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CoastMaster: An Ambient Speedometer to Gamify Safe Driving

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ABSTRACT

We present *CoastMaster*, a smartphone application that serves as an ambient speedometer and driving game display. Our work is motivated by the need to re-engage drivers in the driving task, e.g., in situations where manoeuvering the vehicle is straightforward and does not require high levels of engagement. *CoastMaster* supports drivers during speed limit changes by (a) re-engaging them in the driving task, and; (b) providing feedback on driving behaviour. In a simulator study (*N*=24), we compare a gamified and a non-gamified interface with regards to user experience, driving performance, and visual distraction. Our results indicate an increase in hedonic quality and driver engagement as well as a decrease in speed violations through the gamified condition. At the same time, the gamified version leads to longer glances towards the display suggesting visual distraction. Our study findings inform specific design recommendations for ambient interfaces and gamified driving.

Author Keywords

Ambient interface; gamification; distraction; vehicle-based apps; design approach; interactive experience.

ACM Classification Keywords

H.5.2 User Interfaces: Screen design.

INTRODUCTION

In this paper, we illustrate how ambient in-vehicle displays can offer engaging driving experiences and safety benefits through gamified safe driving. This is, e.g., useful in situations where drivers manoeuver their vehicle on familiar routes, in low traffic, or on long distance drives. The mundane nature of such situations may trigger risky behaviours, such as speeding or checking social media [14].

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We propose to address such situations by enhancing the driving experience. As a result, drivers may feel more engaged in the driving task and less tempted to take risks.

The rationale behind exploring ambient interface design stems from user requirements for gamified driving we had previously identified from an extensive qualitative study [14]. In that study, participants preferred real-time driving data over abstract rewards and simple visualisations over playful themes. As such, the literature around ambient in-vehicle displays provided us with a useful lens through which to analyse and create our design of engaging gamified driving experiences.

In addition, to create more engaging driving experiences, we build upon a previously presented design approach for driving gamification [15]. Traditionally, the *primary* driving task has been enhanced through automotive engineering (more horsepower or vehicle modifications), but with our work, we show how digital technologies and gamifying the primary driving task can create novel driving experiences as well. In this paper, we chose the driving scenario of approaching speed limit signs as an exercise to apply this approach and see the process through to implementation and evaluation. As discussed in our design approach paper, the vision is to gamify several different driving scenarios in the future.

The *research aim* of this study was to explore the implications of designing ambient interfaces for gamified driving. To address this research aim, we developed a smartphone app, *CoastMaster*, which serves as an ambient speedometer and gamifies transitions to new speed limits. It encourages users to coast down to new speed limits without unnecessary pedal usage. Through reflecting on our design process and by conducting a user study (*N*=24), we sought to answer the following four research questions:

RQ1: What is the effect of the gamified component on the user experience?

RQ2: Is the gamified component visually distracting?

RQ3: What is the effect of the gamified component on driving speed?

RQ4: What are the usability challenges in *CoastMaster* and how can future ambient interfaces address these?

This paper discusses our iterative design process, prototype, implementation, and evaluation in terms of user experience, driving performance, and visual distraction. Our data suggests an increase in hedonic quality and decrease in speed violations through the gamified component. An increase in long eye glances indicates a risk of visual distraction in our prototype, which we address in our design recommendations.

CONTRIBUTION STATEMENT

The contribution of this work is threefold. First, we report on the design and implementation of a smartphone application that provides real-time driving feedback to promote safer driving by way of re-engaging drivers in the primary driving task. Second, we present an evaluation of the approach in a driving simulator study with 24 participants. Third, we contribute a set of guidelines for designing ambient in-vehicle interfaces. We believe our work to be useful for both researchers and practitioners who aim to enhance the driver experience without compromising safety.

RELATED WORK

Our work draws on several strands of prior research, most importantly ambient displays in vehicles as well as gamified driving.

Ambient In-Vehicle Interfaces

Ambient systems present information that is important but not critical. Their intent is to subtly reflect updates in information without distracting users, allowing the shift from the periphery to the focus of attention and back [11]. It therefore seems promising to deploy ambient interfaces in the driving context. This approach recently received considerable attention within the research community, e.g., in the *Workshop on Adaptive Ambient In-Vehicle Displays and Interactions*[1] at AutoUI'15.

A common theme among recent ambient in-vehicle interfaces has been the use of lights. For example, Löcken et al. [7] explored several design variations for light patterns to support lane changes and reduce mental workload. Pfromm et al. [10] used a 360 degree colour LED strip to visualise distance and position of nearby traffic objects. Their study findings suggest that ambient interfaces can shorten participants' gaze attention time. Meschtscherjakov et al. [9] presented LEDs mounted along the A-pillar of a car to aid drivers with speed keeping in an ambient way. Their study results suggest that ambient lights have a positive influence on the perception of speed. Laquai et al. [6] developed a colour LED system that fosters anticipatory braking behaviour. In combination with V2V data, they envisioned to inform drivers about upcoming collision targets in an unobtrusive way. Besides light based systems, subtle eco-driving visualisations have been incorporated into dashboard displays, heads-up displays, and smartphone applications. Studies suggest that such in-vehicle systems can have positive effects on fuel efficiency [16]. All the aforementioned examples showcase the potential of ambient displays as automotive user interfaces.

Gamified Driving

Gamified driving has previously been explored as a means to influence eco-driving, driving safety, and navigation. Diewald et al. [2] argue that the design of gamified driving is promising, but needs to be thought out and requires extensive testing. Insurance companies and mobile app developers offer commercial apps that aim at improving driving behaviour using gamification approaches. We reviewed 21 driving-related smartphone applications[2], which are currently available in the iOS, Android, or Windows Mobile app stores. Our search terms included "driving", "game", "OBD" (on-board diagnostics), and "car". Our review focused on four main criteria: *ambient design; gamification; safe driving;* and *real-time feedback. Ambient design* assessed if the apps incorporate any ambient interface elements, either visually or auditorily. *Gamification* assessed if the apps use game elements in the driving context as part of the user experience. *Safe driving* denotes if the apps were designed to foster safer driving. *Real-time feedback* assessed if driving feedback is given in-situ during drives, rather than post-drive.

We found that 14 apps promote safe driving (e.g., Samsung S-Drive, OneTap), 11 use game elements (e.g., Dash, AAMI Safe Driver), 10 provide real-time feedback (e.g., Enerfy, XLR8), and 6 use ambient elements (e.g., iOnRoad, aCoDriver 4). Although all of the latter 6 apps also give real-time feedback, none of them used gamification elements and only 4 of them promote safe driving. Similarly, only 4 apps (e.g., Movon FCW, Speed Advisor) combine the promotion of safe driving behaviour with real-time feedback. One gamified app provides real-time feedback in an ambient way with sound cues, but does not promote safe driving. None of the 21 apps fulfil all four criteria. *CoastMaster* was designed with all four in mind.

COASTMASTER

Many driving scenarios can be gamified, e.g., keeping a safe following distance, approaching traffic lights, lane keeping, or checking mirrors. For all scenarios, there are different ways to gamify them as we have previously pointed out [15]. *CoastMaster* is an outcome of our design approach for balancing safety and fun in gamified driving, where we defined conceptual layers for designing driving gamification such as *verbs, mechanics, core, theme* and *concept* [15]. We chose the driving scenario of approaching speed limit signs. Conceptually, *CoastMaster* allows users to coast, to brake, and to accelerate (the game's *verbs* [15]). The objectives are 1) to stay within the speed limit, and; 2) to do so with limited pedal usage even when the speed limit

[1] waadi.offis.de

[2] For website links, refer to the complete list of apps reviewed: eprints.qut.edu.au/98516

is changing (the game's *mechanics* [15]). As mentioned above, the vision is to extend this to different scenarios, gamified components, and levels.

Iterative Design Process

The rationale behind exploring ambient interface design was not only meant to minimise visual distractions, but is also a response to user requirements as pointed out in the *Introduction*. Overall, one of our design goals was to convey real-time driving feedback in a way that can be perceived as quickly as possible, as research suggests that eye glances greater than two seconds significantly increase crash risk and should therefore be minimised [5]. To convey speed information, pedal usage, and game feedback in an unobtrusive way, we investigated several parameters identified through brainstorming, such as shapes (growing circles, rings, or doughnuts), size, and colour as well as transitions (changing sizes, positioning, colour fading) and text. We iteratively created sketches and video mock-ups as a way to communicate and improve our designs (Figure 1).

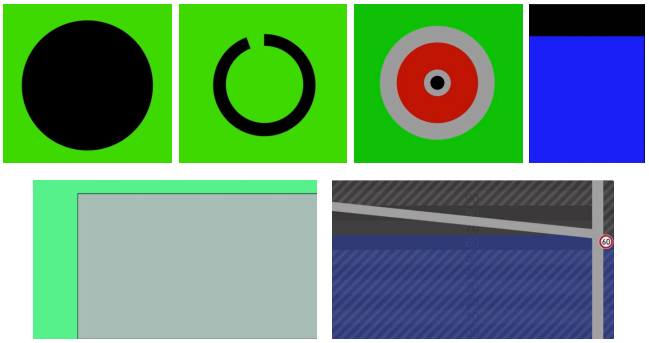

Figure 1. Different visualisations explored as video mock-ups: growing circle, doughnut, growth rings, various progress bars.

Our designs were informed by in-vehicle information system (IVIS) design guidelines [1] and heuristics for ambient displays [8]. Specifically, we followed their recommendations to use sans-serif fonts, standardised icons (e.g., speed limit signs), a maximum of five colours with a defined meaning, and to provide auditory and visual feedback at appropriate times (e.g. showing upcoming speed limit changes). In the end, we independently arrived at a design similar to the digital speedometer proposed by Smith et al. [13], which may suggest a level of maturity in the design of this particular use case.

We presented the final video prototype to a group of accident and road safety researchers (N=4, all male, age M=30.8, SD=4.76) and gathered their feedback in a one-hour workshop. One outcome of this workshop was to further reduce the number of colours to blue, red, green, and yellow only. Furthermore, we decided to display a large speed limit icon notifying user of upcoming speed limit changes and challenges. The design rationale was that the large icon could be perceived in the periphery and therefore 'announce' the start of a challenge in an ambient way.

Final Design

CoastMaster is a smartphone application that acts as an ambient speedometer. In terms of placement, the smartphone could be held in a mount near the vehicle dashboard or windshield. Large, simple, coloured shapes indicate the current driving speed and the current speed limit. Driving speed is represented by a number in the centre and the height of the rectangle. The background colour is blue when the driving speed is under the limit, but will change to red if the maximum allowed speed is exceeded (Figure 2).

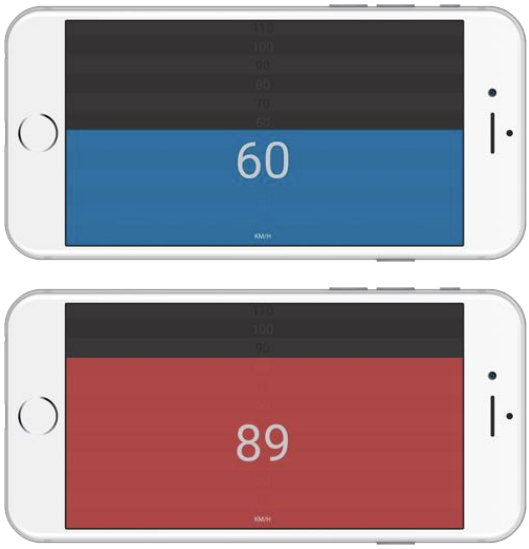

Figure 2: Final design of ambient speedometer. Blue = driving at the speed limit of 60 km/h. Red = exceeding the speed limit.

Apart from being an ambient speedometer, *CoastMaster* integrates a gamified driving component when speed limits change. Upon approaching a lower speed limit, a visual icon and an audio cue signal the beginning of a challenge (Figure 3b). Through game design, users are encouraged to coast down gradually instead of exceeding the speed limit or braking abruptly.

For example, the goal of the challenge may be to coast down (use no pedals) from 80 km/h to a new speed limit of 60 km/h. As such, and contrary to existing driving apps, *CoastMaster* uses pedals as input modalities. During the coast down phase, a vertical bar will move across the screen representing the remaining distance to the approaching speed sign (Figure 3c). Along this vertical bar, a trace visualises pedal use, i.e., using no pedal (blue), using the accelerator pedal (yellow), and using the brake pedal (red). Similar to previous work [3], the game encourages drivers to coast rather than to brake if safe to do so. Once the car passes the speed sign, the app will display an assessment of the gameplay performance (Figure 3d), which is also conveyed through an audio cue. Again, red background colour may signify exceeding the new speed limit (failed challenge), and a reference line allows users to assess their own smooth driving performance.

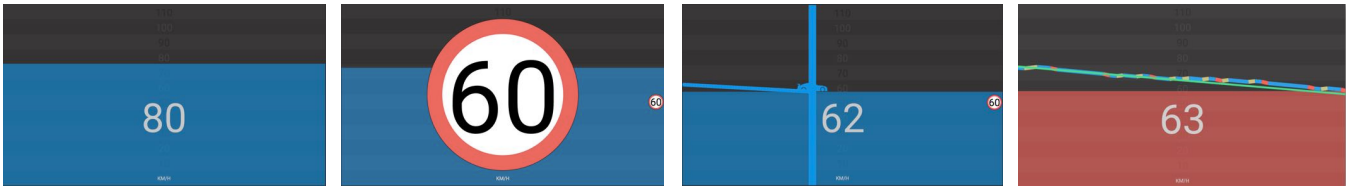

Figure 3: *CoastMaster* is a smartphone app that acts as an ambient speedometer aiming to enhance the driver experience. Left to right: 3a) Blue background colour denotes driving at or below the speed limit of 80 km/h. 3b) Gamified coasting challenges are announced via sound and an icon representing the upcoming speed limit. 3c) Real-time feedback is given during the challenge (coasting – blue, accelerating – yellow, and braking – red). 3d) Post-challenge feedback is provided via sound and a reference performance line (green). The red background colour indicates that the driver exceeds the speed limit (failed challenge).

Prototype Implementation

CoastMaster was prototyped as a web app using HTML5 and JavaScript. This way, it could run on the smartphone provided to participants and on computers available to the study facilitators at the same time. Driving data relevant to the game logic and data visualisation, such as driving speed, upcoming speed limits, and pedal pressure, were acquired from the Oktal SCANeR studio software used in our simulator. The software transmits data via export channels to our custom Intempora RTMaps module over TCP sockets. Our middleware (node.js) logs and broadcasts received messages to instances of the *CoastMaster* web app.

In terms of future real-world implementations, *CoastMaster* could gather vehicle data from the prevalent OBD interface and speed limit data from OpenStreetMap. Considering the ubiquity of smartphones in everyday life, including the driving context, we presented *CoastMaster* as a smartphone app to our participants. However, conceptually, nothing speaks against implementing *CoastMaster* as a more integrated dashboard or head-up display application.

USER STUDY

We conducted a driving simulator study to evaluate *CoastMaster* with regard to user experience, driving performance, and usability.

Participants

Overall, 24 people participated in the study. Nineteen male drivers aged between 18 and 25 years (M=22, SD=2.94) were recruited in-person and via mailing lists. We deliberately recruited the majority of people from this target group since young male drivers are at the focus of the research programme this study is part of. This group is particularly susceptible to risky driving and phone distractions [12]. The remaining five participants were accident and road safety researchers aged between 26 and 36 (M=30.8, SD=4.76) who would provide feedback from their perspective. Before commencing data collection, we obtained approval from the university's ethics committee (approval number 1500000046, in accordance with the *Australian Code for the Responsible Conduct of Research*) and written consent from participants.

Procedure

The study took place in a desktop driving simulator with wall projection, which presents a safe, yet immersive way to conduct controlled experiments. We designed the evaluation as a within-subjects, repeated measures experiment with two counterbalanced conditions across participants, *control* and *game*, and one drive per condition. In the *control* condition, the app acted as a speedometer (Figure 2), providing drivers with their current speed. In the *game* condition (Figure 3), the only difference to *control* was that speed limit changes would trigger gamified challenges through the *CoastMaster* app. Note that our goal was not to compare our ambient speedometer against conventional speedometers, but rather to explore how the added game component impacts the driving experience.

Figure 4. Speed signs trigger *CoastMaster* challenges.

Each session lasted about 90 minutes, and two familiarisation drives ensured that participants were well acquainted with the simulator and the app. An iPhone 6 running *CoastMaster* was placed behind the steering wheel where speedometers are usually positioned (Figure 4). The road network consisted of approximately ten minutes of suburban driving. It was used throughout all drives, allowing participants to become familiar with it and creating an experience resembling routine driving. During each drive, participants would encounter thirteen speed limit signs that resulted in eight slowdown transitions, i.e., eight *CoastMaster* challenges, which each lasted approx. 10 seconds.

Data Collection

We evaluated *CoastMaster* quantitatively and qualitatively. To assess participants' subjective perceptions of the ambient speedometer and the gamified driving, we asked participants to fill in the AttrakDiff 2 Questionnaire [4]. The Likert-scale questionnaire, which is a widely used

instrument in HCI and AutoUI research to quantify hedonic and pragmatic qualities, was administered both after the *control* and *game* drives. To investigate visual distraction, we measured long (>2s) eye glances away from the driving environment. We utilised the ASL Mobile Eye-XG eye tracker to collect glance behaviour. We furthermore recorded data related to driving speed. This allowed us to investigate if participants adhered more to the speed limit in either condition. Lastly, semi-structured interviews were conducted with all 24 participants to complement the quantitative data.

RESULTS

In the following, we present the study results with respect to the four research questions.

RQ1: What is the effect of the gamified component on the user experience?

The AttrakDiff 2 Questionnaire data show participants' perceived hedonic quality (HQ-Stimulation & HQ-Identity) and pragmatic quality (PQ) on a 7-point scale from -3 (lowest HQ/PQ) to 3 (highest). Figure 5 shows the AttrakDiff confidence rectangles for both conditions. The rectangles indicate that both conditions were largely perceived as "task-oriented" as well as slightly "neutral." The *game* condition additionally encompasses the qualities "desired" and "self-oriented." A Shapiro-Wilk normality test revealed that not all measurements are normally distributed. Therefore, a Wilcoxon signed-rank test was used to calculate the significance at $p \leq .05$. In overall HQ (HQ-Stimulation & HQ-Identity), the *game* condition shows a higher value (0.69) compared to *control* (-0.01). A closer look at HQ demonstrates a significantly higher value in HQ-Stimulation (Z=-2.9143, p=.004) in *game* (0.87) compared to *control* (-0.21). We furthermore see an increase of HQ-Identity from 0.2 in *control* to 0.51 in *game,* although with a higher probability of statistical error (Z=-0.3571, p=.72).

The HQ-Stimulation scores, which are in the average area for both conditions, indicate a reasonable level of engagement without drawing too much attention away from other aspects of the driving task. The interview data further support this interpretation. Participants reported having more fun, feeling more challenged, and feeling less bored through the gamified component. Most participants agreed that the game component added *"that bit extra in it"* (P20) that made the drive more fun and challenging. P13 and P19 felt *"satisfied"* when their performance overlapped with the reference line illustrating the desired performance. Other participants felt *"frustrated and betrayed"* (P6) when they failed to achieve the desired performance. Some participants said they would already create games for their everyday drives, which is in line with our previous findings [14]. For example, P9 would often coast down to red lights when he anticipated they were about to turn green. In summary, the gamified component seems to provide an engaging stimulus to otherwise boring drives. It gives drivers something to do and possibly look forward to.

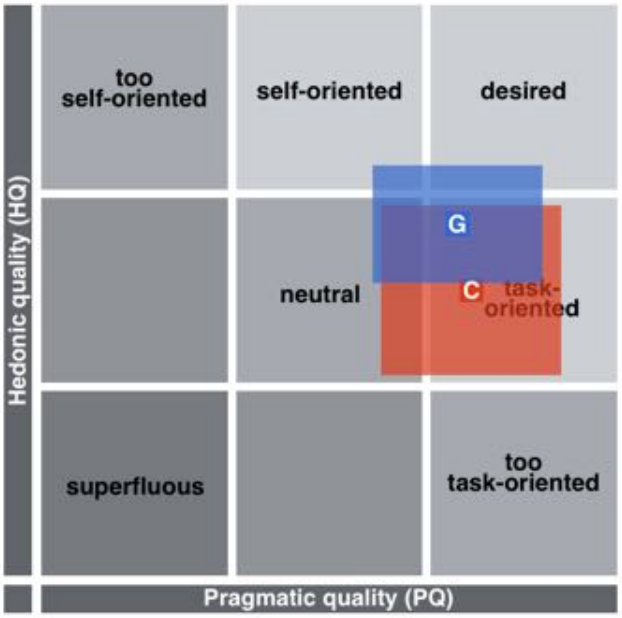

Figure 5. AttrakDiff confidence rectangle for all 24 participants for *control* (red) and *game* (blue).

RQ2: Is the gamified component visually distracting?

To evaluate visual distraction, we counted long (>2s) eye glances based on video footage from the eye tracker. Their number was higher in the *game* condition for most participants. In terms of mean values, the number of long glances was M=7.82 in *control* (SD=8.40) and M=12.12 in *game* (SD=9.31), meaning an increase by approximately 55% in the *game* condition. A Wilcoxon signed-rank test revealed this result with a high significance (Z=-2.8698, p=.004). Despite indicating increased app engagement, the fact that participants glance at the screen more often in the *game* condition suggests visual distraction.

The AttrakDiff data provides some insight into the cause of this: The pragmatic quality (PQ), i.e. the usability, is significantly (Z=-2.4157, p=.016) lower in *game* (1.32) compared to *control* (1.46). This indicates that the ambient speedometer by itself was perceived and understood more easily than the version with the added game component. In the interviews, 22 of the 24 participants pointed out they could see the speedometer information in their periphery. Some participants perceived the red colour as too harsh, describing it as *"over-reacting"* (P7) or making you feel *"more guilty"* (P16) when driving slightly above the limit. However, several participants (P11, P13, P22) said they kept looking at the screen *during* challenges, and P11 said he even ended up in the wrong lane.

RQ3: What is the effect of the gamified component on driving speed?

To evaluate the effect on driving speed, we calculated the mean driving speed throughout the entire drive for each participant in both conditions (similar to Meschtscherjakov et. al [9] who studied an ambient LED system to support speed control). Our results show a significant (Z=-2.1429,

p=.032) mean speed drop of 0.79 km/h in *game* (*M*=62.1 km/h, *SD*=3.14) compared to *control* (speed *M*=62.89 km/h, *SD*=3.1). In addition, *game* shows less driving above the speed limit (*M*=1.814 km/h above the speed limit, *SD=1.7*) compared to *control* (*M*=1.99 km/h, *SD*=1.98), i.e., less pronounced behaviours of speed violations occurred in *game* (*Z*=-2.4, *p*=.016).

We then isolated the road segments that included coasting challenges (i.e., 250 meters before a speed limit sign). Looking into these segments reveals a significant (*Z*=-8.014, *p*<.001) lower mean driving speed in the *game* condition by 4.19 km/h (*M*=63.015 km/h, *SD*=4.887 vs. *M*=67.201 km/h, *SD*=4.224 in *control*). This result is due to earlier and smoother deceleration. Figure 6 illustrates the driving speed for one participant (P13) throughout the entirety of both drives including mean values. In the interviews, several participants reported a positive effect of *CoastMaster* on their driving performance as they focused hard on maintaining speed. For example, P19 said the game *"pushed [him] to perform better"* each time. Finally, several participants pointed out that the speed limits were unexpectedly high in long turning curves where you would normally slow down.

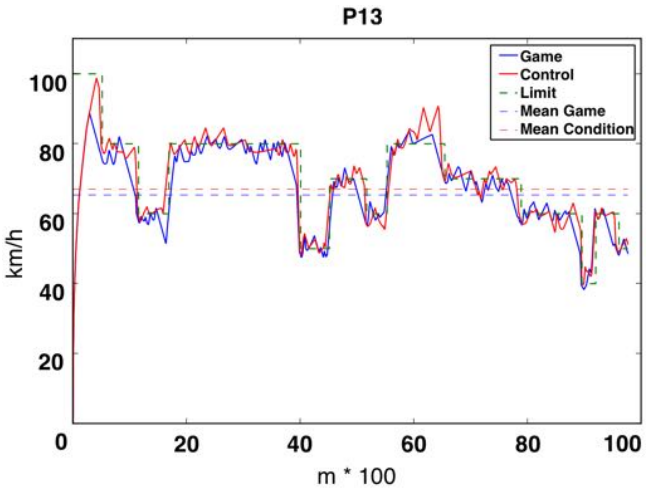

Figure 6. Driving speed by one participant (P13) in *control* (red) and *game* (blue).

RQ4: What are the usability challenges in *CoastMaster* and how can future ambient interfaces address these?
According to the results of the AttrakDiff Questionnaire, both app variations have an above average pragmatic quality (PQ, *see above*) suggesting good overall usability. However, post-hoc interviews revealed several usability challenges, which are presented as a ranked list in order of severity. To avoid these challenges, we present design recommendations in the next section.

Occlusion
The large speed sign icon covers most of the screen (Figure 1b). Therefore, it is difficult to see the driving speed information as a new challenge comes up.

Level of Detail
Some visual elements, e.g., icons, are not large enough. This makes them difficult to read, which can cause confusion during challenges.

Colours
No colour-fading is used to transition between blue (*within* speed limit) and red (*exceeding* it) backgrounds (Figure 3). These sudden colour changes are perceived as too harsh, i.e. they are distracting and not ambient. Additionally, P8, P14, and P15 suggested to replace blue with green, as green is already associated with desirable behaviour.

Lack of Context-Awareness
The app announces challenges even when the current driving speed is already at or below the upcoming speed limit. P11 said he was *"confused"* and *"didn't know what to do"* in this case. Other participants shared this sentiment and suggested to skip challenges in such cases.

DISCUSSION & DESIGN RECOMMENDATIONS

User Experience
The study results are promising in terms of creating engaging driving experiences, as our data (AttrakDiff and interviews) suggest an improved user experience through gamified driving. The fact that participants did coast down smoothly indicates that the game objectives were well understood and desirable enough to be pursued. Our approach furthermore illustrates how smartphones, which are prevalent in many people's cars, can be reframed as ambient in-vehicle interfaces.

Driving Performance and Visual Distraction
In terms of road safety, *CoastMaster* encourages safe driving and we have observed some safe driving behaviours in the *game* condition, e.g., significantly fewer speed violations as well as earlier and smoother deceleration. The mean driving speed drops through the gamified component is comparable with related ambient display studies [9].

We have furthermore observed that visual distraction *during* challenges is too high. This aspect needs to be addressed before potentially having any net safety benefits. As pointed out [9], there is a trade-off between providing ambient information and driver distraction, which needs to be carefully considered when developing novel in-vehicle interfaces. Consequently, a potential avenue to explore is the design of ambient sound, which some participants said they might prefer, and how it might complement ambient visuals. The audio cues signalling the start of new *CoastMaster* challenges were useful on the one hand, as participants perceived it as *"super useful"* (P16, P21) and a *"good distraction"* (P22). On the other hand, we discovered it may have triggered participants to step off the pedal or glance at the screen. The question arises how to signal information in an ambient way. In our case, the large visual speed icon was meant to signal the beginning of challenges. However, it covered other vital information and consequently introduced confusion among users.

Design Recommendations

The ambient speedometer design worked well in terms of conveying driving speed in users' periphery. The study results represent a significant achievement in our aim to create engaging interventions that support safe driving. To synthesise our insights from designing ambient visuals and to address challenges in the current prototype, we present five design recommendations.

Recommendation 1: Use large, coloured shapes and avoid detailed elements to visualise information

Large colour fills worked particularly well in our study, contrary to smaller, more detailed elements such as speed limit icons. We therefore recommend large shapes of high-contrast colours to visually convey information. At the same time, the number of visual elements shown simultaneously should be limited, especially during challenges. It is best to keep the level of detail as low as possible. Literature on pre-attentive processing can guide the design of such visuals. Lastly, avoid occlusion of visual elements. That is, users need to be able to grasp any desired information as part of a short glance, therefore, information should not be covered up by other visual elements.

Recommendation 2: Offer multi-channel feedback

During gamified challenges, we identified visual distraction as the main challenge in offering real-time driving feedback. To overcome this barrier, we recommend delivering ambient sound or tactile feedback to replace or complement visuals. Furthermore, some participants perceive only specific feedback types as distracting, e.g., just the auditory cues. In line with IVIS guidelines, we suggest to implement an option to mute specific feedback types at any point in time.

Recommendation 3: Implement colour-transitions

S Sudden colour changes are perceived as too harsh and should be avoided. We recommend the use of fading when switching between colours to minimise distraction while still offering relevant information through colour changes. This transition also indicates whether the driving speed is 'close enough' to the speed limit, allowing users to make more of this ambient information.

Recommendation 4: Skip gamified challenges when inapplicable or inappropriate.

In our study, we observed that it did not always make sense to gamify speed limit transition. For example, when the driving speed is already at or below the upcoming speed limit, the challenge provided was inapplicable and caused confusion among participants. We therefore suggest to accommodate for such edge cases and automatically skip challenges. Similarly, the driving context needs to be appropriate. For instance, traffic density could be taken into account to disable the gamified component altogether.

Recommendation 5: Introduce multiple levels

Introducing colour transitions results in colours representing 'close to good' performances. To leverage this potential fully, we recommend introducing different game levels. Mastering one level will enable users to advance to the next level where performance accuracy becomes more important. Introducing various levels also addresses the novelty effect, as do gamifying other scenarios such as keeping a safe following distance, approaching traffic lights, lane keeping, or checking mirrors.

LIMITATIONS

Although the study was carefully designed, we are aware of some limitations. The lights in the simulator room were dimmed and consequently the ambient display was well perceivable. As pointed out by previous research on ambient car interfaces [9], different light conditions may lead to different experiences, and a potential solution could be adapting the brightness and colours according to the surrounding. Furthermore, our study does not yet reveal insights regarding the influence of different screen sizes or smartphone locations in the car. Lastly, we acknowledge the difficulties in implementing *CoastMaster* in the real world. In particular, it may be challenging to accurately determine the distance to speed limit signs.

CONCLUSION & FUTURE WORK

Gamified safe driving offers an untapped potential to re-engage drivers in the driving task and to offer novel driving experiences. Following a design approach for driving gamification [15], we developed *CoastMaster*, a smartphone application that serves as an ambient speedometer and gamifies transitions to new speed limits. A gamified and a non-gamified interface were evaluated in a counterbalanced within-subjects driving simulator study (N=24). Our results indicate an increase in hedonic quality in *game* (0.87) compared to *control* (-0.21) measured through the AttrakDiff Questionnaire, and interview data confirm an increase in driver engagement through the game component of *CoastMaster*. In *game,* we have seen significantly fewer speed violations as well as earlier and smoother deceleration, which is associated with safe driving. However, the *game* condition shows a long eye glances increase by approximately 55%, which indicates visual distraction, and the interview data reveal the detailed visual design *during* challenges as a cause for this distraction. We presented design recommendations for ambient and gamified experiences, e.g., making use of colour transitions, multi-channel feedback, and context-awareness. We propose our recommendations to be useful to the AutoUI community's goal of *"enhancing the driver experience,"* and future version may integrate them in dashboard or head-up display applications.

In the future, we will investigate gamified ambient interfaces with respect to driver states such as boredom or flow. We intend to focus on the effects during low-stimulation driving conditions, which often are antecedents of risky driving and unsafe distractions. Semi-automated driving further amplifies the significance of this issue. A cutback in manual control is likely to cause a lack of engagement in the driving task more often, yet requires

drivers to remain vigilant and take over control at any time. With interventions such as *CoastMaster*, which can be extended to include multiple driving scenarios and levels, we hope to re-engage drivers and increase safety.

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