reason for this may have been the reported tension between eco-driving and real-world driving, such as perceptions of holding up other drivers and being slow pulling out at junctions. Such concerns are known to influence road user behaviour (McNabb, Kuzel & Gray, 2017) and additional motivation from extrinsic rewards such as savings on fuel, car insurance, driving-related gadgets or other rewards may help to prolong the period of engagement, although further research would be required to assess this. A further cause of plateauing may have been privacy concerns. To counter this, specific reassurances could be made that data will not be shared with insurance companies or law-enforcement authorities. Some users may also benefit from reassurances that steps are being taken to prevent unintended negative consequences of gamification that undermine eco-driving. Perhaps a user-reporting mechanism could be put in place where such concerns could be raised. Some users did not find the app useful at all. While good design may win over a certain percentage of reluctant users, a proportion of individuals may be unwilling to engage with an eco-driving app. This may reflect the habitual nature of driving in which individual preferences forged over extended time periods become resistant to change (Caraban, Karapanos, Gonçalves & Campos, 2019).

Limitations

This small-scale pilot study had several limitations. A key issue was the small sample size, as already mentioned. While the study indicated beneficial effects of a gamified app for several eco-driving parameters (overall score, braking score, speeding score and higher leader board position), these effects could be artefacts of low statistical power. Consequently, they should be treated with caution until such time as they are verified in a larger-scale study with consequent increased statistical power. Further, the sample was a convenience sample which limits generalisability. Relatedly, the limited data collected should be considered of low reliability and validity. In interpreting the data the reader should bear in mind that this was a pilot study.

A further issue was the absence of an independent measure of eco driving out-with app scoring. An

independent measure would show whether eco-driving was genuinely improving, rather than scores on an app which, though related to eco driving, may capture something else. Participants were asked to report weekly mpg readings from on-board car computer displays but take-up was low, probably because relatively few cars have this feature. Such independent eco-driving scores may be obtained in future from vehicle on-board computers or via customer fuel purchase data alongside present vehicle mileage.

In addition, the thematic analysis lacked investigator triangulation due to the absence of a second data coder. While triangulation has long been known to offer a solution to overcoming individual bias on the part of an investigator (e.g. Campbell & Fiske, 1959) no such undertaking was employed in the present study. This was a consequence of its status as a pilot study designed to trial methods and measures with limited resources. As with the other results in this study, the qualitative findings should be viewed with caution, and the author recommends employing investigator triangulation in future studies applying thematic analysis to gamified approaches to encouraging eco-driving. Further insights may also have been gained with recourse to established qualitative methodologies specific to human computer interaction such as heuristic evaluation and could usefully be explored in future studies.

CONCLUSION

In conclusion, this study finds that a gamified approach to encouraging eco-driving has potential to impact behaviour. A small-scale quantitative evaluation explored statistically significant benefits of regular reflection on scored aspects of eco-driving provided by a smartphone app, specifically, reducing harsh braking and speeding. User experiences reflected a general acceptance of the app including reflection upon specific aspects of eco-driving technique which the app helped improve. Such an intervention has the advantage of being relatively economical, given the wide availability of smartphone technology. Further confirmatory research should optimise study power and balance intrinsic and extrinsic rewards to promote prolonged engagement.

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APPENDIX

Codebook for gamification/eco-driving pilot study (March 2024)

Themes	Codes	Examples
Intrinsic motivation	Motivation intrinsic to use app	“I think the metrics on the whole were pretty good. And they, certainly from an eco-perspective, acceleration and braking, were probably pretty important aspects of that (08)”.
	App scoring is fair	“When I was in the car with other people who aren’t quite as safe drivers. The score was going down. So yeah, I think it was really accurate (26)”.
	Fun	“You get coins, don’t you? You can change your car colour or something (24)”.
	App liked/ ease of use/ recommend	“I like the stars as well... the primary school thing, I think (03)”.
	Should be built in car infotainment	“I was able to show that our trip where she would normally have criticized my braking, a 5 star rating for braking. So I sort of used it like that to say I’m not as bad as you think (08)”.
		“Seeing my MPG go from about 36 to about 43 and thinking, oh, that’s made a difference to me at a time when I could really do with it... kind of actually seeing that (11)”.
		“My son is very paranoid about global warming sustainability. He’s constantly on my case all the time, so if I could show him that I was committed to take that small step to help with that, to help with his future, not mine, but his future, then I think that would be something personal for me (17)”.
		“I think I’d recommend it to somebody who felt like they could improve, like they wanted to improve their driving (12)”.
		“You could do a deal with a manufacturer and actually have it as part of the main infotainment system... instead of having it on your phone (08)”.
		“I did find it fun and I was telling my family about it (26)”.
		“I guess it made me think about things I hadn’t really thought about, but in a way that made it quite fun (12)”.
Eco-driving	Greater awareness of eco-driving	“I didn’t realize how harsh I accelerate until I started using the app. Cos I realize, I don’t speed, but what I do is I get up to the speed limit quite fast instead. And I didn’t realize that until I started using the app (21)”.
	Specific improvement thanks to app	“I definitely watch like my rev counter more now (19)”.
	Longevity	“I didn’t know it, I’m quite a hard accelerator, which I didn’t realize (04)”.
		“The app has shown me that, yes, I brake quite, like, suddenly, or like, hard braking, I should say. So, then, that would say to me, yeah, probably I’m too close to the ones in front (23)”.
		“I think my braking score went up once I was seeing the app and I was kind of more aware of that (26)”.
		“I think it encouraged me to think like, oh, I am actually sticking to the speed limit and doing pretty well (12)”.
		“I think it’s something that is now, when I’m driving without the app on, conscious of it still (25)”.
		“I wouldn’t mind having it there. Would be quite interested to have a look at it every now and again (23).”

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Themes	Codes	Examples
App positives	Leaderboard liked	“I thought the app itself was really easy to use... it was very straightforward and it was very appealing to look at (24)”.
	Overall score good	“When we hadn’t looked at the app for two weeks, it was quite nice to see where I’d been in that two weeks (17)”.
	Tips useful	“I really liked it. Erm, so I could kind of, most of the events that showed, I kind of knew in advance where they would be (08)”.
	Trips useful	“I thought it was really good, really accurate, and it was nice seeing the visual (26)”.
		“I’m used to... running apps and stuff like that. That’s kind of how you see runs laid out or whatever. So it felt like the most visually, like familiar in terms of the app (12)”.
		“That conscious knowing that these are the people are on the road as well as you that are trying to improve their scores and become better drivers. I thought that was quite, it was a bigger picture sort of thing for me (15)”.
		“I could see everyone else’s scores I wanted to win and beat other people’s scores. So yeah, I think it did encourage me slightly (14)”.
		“I think the competition element was quite healthy (16)”.
		“I was never at the top of the leaderboard, but that sort of spurred me on to make sure that I didn’t drop any lower than that and then wondering who is this person, that number one that’s always got 100% in just 100 for everything (27)”.
		“I was able to move up in a positive way on the on the leaderboard (03)”.
		“Yeah, it gives you a bit of a boost, I think when you see that you do well (12)”.
		“So if you kind of advertised it as this, like competing with your friends or your family and see who is the better driver, I think I would be interested in that (13)”.
		“If you could post your scoreboards straight to your socials or something like that might be a way of competing with friends (08)”.
		“I really liked it, and me and my husband both had it, and then we had a bit of healthy competition going on (23)”.
		“I guess it would encourage conversation with friends, maybe about how well you’re doing on the leaderboard and stuff outside of using it (12)”.
		“I think not knowing anybody and it was all like anonymized names anyway. I just kind of lost interest (19)”.
		“Say if people have just passed their test for example like a bunch of 17-18 year olds and they could all get together and have it (04)”.
		“I got tips and yeah, I did take them on board and I think it did increase sort of the scores (26)”.
App niggles	Cornering not eco, but could be if affects wear tear	“It was wrong on the speed limits of a couple of roads where they’ve been redesigned near me, so it would forever say I was speeding and it was a journey I did every week and I was like, well, I know I’m not because I’m doing it and I’m checking my speeds and I’m very conscious and you’re wrong, app! (11)”.
	Emergency braking unfairness	“A couple of spots on the road there was two key points that kept saying I was speeding and I wasn’t. So I’m not sure if it’s the they haven’t adjusted the speed limit (25)”.
	Leaderboard disliked	“I think the speeding registered when you went 15 kilometres over the limit of the road that it recognised you are on (08)”.
	Speeding inaccurate	

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Themes	Codes	Examples
	Tips unhelpful	“It was just the same thing every time... and it was just constantly - Ohh try not to accelerate. Ohh try not to brake so hard (11)”.
	App suggested improvements	“I don’t find those very helpful just because I think the information is pretty self-explanatory (13)”.
	Live feedback unwelcome	“They didn’t tell you like how to improve it. They just said like, don’t accelerate harshly and it’s like OK, but how do I not if like I am doing it, how am I gonna fix that? (14)”.
	Live feedback welcome	<p>“I think that it sort of lacks a bit of a human element to it... it needs somebody who comes from some sort of driving organisation... that can give really practical tips, maybe a video of them like showing you how to brake well (12)”.</p> <p>“Having short term challenges to, especially if there’s a reward or something for it, then yeah, definitely (08)”.</p> <p>“Different scores for each week with your friends so it could refresh the scores and then, say, if you had a bad week one week it wouldn’t affect the scores next week (13)”.</p> <p>“I think it’s quite involved because there’s so many different screens, so I feel like if there was just the one screen with the main driving score, the overall driving score, and then maybe the maps below or something. It felt like there was lots of different elements and I don’t know that, on a daily basis, I would check that outside of the study (12)”.</p> <p>“An alarm on the app to remind you to look at it the end of the day (12)”.</p> <p>“I would have liked something there if something wasn’t your fault (09)”.</p> <p>“I think that would help me because like when I’m driving, obviously like when I’m driving with the app, I wasn’t really thinking, oh, I wonder what I’m gonna get at the end of this day, I was kind of more focused on, like, how I was driving in that moment (14)”.</p> <p>“Tells you if you’re getting too close to the vehicle in front when you’re on motorways and stuff, at high speeds and that, so that’s the one I do keep on (05)”.</p> <p>“But if you accelerating or, like, going over the speed limit, I think that’s fair enough for it to ping, just for your own safety and others (06)”.</p> <p>“I think like you’re saying there, if there is a way to sort of notify you but not annoy you to death that you’re not maybe doing that, then I think that’s where you can probably get a bit of traction (10)”.</p> <p>“I think I find a distraction. I just wanna swear at it (17)”.</p> <p>“Something pinging would do my head in (18)”.</p> <p>“To have something like that constantly telling me, would make me feel like I was doing a really bad job and it would just make me more nervous (04)”.</p> <p>“I guess it must feel like having a back seat passenger, backseat driver kind of thing (16)”.</p> <p>“I feel like it would, I think I’d be more tempted to sort of swipe something off my phone if it was coming up to say that I’d cornered badly or whatever (12)”.</p>

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Themes	Codes	Examples	
Real world context	Privacy concerns	“Whilst I was trying to be aware of the app and not being marked down, I would be irritating the person behind me who was trying to get home faster than me (09)”.	
	Longevity plateau	“On some of the roundabouts, you have to get off pretty quick [i.e. accelerate rapidly]. And so I was like ohh, it’s marked me down for that, but I’d have been there forever if I’d waited (25)”.	
	Miscategorisation fixes	“Can’t always slow down or you trying to keep up with traffic a little bit, you know, not to annoy everybody else on the way home or way too work (10)”.	
	Motivation extrinsic examples	“You’ve got to put your foot down a little bit to actually stay within eco driving, otherwise you’re sitting there for 15-20 minutes, wasting all that fuel just sitting there (05)”.	
	Peer pressure prevents eco driving		“As I started to lose points here and there, I sort of forgot about it a bit and didn’t really care if it dropped down a bit more... if I need to be somewhere relatively quickly, then I won’t take into account the sort of eco side of it (08)”.
			“It’s hit that point where I couldn’t really improve much more. So irritating myself, I think. Really. Yeah. (09)”.
			“It became quite a chore sort of looking at it every day because I come home, got to get the tea on and it’s, it’s another thing I’ve got to do (09)”.
			“There was a little bit of a competition element, I think at first, to try and get it to a certain level. But then for me it kind of plateaued... I couldn’t really improve it (10)”.
			“It was really helpful using it for a few weeks... but then like for me that’s probably enough for me to like become more eco without having the app downloaded anymore (19)”.
			“You can’t carry on with that kind of competitive rate for the rest of your life. You know how it is. It was good that that it all came to an end after three weeks, I think (03)”.
			“Like the insurance thing I talked about where there’s the lower premiums (11)”.
			“For every 10,000 points you get will donate even if it’s 10p, you know, to some kind of you know, sustainability or whatever (17)”.
		“That would be even better, Yes. Definitely (17)”.	
		“That would be really good (15)”.	
	“Earn points which you can then use to put towards like an Amazon voucher for example (04)”.		
	“I think a discount on fuel would be quite effective, actually, especially in this whole fuel crisis thing (16)”.		
	“If it was advertising itself as it increases eco driving so reduce costs and it’s better for the environment (19)”.		
	“Some sort of like car related stuff, So whether that’s like, I don’t know, like a Bluetooth connector (12)”.		
	“Would also be good to get smaller practical freebies that help with driving like petrol vouchers, windscreen covers or even just car de-icer (12)”.		
	“It might be nice if the ‘overall score’ had a ‘you’ve saved xxx amount on petrol this week compared to the average driver’ (12)”.		

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Themes	Codes	Examples
Wider concerns	<p>Secondary benefits of eco driving</p> <p>Gamification distorts</p> <p>More than eco-driving (bigger picture)</p> <p>Thoughts about study organisation</p>	<p>“How fast could you go without them notifying the authorities? Would they never notify the authorities or anything like that? (08)”.</p> <p>“I know personally if, if I saw an offer to have a black box I would 100% not choose that (16)”.</p> <p>“If people wanted to treat it like a game, so they have to find some way to manipulate the data to make them seem like they’re driving better than they actually are. I don’t know whether the scores is like an average on the miles you were doing for each journey. For example, if you start on the motorway for 300 miles doing 70 miles an hour. But if you’re going to get a better driving score, but you just burning fuel for just the sake of it, which is not very fuel, you know, eco friendly (16)”.</p> <p>“If you were really that interested in scoring high, then if you drove like a hooligan on a trip, you just say you’re a passenger and it would take you out of the score (08)”.</p> <p>“We’ve recently moved house and positioned ourselves so that I can walk to work. I can walk my kids to nursery, I can walk them to school, so that’s kind of the way we do it (11)”.</p> <p>“If you were driving, which... shouldn’t be driving 50 in a 30, it would actually probably be more eco but it wouldn’t be safe (08)”.</p> <p>“There was one particular person who only seemed to have travelled 40 kilometres... other people seemed to be doing thousands, so it was, it is quite difficult to know (03)”.</p> <p>“A lot of other people join, then that affects your position on the leaderboard, doesn’t it? (09)”.</p> <p>“Saw that there was people like on 100% and they only done like 14 miles, and then there’s others that had done 2-3 or thousands of miles as well. And it it’s like, well, it’s, it’s not really a scoreboard. So it, it lost all its legitimacy (05)”.</p> <p>“It was either that or mow down the pedestrian in front of me (11)”.</p> <p>“I had passengers in the car and I had to brake. Obviously it was one of those moments where you have no choice. Like we said before. And I just thought in my head. Oh God, the app. And it just came up on the app later that night and I thought ohh look what I’ve done. (Laughs) (15)”.</p> <p>“Driving home in rush hour and you’re having to slam your brakes on because somebody’s done something stupid (09)”.</p>
It’s just not for me	App didn’t work for me	<p>“For me personally, I don’t think I really changed how I drove throughout it (24)”.</p> <p>“I was very much more aware of what I was doing when I knew that I could see it on the app, erm, but it didn’t really make me alter my ways (04)”.</p> <p>“It just got annoying that it was marking me down on other people pulling out and things like that (05)”.</p> <p>“It (the score) just got lower and lower and I found myself getting more frustrated that it was affecting my driving making it worse (05)”.</p> <p>“Personally, I just, I’d rather not have to spend like more time my phone and I already have (19)”.</p> <p>“I want to enjoy... driving without scrutinising myself all the time (09)”.</p> <p>“I wasn’t able just to relax into, at my normal driving pattern (05)”.</p> <p>“It took away, it made it harder for me to drive (05)”.</p>