van Vliet, C., Bautrenaite, P., Yavari, M., McCracken, A., Palmbachs, N., Fontaine, B., & Put, C. (2024). The Safer Driver App Decreases Mobile Phone Induced Distracted Driving: Evidence From a Randomized Controlled Trial. *Journal of Road Safety*, *35*(2), 3–13. https://doi.org/10.33492/JRS-D-24-2-2133200

Article Type 1: Peer-reviewed papers

The Safer Driver App Decreases Mobile Phone Induced Distracted Driving: Evidence From a Randomized Controlled Trial

Christine van Vliet[1a], Patricija Bautrenaite[2], Milad Yavari[2], Anita McCracken[3], Nikki Palmbachs[3], Bertrand Fontaine[2], Claudia Put[2]

[1] Psychology, Open University of the Netherlands, [2] Sentiance, Belgium, [3] Royal Automobile Club of Western Australia

Keywords: mobile phone induced distracted driving, digital coaching, smartphone app, behaviour change, road safety

https://doi.org/10.33492/JRS-D-24-2-2133200

Journal of Road Safety

Vol. 35, Issue 2, 2024

Abstract

When using a mobile phone while driving, people are more at risk of causing or being in a crash. To address distracted driving behaviours related to mobile phone use, we developed a mobile coaching app, Safer Driver. The app collects data on a person's driving behaviour and implements behavioural change techniques to help people make smart changes to reduce their distracted driving behaviour. Initially 814 participants were randomly assigned to a 30-day trial period of the Safer Driver app (intervention group, n=573) or the control app (control group, n=241). The control app did not provide any coaching and only collected driving behaviour data. We measured the relative distraction duration score as a proximal outcome. Only participants who were assessed as distracted drivers at the start of the trial were included in our main analysis. This resulted in 182 distracted drivers in the intervention condition who interacted with the Safer Driver app and 86 distracted drivers in the control condition. In line with our hypothesis, the relative distraction duration score was significantly lower at the end of the trial period for distracted drivers who received digital coaching via the Safer Driver app, compared to distracted drivers who received the control app. The findings from this trial indicate that digital coaching via a smartphone application has the potential to decrease mobile phone usage while driving. Digital coaching is a promising way of changing people's behaviour towards safer driving habits.

Key findings

- The data suggest that the Safer Driver app may contribute to a decrease in mobile phone related distracted driving
- Tracking technology and behaviour science are used to improve road safety
- Digital coaching is a promising way of changing people's behaviour towards safer driving habits

Introduction

Distracted driving, particularly related to using a mobile phone while driving, increases the risk of causing or being involved in a crash, leading to injury (Choudhary et al., 2020). According to a large naturalistic driving study (n > 3500 over a 3-year period), the odds of a crash increase by a factor of 2.7-12.2 due to mobile phone interactions while driving (Dingus et al., 2016). Furthermore, an analysis of predicted fatalities on Australian roads by the Bureau of Infrastructure, Transport and Regional Economics (2018) shows an upward trend in fatalities starting from 2016, with an anticipated 20 percent increase in fatalities by 2030 as a result of distracted driving, despite fatality reductions from road safety measures.

Distracted driving is a growing problem exacerbated by the increasing presence of mobile phones in our lives (Chee et al., 2021). Mobile phones have indeed made their way

a Corresponding Author: christine.vanvliet@ou.nl

into the car, enabling a significant source of driver distractions (e.g., handheld or handsfree calling, texting, using the internet, etc.). This increase of distracted driving is associated with high economic and societal costs, such as soaring insurance rates, considerable healthcare costs, and loss of productivity (Centers for Disease Control and Prevention, 2021).

It is well established that mobile phone use while driving has detrimental effects on road safety due to a shift in attention from the road to the phone. Drivers divert attention from driving to make a phone call (handheld or handsfree) or use the phone without calling (e.g., texting). Adverse effects on road safety may include reduced traffic flow, closer following distance, more errors, narrower visual focus, slower speed, and an overall decrease in performance of the driving task (ERSO, 2018). Although slower speeds are typically associated with improved road safety, the type of slower speeds resulting from distracted driving can lead to a decrease in road safety outcomes (Chee et al., 2021).

Addressing distracted driving behaviours related to mobile phone use is therefore paramount. Oviedo-Trespalacios and colleagues (2019) recently reviewed mobile phone applications targeted at stopping, preventing, or reducing phone usage while driving. They found that most applications relied on blocking specific phone functions (e.g., calling, texting) while driving. However, apps that simply block phone functions may not be used or accepted by drivers who consider the effects of using their phone while driving on their driving performance to be negligible.

Although many countries prohibit mobile phone use while driving, outlawing phone distracted driving has had minimal effects on changing a person's behaviour (Nevin et al., 2017). In Australia, the legislation regarding mobile phone use while driving varies by state, but generally, it prohibits hand-held mobile phone use by drivers. Despite this, Oviedo-Trespalacios et al. (2017) observed that drivers often do not recognize the increased crash risk associated with answering or locating a ringing phone, suggesting a gap in awareness and adherence to these laws. Another approach is therefore needed to change distracted driving behaviours related to mobile phone use.

The effectiveness of coaching in behaviour change, within the context of driving, is supported by several studies. For example, Wang et al. (2018) demonstrated the effectiveness of behaviour-based safety education methods in modifying risky driving behaviours. Molloy et al. (2021) provide insights into the efficacy of different feedback modes in improving young drivers' speed management. They found that verbal and graphical feedback were most effective in reducing speeding behaviour. This finding emphasises the potential of well-designed personalised feedback in driving apps to influence driver behaviour positively.

We therefore developed a smartphone application Safer Driver that aims to decrease mobile phone use while driving by addressing the drivers' attitudes, beliefs, and mobile phone related behaviours, rather than simply blocking phone functions such as texting and calling. The coaching-content in the app is based on scientifically validated behavioural change techniques (BCTs) (Michie et al., 2013) and uses a modified transtheoretical model (TTM) of stages of change as theoretical framework to change "addictive" phone behaviours in a driving context (DiClemente & Prochaska, 1998; Prochaska et al., 2015). The original TTM model was developed to describe how people can change addictive behaviours such as smoking and alcohol abuse. We considered the TTM to be an appropriate framework to change mobile phone use (in the context of driving) as mobile phone use has been described as a habitual behaviour (Billieux, 2012; Shambare et al., 2012) and can even turn into a behavioural addiction. For example, people may experience unpleasant symptoms of withdrawal when switching off or being out of range of their mobile phones (Campbell, 2005; Parasuraman et al., 2017).

The TTM sees change as a process for which people go through distinct stages before they make a (lasting) change. Stages of the TTM are: 1) pre-contemplation, 2) contemplation, 3) preparation, 4) action, and 5) maintenance (Sutton, 2001). During the pre-contemplation stage, the individual is not aware of the problems associated with the behaviour and has no intention to change the behaviour. During the contemplation stage, the individual becomes gradually aware of the problems associated with the behaviour but must perceive benefits as exceeding costs to consider changing the problem-behaviour. In the preparation stage, the individual decides to change the problem-behaviour and starts to prepare for the change. During the action stage, change has taken place, but the individual is at (high) risk to return to the previous problem-behaviour patterns. Finally, in the maintenance stage, the new behaviour has been performed for a longer period, and the new behaviour pattern becomes habitual (i.e., long-lasting change).

We developed the Safer Driver app in line with the TTM. However, the existence of the five distinct stages of TTM has increasingly been questioned, and researchers suggest that a two-stage model with a motivational (pre-action) phase followed by a volitional (action phase) better fits the process of change (Armitage, 2009; Heckhausen & Heckhausen, 2008). Please note, TTM is developed with face-to-face therapeutic settings in mind, while the Safer Driver app is a digital behavioural change intervention, which makes the translation of the five stages into a digital space less straightforward. Therefore, we modified the TTM to a two-stage model of change, resulting in a pre-action stage and an action stage. This modification was aimed at making the model more compatible with the digital format of our interventions.

We hypothesised that this approach would bring about a change in the way of thinking about what behaviour is acceptable, resulting in a decrease of mobile phone induced distracted driving. To test this hypothesis, the current study examined whether drivers who interacted with the Safer Driver app, reduced their mobile phone induced distracted driving, compared to drivers who received a control app without any coaching content.

Methods

Participants

Participants were members of the Royal Automobile Club (RAC) of Western Australia. The study protocol was approved by the review board of RAC before the study started. All participants gave their informed consent for inclusion before they participated in the trial and were informed that they could withdraw from the trial at any time.

Participants were recruited through the RAC's social media channels and via email-invitations. People who expressed interest in the trial were provided a registration form, and upon registration were sent a link to the app store. Participants were excluded from registering for the Safer Driver trial if they did not have a driving licence. The trial was available for both phone operating systems and participants registered on an iOS phone (58%) or Android (42%).

Block randomisations were used to allocate participants (n = 814) to the intervention group (n = 573, 70% of the trial population) or the control group (n = 241, 30% of the trial population). Participants could register interest for the trial from 14 May to 28 June 2021. On 15 July, the final participants downloaded and registered within the app. Participants were onboarding asynchronously during the open registration window. In return for the participation, participants entered a prize draw and had the opportunity to win cash vouchers ranging from $50 to $1,000.

We did not ask participants for their exact age, instead they indicated their age-bracket at registration. Age was categorised into seven brackets (<20, 20-29, 30-39, 40-49, 50-59, 60-65, >65). The Chi-square test compared the frequency of participants within each age bracket across the two groups. Our analysis did not reveal a statistically significant difference in the distribution of age categories between the intervention group and control group ($\chi^2(6) = 8.02$, $p = .24$). This suggests that the intervention and control groups were comparable in terms of age distribution, with no age bracket showing a disproportionate representation in either group. Figure 1 depicts the age distribution of the participants.

Mobile apps

We developed two distinct apps to compare people's driving behaviour when they received coaching informed by psychological theory on mobile phone related distracted driving (Safer Driver app) versus no coaching (control app). Participants were assumed to have their mobile phone switched on while driving to enable collection of distracted driving behaviour. Please note any coaching notifications from the Safer Driver app were not provided to the participants when driving was detected (i.e. to avoid distraction during driving), but these notifications were made available in the app after the trip.

Safer Driver app

The Safer Driver app is a coaching tool we developed to help individuals to drive without a mobile phone and be more focused on the road. The Safer Driver app contains several mobile features with scientifically validated behavioural change techniques (BCTs) (Michie et al., 2013) which are introduced according to a modified stages of change model consisting of a pre-action stage and an action stage (DiClemente & Prochaska, 1998; Prochaska et al., 2015). See Table 1 for an overview of the behavioural change techniques incorporated in the app.

Mobile features

Figure 2, Figure 3 and Figure 4 are screenshots of the Safer Driver app. The homepage shows minutes of distracted driving and the last car-trip taken (BCT: self-monitoring) (Figure 2). Behind the button "Learn how to improve" on the homepage, a list of smart tips to drive without phone distraction is provided. Throughout the trial, participants could receive up to 36 smart tips depending on their distracted driving behaviour (BCTs: shaping knowledge, information about consequences).

In the trip-tab, participants can find more information on their car trip, with phone distractions indicated on the car-trip trajectory as red dots (BCT: self-monitoring). Participants were able to edit their trips if information was incorrect (Figure 3).

Additionally, participants had access to other psychoeducational content in the form of a brief course called "Knowledge Bites". Knowledge Bites are small pieces of text (six pieces in total) aimed at teaching the process of behaviour change to the participants and providing suggestions to improve their behaviour (BCTs: shaping knowledge, information about consequences) (see Figure 4). The challenges set specific focused driving goals for the participant. Challenges start off easy and become more difficult as participants progress through the challenges (examples of easy and difficult challenges respectively: "The next trip in your car will be without using your phone. Deal?"; "The more you practice focused driving, the better you get! Drive focused for 150 km.". Please note the distance target is not specific to one car trip, but additive.). A total of 14 challenges were available in the Safer Driver app (BCTs: goal setting, action planning, habit formation).

To increase engagement and motivate people to continue to drive focused, we introduced a mobile feature counting how many distraction-free trips are made subsequently (streaks - gamification; BCTs: self-monitoring).

User-journey

Participants of the intervention group started in the pre-action stage and remained in this stage for seven days. During the pre-action stage, we increased awareness of distracted driving by allowing participants to monitor their driving behaviour in the app. Also, participants gradually received access to the smart tips and knowledge bites to make participants aware of the problems associated with

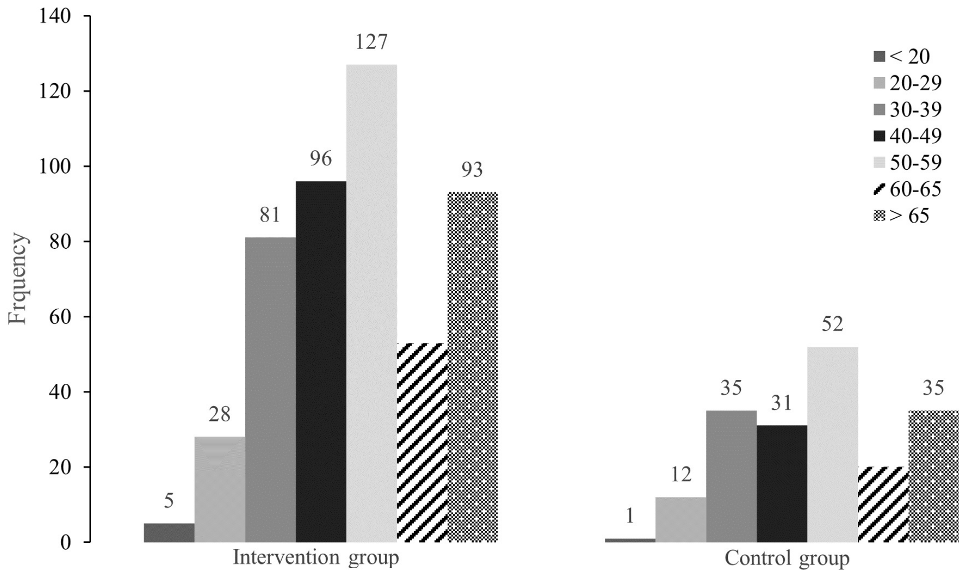

Figure 1. Age distribution of the participants in the intervention and control group

Table 1. Behavioural change techniques (BCTs) selected for the Safer Driver app together with their definition (Michie et al., 2013)

Behavioural change technique	Definition
Self-monitoring and feedback	Establish a method for the person to monitor and record their driving behaviour as part of the behaviour change strategy. Monitoring progress towards the goals and giving users feedback about how well they are doing
Goal setting	Set a goal defined in terms of the behaviour to be achieved
Shaping knowledge	Instructions on how to perform the target behaviour (target behaviour = focused driving / driving without mobile phone)
Information about consequences	Information about social and environmental consequences of (not) performing the target behaviour
Comparison of behaviour	Comparison to past driving behaviour
Action planning	Prompt planning of performance of the target behaviour (e.g., focused driving challenges)
Habit formation	Prompt rehearsal and repetition of the behaviour in the same context (i.e., car) repeatedly so that the context elicits the behaviour

distracted driving and prepare the participants to change their behaviour. Next, participants moved to the action stage and were challenged to drive without using their mobile phone. The challenges increased in difficulty which allowed for distraction-free driving behaviour to be performed over a longer period of time, making the new focused driving behaviour pattern habitual. Throughout the action stage participants received coaching and risk reduction advice in the form of smart tips. Please note these coaching notifications were not provided when driving was detected. Trip-engagement ratio was collected to investigate whether participants engaged with the Safer Driver app after taking a car trip.

Control app

The control app solely has the trip-tab feature in which car trip trajectories are displayed without indications of distracted driving events (see Figure 5). Drivers who had access to the control app, did not receive any coaching during the trial period.

Trial design

The Safer Driver app was evaluated in a 30-day period for each participant. At registration, participants were told they entered a trial to decrease distracted driving and were assigned to the intervention group (Safer Driver app) or the control group (control app). Participants were instructed to allow the necessary permissions to collect data. After the 30-day trial period, participants who received the control app got access to the Safer Driver app. At the end of the trial prizes were distributed.

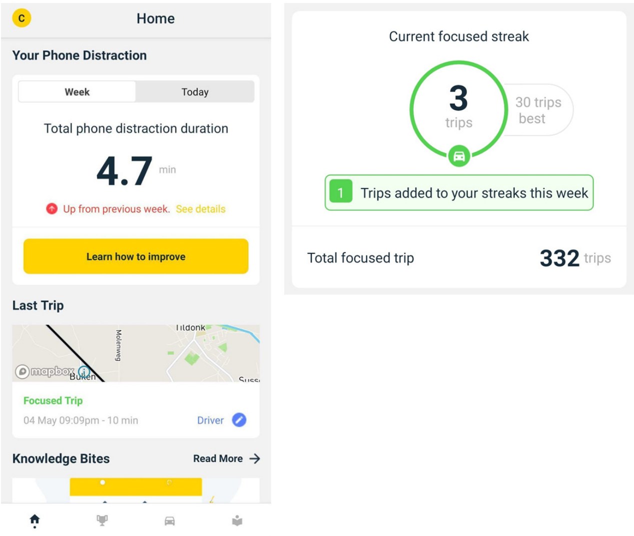

Figure 2. Screenshots of the Safer Driver app

Note. Information for users showing distracted driving behaviours and a focused driving streak count.

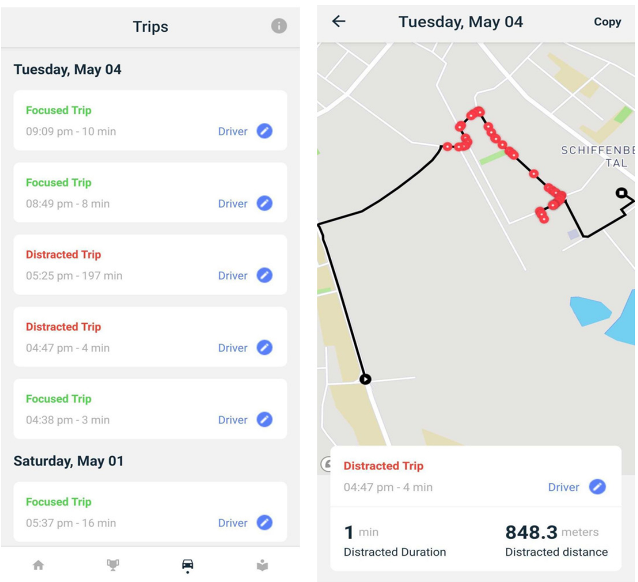

Figure 3. Screenshots of the Safer Driver app

Note. Information for users showing trip details. Red dots on the road trajectory indicate distracted driving behaviour.

From sensor data to phone distraction detection

The software development kit (SDK), developed by Sentiance, NV processes data streams from the mobile device sensors such as accelerometer, gyroscope (if available on mobile device) and GPS, as well as screen, call and crash events. Data collection is initiated once motion is detected. The user location data is lined up with the OpenStreetMap road network to produce map-matching and allow for calculating the distance of the trip (for more information on map-matching methodology see Lou et al. (2009)). The data is processed by the Sentiance platform to create meaningful insights, namely mode of transportation, crash and phone handling detection. Meanwhile sensor data is further calibrated to describe a person's driving behaviour such as acceleration, brakes, turns and speeding. Three types of phone distractions can be detected:

- Handsfree calling;
- Handheld calling;
- Phone usage without calling (i.e. screen events).

Proximal outcome

As the Safer Driver app was intended to help participants drive without phone distractions, we operationalised the proximal outcome as a relative distraction duration score during the first 7 days, and the last 7 days of each participant's trial period (see inclusion criteria and data analysis strategy for more information). The relative distraction duration score is calculated as follows

$$\begin{aligned}&Relative\ Distraction\ Duration\\&= \Big(\sum DistrDuration_{HamdHeldCalling}\\&\quad+\sum DistrDuration_{HamdsFreeCalling}\\&\quad+\sum DistrDuration_{NoCallHandling}\Big)\\&\div TotalTripDuration\end{aligned}$$

The duration of each type of phone distraction during the trip (i.e., handsfree calling, handheld calling, and phone usage without calling) is summed and divided by the total trip duration. The distraction duration is normalised by the trip duration to capture the likelihood of participants using their phone while driving.

Inclusion criteria and data analysis strategy

To answer our research question, whether the Safer Driver app decreases mobile phone related distracted driving, we first determined the distracted drivers in the sample. We defined distracted drivers in the following way. We considered drivers to be distracted when the driver had a minimum of 0.01 relative distraction duration score at the beginning of trial at time T0 (pre-time point: first week on the app; day 1-7), indicating that the participant had used their phone while driving. Bootstrap analysis showed that 7 car trips was enough to have a stable aggregation. Only drivers who had at least 7 car trips at each timepoint, T0 (pre) and T1 (post-time point: last week on the app; day 23-30), were included in our analysis. Furthermore, distracted drivers from the intervention group had to interact with the coaching content provided in the Safer Driver app at least once to be included in our analysis.

We hypothesised that distracted drivers who receive coaching via the Safer Driver app (intervention-Distracted Drivers(-DD) group), decrease significantly in relative distraction duration score compared to distracted drivers who do not receive coaching and receive the control app (control-Distracted Drivers (-DD) group). To test this hypothesis, we performed a 2 x 2 Group (intervention-DD, control-DD) x Timepoint (T0, T1) Mixed-ANOVA on the relative distraction duration scores. With planned comparisons (t-tests), we assessed: (1) if the relative distraction duration score for the intervention-DD group was significantly lower at the end of the trial (T1) compared to the start of the trial

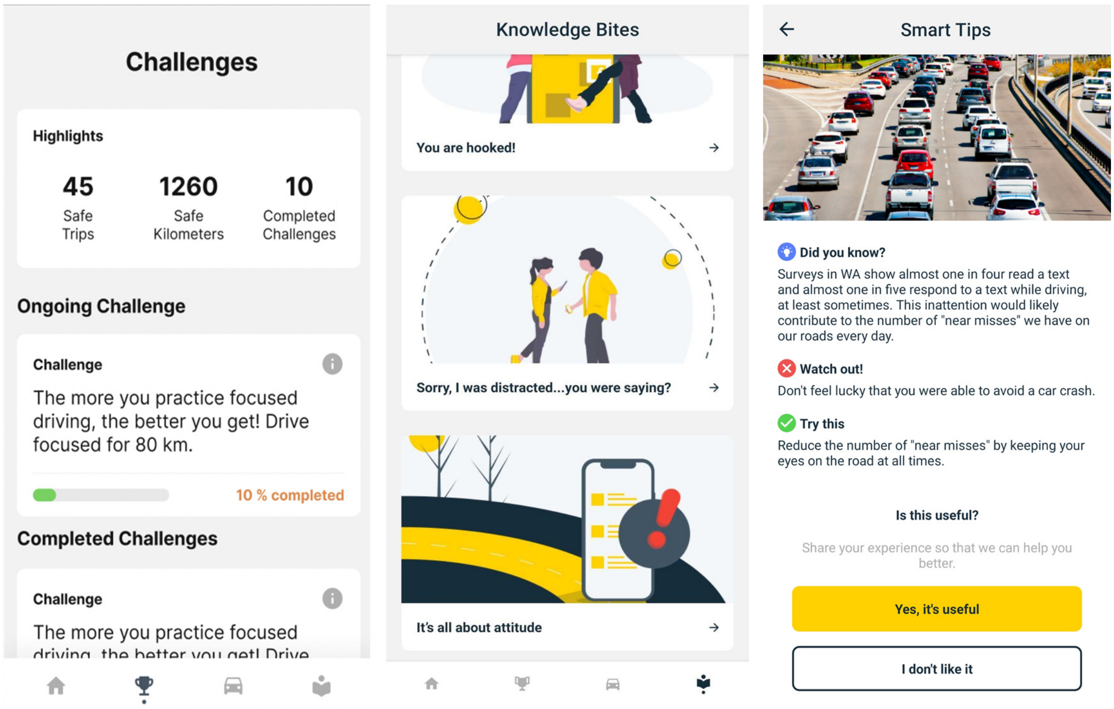

Figure 4. Screenshots of the Safer Driver app

Note. Coaching content for users aimed at changing distracted driving behaviour.

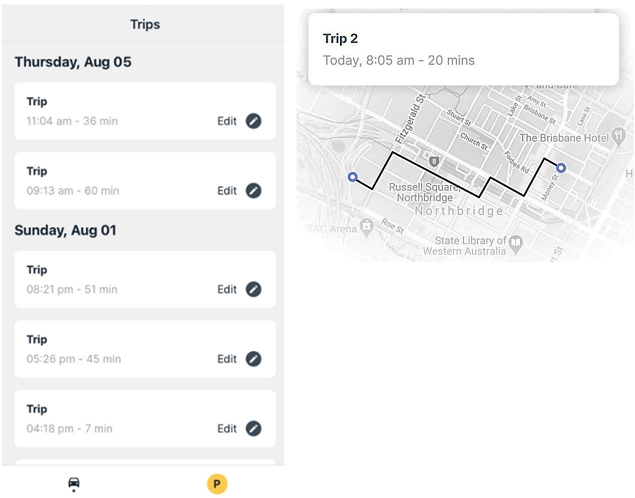

Figure 5. Screenshots of the control app

Note. No behavioural change techniques were implemented in the control app.

(T0) and, (2) if the relative distraction duration score for the intervention-DD group was significantly lower compared to the control-DD group at the end of the trial (T1).

For each significant Mixed ANOVA effect, η^2 is reported. All statistical tests were considered significant at $p < 0.05$. Statistical analyses were run with python software (version 3.9.1).

Results

Participant sample

Of the 814 recruited participants, 268 participants were considered distracted drivers (target population; prevalence of distracted drivers in our trial population: 33%) and remained in the analysis sample (see Figure 6 for the CONSORT diagram). 182 distracted drivers were assigned to the intervention-Distracted Drivers group (intervention-DD group), and 86 distracted drivers were assigned to the control-Distracted Drivers group (control-DD group). See Table 2 for the distracted drivers' sample and trip statistics.

Furthermore, we looked at the trip-engagement ratio to investigate whether intervention group participants engaged with the Safer Driver app after taking a car trip. If a participant engages with the Safer Driver app every time they take a trip (i.e., opening the app on the same or the next day), the ratio would be 1. An average user's trip-engagement ratio was 0.34. In other words, on average, Safer Driver intervention users interacted (i.e. engaging >=10 seconds) with the Safer Driver app 34% of the time after they had a car-trip.

Proximal outcome: relative distraction score

Figure 7 shows the relative distraction scores for both groups. The analysis on relative distraction scores revealed a significant main effect of Group, $F(1, 266) = 4.99$, $p < .05$, $\eta^2 = 0.02$, a significant main effect of Timepoint, $F(1, 266) = 4.99$, $p < .05$, $\eta^2 = 0.02$, and a significant Group x Timepoint interaction, $F(1, 266) = 5.74$, $p = .017$, $\eta^2 = 0.02$. At the start of the trial participants from the intervention and control group did not significantly differ in their relative distrac-

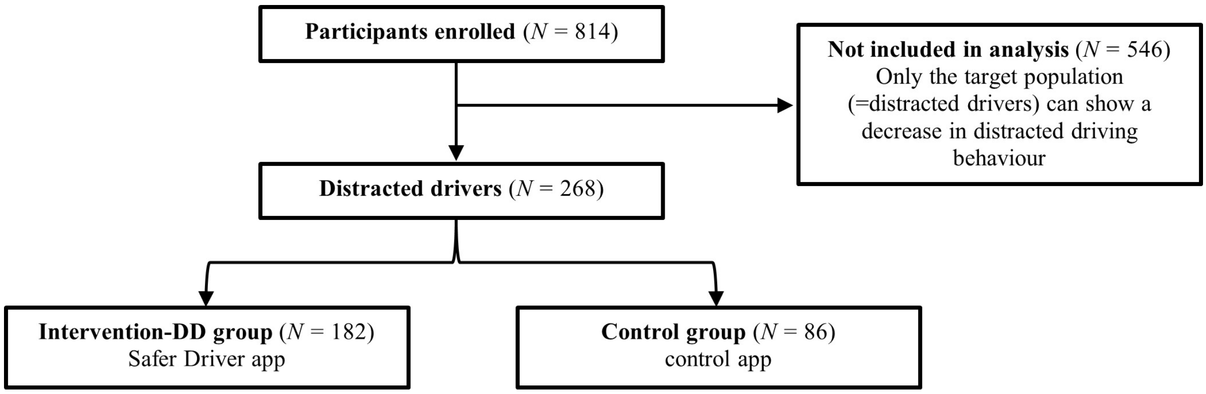

Figure 6. CONSORT diagram

Table 2. Distracted drivers' sample and trips statistics

	Intervention-DD (n = 182)		Control-DD (n = 86)		p-value
	n	**%**	**n**	**%**	
Gender					
Female	85	46.7	38	44.2	ns
Male	67	36.8	35	40.7	ns
Gender not mentioned	30	16.5	13	15.1	
Number of trips	20042	-	9908	-	
	Mean	**SD**	**Mean**	**SD**	
Daily trip count	4.30	0.39	4.70	0.39	ns
Trip distance (in km)	12.70	19.90	11.90	19	ns

tion duration score (t(181) = -1.23, p = .22). Participants who received coaching from the Safer Driver app (intervention-DD group), scored significantly lower at the end of the trial compared to the start (t(181) = 5.30, p < .001, Cohen's d = 0.39), and compared to participants who did not receive coaching (control-DD group; t(266) = -3.75, p = .002, Cohen's d = 0.49).

Discussion

We hypothesised that distracted drivers who interacted with the interventions of the Safer Driver app would decrease in mobile phone induced distracted driving compared to drivers who received the control app without digital behaviour change interventions. We developed two apps to compare people's distracted driving behaviour over a 30-day period: 1) the Safer Driver app containing digital behavioural change interventions aimed at reducing mobile phone induced distracted driving, 2) the control app only displaying car trip trajectories. Both apps recorded trips and mobile phone use while driving.

The results support the above hypothesis. Providing distracted drivers with digital interventions such as: 1) tailored feedback of their driving performance, 2) education on the effects of distracted driving on driving performance, 3) smart tips on how to stay focused while driving, and 4) challenges to drive focused, significantly decreased mobile phone related distracted driving.

In line with our findings, research by Michelaraki et al. (2021) showed the effectiveness of post-trip interventions such as retrospective visual feedback, gamification, rewards, or penalties. They found that gamification and appropriate rewards, combined with strategies like driver coaching and support, appeared to be effective solutions for improving driving skills. This insight complements our approach in the Safer Driver app, where post-trip analysis and feedback could serve as crucial elements in influencing driving behaviour. Furthermore, the role of technology in enhancing coaching interventions is highlighted in the study by Morris et al. (2022). They examined driving performance using the RoadCoach app, a smartphone application targeting risky driving behaviours in older drivers. They observed a reduction in the rates of hard braking and stop sign violations, illustrating the potential of such apps as effective interventions to mitigate risky driving behaviours. This finding is particularly relevant to our study as it demonstrates the efficacy of digital tools in real-world settings, reinforcing the potential impact of the Safer Driver app.

Research shows that theory-informed interventions are more likely to target theoretically consistent or empirically supported mechanisms of behaviour change (Michie et al., 2018). We selected the transtheoretical model (TTM) of Di-

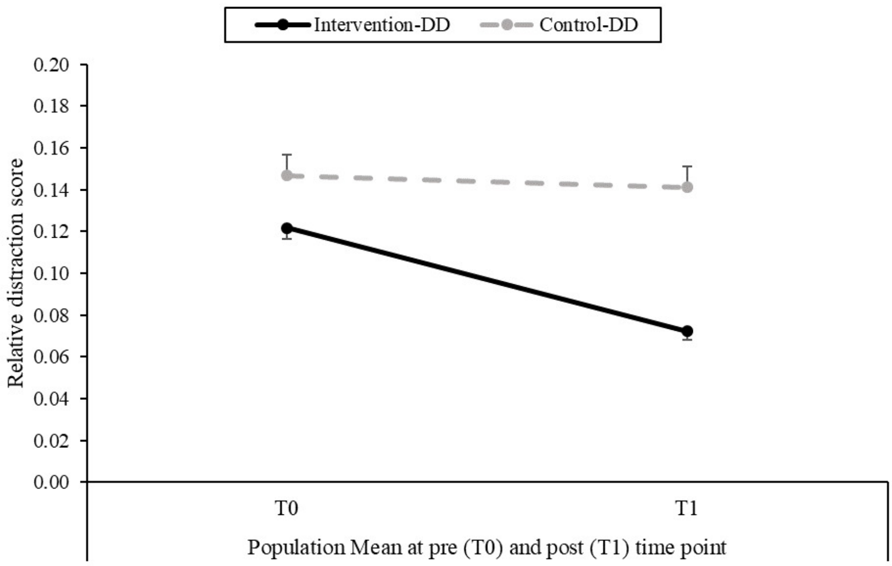

Figure 7. Mean relative distraction duration scores

Note. Mean relative distraction duration scores with standard error bars for the intervention-DD group and control-DD group at pre-timepoint (T0) and post-time point (T1) of the trial, ** p < .01.

Clemente and Prochaska (1998) to design the Safer Driver app.

Study limitations

One of the limitations of this study is that we did not measure ongoing attitudes and beliefs about distracted driving throughout the trial and therefore we might have been too quick or too slow with introducing the challenges in the action stage. However, drivers were free to accept or decline a challenge as they pleased. If a driver did not feel ready to make the change, the challenge would remain pending.

A second limitation is that we did not measure other constructs underpinning behaviour change. According to prominent (health) behaviour theories like Social Cognitive Theory (Bandura, 1986; McAlister et al., 2008), Health Belief Model (Champion & Skinner, 2008; Rosenstock, 1974), Reasoned Action Approach Model (Fishbein & Ajzen, 2011)/Theory of Planned Behaviour (Ajzen, 1991, 2011) constructs such as self-efficacy, subjective norms, perceived risk, perceived barriers, and perceived benefits are important determinants/ predictors for behaviour to change. However, the main purpose of the Safer Driver app was to see whether behavioural change techniques embedded in scientific theory (i.e., TTM) and translated into digital interventions in fact decrease distracted driving. We did not want to burden the drivers with questions related to these constructs and potentially have them disengage from the app. Future research should include metrics capturing various constructs from (health) behaviour theories to be able to investigate the mechanisms behind the observed decrease in distracted driving.

A third limitation is we did not have full control over the quality of the data we collected. In rare cases Sentiance technology can misclassify information. For example, classifying a bus trip as a car trip, or classify the participant as a driver while s/he was a passenger. However, participants had the opportunity to edit these misclassifications. Sometimes, false positive phone handling detections occurred. This happens, when a short trip with a transport mode other than a car (e.g., walking) is detected very shortly before or after the car trip and the two get falsely merged into a single car trip. Again, participants could indicate whether a detected phone distraction was false or correct.

A fourth limitation to consider is the potential for social desirability bias, where participants may have altered their behaviour to 'fake good' due to awareness of being monitored. Despite this type of bias being a concern in studies where participants are aware that their behaviour is being observed, our study design included a control group that was also aware of being monitored through the control app. Nonetheless, we still observed a significant difference in distracted driving behaviour between the intervention group and the control group. This suggests that while social desirability bias may have influenced the behaviours in both groups to some extent, the behaviour change techniques and coaching provided by the Safer Driver app had a more significant impact on reducing distracted driving. Future studies could mitigate this effect by extending the observation periods to reduce the novelty effect of being observed. Furthermore, the possibility of a self-selection bias within our sample, along with the influence of external incentives like vouchers, could have influenced the drivers' motivations and engagement with the app, potentially skewing our findings. As reported by Stevenson et al. (2021), the potential for telematics-based feedback to reduce risky driving is more evident when financial incentives are included.

A fifth limitation is related to which aspects of the app are responsible for having an impact on distracted driving. From the data collected we cannot conclude the individual effects of the mobile features of the app on impacting distracted driving behaviour. For example, we do not have detailed information about what exposures the individual members of the intervention group actually had in relation to the app (e.g., whether they read all the smart tips which were provided by the app). However, the main aim of using the Safer Driver app was to investigate if it would be possible to influence distracted driving behaviour through digital coaching. Future research may focus on which aspects of the app are most effective in changing behaviour.

Finally, the trial ran over a 30-day period, therefore we cannot make claims about long-lasting change, but the observed trend is promising and should encourage researchers, policy makers, insurers, and other stakeholders to consider using a combination of mobile tracking technology and behaviour science to help people to reduce their mobile phone use while driving.

Despite these limitations, this study presents valuable findings. A strength of the study is that we investigated our hypothesis in a naturalistic setting, rather than in laboratory-type settings. Additionally, the Safer Driver app provides interactive, tailored behavioural change interventions on a large scale, making it a cost-effective and scalable solution. Every individual with a smartphone can be coached in a time-efficient and personalised way.

Conclusions

To conclude, the results show that digital coaching through a smartphone application may contribute to reducing mobile phone induced distracted driving. Educational, awareness and outreach campaigns are essential elements to create a shift in mindset about our dangerous driving behaviours. Mobile applications with tracking abilities, such as the Safer Driver app, offer a possible medium whereby such campaigns can be held. Digital coaching based on behaviour change techniques embedded in theory, is a promising way of changing people's behaviour towards safer driving habits.

Acknowledgements

The authors would like to thank the Royal Automobile Club of Western Australia (RAC WA) for their efforts to recruit participants and help. The following team of engineers and designers eventually made the Safer Driver app see the light of day: Prakash Raman, Gurcan Gercek, Oliver Chan, Ankur Banerjee, Akanksha Chaudhary, Ankit Aneja, Max Luykx. Heartfelt thanks to all of them.

Author contributions

Christine van Vliet, Milad Yavari, Bertrand Fontaine, Anita McCracken, Nikki Palmbachs and Claudia Put contributed to the concept and design of the study. Patricija Batrenaite and Bertrand Fontaine conducted the statistical analyses. Furthermore, Christine van Vliet wrote the manuscript and all authors contributed to and have approved of the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Human Research Ethics Review

Study protocols were reviewed and approved by the RAC WA review board, Safer Driver app trial_202103 on 29 March 2021.

Data availability statement

In support of the transparency and reproducibility of our research findings, data related to the relative distraction score utilised in this study can be made available upon reasonable request. Interested researchers are encouraged to contact Sentiance via their contact form at https://sentiance.com/contact for access to these data.

Please note, however, that detailed data regarding the underlying motion technology, including specific algorithms and proprietary methodologies employed in this research, are not available for public disclosure. This restriction is in place due to business confidentiality and the proprietary nature of the technology developed by Sentiance.

Conflicts of interest

The authors were employed by their respective institutions during the conduct of the study and preparation of the manuscript. The employment relationships with Sentiance and Royal Automobile Club of Western Australia (RAC WA) have provided the context for the study's inception, design, and execution. It is acknowledged that the affiliations with Sentiance and RAC WA may constitute potential conflicts of interest. However, the authors assert that all findings and conclusions presented in this manuscript are the result of unbiased investigation and analysis of the data collected during the study.

Submitted: June 08, 2023 AEST, Accepted: February 16, 2024 AEST

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Ajzen, I. (2011). The theory of planned behaviour: Reactions and reflections. *Psychology & Health*, *26*(9), 1113–1127. https://doi.org/10.1080/08870446.2011.613995

Armitage, C. J. (2009). Is there utility in the transtheoretical model? *British Journal of Health Psychology*, *14*(2), 195–210. https://doi.org/10.1348/135910708X368991

Bandura, A. (1986). *Social foundations of thought and action* (pp. 23–28).

Billieux, J. (2012). Problematic use of the mobile phone: A literature review and a pathways model. *Current Psychiatry Reviews*, *8*(4), 299–307. https://doi.org/10.2174/157340012803520522

Bureau of Infrastructure, Transport and Regional Economics. (2018). *Modelling Road Safety in Australian States and Territories: Information Sheet 94*. BITRE.

Campbell, M. (2005). The impact of the mobile phone on young people's social life. In *Social change in the 21 century 2005 conference proceedings* (pp. 1–14). Queensland University of Technology.

Centers for Disease Control and Prevention. (2021). *Distracted driving*. https://www.cdc.gov/transportationsafety/distracted_driving/index.html

Champion, V. L., & Skinner, C. S. (2008). The health belief model. In *Health behavior and health education: Theory, research, and practice* (4th ed., pp. 45–65). Jossey-Bass.

Chee, P., Irwin, J., Bennett, J. M., & Carrigan, A. J. (2021). The mere presence of a mobile phone: Does it influence driving performance? *Accident Analysis & Prevention*, *159*, 106226. https://doi.org/10.1016/j.aap.2021.106226

Choudhary, P., Pawar, N. M., Velaga, N. R., & Pawar, D. S. (2020). Overall performance impairment and crash risk due to distracted driving: A comprehensive analysis using structural equation modelling. *Transportation Research Part F: Traffic Psychology and Behaviour*, *74*, 120–138. https://doi.org/10.1016/j.trf.2020.08.018

DiClemente, C. C., & Prochaska, J. O. (1998). Toward a comprehensive, transtheoretical model of change: Stages of change and addictive behaviors. In W. R. Miller & N. Heather (Eds.), *Treating addictive behaviors* (2nd ed., pp. 3–24). Plenum Press. https://doi.org/10.1007/978-1-4899-1934-2_1

Dingus, T. A., Guo, F., Lee, S., Antin, J. F., Perez, M., Buchanan-King, M., & Hankey, J. (2016). Driver crash risk factors and prevalence evaluation using naturalistic driving data. *Proceedings of the National Academy of Sciences*, *113*(10), 2636–2641. https://doi.org/10.1073/pnas.1513271113

European Road Safety Observatory (ERSO). (2018). *Driver distraction 2018*. European Commission.

Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behavior: The reasoned action approach*. Taylor & Francis.

Heckhausen, J., & Heckhausen, H. (2008). *Motivation and Action*. Cambridge University Press. https://doi.org/10.1017/CBO9780511499821

Lou, Y., Zhang, C., Zheng, Y., Xie, X., Wang, W., & Huang, Y. (2009). Map-matching for low-sampling-rate GPS trajectories. In *Proceedings of the 17th ACM SIGSPATIAL international conference on advances in geographic information systems* (pp. 352–361). https://doi.org/10.1145/1653771.1653820

McAlister, A. L., Perry, C. L., & Parcel, G. S. (2008). How individuals, environments, and health behaviors interact. *Health Behavior*, *169*, 169–188.

Michelaraki, E., Katrakazas, C., Yannis, G., Filtness, A., Talbot, R., Hancox, G., ... Taveira, R. (2021). Post-trip safety interventions: State-of-the-art, challenges, and practical implications. *Journal of Safety Research*, *77*, 67–85. https://doi.org/10.1016/j.jsr.2021.02.005

Michie, S., Carey, R. N., Johnston, M., Rothman, A. J., De Bruin, M., Kelly, M. P., & Connell, L. E. (2018). From theory-inspired to theory-based interventions: a protocol for developing and testing a methodology for linking behaviour change techniques to theoretical mechanisms of action. *Annals of Behavioral Medicine*, *52*(6), 501–512. https://doi.org/10.1007/s12160-016-9816-6

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., ... Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine*, *46*(1), 81–95. https://doi.org/10.1007/s12160-013-9486-6

Molloy, O., Molesworth, B., & Williamson, A. (2021). On-road study investigating the mode of feedback delivery on young drivers' speed management. *Transportation Research Part F: Traffic Psychology and Behaviour*, *76*, 393–402. https://doi.org/10.1016/j.trf.2020.11.009

Morris, N. L., Tian, D., Libby, D. A., & Craig, C. M. (2022). Multistate pilot study evaluating the short-term efficacy of a smartphone-based older driver support system on modifying risky driving behaviors. *Transportation Research Record*, *2676*(6), 207–216. https://doi.org/10.1177/03611981221074363

Nevin, P. E., Blanar, L., Kirk, A. P., Freedheim, A., Kaufman, R., Hitchcock, L., ... Ebel, B. E. (2017). "I wasn't texting; I was just reading an email...": a qualitative study of distracted driving enforcement in Washington State. *Injury Prevention*, *23*(3), 165–170. https://doi.org/10.1136/injuryprev-2016-042021

Oviedo-Trespalacios, O., King, M., Haque, M. M., & Washington, S. (2017). Risk factors of mobile phone use while driving in Queensland: Prevalence, attitudes, crash risk perception, and task-management strategies. *PLoS One*, *12*(9), e0183361. https://doi.org/10.1371/journal.pone.0183361

Oviedo-Trespalacios, O., King, M., Vaezipour, A., & Truelove, V. (2019). Can our phones keep us safe? A content analysis of smartphone applications to prevent mobile phone distracted driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *60*, 657–668. https://doi.org/10.1016/j.trf.2018.11.017

Parasuraman, S., Sam, A. T., Yee, S. W. K., Chuon, B. L. C., & Ren, L. Y. (2017). Smartphone usage and increased risk of mobile phone addiction: A concurrent study. *International Journal of Pharmaceutical Investigation*, *7*(3), 125. https://doi.org/10.4103/jphi.JPHI_56_17

Prochaska, J. O., Redding, C. A., & Evers, K. E. (2015). The transtheoretical model and stages of change. In *Health behavior: Theory, research, and practice* (p. 97).

Rosenstock, I. M. (1974). Historical origins of the health belief model. *Health Education Monographs*, *2*(4), 328–335. https://doi.org/10.1177/109019817400200403

Shambare, R., Rugimbana, R., & Zhowa, T. (2012). Are mobile phones the 21st century addiction? *African Journal of Business Management*, *6*(2), 573–577. https://doi.org/10.5897/AJBM11.1940

Stevenson, M., Harris, A., Wijnands, J. S., & Mortimer, D. (2021). The effect of telematic based feedback and financial incentives on driving behaviour: a randomised trial. *Accident Analysis & Prevention*, *159*, 106278. https://doi.org/10.1016/j.aap.2021.106278

Sutton, S. (2001). Back to the drawing board? A review of applications of the transtheoretical model to substance use. *Addiction*, *96*(1), 175–186. https://doi.org/10.1046/j.1360-0443.2001.96117513.x

Wang, X., Xing, Y., Luo, L., & Yu, R. (2018). Evaluating the effectiveness of Behavior-Based Safety education methods for commercial vehicle drivers. *Accident Analysis & Prevention*, *117*, 114–120. https://doi.org/10.1016/j.aap.2018.04.008