DRIVINGBEACON: Driving Behaviour Change Support System Considering Mobile Use and Geo-information

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Abstract

Natural Language Generation has been proved to be effective and efficient in constructing health behaviour change support systems. We are working on DRIVINGBEACON, a behaviour change support system that uses telematics data from mobile phone sensors to generate weekly data-to-text feedback reports to vehicle drivers. The system makes use of a wealth of information such as mobile phone use while driving, geo-information, speeding, rush hour driving to generate the feedback. We present results from a real-world evaluation where 8 drivers in the UK used DRIVINGBEACON for a period of 4 weeks. Our preliminary results are promising but not conclusive.

1 Introduction

There has been a long tradition of adopting Natural Language Generation (NLG) techniques in health care (Cawsey et al., 1997; Portet et al., 2009; Schneider et al., 2013; Enarvi et al., 2020). One line of work focus on building Behaviour Change Support Systems (BCSSs) to help people live healthier and more safely. These include systems for encouraging people to stop smoking (Reiter et al., 2003), for ecological driving (Endres et al., 2010; Boriboonsomsin et al., 2010; Tulusan et al., 2012), and for safer driving (Braun et al., 2015, 2018)[1]. Such BCSSs can generate feedback automatically based on users' current behaviours by employing NLG techniques.

Within the domain of safe driving, personalised feedback via postal mail has proved to be useful to improve users' driving habits (Ouimet et al., 2004; Lefèvre et al., 2015). For example, DriveSafe (Bergasa et al., 2014) is a mobile application that utilises data from vehicle cameras combined with GPS and audio data from the mobile phone to identify unsafe driver behaviours. DriveSafe estimate a driving score for each driver and then provides alerts when the score crosses a certain threshold. Eco-Driving (Allison and Stanton, 2019) is a study about reducing gas emissions arising from bad driving styles. Minimising unnecessary acceleration and braking can improve eco-driving and fuel consumption and eventually reduce emissions. The study also highlights that despite the benefits of eco-driving, drivers also require feedback about their actions in order to promote long-term behavioural change. Another study by Jannusch et al. (2021) investigated the high fatality rate amongst Young Novice Drivers and their use of mobile phones while driving. A survey among 700 young drivers was conducted, where they compared distracted driving behaviour. They focused on participants' use of smartphones during driving and found that most of those uses are music-related activities (e.g., playing the next song or increasing the volume).

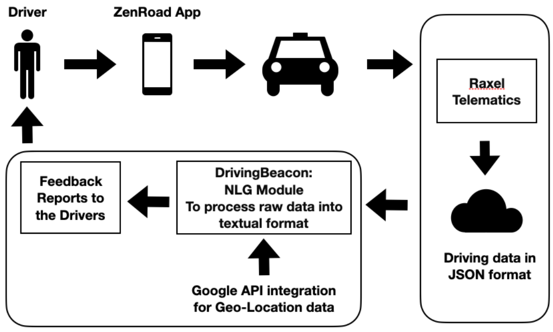

Figure 1: DRIVINGBEACON System Design

Braun et al. (2018) built SAFERDRIVE, the first NLG based driving BCSS, which generates weekly textual driver feedback from telemetric data[2] and the feedback is delivered through mobile phones.

[1]The United Nations considers unsafe driving to be a health issue and lists the target of fewer road traffic accidents as a health goal for sustainable development. See: https://sdgs.un.org/goals/goal3.

[2]The data was gathered by a mobile phone app to track individual driving styles.

It was reported that the generated textual feedback is more helpful to drivers than the traditional score-based and map-based feedback, especially to learners and young drivers (Braun et al., 2015). This is because textual feedback gives drivers a more concrete idea of how to change their driving behaviours. For example, for a speeding incident, SAFERDRIVE could generate feedback such as "*You speeded 7 times on roads with 20 mph speed limit and 12 times on roads with 30 mph speed limit*".

This paper introduces DRIVINGBEACON which is able to make use of richer information compared to SAFERDRIVE aiming at generating better feedback reports. Vital additional information includes (i) the mobile phone use information of drivers during driving; and (ii) geofencing, which highlights driving incidents that take place near crowded places such as schools, mosques, superstores, etc.

To assess our DRIVINGBEACON, we conduct a real-world A/B test on 8 drivers in UK. This is not a lot of drivers, but it is more than the 6 drivers used by Braun et al. (2018). Concretely, we generated basic feedback (not considering rich information) and enhanced feedback (considering rich information) using DRIVINGBEACON. We divided our 8 drivers into two groups, one of which is sent the basic feedback while the other is sent the enhanced feedback. The experiment lasted for 4 weeks, during which we monitor the change in their driving behaviours. To summarise, the key contributions of our work are two-fold:

1. We designed and implemented the DRIVINGBEACON system which makes use of the mobile use information and Geo-information in addition to telemetric data;
2. We evaluated DRIVINGBEACON through a four-week period A/B test on 8 real drivers.

2 System Design of DRIVINGBEACON

We implemented DRIVINGBEACON using Java and connected it to two third-party APIs to acquire required information: the Google Map API[3] and the Damoov API[4]. Figure 1 shows our system architecture.

ID	Driving Behaviour
1	Brake and Acceleration
2	Speeding
3	Speeding near crowd areas
4	Using mobile while driving

Table 1: Driving behaviours that DRIVINGBEACON monitors

Specifically, Damoov Telematics uses a mobile phone application called ZenRoad[5] to collect driving behaviour related information. It collects driving data from embedded sensors in the mobile device, such as gyroscope, GPS and accelerometer. This data is then uploaded to the data hub of Rexel Telematics.

DRIVINGBEACON pulls raw data from the datahub using the Damoov API and extracts related Geo-information using Google MAP API. With these data, we use a rule-based NLG system to generate feedback reports.

3 Feedback Generation

We classify the information we obtain into two sets: one contains the information that also has been used in SAFERDRIVE (Braun et al., 2018) (henceforth basic information), including information such as location, speed, speed limit, time, etc. The other contains additional information, including mobile phone usage, geo-fencing (driving near crowded places), traffic law and penalty points. Basic feedback reports include only the first set, while Enhanced feedback reports include both sets.

We also list the driving behaviours that DRIVINGBEACON captures in Table 1. DRIVINGBEACON will detect driving behaviours based on the information it collects and generates feedback accordingly.

3.1 Basic Feedback Report

Without the additional information, we generate what we call the *basic feedback*. It uses similar parameters as Braun et al. (2018). Since the system access only basic information, it detects limited types of driving behaviours (i.e., only the first and second driving behaviours in Table 1). Based on the detected behaviours, it generates basic feedback,

[3] https://developers.google.com/maps; Terms of Service: https://developers.google.com/maps/terms-20180207

[4] Damoov - Mobile Telematics as a service, www.telematicssdk.com; License: https://docs.damoov.com/docs/license

[5] tinyurl.com/ZenRoadApp

Basic Report	Enhanced Report
Last week, your total number of driving incidents was nine, including speeding on Low Rd, Grantham. Your speed was 51mph on a 30mph road. Remember that fast driving can cause serious accidents and will lead to points on your driving licence and fines of up to 150% of your weekly income. When driving, a few miles per hour can mean the difference between life and death. The total number of braking incidents was two; your braking counts are less than five; Well done! Acceleration incidents were two; your acceleration counts are less than five, Keep it up! Unnecessary acceleration and harsh braking can impact fuel costs and car maintenance costs.	Last week, your total number of driving incidents was nine;including mobile phone usage on Tuesday, 4th May at 8:56 AM. You used a mobile phone while driving near Helmsley Rd, Grantham. It was during rush hour where distracted driving could have caused a serious accident with up to 6 penalty points and a £1,000 fine. On Wednesday, 5th May at 3:27 PM, you exceeded the speed limit near a crowded place; the location was Barrowby Preschool, Low Rd, Grantham. Schools, mosques, train stations and superstores are sensitive and often crowded zones. Your speed was 51mph on a 30mph road. Remember, driving fast near a crowded place can cause a serious accident and may lead to points on your driving licence and fines of up to 150% of your weekly income. On Wednesday, 5th May at 8:30 AM, you drove at extreme speed near Alberic cottage, Low road, Grantham. Your speed was 50mph on a 30mph road. Remember, when driving, a few miles per hour can mean the difference between life and death. Unnecessary acceleration and harsh braking can impact fuel costs and car maintenance costs. Last week, your total number of braking incidents was two, the total count is less than five; Well done! You did acceleration near a crowded place on Wednesday 5th May at 3:27 PM, however, your acceleration counts are less than five, Keep it up!

Table 2: Example of basic feedback and enhance feedback (difference highlighted in blue)

which tells drivers about speeding, road speed limits, unnecessary acceleration and harsh braking. For example, in the example basic feedback in Table 2, with the information about location, speed and speed limit, the system detected that the driver overspeeded on Low Rd, Grantham and generated a message about both the detail of this poor driving behaviour (i.e., "*... speeding on Low Rd, Grantham. Your speed was 51mph on a 30mph road.*") and its consequences (i.e., "*Remember that fast driving can cause serious accidents and will lead to points on your driving licence and fines of up to 150% of your weekly income ...*")

3.2 Enhanced Feedback

With both the basic and additional information, DRIVINGBEACON generates *enhanced feedback* reports, an example of which is shown in Table 2. This additional information can help the system detect more kinds of poor driving behaviours (see Table 1) and can be useful to drivers to understand where and when they did drive unsafely and the potential impact on them and others of their unsafe driving. It highlights the dangers of the incidents.

We use geofencing (illustrated in Figure 2) to identify regions near schools and other sensitive or crowded areas (e.g., shopping malls, hospitals). We highlight to drivers unsafe driving within a geofenced area as it is more likely to result in incidents in these areas compared to less crowded places. For example, in addition to tell the driver that s/he was speeding, the enhanced feedback add a message that the speeding happened near a school

Figure 2: Geo-fencing around sensitive areas

(i.e., "*you exceeded the speed limit near a crowded place; the location was Barrowby Preschool*").

Mobile phone use is classed as distracted driving and a major cause of serious accidents (Jannusch et al., 2021). Due to the high usage of mobile phones these days, we included mobile phone usage in our feedback reports, as shown in Table 2: "*You used a mobile phone while driving near ...*".

Additionally, the Enhanced report also adds the detail of when each incident happened (e.g., "*... mobile phone usage on Tuesday, 4th May at 8:56 AM.*").

3.3 Hypothesis

Having two types of feedback reports, we show them to two groups, i.e. the Basic Group with basic feedback and the Enhanced Group with enhanced feedback report. We define our hypotheses for this experiment as follows:

1. Across basic and enhanced groups, there will be fewer incidents per mile of bad driving[6] at

[6] "Bad driving" means behaviour such as over speeding,

the end of the experiment (week 4) compared to the beginning (week 1).

2. Bad driving incidents per mile will reduce more in the Enhanced group than the Basic group, looking at all weeks (not just week 4).

4 Evaluation

In order to evaluate our system in a real-world scenario, we conducted a short longitudinal study where we evaluated the system with real drivers.

4.1 Materials and Participants

On 30th April 2021, we started a field experiment that lasted for 30 days. Eight participants (including both males and females) between the age of 20 and 45 were given the ZenRoad app. There were no incentives given related to driving performance. On the consent form, we explained that we would collect their driving data through the ZenRoad app and generate textual feedback reports with the intention of helping drivers to improve their driving habits. To protect the anonymity of the users, Damoov provided us with Data-Hub and Device and Track IDs (a unique number created for each driver and each trip), where all personal identifiers were removed. This anonymised data was then used for our analysis and feedback reports.

We divided the eight drivers into two groups (four drivers in each group): the Basic Group who received the basic feedback report and the Enhanced Group who received the enhanced feedback report. They drove a total of 3,179 miles around the UK with 239 trips in total. From driving data, we calculated the driving incidents per mile (I/M), an indicator for measuring drivers' relative performance. Basic group drove a total of 963 miles and did an average of around 0.098 driving I/M, while the Enhanced group drove a total of 2216 miles (enhanced group drivers went on long drives over the weekend hence more mileage as compared to basic group)[7] and did an average of 0.014 driving I/M. Throughout the experiment, we have noticed a decline in I/M in both groups but the enhanced group improved in their driving behaviours more quickly as compared to the basic group. Driver's feedback about Enhanced reports shows that it has made an impact on their driving behaviours during this experiment (see Section 4.3 below).

Our system monitored the following types of incidents: speeding, harsh braking, acceleration, mobile use while driving, unsafe driving near sensitive zones. These were highlighted in the Enhanced reports for the drivers.

Group	Week1	Week4	p-value
Basic	0.22	0.07	.321051
Enhanced	0.05	0.01	.243089

Table 3: Numbers of I/M; Week 1 vs Week 4

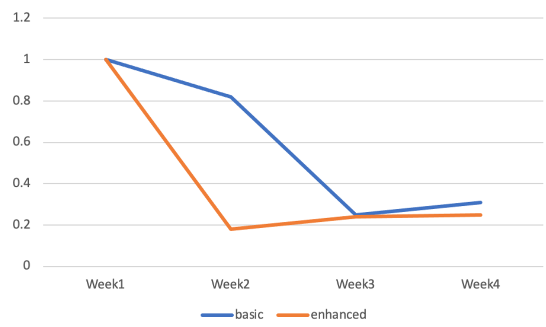

Figure 3: The number of incidents per mile (I/M) was normalised by that of week 1 in all four weeks.

4.2 Driving Behaviour Change

Table 3 shows the I/M of the drivers in the two groups. We conduct paired t-test to compare the incident per mile ratio in week 1 (i.e., the beginning of our experiment) and week 4 (i.e., the end of our experiment) for both Basic and Enhanced groups, where the results are shown in Table 3. It can be observed that numerically, there were fewer incidents in Week 4 than in Week 1. However, the difference is not significant and hence our Hypothesis 1 is not supported. We also like to mention here that, coincidentally, the drivers in the Enhanced group did fewer incidents in Week 1 as compared to the Basic group, which again might be attributed to the scale of our experiment.

To validate the second hypothesis, we quantified how much was I/M reduced by normalising the I/M of each week using that of week 1. The results are presented in Figure 3. We conducted a t-test on the results, but, unfortunately, there is no significant difference between the Enhanced group and the Basic group ($p > 0.05$). This embodies that our second hypothesis is also rejected. Nonetheless, we found that the enhanced report affects drivers much

harsh braking, speeding near crowded places etc.

[7]Reason for high miles driven by the Enhanced group is two out of four drivers went onto long journeys over the weekends.

Metric	Basic	Enhanced
Usefulness	4.00	4.17
Readability	4.50	4.17
Intervention	3.00	3.33

Table 4: Average scores for the human evaluation.

faster than the basic report since, as we can see from Figure 3, the largest decline of the enhanced group happened in the second week whereas that of the basic group happened in the third week. This suggests that enhanced reports are more efficient basic reports. More importantly, higher efficiency often results in fewer accidents in total.

4.3 Human Evaluation of the Feedback

With the weekly feedback report, we asked the participants to rate each generated report in the following categories on a scale from 1 (Strongly disagree) to 5 (Strongly agree): (1) **Usefulness**: *the feedback is useful to you*; (2) **Readability**: *the content is easy to understand*; and (3) **Intervention**: *the feedback has intervened your bad driving behaviour*.

Table 4 charts the results of the human evaluation. We found that the enhanced reports were rated higher in usefulness and intervention whereas the basic reports achieve higher readability, although no significant difference can be established on any criterion.

4.4 Feedback of the Generated Reports

At the end of the trial, we showed both the basic and enhanced feedback reports to all participants and asked about their opinion of this experiment and approach. The feedback was overall positive. Participants understood the idea and liked the approach where they can see their driving styles with details of their journeys, day and time when they make mistakes and most importantly the locations. Two drivers explicitly said they preferred the Enhanced report and no drivers said they preferred the Basic report. All comments are shown in Appendix A. Encouragingly, some of the subjects told us months after the experiment that they are still driving more carefully because of their experience with DRIVINGBEACON, even though they no longer use the system.

5 Conclusion

We presented DRIVINGBEACON, a behaviour change support system which can generate enhanced feedback reports by utilising the mobile use information and Geo-information in addition to telemetric data. Experimental results suggest that enhanced reports are more effective than the basic reports, although the difference is not significant. In the future, we plan to make the enhanced reports more effective by personalising feedback reports for individual drivers based on their interests, background, and driving history. We also plan to test our system in a larger-scale experiment with regard to both the number of participants and the duration of the experiment.

Acknowledgements

We thank Damoov for their help in setting up the experiment. We also thank the anonymous reviewers for their helpful comments.

Ethical Considerations

The current study has been approved by the ethics review board of the University of Aberdeen. The use of each API and Software (i.e., Google Map API, Damoov API, and ZenRoadAPP) is consistent with its licence or terms of use.

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A Feedback Examples

In what follows, we list some feedback examples, where feedback from the basic group is marked as B and feedback from the enhanced group is marked as E.

Group	**Give us your thoughts about the feedback approach ?**	**Will you use mobile phone app to improve your driving behaviours?**
B	*"I think the consistent feedback is encouraging; I have 4 kids of different age groups and in different schools so my speeding incidents are due to my rush hour driving as I have to drop my kids to three different schools. By September, the youngest will join the same school as my other kids and my daughter will join the secondary school which will reduce a lot of extra driving in the morning and afternoons."*	*"yes I like the idea. I am very busy but an extra app on my mobile which can show my driving behaviours will not harm. After being part of this experiment, I am thinking of changing my car insurance to a company which calculates annual premiums based on driving styles. I think having an incentive attached to this process can definitely change my driving behaviours."*
B	*"Its a good method, it tells me how I drive. Reading textual paragraph gives you a good idea; however, it should be shorter or may be only regarding extreme speeding related incidents which could fit in a mobile phone notification or an SMS. This process regularly will help me improve my driving behaviours. We receive M&S and Next clothing related promotional SMS messages every weekend, why not if an app on my phone generate an SMS or a notification with a report about the most dangerous driving incident of the week with location and time. I think it will definitely encourage me to change my style over time."*	*"Yes, definitely. I want to improve."*
B	*"The feedback report process is like a reminder to me to behave. But it didn't manage to connect me to this process so that it can sit in the back of my mind all the time when I drive. There should be some kind of incentive attached to this process. Like a reward or make me feel like I am part of saving the world. If there is a week when I did not have any incidents or bad driving, the app or process should share this to my friends and family that I am part of some noble cause or I receive a certificate or title or money."*	*"yes I will use a mobile phone app to improve my behaviours."*
B	*"I did not completely agree that the feedback report gives me a good summary of my driving. A enhanced version with lot more details and locations will be better. The basic reports which I have received were good but I was confused when and where did I do that speeding. Definitely, detailed summary of driving but not too lengthy."*	*"Yes, I like the idea and I think I have improved a lot in the last 4 weeks. I might keep the ZenRoad app for looking at my driving scores."*

Group	**Give us your thoughts about the feedback approach ?**	**Will you use mobile phone app to improve your driving behaviours?**
E	*”For me, feedback approach did work. Its a reminder for me to be careful while driving. In the last 4 weeks, I have tried my best to understand my driving behaviours through these reports and noticed that I should be extra careful at motorway. The reports shows that I did a lot of speeding during long journeys and I should change that habit.”*	*”Yes, I will use mobile phone app to improve my driving behaviours.”*
E	*”The textual feedback was concise and to-the-point and that was informative so it was quite a useful part of the feedback. The eco score was also simple enough to understand, and was useful. Risk score chart can be simplified a bit by adding some more explanation around it, or a simple kind of pie chart or something similar can be used instead. The rest was good.”*	*”Maybe”*
E	*”Possibly weekly prompts on the app like, ”Here is your weekly progress report on your driving”. Similar to how screen-time reports work on IOS.”*	*”Yes, it’s instant and I can get instant feedback.”*
E	*”I like the enhanced reports but its bit lengthy though.”*	*”Yes, I want to see my driving insights.”*