2024年臺灣國際科學展覽會
優勝作品專輯

作品編號　130010

參展科別　行為與社會科學

作品名稱　NUDGE TO ZERO. Using on-device, nudge-based interventions to improve road safety equity: Building on and democratising in-vehicle technologies.

得獎獎項　三等獎

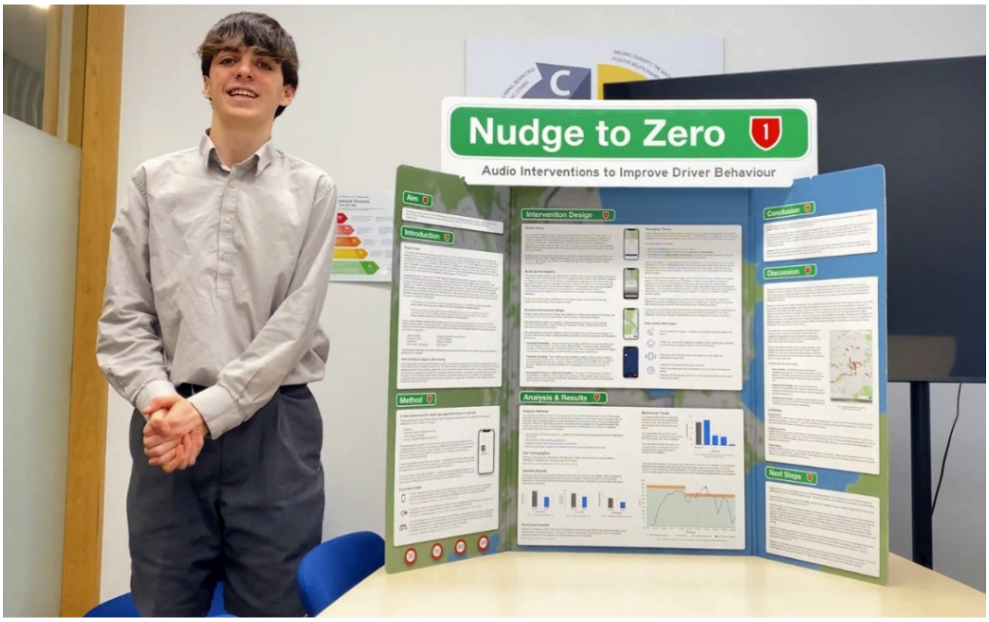
就讀學校　Wellington College

指導教師

作者姓名　Jesse Patrick Rumball Smith

關鍵詞　Equity, Road safety, On-device

作者照片


Nudge to Zero
Audio Interventions to Improve Driver Behaviour
Aim
Introduction
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Aim

To develop a mobile application that complements the Waka Kotahi **Road to Zero** campaign. It aims to incentivise safe driving by identifying behaviours and situations that increase the risk of crashes and providing audio interventions.

Introduction

Road to Zero

On average, someone dies on New Zealand's roads in a motor vehicle accident every day, and another seven are seriously injured. And it's getting worse. After a steady decline in fatal crashes between 1987 to 2013, the trend has reversed, and between 2013 and 2018, road deaths increased by 50 per cent.[1] New Zealand now ranks 29th out of the 33 OECD countries for road fatalities, with a rate of 7.9 deaths per 100,000 people. Norway - a country with a similar geography and population, and often used as a comparison - has a rate of just 2 per 100,000. Our road toll affects people, whanau and communities, and also costs our nation economically an estimated $5.6 billion each year (when all loss is accounted for: life, disability, vehicle damage, medical care).[2]

Understanding this, in December 2019 New Zealand's 'Road to Zero by 2030' campaign was introduced: a programme that sets out an ambitious goal of a 'New Zealand where no one is killed or seriously injured in road crashes'. Road to Zero emulates a successful international programme 'Vision Zero' which uses a holistic approach to road fatalities and crashes, looking at interventions within multiple dimensions. These include infrastructure investment, vehicle safety, work-related road safety, and a 'safe system' (eg. Public transport, drunk driving policy etc.). While it does aim to encourage safer behaviour on the roads, this is only one of the five focus areas and not the priority. The approach is also one of understanding and accommodation for potential driver error, to reduce the impact and harm of a crash. As stated in the strategy:

'In designing our road system, we must acknowledge the limits of our capabilities and plan for human error, so that the impact of a collision does not cause fatal or serious injuries.'

'Most serious crashes are not caused by people deliberately breaking the law, but rather the result of a momentary lapse or error in judgement. Even really well-trained drivers and riders make mistakes. These mistakes should not result in loss of life or serious injury.' [3]

This is a valid strategy; however, it leaves plenty of room for a complementary approach.

One that, whilst Waka Kotahi (NZ Transport Agency) mitigates fatality risk following a crash, it should also focus on addressing the driver behaviour causing them. Especially as recent data finds that the top causes of fatal crashes in New Zealand include (understanding factors can work in conjunction): [4]

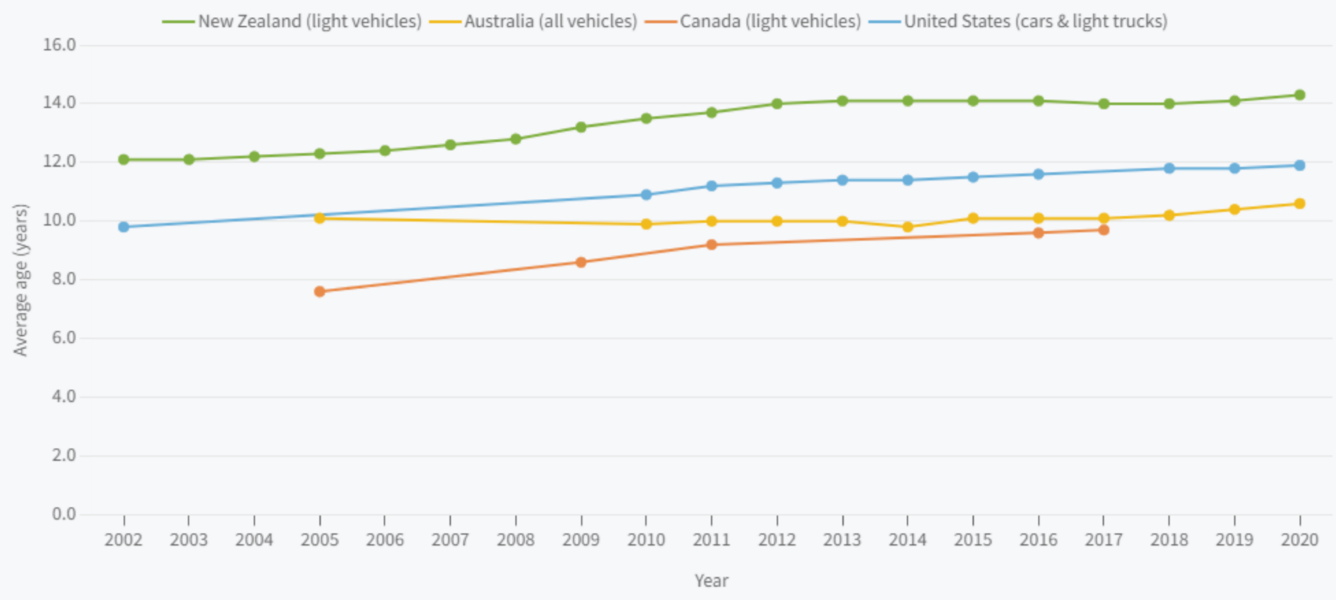
- Loss of control
- Alcohol or drugs
- Inattention
- Driver tired or fell asleep
- Excessive speed for the conditions,
- Failed to keep left,
- Attention diverted
- Road factors

These NZ domestic data align with recent international studies which showed that driver-related factors were present in almost 90% of crashes.[5]

Interventions to support safer driving

Car manufacturers have long known about the ability to use real-time visual and audio cues to support safer driving. The Intelligent Speed Adaptation (ISA) system is a vehicle-based tool designed to aid drivers in managing their driving speed according to the prevailing speed limits and is required for all new cars from 2024 in the EU. After detecting the vehicle has exceeded the speed limit, it generally uses audio 'beeps' or warnings to cue the driver to slow down. However, its current deployment is limited, typically only featured in high-end, luxury vehicles, thus reducing its accessibility and potential impact on improving road safety on a larger scale, especially in New Zealand where the market for newer cars is lower (and thus the fleet's age is greater).[6]

Figure 4 Average age of vehicle fleets, international comparison, 2002–20

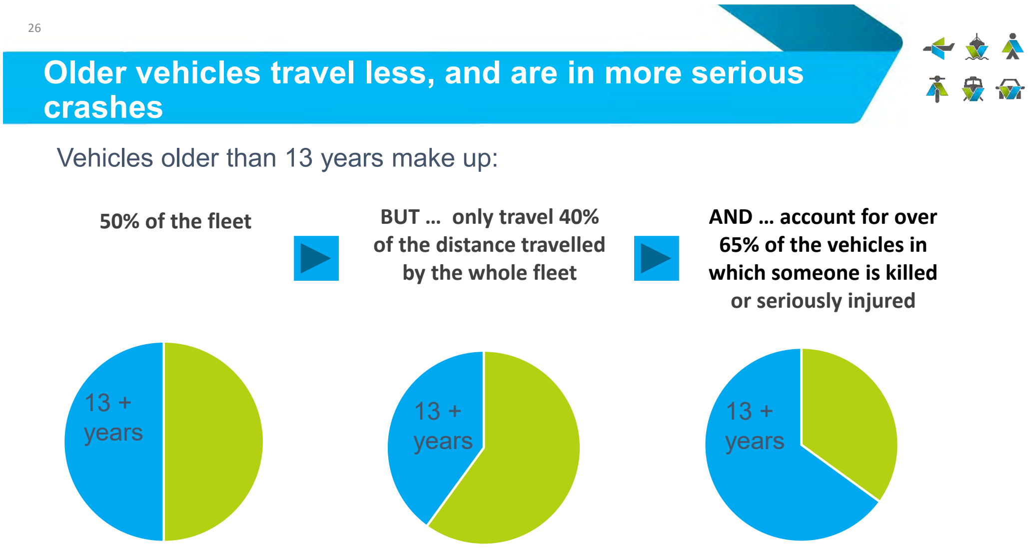


Note: The comparisons above are limited to countries with high levels of motorisation and similar patterns of development as New Zealand. More recent data for Canada is not available

Source: Ministry of Transport 2021

Inequitable safety and importance:

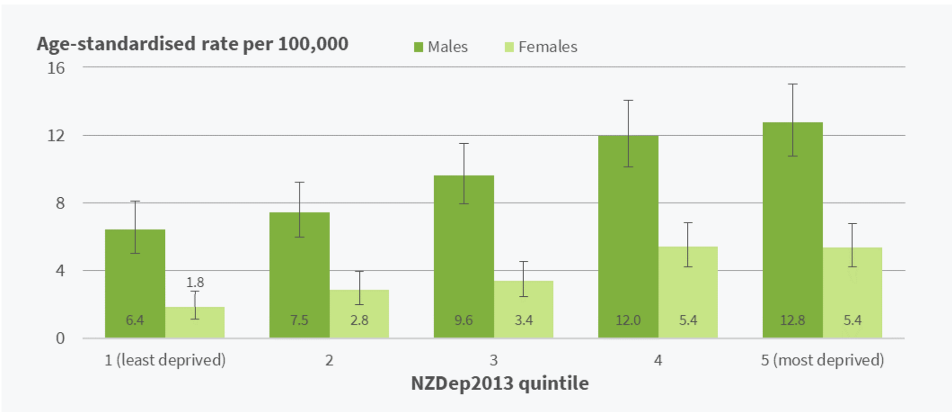
This inequitably, which essentially restricts road safety to the richest in our society, is reflected and proven true in in road safety statistics. Currently, it is the oldest cars[7] and the most deprived[8] people who have the highest risk of fatal crashes:



People living in more deprived areas had higher mortality rates

Road traffic injury mortality rates in the most deprived areas (NZDep2013 quintile 5) were much higher than those in the least deprived areas (quintile 1) in 2014–16, for both sexes (Figure 7). Standardising for age, people living in the most deprived areas were twice as likely to die as the result of a road traffic injury than those in the least deprived areas (standardised rate ratio = 2.2, 95% confidence interval 1.7–2.8).

Figure 7: Road traffic injury mortality rates, by NZDep2013 quintile and sex, 2014–16



Source: New Zealand Mortality Collection.

Understanding this, the lower market for newer cars in New Zealand, our aging vehicle fleet and unacceptable crash rates. It is unacceptable to just “wait” for the fleet to turn over to these newer and safer vehicles we need a retrofittable solution. This project aims to be that solution one that democratises safety, gifting and improving the safety tech, previously restricted to only the richest in society, to all.

Method

A New Zealand-specific mobile app supporting drivers in real-time

This project aims to support safer driving through a digital app-based medium. The programme strategically addresses the main causes of crashing:[4]

- Speeding
- Distraction due to mobile phone use
- Driver fatigue/tiredness
- Driving in Adverse Weather Conditions.

The development of a safety-focused real-time app for use is a timely response to the increasing need for effective interventions to combat risky driving behaviours. As the use of smartphones and navigation apps continues to rise (roughly 75% of all smartphone users use navigation apps),[9] there is an opportunity to leverage this technology to promote safer driving practices. A digital app-based solution has other benefits - by developing it for New Zealand, rather than an international one-size-fits-all approach - a customised more effective solution will be made for our unique road, vehicle, and weather conditions. The app's design incorporates navigation - enabled by industry-leading trusted services, to provide utility to users while also incorporating real-time interventions to address some of the major contributing factors to New Zealand's unacceptable road toll.

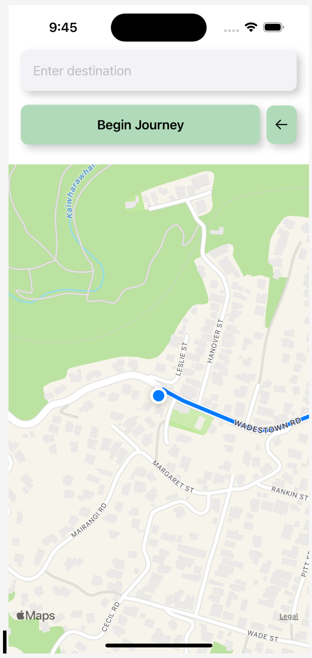
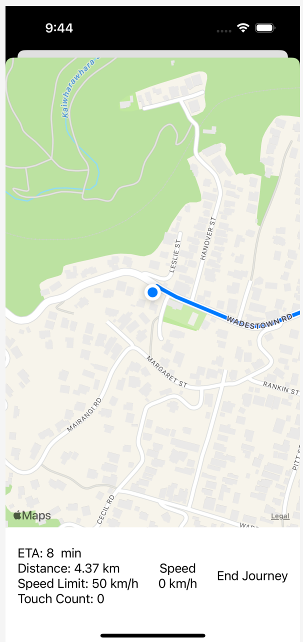
Stages

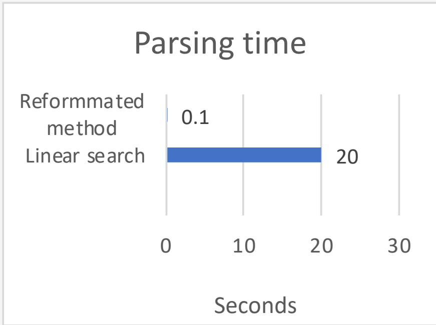
An iOS navigation app was created that collects GPS mapping, accelerometer, phone interaction and weather data over typical user journeys. The phone's calculated speed data was combined in real-time with Waka Kotahi's National Speed Limit Registry to identify episodes of speeding. And similar detection methods were created to identify other crash-causing factors.
Please refer to **Technical Methods.**

Intervention methods were created and suitable "nudge" messaging was developed to provide audio messages that were triggered when risk-inducing activities were detected (infractions).
Please refer to **Intervention Design and Messaging Design**

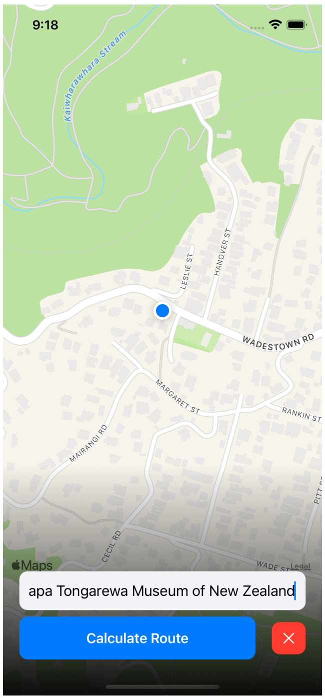
A real-world deployment of the application was undertaken with members of the public to understand the potential effectiveness of the application. An opt-in data collection methodology was developed enabling the application to collect large volumes of driver data. Apple's TestFlight platform was used to distribute the app to volunteers recruited via a variety of methods.
Please refer to **Experiment Design**.

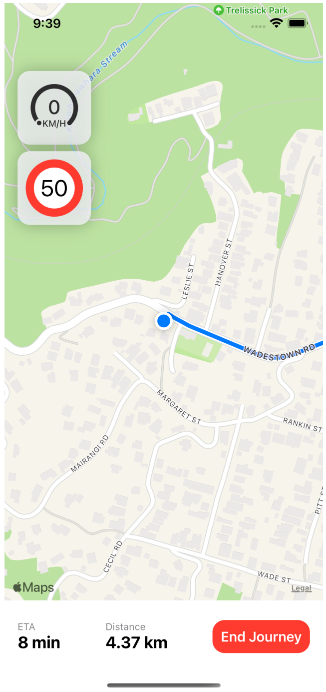
Calendar/Log

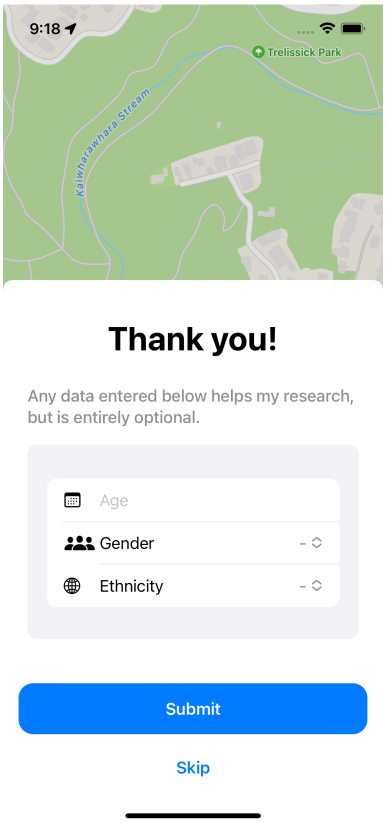
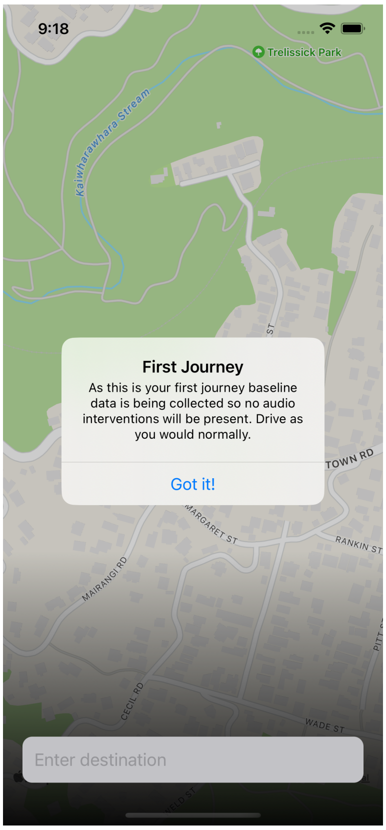
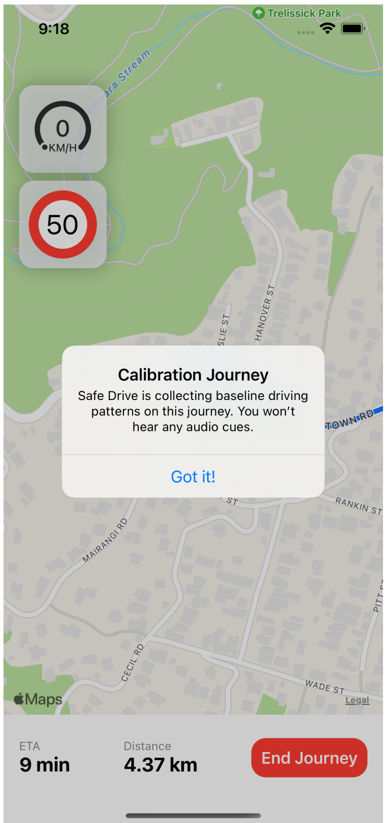
Date	Progress
Febuary 1st	Began planning and brainstorming: What impacts on the road should this project combat?
March 20th	Research done on nudge based interventions and use of technology/apps.
March 25th	Decided on development program - Xcode as I have an iPhone and that was the most convient for devoping.
April 1st	Began working on baseline mapping functionality - designing a barebones mapping app with route calculation etc.
April 28th	Barebones map and route calculation working. Done using Mapkit and Swift UI  
April 30th	Began working on developing the speeding intervention. Did research on where to source accurate speed limit data.
May 5th	Decided on the National Speed Limit Register (NSLR) with a direct download (Saved on user device) rather than using API calls, as using API calls would not allow for offline use.
May 15th	Tested bespoke methods to istantanously search the speed limit datbase although having quite a bit of difficulty.
May 20th	Tried using R-Trees but found it difficult to implement - finally got a bespoke linear search working however the process was unusably slow and CPU intensive, inducing lag in other parts of the app.

May 23rd	Got in contact with the creaters of the GeoJSON framework who assisted by revising their own framwork to solve my issue and provide a fix for all future people with similar problems:
May 30th	After implementing the new solution, infromed by the GEOJSON the parsing time decreased immensely, with testing showed this improvement: 
June 2nd	Finally finished implementing the speeding intervention detection by adding functionality to backround monitor and detect when the user is speeding.
June 10th	Coded the distraction intervention detection - Is the user touching the phone and moving?
June 20th	Did reasearch on how to source free, accurate and importantly realtime weather data, settled on https://www.weatherapi.com/. Then finshed of the driving to conditions intervention.
June 23rd	Built out the logic for the final intervention type that being: driver fatigue.

<table>
<tr><td>July 1st</td><td>Extensive weeks of internal/beta user testing of use. Are the interventions being called correclty, is the ui working as expected, etc?

This led to many bug fixes and polishing/optimization. I also modified the UI here for optimisation and clear communication:



</td></tr>
<tr><td>July 12th</td><td>Built out the data logging system utilising Firbase analytics connected to Google Big Querey's SQL database.</td></tr>
<tr><td>July 15th</td><td>I then had to begin designing the experiment/testing set up which first meant linking the app up to apples testflight framework. This allowed for easier distribution. Then having to learn web design to build out a website which offered instruction on the install process and backround - <u>safedrive.nz</u></td></tr>
<tr><td>July 17th</td><td>The app was now live on the apple app store connect platform which was the portal for TestFlight distrubution and user tracking:</td></tr>
<tr><td>July 20th</td><td>Met with clinical psychologist Kennedy Mclauchlan and trasport psychology expert Bridget Doran to refine/design the interventions.</td></tr>
</table>

July 23rd	I then had to do further testing alpha testing with a small group of friends and family testing the data collection - this introduced a few errors which had to be promptly adressed. Another aspect of this alpha testing was user onboarding modifications many alpha users had problems with the UI and a lack of understanding of the experiments “basline” journey. So I introduced better onboarding and explanation:
  	
July 26th	Finally I sourced the data collection testers from further friends, family, teachers, parents collegues, grandparents, grandparents friends - as many people as possible. As alpha testing was complete, and the apps functionality had been tested along with any bugs quashed, this second group of testers would be collecting the projects data. From here began the study which continued for around two weeks (users were suggested to complete 4+ journeys)
August 18th	Data analytics and writeup

Technical design

Detailed technical methods have been omitted due to the public nature of this report. They will be present at the in-person science fair.

1. Technical Design and App Development:
The app was developed using Apple's XCode and Swift programming language, leveraging the “MapKit” for basic mapping functionality. Significant custom development was necessary as many navigation app features were not pre-built. The use of Apple’s SwiftUI framework facilitated UI/UX construction and optimization for lower-end smartphones.

2. Speeding Intervention Design:
The app's design addresses speeding by integrating complex technical components:

- **User Speed Determination:** This involved accessing the phone's accelerometer, gyroscope, and GPS to obtain raw speed data, which was then smoothed using an Exponential Moving Average algorithm for accuracy.
- **Nationwide Speed Limits:** Instead of camera-based systems, this project utilized the National Speed Limit Register (NSLR) from Waka Kotahi, providing updated GeoJSON files of New Zealand's speed limits.
- **Real-time Speed Comparison:** The app identifies the polygon (from NSLR) the user is in, compares it with the user's speed, and triggers interventions if necessary. Initial methods were inefficient, leading to collaborations with GeoSwift for an optimized solution.

3. Calculating Time and Risk Estimates:
The speeding solution categorizes severity based on the duration of speeding and the amount that exceeded the speed limit. The app calculates time saved from speeding using a general formula, and the risk of crashing is assessed using Nilsson's power model.

4. Driver Distraction:
To counteract driver distraction, the app silences notifications during journeys, detects phone usage while driving, and issues audio warnings. A stand-down period is set to prevent repeated alerts.

5. Driver Fatigue:
For long journeys, the app prompts drivers to take breaks every two hours, adhering to Waka Kotahi's recommendations for combating fatigue.

6. Driving to Weather Conditions:
The app integrates weather data to provide real-time audio cues for driving safely according to varying weather conditions. This feature was enabled using a weather API that suited the project's budget constraints.

Intervention Design

Nudge theory

The proposed safety-focused mapping app embodies principles of ‘nudge theory’, a concept developed by Thaler and Sunstein.[10] This theory suggests that subtle changes in the way choices are presented can influence behaviour, steering people towards safer or more beneficial actions without the need for legislation, regulation, or overt coercion, much like the ISA system, which provides audio feedback when drivers exceed speed limits, the project app ‘nudges’ positive behaviour with real-time audio alerts.

Nudge-based interventions have shown success in various domains; for example, the National Highway Traffic Safety Administration found that seat belt reminder systems, a form of nudge-based intervention, increased seat belt use, leading to fewer vehicle occupant fatalities.[11]

Audio as the modality

The solution uses audio as the intervention modality. First, audio is less distracting than a visual cue, and it was important not to encourage drivers to look at their phones. Second, it creates accountability for the driver by allowing the passengers in the car to also hear the alerts. A 2001 study by Monash University Accident Research Centre discussed the effect passengers can have on driver behaviour.[12] It concluded with a recommendation ‘to empower people to speak up as passengers if they feel that the driver is compromising their safety’ due to its largely positive impact on driver speeding behaviour.

Finally, the auditory alert complements the predominantly visual nature of driving, supporting safety stimuli from multiple senses.

Avoiding intervention fatigue

Nudge-based interventions, though often effective in influencing behavioural change, are not without their potential downsides, one of which is ‘intervention fatigue’. This phenomenon refers to a decline in responsiveness over time as the recipient becomes desensitised or even irritated by repeated nudges, thereby reducing the effectiveness of the intervention.

The interventions were then designed, with the assistance of a clinical psychologist, to combat intervention fatigue using graduated prompting, thematic grouping, and temporal scheduling.

- **Temporal Scheduling** - This involves timing nudges optimally to ensure that they are not too frequent, which can reduce their effectiveness. This also means scheduling nudges at intervals that allow sufficient time for the user to process the previous nudge and respond without feeling overwhelmed by continuous notifications.

- **Thematic Grouping** - This entails grouping related nudges to form a more cohesive and meaningful intervention. This can help the recipient see the larger picture, making the intervention feel less like a series of disjointed prompts and more like a guided journey, thereby increasing the likelihood of engagement and reducing the risk of fatigue.

- **Graduated prompting/ Intensity Escalation** - This refers to the gradual increase in the strength or urgency of the nudge. For example, initial nudges might have more subtle phrasing, but if these are ignored, subsequent nudges could be more emphatic and describe consequences.

Messaging Design

The audio messaging of the interventions had to be carefully designed using guidance from published research, existing ISA methods, and the fundamentals of nudge theory. In conjunction with this, the expertise of a clinical psychologist and a specialist in transport psychology was sought.

Important factors included:

- **Accuracy/timeliness** and the 'Cry wolf' effect.
- Ensuring the intervention itself was **not a source of distraction.**
- The methods of **nudge-based intervention**, including thematic grouping, temporal scheduling, and graduated prompting/intensity escalation

The cry wolf effect is a psychological term that refers to '*a user's tendency not to trust automation or failure notifications after there have repeatedly been false alarms'* and is often applied in the context of evacuation and weather warnings. This was raised in meetings with clinical psychologist Dr McLachlan around the importance of accuracy and timeliness.

As discussed in the intervention design, all the interventions were auditory for several reasons, including the need to limit distraction. Unlike a visual alert that pops up, requiring the driver to take attention off the road, the use of audio ensures that distractions are minimised. However, in using audio, messages had to be concise and digestible. Long messages could potentially create confusion or become a distraction in themselves, so careful consideration was needed in crafting the content of these auditory alerts. The content of the messaging was guided by the results of the article 'Effects of Different Intervention Methods on Novice Drivers' Speeding[13] and these discussions with experts to lean towards the more factual and consequence tone.

A study commissioned by Microsoft placed the average attention span of adults (those who drive) at 8 seconds when listening to unexpected audio messages[14] i.e. not radio, podcasts, music etc, thus the interventions were all designed to be less than this.

Individual messaging design:

Speeding

To ensure the act of exceeding the speed limit was indeed a “speeding infraction”, a duration and speed threshold was defined. This was set at 4km/h over the speed limit which generally aligns with the level for police infringement and greater than 10 seconds of exceeding the speed limit. 10 seconds is the accepted time it takes to overtake (at least under urban environments), which aligned with what was noted during physical testing in and around Wellington.

Temporal scheduling was especially important for the speeding intervention as following the audio message, the driver had to be provided time to react, and lower their speed below the limit/threshold, if not annoyance and intervention fatigue would arise.

Accordingly, a buffer period (around 7 secs), if the speed remained above the limit of the 4km/h threshold, was instituted, a stand-down period, after which the ‘severity level’ would increase if the speed stayed high - following the principles of graduated prompting. That is, more information about the potential ramifications was provided with each severity level: at Level 1, a reminder of the current speed limit, at Level 2, highlighting the minimal time gained in the journey by speeding, and at Level 3 the increased risk of a crash. Together these interventions help inform and guide a user towards the counter intuitiveness of speeding, minimal benefit, and maximum risk, and in turn a response to the intervention.

The language of each level was also modified in line with graduated prompting/ intensity escalation, with changing from “Heads up”, to “Hey!” to finally “Warning!” Another example of this intensity escalation is the duration of audio increases at each severity level, whilst keeping below the 8 sec threshold, thus commanding more attention as the user’s risk and risk to others on the road increases. The idea of thematic grouping is also seen here as we “tell a cohesive story” Of risk with each new prompt.

Adverse Weather Conditions

In terms of timeliness, it was decided that the weather intervention be called at the beginning of the journey and whenever the conditions changed. The accuracy was then essential as if the audio intervention were to contradict something as blunt and visually clear as the weather, trust in the app would be lost and it would undermine future alerts. The accuracy was validated through a series of in-vehicle tests where it was ensured that conditions described by the app aligned with reality through Wellington-based suburbs. The message utilised aimed to convey the recommendations of Waka Kotahi around driving in adverse weather conditions (headlights, slippery roads etc.)

Distraction

The distraction audio cue plays when the phone detects interaction whilst the user is in motion. This in its nature aligns with the goals of accuracy and timeliness and is an important design feature as it prevents false flags i.e., an alert is triggered when the user is not at risk. This could have occurred (for example) at a red light when interacting with your phone does not generate any additional risk.

The intervention for distraction due to mobile phone use is an easily triggered one so temporal scheduling was important. The stand down between each intervention was 30 sec, a “cooldown” timer before the next intervention could be triggered. The 30-second allows for a measured approach that respects the urgency of some situations where phone usage might be unavoidable.

Fatigue

The Driver fatigue intervention's design, in line with Waka Kotahi’s suggested 15-minute break every 2 hours featured a simple 2-hour timer activated during long journeys, inherently ensuring both timeliness and accuracy.

Like the speeding intervention, the driver fatigue one reflected the ideas of repetitive prompting though in a slightly less aggressive nature to respect autonomy and choice, limiting the impact of intervention fatigue. Temporal scheduling was applied here, after the first intervention was triggered, allowing up to a few hours before further reminding the user.

The messages ultimately designed and used are given in the table below:

“You’ve driven for 2 hours. Consider a 15-minute break for safety and focus”

“Heads up. The current weather condition is rain. Please drive carefully as roads may be slippery and turn on your low beam headlights to lower crash risk”

“Stay safe while driving. Phone use leads to a 2.8x crash risk.”

“Heads up! The speed limit here is 50km/h.”
“Hey! If you keep driving at this speed, you'll only arrive 45 seconds earlier."
“Warning! At this speed, you're 1.5x more likely to have a major crash. Please slow down.”

Expert input in the design process:

In meetings with both clinical psychologist **Kennedy Mclauchlan** and transport expert **Bridget Doran**, I gathered the following feedback, advice and insights:

Kennedy Mclauchlan:

From a psychology standpoint, the meeting mostly confirmed what I already knew. That nudge-based intervention through making the driver aware of risks was the best. Kennedy also suggested further embodying the idea of intensity escalation by making the initial messages more positive. g "Heads up" and "Hey" The thinking behind this is that individuals would be more likely to respond to more positive messaging. Kennedy also raised the aforementioned "Cry wolf effect"

Bridget Doran:

Bridget was invaluable in providing insight into the status quo (Road to Zero) of transport safety and in doing so was able to help edit, modify and agree with my project. Furthermore, she helped decide on what data would be useful to collect (See experiment design)

Experiment design

Definition of terms:

Infraction – refers to the act of speeding, becoming distracted, or becoming fatigued.

Intervention – refers to the subsequent audio messaging of infractions for non-baseline (audio-enabled) journeys.

This was not designed to be a full trial, but a proof-of-concept with a smaller number of users to determine accessibility and see if there was evidence of effectiveness. There were two main components in designing this project: first, was it technically feasible, and second, would it influence human behaviour to create safer driving? To assess the latter, the app had to collect data and analyse behaviour before and then with the audio interventions.

Sourcing testers

One of the most difficult parts of a research project was to find willing participants. The following methods were used to find testers: presentation to a large cohort of teachers at school, friends and family, and the online Geek Zone forum. These willing testers were then asked to complete 4+ journeys with the app-enabled.

Collecting baseline data

The experiment must be designed in a way such that we have a level of baseline behaviour to compare against and thus measure the effectiveness of the interventions. To do this, a technical solution was created to detect if it was the user's first journey using the app, which then disabled the audio interventions whilst still logging all data just with the added parameter to identify that data as a baseline. As an additional step, the user had to officially 'finish' this first trial by arriving within 200m of their destination. This ensured that in exploring the app's interface the user did not instantaneously start and finish a baseline journey with no logged data.

User instruction and accessibility

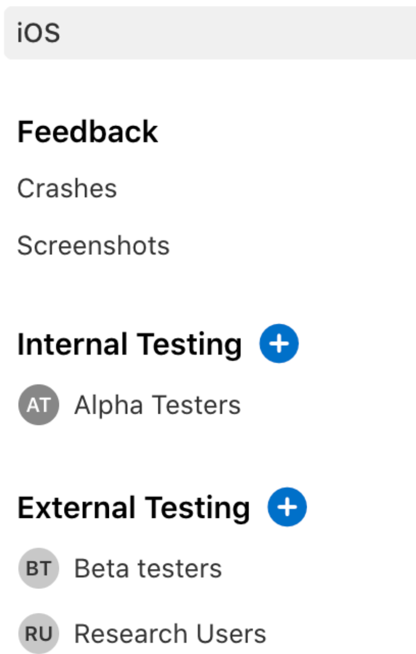
To distribute the app to many users in an efficient manner and accessible manner, the in-built TestFlight framework was used which allowed distribution with a simple link. However, the installation process can still be confusing for those not familiar. A user-friendly explanatory website - safedrive.nz - was created detailing the installation process and what to expect.

- "Easy to install for an "older person!"

To ensure the authenticity of the data the participants had to be blinded from the nature of the app's interventions. Thus, the website did not specify the interventions in detail and instead described it as a "Safe driving app". Following the installation, the users were informed at three separate points about baseline data collection and that audio interventions were switched off for their first journey(s) and thus they will not hear anything. This was important as early in the developing process, alpha (testing basic functionality) feedback was received suspecting the app was broken as there was "nothing safe about it." - (See calendar July 23rd)

Data collection and anonymisation

The app was released to both alpha (testing basic functionality/ui/ux see **calendar**) and then beta (for data collection) testers sequentially to ensure smooth data collection. To ensure the anonymity of drivers, a randomly generated user ID was created for each device which was then logged with all subsequent data. A similar ID was also created for each journey that was logged and then was affiliated and logged with all infractions and events occurring within that individual journey. The platform used for this cloud-based data logging was the free Google Firebase, as it allowed linkage of the logged events to the free Google Big Query SQL data analysis platform, where the data could then be exported to Excel sheets.



Data logged:

To perform analyses of the effectiveness of interventions the experiment had to be designed such that all relevant and important data was logged. The specifics of that data are in the table below:

Data Logged

Frequency	Once on start-up	Every 4 secs during journey	At the beginning of a journey and when conditions change	At the beginning of a journey	On the event of a speeding infraction	On the event of a distraction infraction	On the event of a fatigue infraction
Event Name	**user_event**	**speed_log**	**weather**	**journey_event**	**speeding_intervention**	**distraction_intervention**	**fatigue_intervention**
Data Logged	*age*	*journeyId*	*journeyId*	*destination*	*current_speed_limit*	*journeyId*	*timestamp*
	ethnicity	*speed*	*timestamp*	*distance*	*error_value*	*timestamp*	*journeyId*
	gender	*timestamp*	*userId*	*eta_hours*	*firebase_error*	*touchCount*	*userId*
	name	*userId*	*weather_condition*	*eta_mins*	*journeyId*	*userId*	*legnth_into_journey*
	userId			*is_first_journey*	*location*		
				journeyId	*risk*		
				location	*speed*		
				timestamp	*threshold_level*		
				userId	*timestamp*		

User Demographics

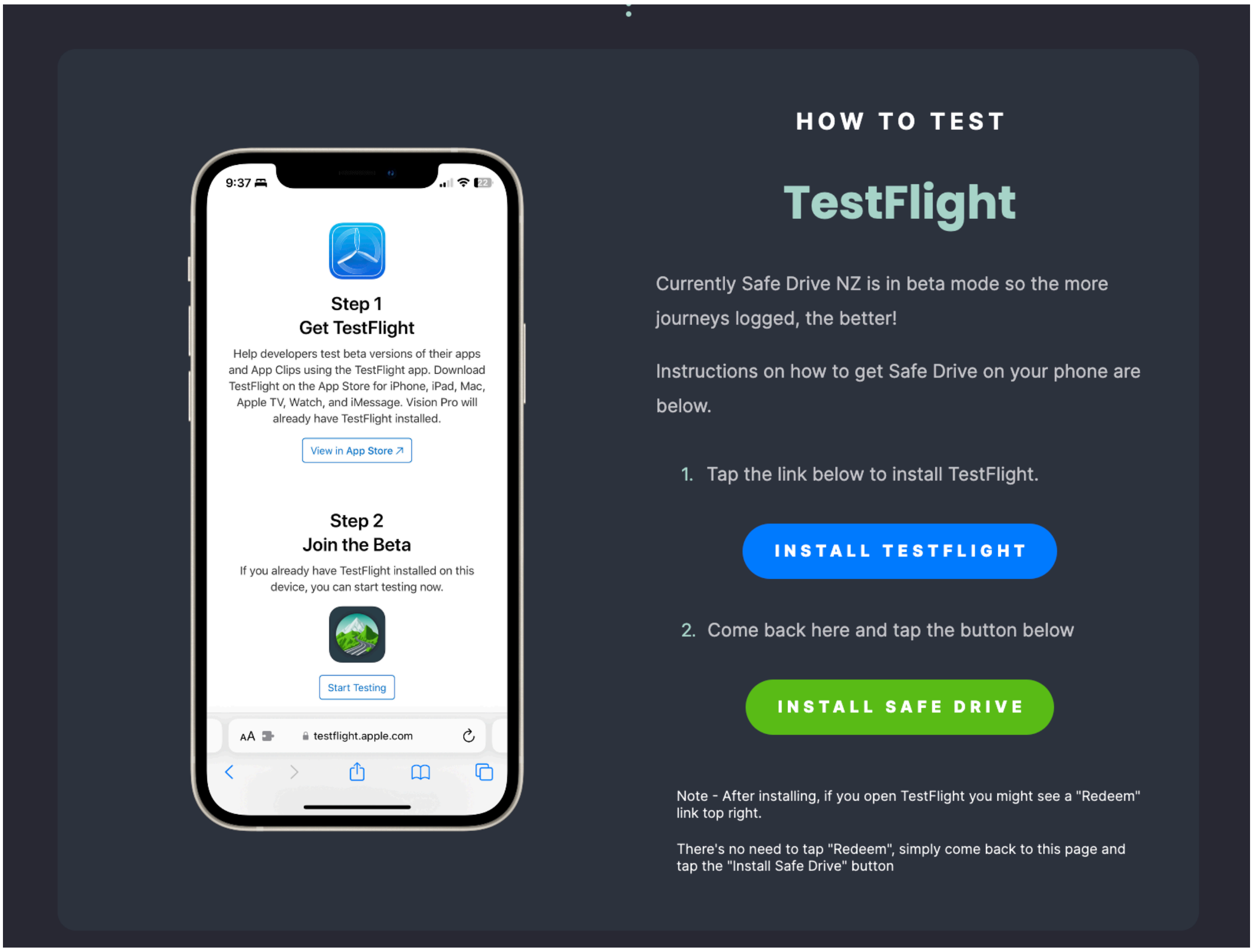
Testing of the app was undertaken with 30 users. These users were from 3 cities (Nelson, Wellington, and Christchurch). Their age was 16-75 years

Type	Values	n	%
Age	16-25	4	17.39
	26-35	4	17.39
	36-45	9	39.13
	46-55	4	17.39
	56-65	0	0
	66-75	2	8.7
	Total	23	100%
Ethnicity	NZ European	23	79.31
	Maori	2	6.9
	Other	2	6.9
	Pasifika	2	6.9
	Total	29	100%
Gender	Male	19	65.52
	Female	8	27.59
	Other	1	3.45
	Prefer not to say	1	3.45
	Total	29	100%

Note: As submitting was optional there may be some discrepancies in the totals.

Website design

During the trial period, the website was designed to provide clear concise and accessible instructions on how to install the app using TestFlight, the design was done using CARRD a website design software (Similar to Wix etc) for its simplicity. I also decided to purchase the domain safedrive.nz as it creates a memorable and easy experience to locate the project.



Analysis & Results

Analysis Methods

To evaluate the effectiveness of the interventions, two methods were used. One, in which each user acted as their own 'control' where the driving behaviour in journeys using the audio cues of the app was compared against their driving behaviour in journeys without the audio (baseline). Second, this data was pooled for all users and the rate per km was compared between the audio journeys and the no-audio (baseline) journeys. Additionally, other outcome measures calculated from the data were included:

- The number of infractions per km - pooled and paired analysis (speeding infractions, distraction infractions)
- The severity of the speeding infractions
- Change in speed after hearing audio interventions.
- Behavioural trends: number of infractions per km on each subsequent journey

Speeding Results

Speeding was the most frequent infraction type with over 300 records logged. When comparing the overall ratio of speeding infractions to journey distance (infractions per km), for both the baseline (no audio) and subsequent audio journeys, we see a significant decrease of around 35% with the project's audio interventions enabled.

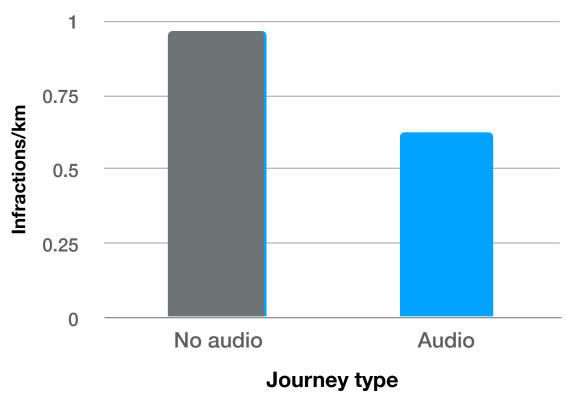


Fig. 1 - Speeding infractions / km

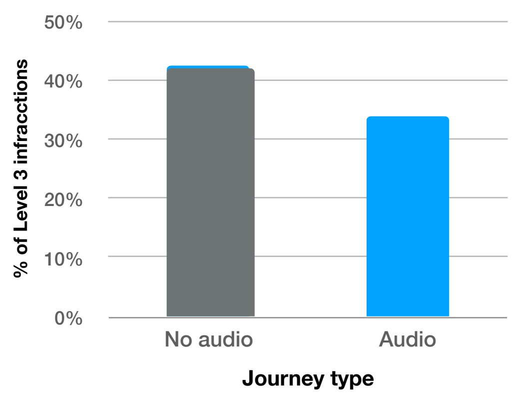


Fig. 2 - Level 3 infarctions / km

Distraction Results

Similar to speeding, a 35% reduction in distraction infractions per 100km was observed when the app's audio interventions were active. As the volume of data for distraction infractions was much lower than speeding infarctions the results may have less precision or reliability.

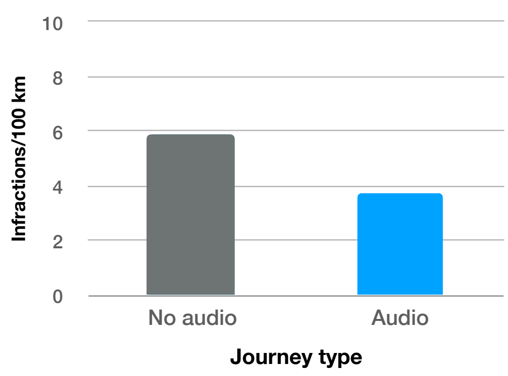
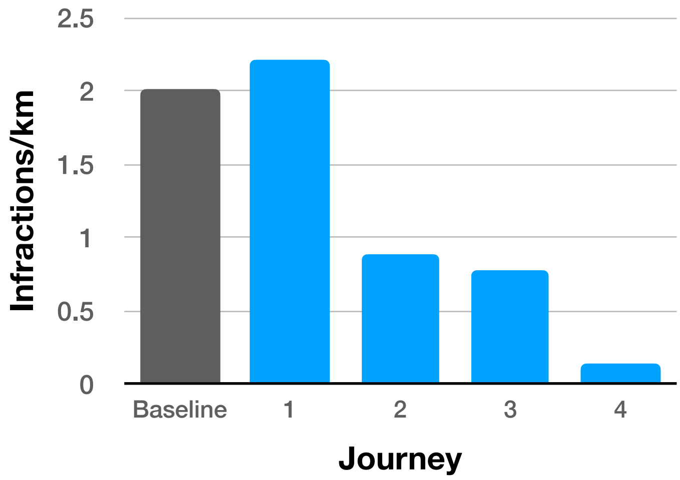


Fig. 3 - Distraction infractions / 100km

Behavioural Trends

In comparing the ratio of speeding infractions per km over subsequent journeys there was evidence of an encouraging trend across the user group. An unexpected observation was a consistent peak in interventions during the first journey with audio enabled. This was determined to be due to a 'novelty factor' to the app and user experimentation (see discussion limitations for details.)



The chart below shows a subset of a typical journey with audio interventions enabled. The behaviour changes were evident were replicated across multiple users and journeys. The chart shows a driver exceeding the threshold for >10 seconds with subsequent audio intervention and immediate rapid reduction of speed. No further escalating interventions are triggered.

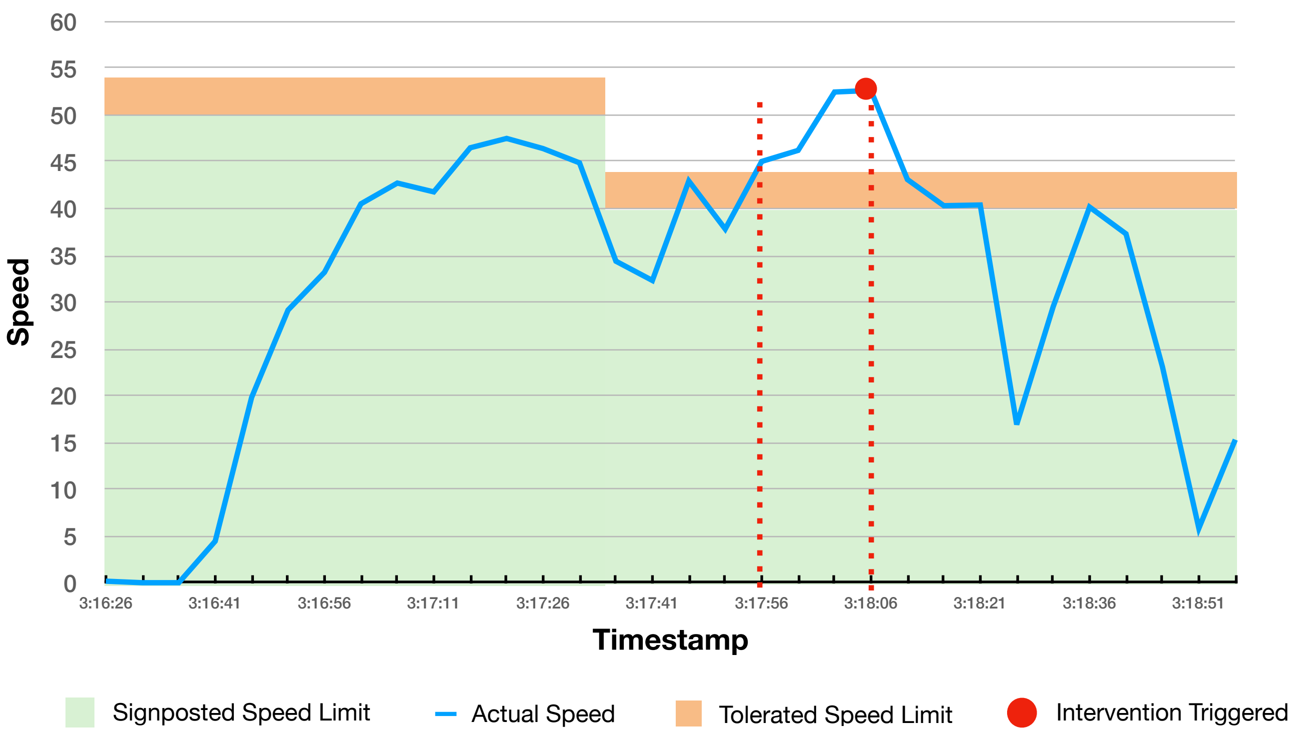


Fig. 5 - Speed and infractions over the course of a journey, case study from a Nelson user.

Paired analysis data:

A paired analysis is the preferred approach as it offers more unique insight into individual driver improvement where each driver acts as their own control. However, due to data collection issues, this was only able to be done on a subset of the drivers so I would need more data to be able to draw any meaningful conclusions. Nonetheless, with that data, we see the majority of drivers displaying improvements in behaviour with the average being a positive.

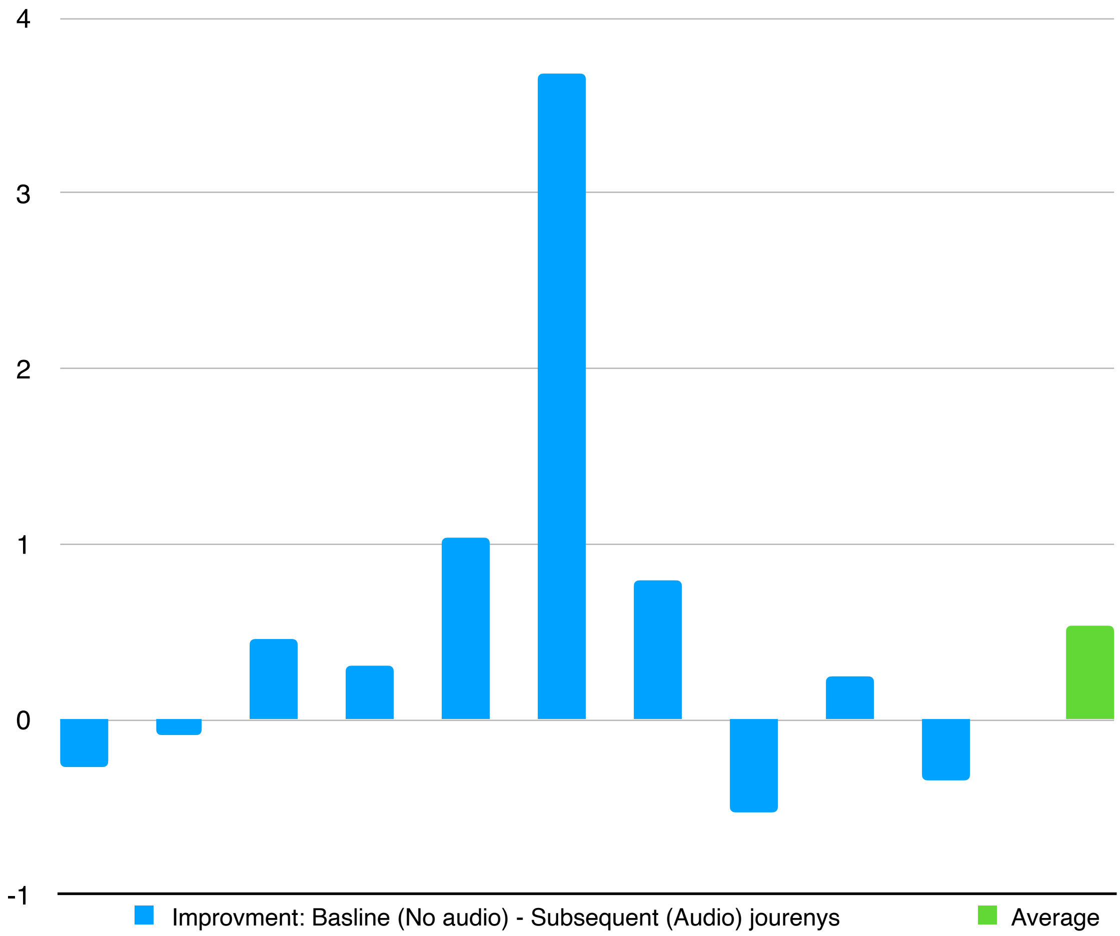
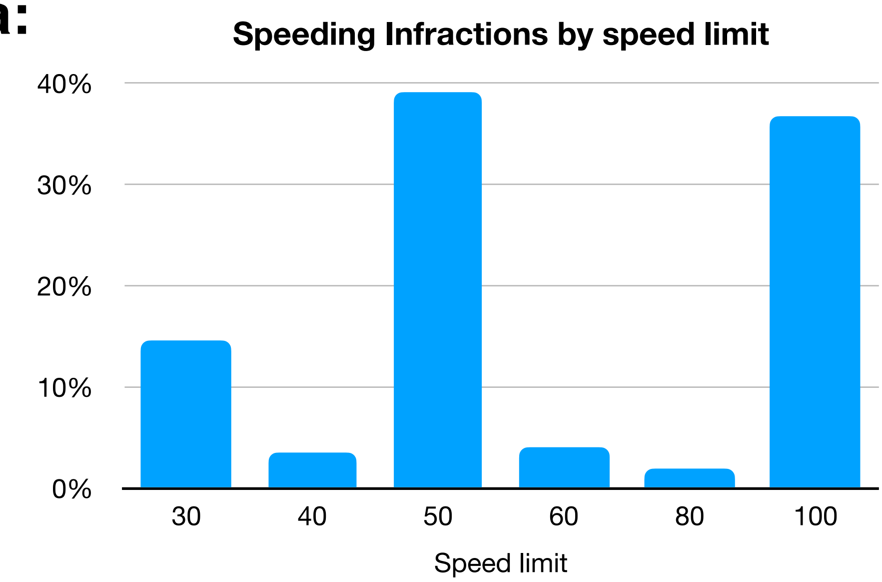


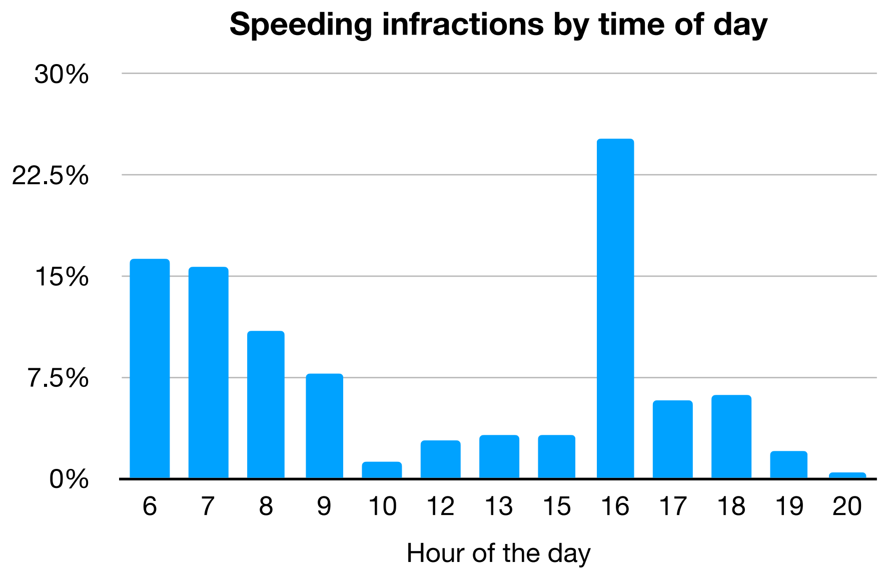
Fig. 6 - Paired analysis data from applicable drivers

Additional data:

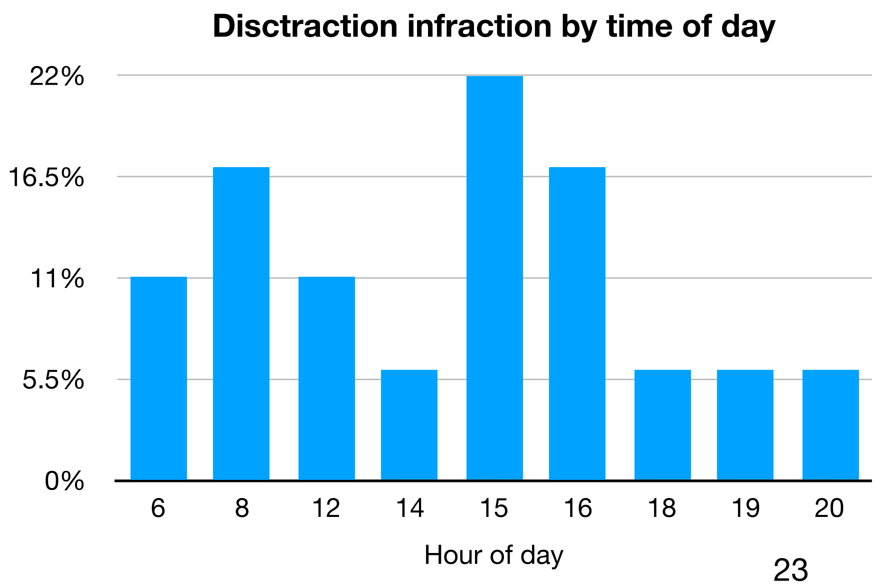
Hour of the	% of total infractions
30	14.7%
40	3.5%
50	39.2%
60	4.1%
80	1.9%
100	36.62%



Hour of the	% of total infractions
6	16.2%
7	15.6%
8	10.8%
9	7.6%
10	1.3%
12	2.9%
13	3.2%
15	3.2%
16	25.2%
17	5.7%
18	6.1%
19	1.9%
20	0.3%



Hour of the Day	% of total infraction s
6	11.1%
8	16.7%
12	11.1%
14	5.6%
15	22.2%
16	16.7%
18	5.6%
19	5.6%
20	5.6%



Comments on additional collected data

The additional data presents an intriguing overview of traffic infractions, breaking them down by type and time of occurrence. For speeding infractions by the speed limit, it's evident that the most common speed limit zones where infractions occur are at 50 km/h, accounting for a whopping 39.2% of all violations, closely followed by the 100 km/h limit at 36.62%. Interestingly, the lower speed limit of 30 km/h sees a relatively high violation rate of 14.7%, which might be unexpected as it's generally perceived as a slow driving speed. The speed limits of 40 km/h and 80 km/h see minimal violations, with only 3.5% and 1.9% respectively. The data indicates that middle-tier speeds (50 and 100 km/h) are the most problematic zones for speed limit violations, which is understandable as these are generally the

When looking at speeding infractions by the time of day, the late morning to early afternoon, specifically around 10 am, witnesses the highest surge of infractions at 22.5%. The subsequent high infractions are during the early morning hours from 6-8 am, ranging from 10.8% to 16.2%. This could be attributed to the rush of morning commuters or the lack of vigilance by drivers during these hours. Similarly, the potential post-work/lunchtime rush at 4 o'clock may be an explanation for the spikes later in the day.,

Lastly, the distraction infraction data by time of day offers a fairly similar perspective. The highest rate of distraction-based infractions occurs around 15:00, accounting for 22.2% of the total, followed closely by 8 a.m. and noon, both hovering around 16.7% to 11.1%. These hours can be surmised as transition periods: morning commute, lunch breaks, and school or work dismissal times. Surprisingly, the evening hours, from 18:00 to 20:00, report consistent distraction infraction rates of 5.6%, suggesting that while the total volume might be less, the consistent rate is still a matter of concern.

Conclusion

An app-based audio road safety intervention program was developed and employed successfully in a sample of ~30 people based in Nelson, Christchurch, and Wellington.

The results of this project were positive, with results suggesting success in promoting safer driving behaviour around excessive speed and distraction due to interaction with a mobile phone. In the pooled analyses, reductions of around 35% of the frequency of these two factors were observed. Additionally, the audio-based interventions led to behavioural change in users, whereby infractions and therefore interventions decreased in frequency with each subsequent journey.

Analyses of the effectiveness of Adverse Weather Conditions and Fatigue interventions were not possible due to a lack of data. More testing is also required to quantify the true effect of the app in a larger sample, in different types of people and road conditions, and over longer periods.

Discussion

This project aimed to support safer driver behaviour. A 35% reduction in speeding and distraction events was achieved in the study sample in the pooled analyses, as well as a reduction in the severity of speeding infractions. The paired analyses, although limited by a small sample, were also positive. Additionally, promising behavioural trends were observed in several study participants, with users showing displays of learning and improvement on subsequent journeys.

Reducing socioeconomic health inequalities in New Zealand is an immediate goal, unfortunately, safety on our roads is currently one of those disparities. New Zealand research shows the mortality rate among Māori is around 2.4 times that of non-Māori and that mortality rates for vehicle occupants increase with socioeconomic deprivation with those most deprived having the highest mortality rate.[15] This inequality stems from the inaccessibility of safety features, such as side airbags and ISA, which are typically found in higher-end vehicles. This app would bridge this gap by providing a cost-effective solution, ensuring that these technologies are available to all drivers, regardless of economic status. The result would be a more equitable road safety landscape, reflecting a commitment to those more likely to be impacted by road fatalities.

The status quo under Road to Zero, is relying on the fleet to organically transition to these newer, more expensive, safer vehicles. Inequitably allowing only the richest in our society to be safer on the roads. Furthermore, New Zealand is a country of older cars, we have one of the oldest car fleets in the OECD and it is these old cheap cars that are making up the majority of the fatal crashes. The solution created here essentially retrofits these older cars with safety features on par and above those of the newer cars, allowing for an equitable road environment.

The project has other positive applications, including access to data. This proof-of-concept demonstrates the capability to aggregate and share anonymous driver data, which could significantly contribute to our understanding of road safety using transportation analytics. Unlike conventional methods such as speed cameras, video analysis, and manual counts, which offer a small number of insights only, this system gathers multiple factors on driving behaviours, road use, and environmental conditions in real-time which is to date unattainable.

This unparalleled access to driver road data has several potential impacts

- **Policy making -** Analysing such a diverse and comprehensive data set, it enables policymakers, urban planners, and traffic authorities to formulate more effective and responsive strategies to traffic flow and road safety risk.
- **Insurance and Liability -** By understanding driving behaviour on a granular level, insurance companies could create more tailored plans and policies. This can also aid in accident investigations.
- **Environmental Impact -** Insights from this data could lead to solutions that minimise fuel consumption and emissions, contributing to environmental sustainability.

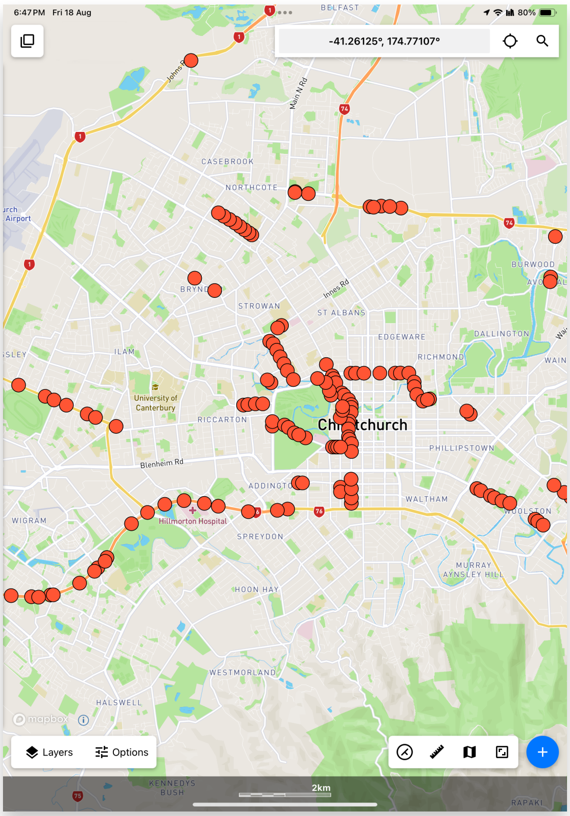


Fig. 7 - Speeding infractions created by Christchurch-based testers

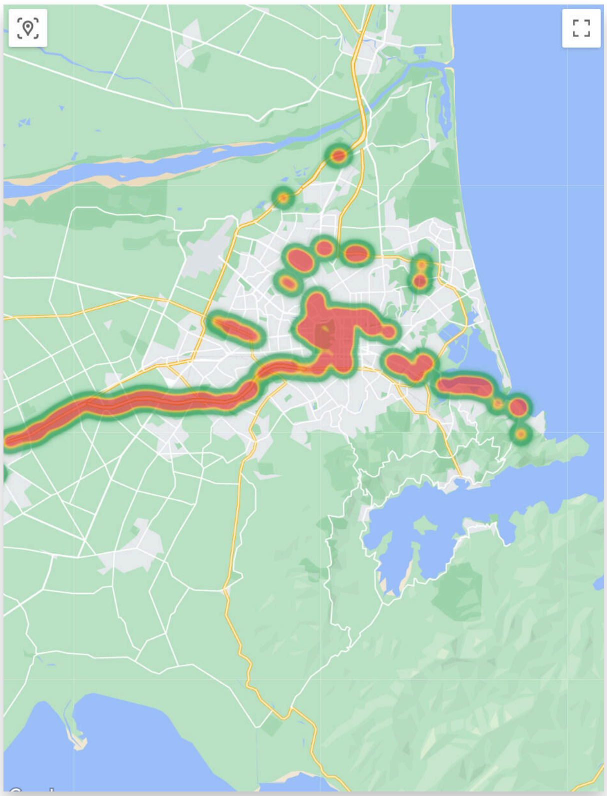


Fig. 8 - Heat map of speeding infractions created by Christchurch-based testers

Limitations

Novelty factor

This led to some users trying to speed to trigger them. One tester said: *“I would have to be honest and say it hasn’t reduced my speeding....perversely it may have increased it as I tried out the travel time feedback!*”. This novelty of the interventions did however dissipate on subsequent journeys.

Small Sample Size

Despite pitching to a cohort of 200 teachers and posting on several local online forums, the number of users was limited, and only 500km of data was collected. This has meant that it has not been possible to analyse the impact of interventions on different people, areas (rural/urban), and road traffic situations. It also limited the interpretation of the paired data analyses.

Driver Fatigue

Another limitation comes when considering the driver fatigue intervention. Waka Kotahi’s generalisation of 15 mins per 2 hours is exactly that - a generalisation. Drivers may fatigue at markedly different rates depending on the time of day, the individual, and various other factors.

Next Steps

Overall, this has been a successful endeavour, demonstrating the technical solution and the potential effectiveness to driver behaviour. There are, however, many areas for improvement and future steps.

It was intended to analyse usability and design using an industry-standard System Usability Scale (SUS), however, the time constraints of the project did not allow it. Understanding this a future step would be to follow up with the users using a System Usability Scale form. This would provide further insight into the accessibility and usability of the app's interface.

One future step would be to introduce feedback at the end of each journey, analogous to a screen time breakdown, giving a 'report-back' to the driver of their behaviour to enhance self-awareness. By presenting a clear and detailed summary of driving habits and trends, users are encouraged to reflect on their behaviour behind the wheel. This reflection triggers a psychological response rooted in self-assessment and motivation for improvement. People naturally respond to visual representations of their actions, and by leveraging this tendency, the feedback system promotes improvement. Additionally, drivers would receive feedback about positive risk-reducing changes they were making.

Another future step would be to run a much larger study with more people from diverse backgrounds across the country. This would provide insight into important variations in how different populations respond to the interventions, potentially leading to more tailored and effective strategies that account for regional, cultural, or demographic differences.

Following on from above an interesting incorporation could be personalising for driver history and details. This could involve considering medical history, car make and model and previous infractions to provide a much more individualised and user-centric system of nudge-based interventions. AI could be of potential use here.

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This is a very interesting study. The social impact will be significant if the App can be released to the market.

This study started from the App development and then was tested with 30 users of different ages (at present). The App design looks efficient and responsive. It is good to see that the App also integrates some psychological features, taking into account human factors. A user study is also included. It seems that the author is now doing follow-up data collection. Overall, the project is highly practical.

However, data presentation needs some improvements. The data analysis is rather descriptive. Whether the improvement is significant is unsure. Measure of fatigue is not included currently. In addition, it is not clear about the propose of ""paired analysis."" We only see the difference between baseline and subsequent journeys. Whether the difference is significant cannot be known without further statistical testing. Besides, Fig 6 needs more illustration. If improvement is (Baseline - subsequent), readers should see more downward histograms (indicating negative) because subsequent is in general larger than the baseline. It is also not clear why ""additional data"" is presented. Can the additional data give any insight to the research questions and findings? Explanation is needed.

Even though there are shortcomings, this study is promising. We expect to see further development of the App with more on-road tests. In particular, to see the actual effects of the App, it is suggested that drivers from different ages should be examined and more complicated statical methods are recommended to apply.