DRIVER BEHAVIOR & PERFORMANCE

TECHNICAL REPORT

FOUNDATION FOR TRAFFIC SAFETY

Increasing the Use of Smartphone-Limiting Technology to Combat Distracted Driving

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Title

Increasing the Use of Smartphone-Limiting Technology to Combat Distracted Driving

(April 2025)

Authors

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Foreword

Examining the behavior of drivers to encourage safe operation of vehicles is one of the core research areas at the AAA Foundation for Traffic Safety. This technical report presents research findings on one such driver behavior, distracted driving, because it remains a significant traffic safety concern. Technology-based countermeasures such as smartphone blocking features can effectively limit opportunities for distraction. These features can block or restrict incoming notifications whenever vehicle motion is detected. Despite their promise to reduce distraction, these features are not widely used by drivers.

The current study adopted a mixed approach to offer insight into factors that discourage the use of smartphone blocking apps as well as those that might encourage their use. An on-road experiment was used to evaluate an approach to raising drivers' awareness and knowledge of blocking apps. The results should be of interest to safety advocates and stakeholders in both the public and private sectors, including those in the technology industry.

C. Y. David Yang, Ph.D.

President and Executive Director

AAA Foundation for Traffic Safety

About the Sponsor

AAA Foundation for Traffic Safety
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Founded in 1947, the AAA Foundation for Traffic Safety in Washington, D.C., is a nonprofit, publicly supported charitable research and educational organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, individual members, AAA-affiliated insurance companies, and other organizations or sources.

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Executive Summary

Distraction from smartphones is an important road safety issue and efforts to identify effective countermeasures remain a priority. Most U.S. consumers use either an Android or iOS smartphone device that comes with a feature that can block or limit distractions, referred herein as Do Not Disturb (DND). Unfortunately, only a small percentage of drivers use this feature while driving and often only on a subset of their driving trips. The current study aimed to (a) understand the barriers to using DND countermeasures for smartphone use while driving and (b) determine the feasibility of overcoming these barriers through educational materials to improve driver awareness and knowledge of DND.

Part I of the study explores the characteristics of drivers prone to smartphone use through a literature review of recent scientific findings. The review identified 132 candidate articles of which 32 were reviewed in depth. The studies examined a wide array of factors that characterize drivers who are likely to use their smartphones while driving. While the literature is inconclusive on the role and direction of some factors, driving experience and age show clear relationships to smartphone use. Younger drivers (18–24) and those with less driving experience have increased likelihood of smartphone use while driving. Research also highlights the role of a number of cognitive and behavioral factors, as well as maladaptive phone use.

In Part II, an online survey was administered to gather driver perceptions and experiences related to DND app features and to explore some of the factors that impact drivers' willingness to use the features. Three hundred licensed drivers participated in the survey and were classified by their DND use: current users, non-users, or previous (or former) users. In general, younger users, compared to older users, were more knowledgeable about DND and more likely to report current DND use, but were also more likely to have discontinued use of DND. Moreover, younger previous users of DND were far more likely to believe they can drive safely and message than older users, suggesting that they might believe DND is not necessary because they can use their phone safely while driving.

Wanting to use music and navigation apps were the most frequently selected reasons for not using DND, outcomes that underscores an important lack of understanding of DND, which does allow music and navigation use when activated. Sixty percent of previous users reported that they forget to turn on DND and 32% of non-users reported they did not know about the feature. These outcomes suggest that drivers could benefit from training on DND features so they have a more accurate understanding of what actions DND restricts and awareness of the feature itself (e.g., can be turned on to automatically activate when driving is detected).

Most respondents reported they were in favor of automatic DND activation during stressful driving environments, including heavy rain, snow, or traffic. The selection of these environments suggests that drivers recognize the challenges associated in these situations. Contextual awareness for DND activation as opposed to an all-or-nothing approach may increase usage. Also, improved accuracy in recognizing when a user is not a driver was cited as an important factor that could influence the likelihood of using DND. Control over what apps are restricted and insurance discounts were also identified as factors that would increase DND usage.

In Part III, an on-road naturalistic study was undertaken to examine (a) whether training or educational material could improve drivers' awareness and understanding of DND and (b) the effects on subsequent smartphone behaviors while driving. The training was designed to address misconceptions about DND functionality. Pre-training knowledge of the DND feature ranged from 50% to 85% accuracy. However, post-training, all participants reported they knew how to use DND, that the feature was readily available on their phones, and that it could be set to automatically activate. However, participant opinions of DND did not change after receiving DND training.

Results also revealed a 41% decrease in the odds of a smartphone task after DND was activated, suggesting that DND was effective in lowering the number of smartphone interactions while driving. Although phone tapping duration decreased post-training for some participants, they were 5% more likely to have a tapping event following training. This could be due to the additional steps (and phone taps) needed to disengage DND to unlock their phone (e.g., iPhone users must clear a prompt in order to unlock the phone). Finally, participants were 6% less likely to pick up their phone following DND training, which supports the idea that DND lowers the potential for smartphone interactions while driving.

Collectively, outcomes from this study help to identify important barriers for using DND while driving as well as opportunities to increase the likelihood drivers will use the feature, including design considerations for future versions of these applications.

Introduction

In the last decade, engagement with smartphones while driving has emerged as a critical transportation and public safety issue. Smartphone-distracted driving leads to repetitive off-road glances (Owens et al., 2011), reducing the driver's capacity for hazard detection (Owens et al., 2018) and delaying the reaction time to critical driving events (Choudhary & Velaga, 2017). Additionally, smartphone use while driving can result in inconsistent lateral control and speed in relation to lead vehicles, forcing surrounding drivers to adapt to the distracted driver's erratic behavior (Morowatisharifabad, 2009).

Most U.S. consumers use either an Android (40.8% market share) or iOS (58.8% market share) smartphone device that comes with a free, native, driving-mode feature, generally referred to as Do Not Disturb (DND), to block or limit distractions (Howarth, 2024). For both Android and iOS, driving is detected when the phone is connected to the vehicle's Bluetooth or when the phone accelerometer detects motion consistent with vehicle movements. Both aim to limit the potential for distraction in different ways. The *Do Not Disturb while Driving* feature on Android devices allows the user to grant notifications while driving only from specific apps and contacts. Access to other phone functions (e.g., texting) is not limited. The *Driving Focus* feature on iOS devices allows only calls from certain contacts while driving and sends an auto-reply to incoming text messages. Notifications from all apps are silenced and the user is unable to unlock their phone unless they clear a prompt stating "I am not driving." Unfortunately, only 20.5% of iOS users used this feature, and those who did use the feature only used it on a quarter of their driving trips (Reagan & Cicchino, 2020). Despite its ease of access, this safety feature is rarely applied, suggesting a critical disconnect between perceived utility and the actual implementation of technology-based countermeasures for smartphone use while driving.

Common reasons for the non-use of such technological countermeasures include "nomophobia," which is the irrational fear of being without a mobile phone, and FOMO, "fear of missing out," and FOMSI, the "fear of missing something important" (e.g., emergency texts/calls; van Velthoven et al., 2018). Moreover, many users overestimate the restrictions, fear lacking access for emergency calls/texts, have a negative outlook on ease of access to launch/disable countermeasures, and lack knowledge of personalization features (Oveido-Trespalacios et al., 2020; Reagan & Cicchino, 2020).

Previous research suggests that feature customization and informed awareness of an app's functionalities are instrumental in enhancing the perceived effectiveness to create lasting behavioral change. The perceived effectiveness of smartphone-blocking apps increases with driver awareness of the automatic enablement feature based on kinematic sensor data, phone contact filtering for emergency notifications, and auto-reply messaging to alleviate the pressure of non-response (Reagan & Cicchino, 2020). Soft-blocking, which silences notifications rather than limits functionality, also has the potential to improve perceived effectiveness (Albert & Lotan, 2019). Improving awareness through education should help reinforce findings from studies based on the health belief model, which suggest that self-realization through hands-on practical self-application and increased understanding through feedback are crucial beginning steps to lasting behavioral change (DiClemente et al., 2001).

Objectives

The current study aimed to (a) understand the barriers to using DND countermeasures for smartphone use while driving; and (b) determine the feasibility of overcoming these barriers through educational materials to improve driver awareness and knowledge of DND. The study was conducted in three parts. In Part I, the characteristics of drivers who are prone to smartphone use were explored through a literature review of recent scientific findings. In Part II, an online survey was administered to gather driver perceptions and experiences related to DND app features and to explore some of the factors that impact drivers' willingness to use the features. Lastly, in Part III, an on-road study was undertaken to examine whether training or educational material could improve drivers' awareness and understanding of DND and the effects on subsequent smartphone behaviors while driving. This study employed a naturalistic driving approach. The collective outcomes from these parts can potentially identify additional barriers, determine changes in perceived application effectiveness, and provide data that influence design considerations for future versions of these applications.

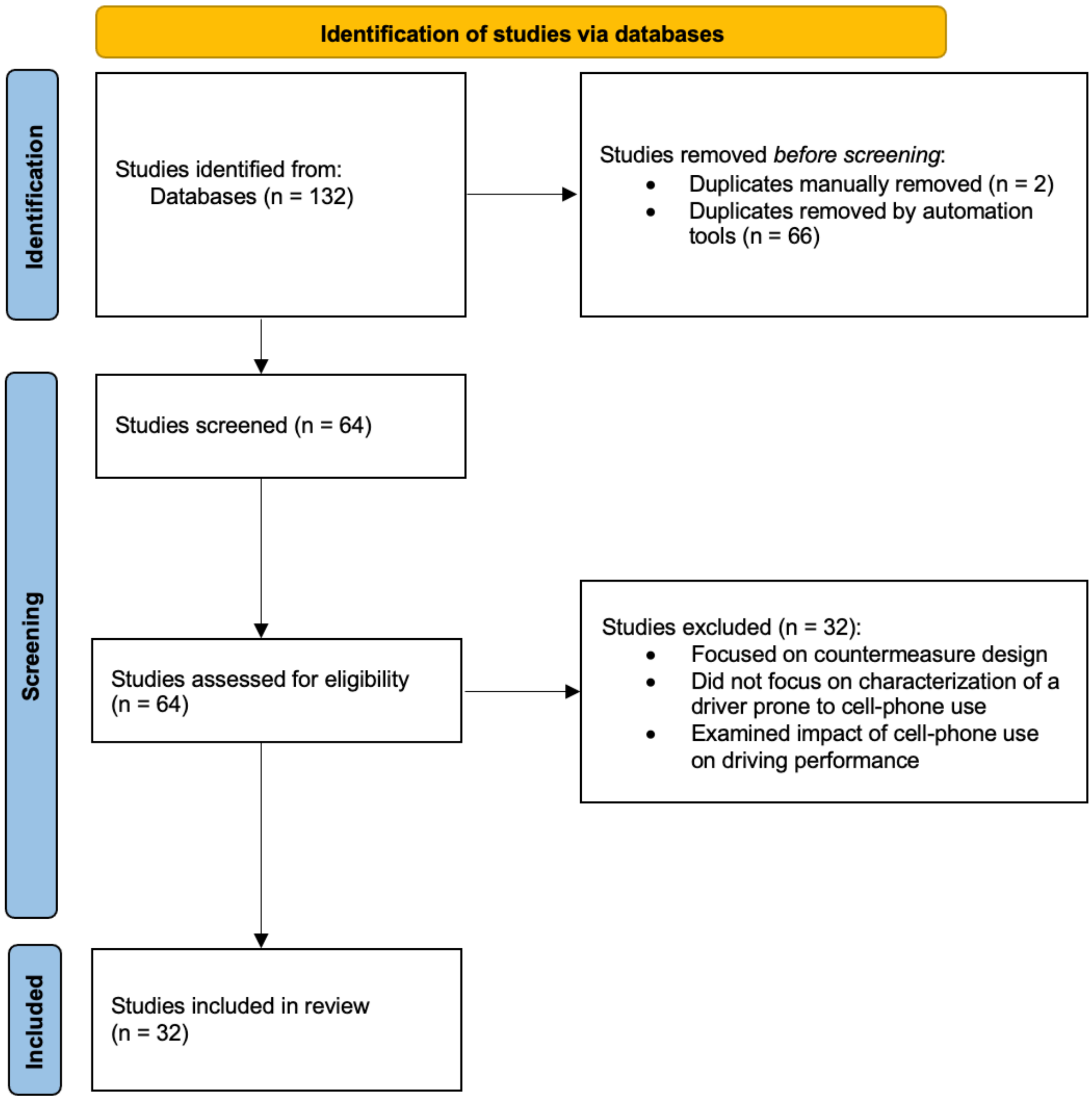
Part I: Characterizing Drivers Who Use Smartphones While Driving

A literature scan was performed to understand the characteristics of individuals who are likely to use their smartphones while driving and to inform subsequent study tasks. This review focused on the most recent available literature: articles published in the past eight years using a list of terms augmented by Virginia Tech librarians. Relevant terms included those related to the project objectives (e.g., smartphone, distraction, driving, countermeasures) and were formed into the following Boolean logic: (driver OR driving) AND (distracted or distraction) AND (smartphone OR cell phone) AND (countermeasures OR soft block OR do not disturb). This logic was applied to the following databases: Transportation Research International Documentation (TRID), Web of Science, PubMed, Google Scholar, EBSCO, Elsevier's Engineering Village, ProQuest, and ASCE. In some instances, highly relevant articles older than eight years were identified from the background section of reviewed articles.

Figure 1 summarizes the literature scan process. The initial scan returned 132 possible matches from the multiple databases. Following the removal of duplicates, three researchers independently reviewed the abstracts of 64 unique articles using Covidence software (https://www.covidence.org/). While many of the 64 articles contained relevant keywords, further examination of the abstract by the research team revealed they did not inform the purpose of characterizing smartphone users. Rather, they related to other topics such as the effectiveness of countermeasures for reducing cell phone use while driving. Many of the 32 excluded sources were solution-based studies focused on how to improve interface design, smartphone applications, or soft-blocking as effective countermeasures. Other studies sought to characterize cell phone distraction (e.g., eye glance patterns, behavioral scenarios of phone use, cognitive impacts of use).

Another common theme was the examination of driving performance related to situational cell phone use (e.g., voice-based text response vs. visual–manual manipulation). While these studies may have indirectly provided insight into users' propensity of cell phone use while driving, they did not directly indicate what characteristics would distinguish them from other driver types. Therefore, the general inclusion criteria were that a given study must focus on demographic or dispositional traits that influence cell-phone use while driving. Disagreements on an article's relevance were discussed and resolved following independent review. In total, 32 full-text articles were included as relevant to the current objective. The following sections provide summaries from the literature review, broken out by demographic or individual variables.

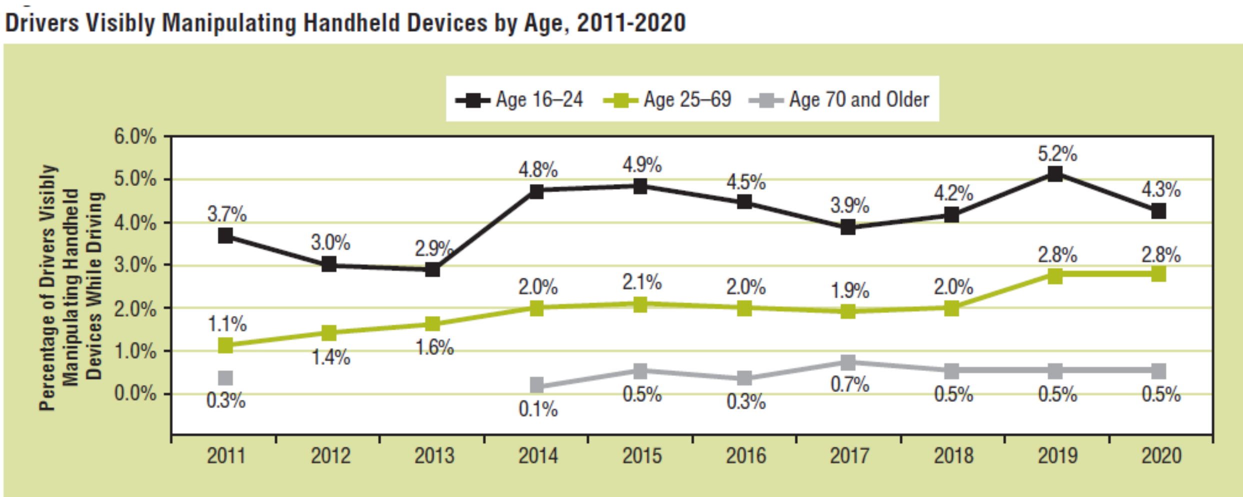
Figure 1. Summary of literature scan process.



Age

Phone manipulation while driving has been increasing since 2011 (National Center for Statistics and Analysis [NSCA], 2022). Figure 2 shows trends in phone manipulation stratified across various age groups from 2011 to 2020. During that time, younger drivers (16–24) have shown higher rates of smartphone manipulation while driving than middle-aged (25–69) or senior drivers (70+).

Figure 2. Drivers observed manipulating handheld devices while driving, 2011–2020 (from NCSA, 2022).



Note: Missing data points signify insufficient data to produce reliable estimates.

Naturalistic driving studies (NDS) identified in the literature review also support this trend. For example, Guo et al. (2017) analyzed data from NDS in the Second Strategic Highway Research Program (SHRP 2) and found that smartphone use and crash risk were higher for drivers aged 16–29 years compared with older age groups (ages 30–64 and 65–98). Further, smartphone visual–manual tasks represented 5.5% of the observed secondary tasks for this group compared to 3.2% and 0.7%, respectively, for the older groups, which is similar to results shown in Figure 2.

Younger drivers may be more prone to distracted driving from smartphone engagement due to a less-developed executive control system in the prefrontal cortex, which supports self-regulation of behavior relative to risk perception (Lipovac et al., 2017; Albert & Lotan, 2019; Kaviani et al., 2021). This lack of executive control results in increased sensation seeking, variable risk-taking, and high impulsivity (e.g., those with attention deficit hyperactivity disorder [ADHD] or under the influence of alcohol or cannabis are particularly at risk; Walshe et al., 2021). Other studies have shown that age is related to other cognitive variables that influence smartphone use while driving, such as smartphone addiction (Nguyen-Phuoc et al., 2020) and FOMO (Matias et al., 2021).

Gender

The literature was inconclusive regarding whether one gender uses smartphones more often than another. Lipovac et al. (2017) performed a systematic literature review on variables influencing smartphone use while driving. Findings from their review suggest that males, on average, interacted with a handheld cell phone while driving for 9.3 minutes per week compared to 6.5 minutes for females (Hallett et al., 2011). Other findings showed that being younger and being male were significant predictors of smartphone use while driving (Tabuñar, 2019). In contrast, other studies suggest that reduced smartphone use in males is due to their ability to self-regulate and withhold responding (Struckman-Johnson et al., 2015). Other studies suggest smartphone use is higher in females (Fakhrmoosavi et al., 2020; Oviedo-Trespalacios, Nandavar et al., 2019; Kaviani et al., 2022b) and that this could be influenced by gender differences in communication, with females experiencing higher fears of social loss (Kimbrough et al., 2013; Kaviani et al., 2022a). Finally, some studies suggest no difference between genders with respect to smartphone use (Struckman-Johnson et al., 2015).

Driving Experience

Previous research has shown that drivers with less driving experience used their smartphones while driving more often than those with more experience. Importantly, driving experience is often confounded with age and the influence of each is often difficult to disentangle. Drivers with less experience may display attributes of immature risk-management skills compared to an advanced driver, resulting in overconfidence in driving skills and their ability to multitask (Cao et al., 2020; Stavrinos et al., 2013; Oviedo-Trespalacios, 2018; Oviedo-Trespalacios et al., 2017).

Education

Level of education also influences phone use. Some studies have shown that those who have completed higher levels of education are less likely to use a smartphone while driving (Lipovac et al., 2017; Shaaban et al., 2022). Other studies show that those with a college degree are more likely to use hands-free headsets to interact with their smartphone while driving instead of manual interactions (Bendak et al., 2019). However, there is some conflicting evidence, with some studies showing increased smartphone use with increasing education (Fakhrmoosavi et al., 2020; Russo et al., 2014; Schroeder et al., 2018). In one study, smartphone usage decreased on weekends compared to weekdays, suggesting that educated workers may feel obligated to use their device while driving for incoming work notifications (Musicant et al., 2015).

Income

There is conflicting evidence on the effect of income and smartphone use while driving. For example, some studies have found that individuals who have a lower income than the national median or who come from a low-income household were more likely to use a smartphone while driving, although this was only significant for males (Kita & Luria, 2020). In contrast, a national review of smartphone use while driving indicated that those with incomes greater than $100,000 used their phone more often while driving compared with other income levels (Tison et al., 2011).

Cognitive and Behavioral Factors

The theory of planned behavior (TPB) was the most referenced cognitive theory seen across studies gathered in the literature review. In this context, the TPB posits that attitudes (risk perceptions, perceived needs), social norms, and perceived behavioral control (related to self-regulation) strongly predict a driver's intention to engage in distracting behaviors with smartphones while driving (Eijigu, 2021; Hansma et al., 2020).

Risk Perception

Risk perception has been shown to influence smartphone use while driving and is often linked to some of the demographic variables mentioned in the sections above. For example, females have been found to have a higher perception of risk regarding using smartphones while driving compared to males, while higher education has the same effect (Shaaban et al., 2022).

As age increases, the perceived risk of using a smartphone while driving also increases (Lipovac et al., 2017). This could be related to driving experience: as experience goes up, perceived crash risk rises, suggesting that older drivers are more sensitive to varying road and context conditions (Andrews & Westerman, 2012; Tractinsky et al., 2013; Cao et al., 2020). Another study suggested that this increase in perceived risk in older drivers is related to self-recognition of cognitive decline and the increased attentional demand needed when interacting with a smartphone (Cao et al., 2020).

The perception that there is a "safe" level of distraction or "safe" situational context for distraction can be considered a measure of risk-taking that is found to increase smartphone usage while driving (Shaaban et al., 2018). Moreover, drivers who perceived hands-free devices as lower risk when compared to manual manipulation of a phone showed no difference in their overall attitudes towards safety (Russo et al., 2014).

Other studies have found this to be more closely aligned with a driver's self-regulation, where they consciously manage competing demands of attention while simultaneously performing safe driving behaviors to avoid collisions. This dynamic complex processing would suggest that self-regulation is executed in the form of operational, tactical, and strategic methods (Cao et al., 2020). As such, drivers likely to use their smartphone while driving may vary in their level of self-regulation and in their employment of strategic methods that they have deemed "safe," such as limiting smartphone use in certain situations or limiting certain types of phone interactions.

Those who generally believed that using a smartphone while driving was a source of crash risk were less likely to do so (Oviedo-Trespalacios, 2018). Other studies show that those who do not wear a seatbelt while driving are also more likely to engage in smartphone use (Fakhrmoosavi et al., 2020), suggesting these drivers may have a lower general perception of risk. It follows that those who used their smartphone while driving were found to engage in other risky driving behaviors, such as speeding or driving under the influence (Walshe et al., 2021). Yet, studies have also found that drivers tend to perceive driving under the influence of alcohol or cannabis as riskier than driving while using a smartphone (Walshe et al., 2021).

Social Norms and Influences

Social norms and perceptions also influence smartphone use while driving. For example, individuals who overestimated how often other drivers used a smartphone tended to use their own smartphone more (Kaviani et al., 2021; Taylor & Blenner, 2021). Those who felt high social pressure to respond were found to show increases in responding behavior (e.g., answering calls and reading text messages) more frequently than initiating behaviors (e.g., making calls and sending text messages; Eijigu, 2021). Relatedly, younger people tend to have more severe levels of nomophobia, which is the irrational fear of being without a mobile phone (Kaviani et al., 2022a), and phone addiction (Shokri et al., 2018), which in turn influence smartphone use while driving. FOMO, the fear of missing out, is related to missing potential social interactions by not engaging with a phone. Those with higher levels of FOMO or obsessive–compulsive disorder have been shown to use their smartphone more frequently while driving (Matias et al., 2021; Rahmillah et al., 2023). Phone addiction mediates the relationship between certain personality traits and use of smartphones while driving (Luria, 2018). Those who believed phone use would harm others or who reported higher levels of regret post-use were less likely to engage their smartphones while driving (Ogden et al., 2022). Drivers are less likely to use their smartphone while driving when a spouse, children, family, or friends are in the vehicle (Tabuñar, 2019).

Maladaptive Mobile Phone Use

Younger individuals have high rates of phone use—some studies estimate as frequently as 1.7 times per minute (Nguyen-Phuoc et al., 2020)—and use them for longer periods of the day than other age groups (Kaviani et al., 2021). Spending more than 3 hours on a smartphone daily was found to significantly increase the likelihood of smartphone use while driving (Rahmillah et al., 2023). Others have cited that frequency alone cannot be a sole predictor (Musicant et al., 2015). In addition to frequency, the level of attachment, or perceived need, related to the usage warrants consideration. The notifications on smartphones from apps, phone calls, and text messages are ubiquitous; thus, the usage patterns and behaviors of engagement with smartphones in general are important to consider in this theory (Musicant et al., 2015).

Research in the last decade has revealed the safety implications of maladaptive phone usage and its relationship to using smartphones while driving. Maladaptive mobile phone use (MMPU) has been discussed under many different terms, such as problematic phone use, mobile phone dependence, smartphone overuse, and compulsive mobile phone checking. While these terms vary in definition across the literature, they all convey the same behavioral addiction related to an excessive use of smartphones that interferes with lifestyle or incurs unsafe consequences (e.g., driving) through cognitive and behavioral salience, withdrawal, and loss of control (Rahmillah et al., 2023).

In particular, the ongoing maturation of the prefrontal cortex and the associated executive control system that supports self-regulation and cognitive control over behavior may explain weaker impulse control. Rising dopaminergic activity in the brain's reward circuit may also indicate increased sensation seeking, which may explain variable risk-taking in young drivers and those with high impulsivity, such as those with ADHD or those under the impulsivity influence of alcohol or cannabis (Walshe et al., 2021).

Drivers who score high on measures of MMPU have shown that their smartphone usage outside the vehicle is a good predictor of their usage behaviors in-vehicle. Higher MMPU scores indicate lower risk perception, more favorable attitudes and beliefs toward mobile phone use while driving, and low impulse control around usage when inside the vehicle.

Habitual usage patterns are important to consider as a component of MMPU. These patterns are originally created through goal-oriented and intentional behaviors for an expected reward yet have evolved to be performed automatically without deliberate intention. Usage patterns may also be related to certain stimuli. For example, a user who typically checks their smartphone when there is low external demand on their attention may check their phone out of habit when driving in low-demand environments. Or, if they are used to checking their phone immediately upon receipt of a notification and have low impulse control, that same habitual automatic tendency may occur in a driving environment despite the increased risk (Walshe et al., 2021). As such, eliminating the ability to act on this habit via countermeasures such as DND modes on smartphones has proven effective in initial findings (Hansma et al. 2020; Rahmillah et al., 2023; Cao et al., 2020).

Summary

A review of recent studies has helped identify many factors that characterize drivers who are likely to use their smartphones while driving. The literature is inconclusive on the direction of influence for some of the factors. That is, gender, level of education, and income all have conflicting evidence suggesting that those variables influence smartphone use differently. However, level of driving experience and age show clear relationships to smartphone use. For example, younger drivers (18–24) and those with less driving experience all have increased likelihood of use while driving. Research also suggests that a number of cognitive and behavioral factors, as well as maladaptive phone use (which in turn measures level of self-regulation) and risk perception, influence phone use.

Part II: Understanding Barriers to Using DND While Driving

A survey was administered to 300 drivers to gather perceptions and experiences related to DND app features, as well as to understand some of the factors that impact drivers' willingness to use the features. This online survey was performed using the Prolific crowdsourcing platform that has been employed and validated in previous research (Palan & Schitter, 2018; Peer et al., 2021).

Participants

Three hundred licensed drivers who met the following criteria participated in the survey:

- Lived in the United States
- Currently held a driver's license
- Drove at least 1 hour per week
- At least 18 years old
- At least 100 previous Prolific submissions and an approval rate >99%
- Used a phone that supported either the iOS or the Android operating software

These inclusion criteria were selected from the Prolific interface; given constraints in the use of unique screener questions, the decision was made to focus on all demographic groups (versus targeting specific groups based on Part I). Supplemental batches were run to replace rejected surveys for participants who failed two attention check questions. Prolific IDs (i.e., unique strings given to each Prolific respondent) were used to exclude previous participants from participating in these supplemental batches.

Participants were on average 33.6 years old (SD = 12.95; Range = 18–71 years old) with 50.3% female, 47.3% male, and 2.3% identifying as other. Eighty percent had over 5 years of driving experience, 15% had 3-to-5 years, and 5.6% had less than 36 months. Sixty percent of participants used iPhones and 40% used Android phones. Sixty-three percent reported not ever using DND, 21% reported current use, and 16% reported being previous users.

Survey

Participants responded to the questions outlined in Appendix A. The survey included several different sections: demographic information and driving history; smartphone use, dependence, and use when driving; and DND use. DND questions referenced either *Driving Focus* (iPhone) or *Do Not Disturb while Driving* (Android) depending on which phone the participant had.

Maladaptive phone use was measured by the Problematic Phone Use Questionnaire (PPUQ; Billieux et al., 2008; Lopez-Fernandez et al. 2017) and level of distracted driving by the Susceptibility to Distracted Driving Questionnaire (SDDQ; Feng et al., 2014; see Appendix A). The SDDQ includes six subscales: Involuntary Distraction, Voluntary Distraction, Distraction Engagement, Vehicle Control (i.e., perceived ability when driving distracted), Social Norms A (i.e., beliefs about distraction behaviors of other drivers), Social Norms B (i.e., beliefs held by people important to the respondent).

Respondents were also asked about their knowledge and understanding of DND features, social norms related to DND use, barriers that prevent them from using DND (and, conversely, factors that might increase the likelihood they would use them), and situations they believed DND should be automatically enabled. Selected independent and dependent variables are outlined in Table 1 and Table 2.

Table 1. Objective 2 Independent Variables of Interest

Independent Variables			
Variable	**Description**	**Levels**	**N**
Age	Age of the participant split at 24 years of age (see Literature Review)	18–24 years of age	112
		25+ years of age	188
DND use[1]	Self-reported history of DND use while driving	Current user	62
		Previous user	48
		Non-user	190

Note. User groups were defined by participant response to DND use in Appendix A (Part 1 Question 10/11). "Yes" responses were categorized as current users, "No" as non-users, and "No, but I have in the past" as previous users.

Table 2. Objective 2 Dependent Variables of Interest

Dependent Variables		
Variable	**Description**	**Metric**
Current knowledge of DND	Various questions to probe a user's current understanding of DND	Yes/No
Reasons for non-use	Various reasons that a user chooses to not use DND	Yes/No
Preference for automatic DND activation	Preference for scenarios where DND would automatically activate beyond when driving is detected	Yes/No
Factors that impact use	Various factors that increase likelihood to use DND	Yes/No

Results

Chi-squared tests of independence were used to investigate differences between DND usage groups, age groups, and the categorical dependent variables. For some questions, responses were rank-ordered from highest to lowest to illustrate how responses varied by usage group.

DND User Group Characteristics

There were 36 male and 26 female current users (age M = 32.18; SD = 13.46); 89 male, 94 female, and 7 other non-users (age M = 35.53; SD = 12.98); and 17 male and 31 female previous users (age M = 27.96; SD = 10.15). Table 3 represents each DND user group and their phone use and distraction propensity while driving. For the PPUQ, results were averaged across all items on that questionnaire (i.e., composite score); the SDDQ results were aggregated according to each subscale (6 total).

Table 3. DND User Group Phone Use Characteristics.

	PPUQ	**SDDQ**					
M (SE)	**Composite**	**Involuntary Distraction**	**Distract Engage**	**Voluntary Distraction**	**Vehicle Control**	**Social Norms A**	**Social Norms B**
Current user	6.22 (0.15)	3.48 (0.10)	2.57 (0.07)^{A}	2.94 (0.08)	3.14 (0.09)	3.90 (0.07)	3.26 (0.09)
Non-user	6.46 (0.09)	3.32 (0.06)	2.77 (0.04)^{B}	3.15 (0.05)	3.23 (0.05)	4.07 (0.04)	3.32 (0.05)
Previous user	6.60 (0.17)	3.41 (0.10)	2.94 (0.08)^{B}	3.18 (0.09)	3.31 (0.10)	4.09 (0.08)	3.38 (0.10)

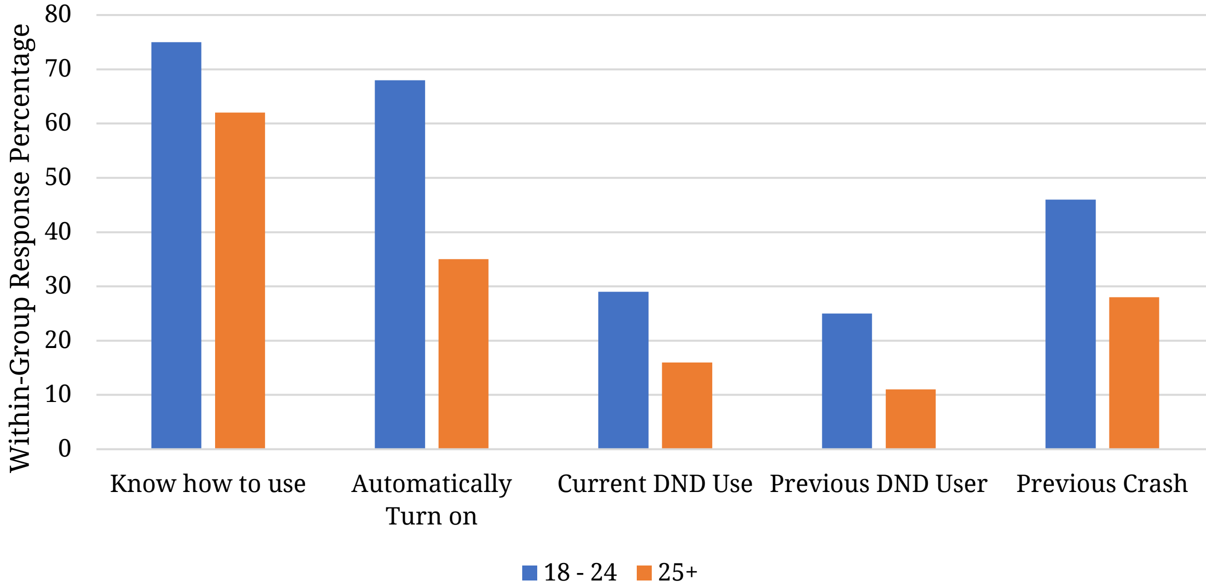
Note. M = mean, SE = standard error. ^{A,B} Denote significant contrasts (see text for details).

There were no significant differences between DND user groups on the PPUQ ($F(2, 297) = 1.46$, $p = 0.23$) and some of the SDDQ subscales: Involuntary Distraction ($F(2, 297) = 1.06$, $p = 0.35$), Vehicle Control ($F(2, 297) = 0.76$, $p = 0.47$), Social Norms A ($F(2, 297) = 2.15$, $p = 0.12$), and Social Norms B ($F(2, 297) = 0.38$, $p = 0.68$). Voluntary Distraction approached significance, with current users scoring lower than non-users and previous users (see Table 3; $F(2, 297) = 3.08$, $p = 0.05$). There was a significant difference for Distraction Engagement ($F(2, 297) = 5.73$, $p < 0.01$) where current users scored lower than non-users ($\Delta = 0.19$; $SE = 0.08$; $p < 0.05$) and previous users ($\Delta = 0.36$; $SE = 0.11$; $p < 0.05$).

Age-Related Differences in DND Use and Knowledge

Compared with drivers aged 25+, the 18-to-24-year-old group was more likely to say they know how to use DND ($\chi^2(1, 300) = 5.72$, $p < 0.05$), more likely to know DND can be set to automatically turn on ($\chi^2(1, 300) = 30.69$, $p < 0.0001$), more likely to report current DND use ($\chi^2(1, 300) = 6.64$, $p < 0.05$), and more likely to report being a previous DND user than 25+ year olds ($\chi^2(1, 300) = 10.42$, $p < 0.01$), see Figure 3. With respect to driving experiences, young drivers were more likely to report a crash in the past 5 years ($\chi^2(1, 300) = 10.80$, $p < 0.01$).

Figure 3. Differences Between Age Groups.



Factors Associated with Non-Use of DND

As noted previously, 62 participants reported current DND use, 190 were non-users of DND, and 48 were previous users. Participants were asked to indicate any reasons that stopped them from using DND while driving (see Appendix A, Countermeasure Apps section, Question 10). The rank orders of reasons are provided in Table 4, broken out by user group.

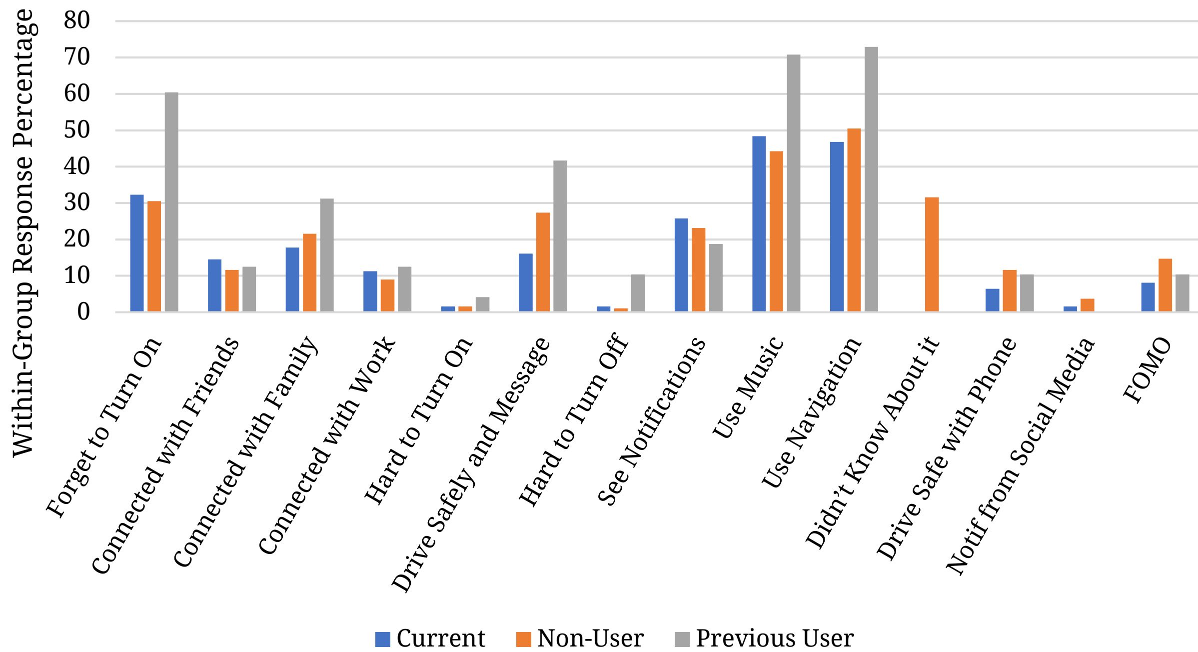
Table 4. Rank Order of Reasons for Non-Use of DND by User Group.

	Current (n = 62)	**Non-user (n = 190)**	**Previous (n = 48)**
1	Use music (48%)	Use navigation (51%)	Use navigation (73%)
2	Use navigation (47%)	Use music (44%)	Use music (71%)
3	Forgot to turn on (32%)	Didn't know about it (32%)	Forgot to turn on (60%)
4	See notifications (26%)	Forgot to turn on (31%)	Drive safely and message (42%)
5	Stay connected with family (18%)	Drive safely and message (27%)	Connected with family (31%)
6	Drive safely and message (16%)	See notifications (23%)	See notifications (19%)
7	Stay connected with friends (15%)	Connected with family (22%)	Connected with friends (13%)
8	Stay connected with work (11%)	FOMO (15%)	Connected with work (13%)
9	FOMO (8%)	Connected with friends (12%)	Too hard to turn off (10%)
10	Drive safe with phone (6%)	Drive safe with phone (12%)	Drive safely and phone (10%)
11	Too hard to turn off (2%)	Connected with work (9%)	FOMO (10%)
12	Too hard to turn on (2%)	Notifications from social media (4%)	Hard to turn on (4%)
13	Notifications from social media (2%)	Hard to turn on (2%)	Didn't know about it (0%)
14	Didn't know about it (0%)	Hard to turn off (1%)	Notifications from social media (0%)

Across each user group, use of navigation and music apps were listed as the top reasons for not using DND. Interestingly, a third of current users and 60% of previous users reported that forgetting to turn on DND was as a barrier to using the feature. Moreover, a third of non-users reported that they did not know about DND features. It is noteworthy that a significant percentage of respondents believed that they could drive safely while receiving messages (27% of non-users and 42% or previous users versus 16% in current users).

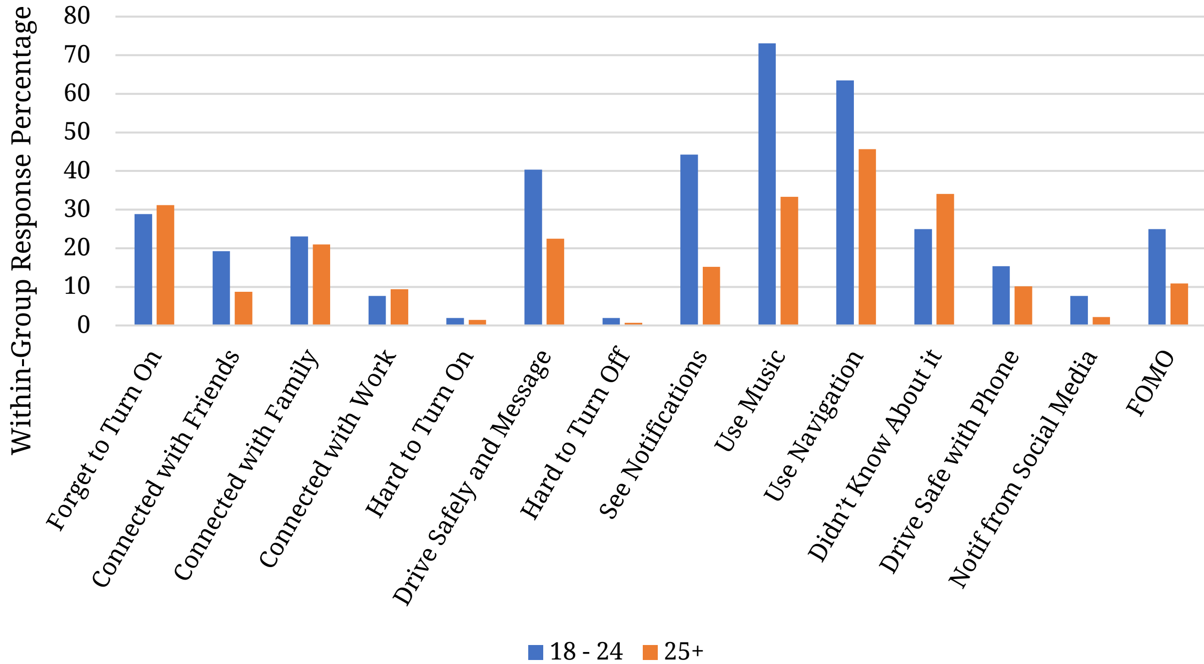
Differences between reasons for not using DND were investigated further, with particular focus on non-users and previous users as a goal of the current project is to increase DND use. Previous users were more likely to say they would like to use navigation ($\chi^2(1, 238) = 8.07$, $p < 0.01$), use their music ($\chi^2(1, 238) = 11.13$, $p < 0.001$), that they forget to turn on DND ($\chi^2(1, 238) = 14.27$, $p < 0.001$), and that DND is too hard to turn off ($\chi^2(1, 238) = 14.27$, $p < 0.001$), as reasons for not using DND compared to non-users (see Figure 4).

Figure 4. Differences for not using DND by DND usage group.



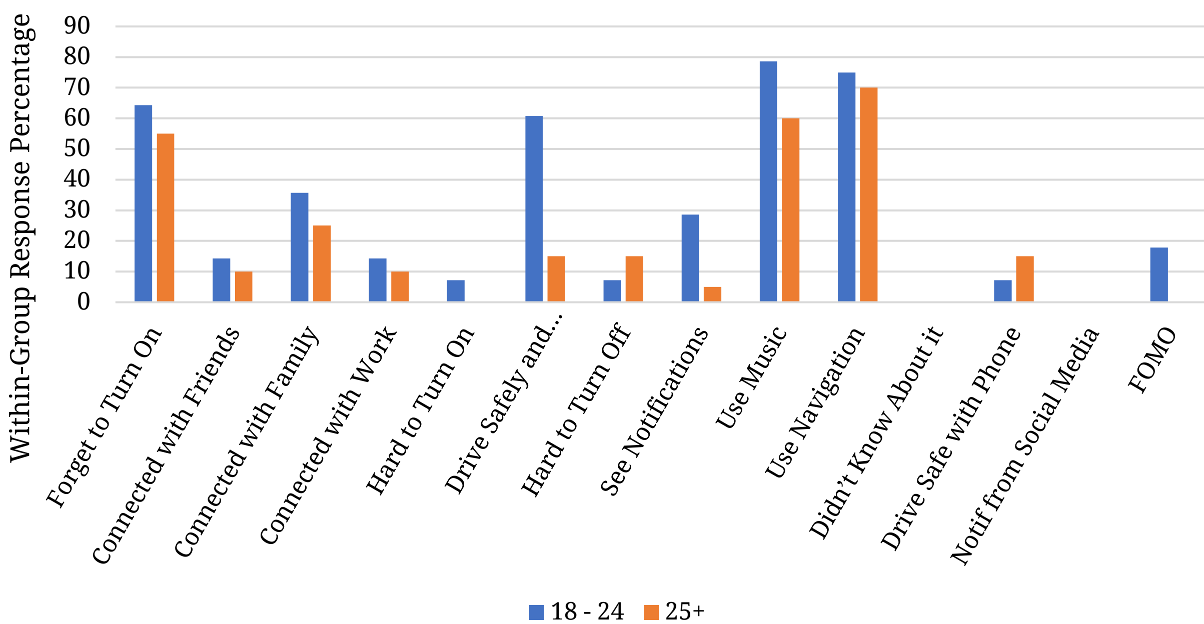
The non-user and previous user groups were further split by age group to better understand differences for not using DND. As shown in Figure 5, among non-users, 18–24 year olds were more likely to think they can drive safely and message 5.84, p < 0.05), want to see notifications ($\chi^2(1, 190) = 16.55$, $p < 0.0001$), want to use music ($\chi^2(1, 190) = 24.59$, $p < 0.0001$), want to use navigation ($\chi^2(1, 190) = 4.84$, $p < 0.05$), and have FOMO ($\chi^2(1, 190) = 5.52$, $p < 0.05$), than drivers who are 25 and older (see Figure 5).

Figure 5. Differences for not using DND by age group among non-users of DND.



Among previous users, shown in Figure 6, 18–24-year-olds were more likely to think they can drive safely and message and to say they want to see notifications compared to drivers who are 25 and older. Only 18–24-year-olds reported FOMO as a reason for non-use (see Figure 6).

Figure 6. Differences for not using DND by age group among previous DND users.



Preferences for Automatic DND Activation

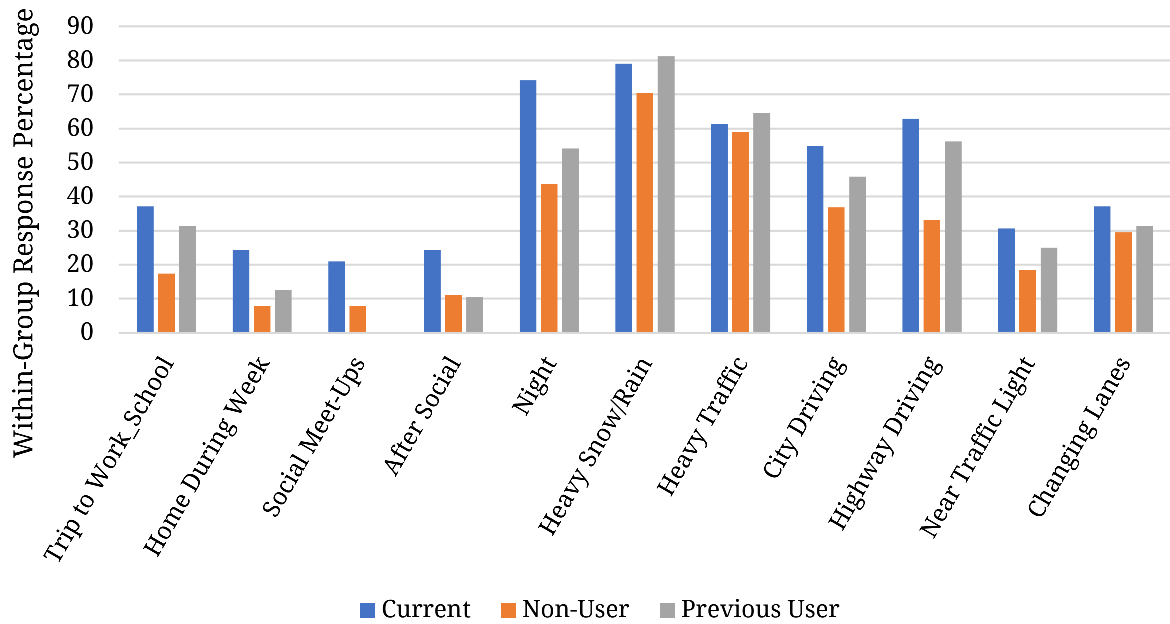
Respondents were asked what situations they believed to be appropriate for automatic DND activation. Specifically, participants were asked when driving becomes difficult, which scenarios would they prefer DND automatically activate (see Appendix A, Countermeasure Apps section, Question 11). It is important to note that these scenarios expanded beyond the current offering of automatic activation after driving is detected. Table 5 shows the percentage of responses across user groups.

Table 5. Rank-Ordered Responses for Automatic DND Activation Scenarios by User Group

	Current (N = 62)	**Non-User (N = 190)**	**Previous (N = 48)**
1	Heavy snow/rain (79%)	Heavy snow/rain (71%)	Heavy snow/rain (81%)
2	Night (74%)	Heavy traffic (59%)	Heavy traffic (65%)
3	Highway driving (63%)	Night (44%)	Highway driving (56%)
4	Heavy traffic (61%)	City driving (37%)	Night (54%)
5	City driving (55%)	Highway driving (33%)	City driving (46%)
6	Changing lanes (37%)	Changing lanes (29%)	Changing lanes (31%)
7	Trip to work/school (37%)	Near traffic light (18%)	Trip to work/school (31%)
8	Near traffic light (31%)	Trip to work/school (17%)	Near traffic light (25%)
9	After social meet-up (24%)	After social meet-up (11%)	Driving home during week (13%)
10	Driving home during week (24%)	To social meet-up (8%)	After social meet-up (10%)
11	To social meet-up (21%)	Driving home during week (8%)	To social meet-up (0%)

Adverse weather (heavy snow/rain), heavy traffic, and nighttime were highly rated across all three groups. Compared to non-users, previous users were more likely to prefer automatic DND activation during highway driving ($\chi^2(1, 238) = 8.46$, $p < 0.01$), when traveling to social meet-ups ($\chi^2(1, 238) = 7.01$, $p < 0.05$) and trips from work/school ($\chi^2(1, 238) = 4.23$, $p < 0.05$); see Figure 7.

Figure 7. Preferences for automatic DND activation among different user groups.



Age-related differences were also examined within non-user and previous user groups; however, no significant differences were found for DND activation preferences (see Figure 8 and Figure 9).

Figure 8. Preferences for automatic DND activation among non-users by age group.

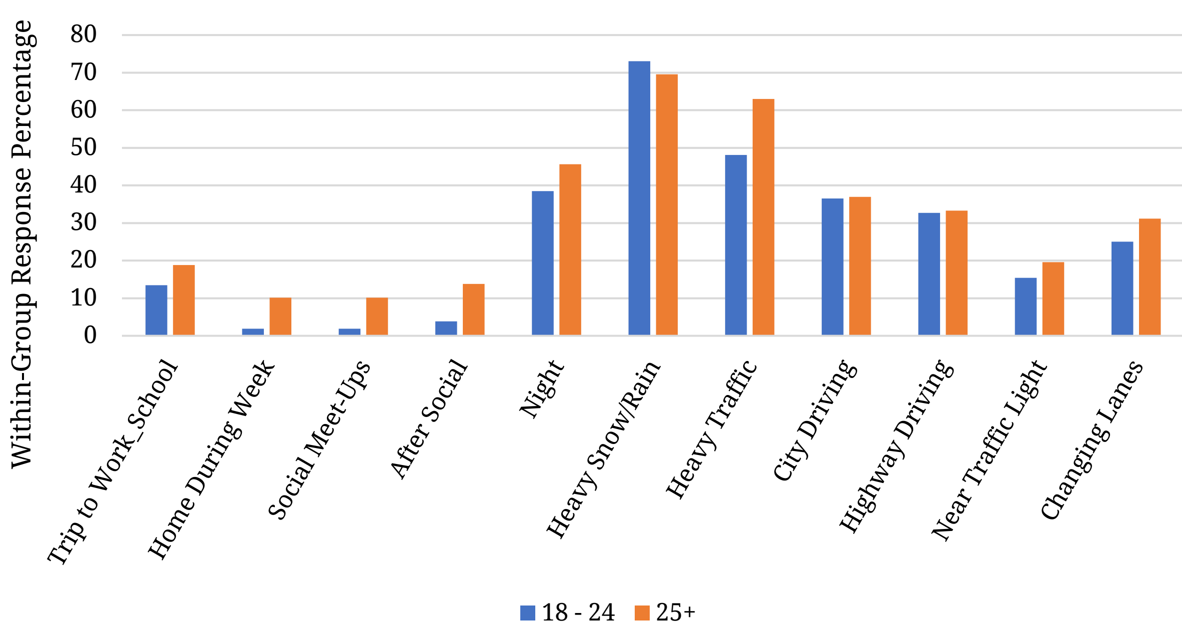
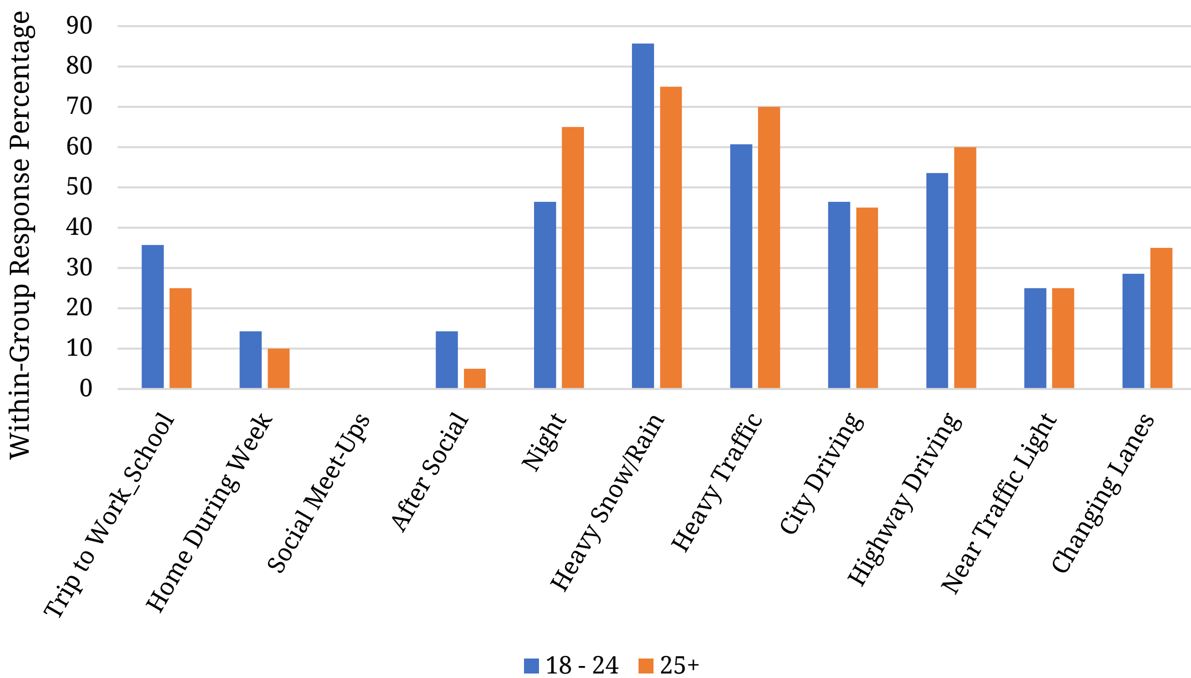


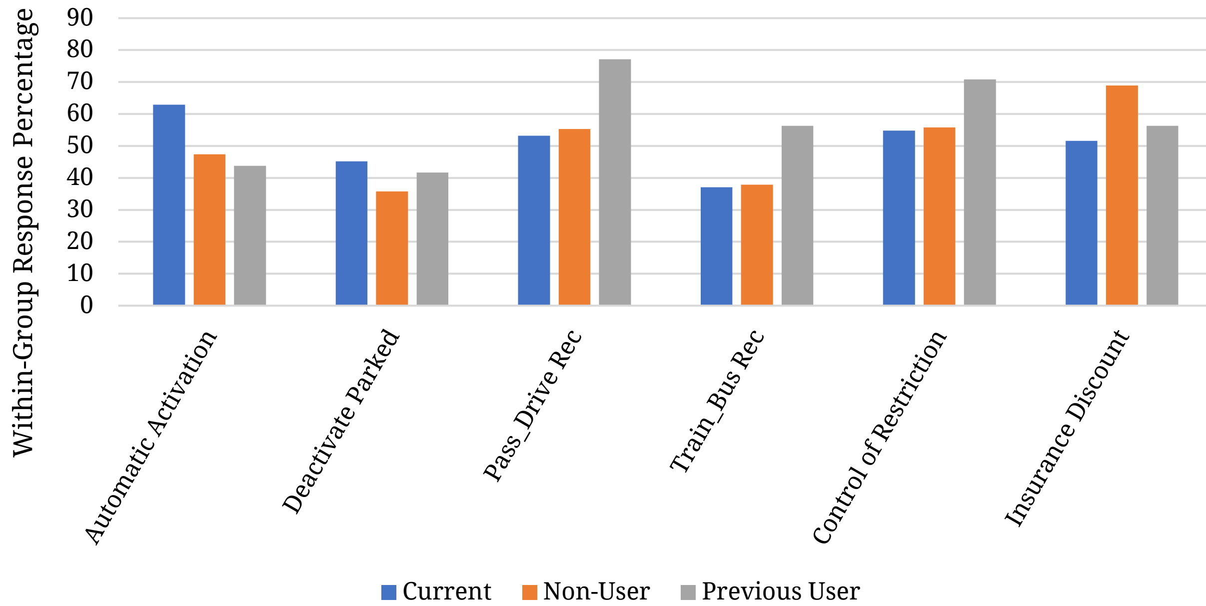
Figure 9. Preferences for automatic DND activation among previous users by age group.



Factors that Increase Likelihood of Using DND

Current users, non-users, and previous users of DND were compared on factors that would influence their DND use (see Appendix A, Countermeasure Apps section, Question 12). Compared to non-users, previous users reported they were more likely to use DND if it was better at recognizing when a user is a passenger or a driver (Pass_Drive Rec in Figure 10; $\chi^2(1, 238) = 8.03$, $p < 0.01$), and when a user is on public transit (Train_Bus Rec in Figure 10; $\chi^2(1, 238) = 5.25$, $p < 0.05$). Nominally, previous users rated control over what apps are restricted as higher than the other groups; non-users rated insurance discounts more highly; and current users rated automatic activation more highly (see Figure 10).

Figure 10. Factors that would increase likelihood of using DND among all users.



To examine age-related effects, results for non-users and previous users were broken out into age groups. Among non-users, those 25 and older would be more likely to use DND with automatic activation ($\chi^2(1, 238) = 4.74$, $p < 0.05$) and deactivation once parked ($\chi^2(1, 238) = 7.06$, $p < 0.01$); see Figure 11. No differences were found by age group for previous users on factors likely to influence DND use (see Figure 12).

Figure 11. More likely to use DND factors among non-users by age group.

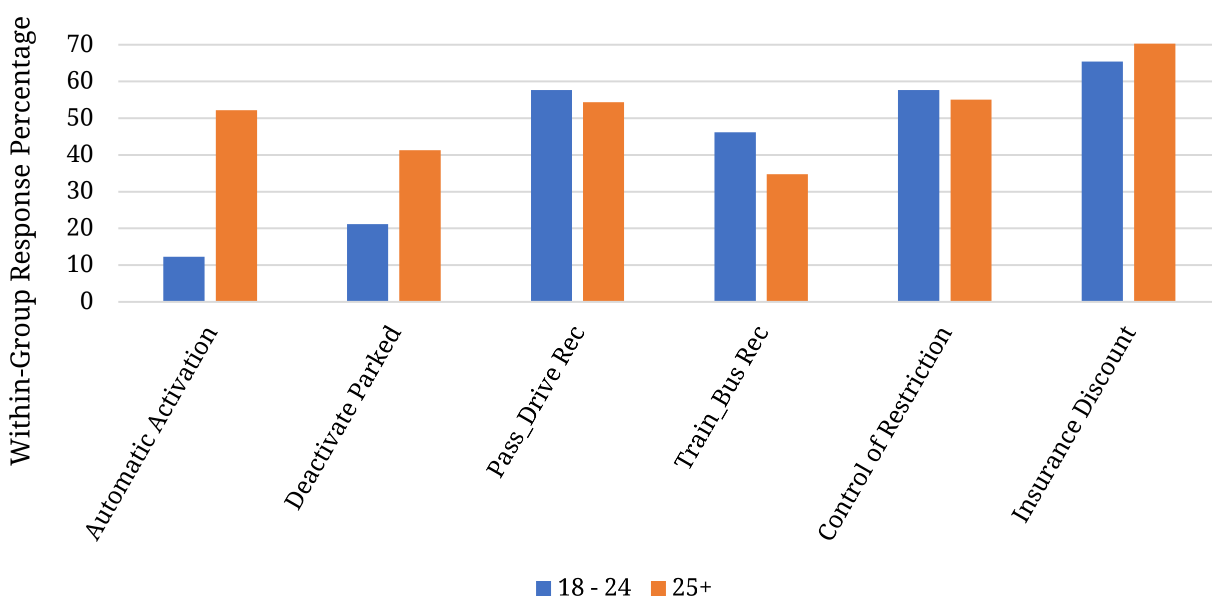
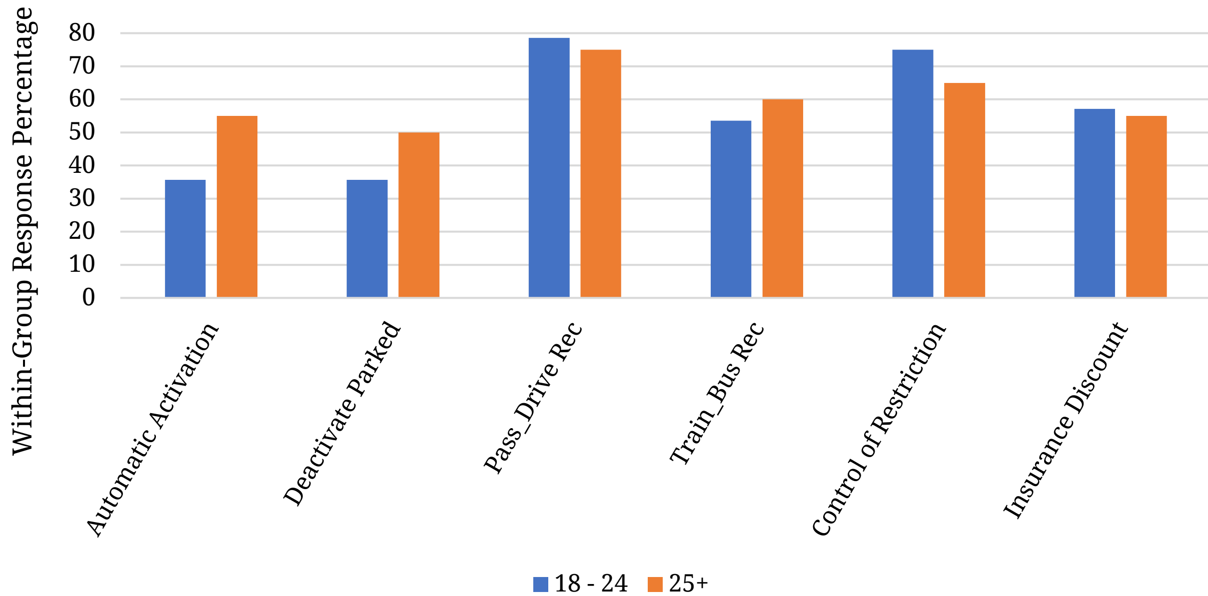


Figure 12. More likely to use DND factors among previous users by age group.



Discussion

Three hundred licensed drivers responded to an online survey about DND use. Questions investigated knowledge of DND, reasons for not using DND, preferences for automatic DND activation, and improvements to DND that would likely increase usage of DND. Participants were classified by DND use: current users, non-users, or previous users. Each user class measured similarly on levels of maladaptive phone use, but current users scored lower than non-users and previous users on their distraction engagement while driving.

Reasons for Non-Use

The current findings suggest that younger users, compared to older users, are more knowledgeable about DND and report current DND use, but are also more likely to have discontinued use of DND (i.e., are classified as previous DND users). This is contrary to previous research regarding younger users and their limited knowledge and use of DND (Delgado et al., 2018; Oviedo-Trespalacios, Williamson, & King, 2019). However, younger previous users were far more likely to believe they can drive safely and message than older users. This suggests that although younger users know more about DND than older users, they are more likely to believe DND is not necessary after using it because they can use their phone safely while driving.

Among all three user groups, wanting to use music and navigation apps was the most frequently selected reasons for not using DND. This is consistent with previous research showing these apps are important to drivers (Oviedo-Trespalacios, Williamson, & King, 2019). However, this also underscores an important lack of understanding of DND as each operating system (i.e., *Driving Focus* on iPhone and *Do Not Disturb while Driving* on Android) allow music and navigation use when activated. Sixty percent of previous users reported that they forget to turn on DND and 32% of non-users reported they did not know about the feature. These outcomes suggest that users across all usage groups could benefit from training on DND features so they have a more accurate understanding of what actions DND restricts and awareness of the feature itself (e.g., can be turned on to automatically activate when driving is detected).

Preferences for Automation Activation

Current apps, *Driving Focus* and *Do Not Disturb while Driving*, can both be set to activate automatically when driving is detected. The current study gathered user preferences for scenarios for automatic activation beyond this. Most users, regardless of previous experience, reported they were in favor of automatic DND activation during stressful driving environments, including heavy rain, snow, or traffic. Research suggests that complex driving environments such as snow (Wu et al., 2012) and heavy traffic (Xie et al., 2021) can increase driver mental workload (Paxion et al., 2014). The selection of these environments for automatic DND activation in the current study suggests that drivers recognize this increase in workload and would welcome a decrease in distractions. Contextual awareness for DND activation as opposed to an all-or-nothing approach may increase usage.

Factors Likely to Increase DND Use

Factors that could influence the likelihood of using DND were also investigated. Improved accuracy in recognizing when a user is not a driver was a common factor across all user groups, though especially in the previous user group. Automatic detection of driving, control over what apps are restricted, and insurance discounts also were identified as factors that would increase DND usage.

Currently, *Driving Focus* for iPhones allows a user to specify “I’m not driving” if phone access is requested while vehicle motion is detected. Although this simple prompt is one solution to misidentifying the user as a driver, it still represents a recurring false alarm that merits resolution. False alarms, in general, can decrease user acceptance of technology such as driver monitoring systems in commercial motor vehicles (Camden et al., 2022) and hazard detection systems (Naujoks et al, 2016). Improving accuracy of driver versus passenger recognition may decrease the number of current DND users who stop using DND due to inaccuracies.[1]

For non-users, those 25 and older would be more likely to use DND if it automatically activated and deactivated at the beginning and end of a trip. As stated above, DND can be set to turn on automatically when motion is detected and turn off when motion has stopped. Non-users citing this as a barrier to use suggests that training on DND could be beneficial as this feature is currently available on both operating systems.

Summary

Many factors were identified in the survey that facilitated or detracted from the use of DND across different user groups. Due to the consistent misunderstanding of DND features and restrictions across all user groups, training on DND and its associated features could increase awareness and usage of the app. The next phase of the study sought to explore this.

Part III: Using Educational Materials to Improve Driver Awareness and Use of DND

The purpose of this phase was to examine whether training or educational material could improve drivers' awareness and understanding of DND and the effects on subsequent smartphone behaviors while driving. This study was accomplished through an NDS approach with 30 participants. Participants had their personal vehicles instrumented with a data acquisition system (DAS) for 10 weeks to record their behavior while driving. They also downloaded the *DriveWell Go*™ app (referred to as the CMT App) developed by Cambridge Mobile Telematics (CMT) to record smartphone use while driving. NDS participants drove the first 5 weeks with no intervention. At the 5-week mark, participants received training and were asked to activate DND for the remaining 5 weeks of participation. The study sought to address two key questions:

1. What was the effect of DND training on a driver's knowledge and opinion of DND?

2. What effect does DND have on a driver's phone use while driving?

[1] Given the relevance for product development, the research team reached out to Google and Apple to share the findings from the survey. Google responded and the findings were shared on October 12, 2023.

Method

Participants

Thirty NDS participants from the New River Valley in Virginia agreed to participate by having their personal vehicles instrumented with a VTTI DAS and downloading the CMT App to their cell phone. Participants self-reported phone use while driving, that they do not use DND, and did not drive a vehicle that was compatible with Apple CarPlay or Android Auto (since those features could confound participant phone interactions). Of those 30, two dropped out, one had CMT App data missing, and another had DAS data missing. Due to the within-subjects design of this study, this missing participant data were excluded from the analysis. Of the remaining 26 participants, 17 were female, 9 were male, and all ranged from 18 to 24 years in age (M = 21.15; SD = 1.91). Participants were split 81% to 15% on iPhone versus Android phone use (one participant switched from iPhone to Android before the DND training session).

Materials

There were two sources of continuous driving performance data used for this study: the VTTI DAS and CMT *DriveWell Go*™ smartphone app.

VTTI DAS. The VTTI-designed MicroDAS was used to collect naturalistic data for this study. The MicroDAS is 6.5 inches × 3 inches × 2 inches and was mounted in the footwell near the onboard diagnostic vehicle network connector (aka OBD-II port; see Figure 13).

Figure 13. VTTI MicroDAS.

The MicroDAS uses intelligent power management to operate using a wide range of voltages from 9 to 24 V with a low sleep current. The MicroDAS features an onboard inertial measurement unit, an onboard global navigation satellite system (GPS) receiver digital input/output, audio input, onboard Wi-Fi and Bluetooth, and a long-term evolution (LTE) option for data uploads and software updates. It can record two Controller Area Network Flexible Data-Rate channels to capture data from modern vehicle networks, record data from up to five high-definition USB cameras, and store data onto multiple media, including microSD, USB, and SSD. Each component was activated when the vehicle ignition system was turned on; the DAS itself remained active and recorded data as long as the engine was on. The system shut down when the ignition was turned off and paused if the vehicle ceased motion for 5 minutes or longer.

Video data were collected from three channels: forward view, driver's face, and over the driver's shoulder (see Figure 14). The forward view provided context on the driving environment, the driver's face view showed where the driver's gaze was directed, and the over-the-shoulder view showed what the participants were doing with their hands (i.e., smartphone interactions).

Figure 14. Camera views collected by VTTI MicroDAS (VTTI employee shown).

There were two main DAS output files—digital video files and vehicle dynamic performance data files—which were stored on the DAS's external hard drive. The vehicle performance file contained the kinematic driver input measures (e.g., lateral and longitudinal acceleration, steering movement, vehicle speed) and the vehicle-related measures (e.g., GPS, light level). The digital video file contained the video recorded continuously during the trip.

DASs were installed in the personal vehicles driven by participants. Data were encrypted in real time using an AES128 cipher with an RSA public-key encrypted, randomly generated key and stored on a USB flash drive associated with each DAS. At the end of data collection, VTTI researchers removed the USB flash drives, where the data were unencrypted into a Structured Query Language (SQL) database format. The data on these flash drives were then copied to secured VTTI databases, where they were unencrypted and stored. Once the data were safely transferred to VTTI, the USB flash drive was erased and refurbished to be placed in the field again.

CMT *DriveWell Go*™ Data. All participants downloaded the *DriveWell Go*™ smartphone app that was developed by CMT. This app can be used in a variety of ways (e.g., monitoring driving behaviors and providing driving performance feedback); however, this study only used the app to collect phone use data in the background without needing any participant intervention. Drivers were not provided with any feedback from the CMT App. As part of the download process, participants were given a key code to identify their driving data as part of this specific study.

The app collected data whenever it detected that the smartphone was in motion. Once motion was detected, kinematic speed, longitudinal acceleration, and interactions with the cell phone (e.g., tapping on the screen, phone movement in the cabin) were continuously collected. These measures or interactions are specified in the next section. Overall, the CMT App data were collected using unique participant IDs that were not tied to personally identifiable information and then transferred from CMT to VTTI via encrypted JSON files. These data were stored in a secured database and post-processed by VTTI database programmers into a format useful for analyses.

Surveys. A number of surveys were completed at different time points: at the start of the study (Pre-Trial), at the 5-week midpoint of the study (Mid-Point), and at the conclusion of the 10-week trial (Post-Trial). The Pre-Trial survey asked NDS participants what type of phone they used as well as some of their perceptions about smartphone use and driving abilities. The Mid-Point survey, conducted in two parts (before and after the training) asked NDS participants about their awareness and knowledge of DND and their perceptions of DND usability (System Usability Scale). The Post-Trial survey matched the online survey administered in Part II, and included several different sections: (a) demographic information and driving history, (b) smartphone use, dependence, and use when driving, and (c) DND use. NDS participants were also asked about their knowledge and understanding of DND features, social norms related to DND use, barriers that prevent them from using DND (and, conversely, factors that might increase the likelihood they would use them), and situations they believed DND should be automatically enabled. Complete surveys can be found in Appendix B.

Procedure

Procedures for this study were approved by the Virginia Tech Institutional Review Board (IRB# 23-1136). Participants were told they would participate for 10 weeks. During the intake session, participants read and signed an informed consent form and were instructed to download the CMT App while their personal vehicle was instrumented with a DAS. The Pre-Trial survey (Appendix B) was completed while the participants' vehicle was being instrumented, which gathered their initial impressions of DND.

For the first 5 weeks of the driving trial, NDS participants were told to simply drive as they normally would and to keep the CMT App downloaded. At the 5-week mark, each participant was brought back to VTTI to receive DND training. Prior to the training, NDS participants completed a survey that assessed their current DND knowledge (Mid-Point Part A survey, see Appendix B). For the training, NDS participants were asked to review a handout that emphasized what smartphone tasks could still be accomplished when DND was activated (e.g., play music). They also viewed a short video developed by the Distracted Driving Coalition (www.NDDC.org) explaining how to set up DND. The handout (shown in Appendix C) was developed to counter some of the misperceptions observed in the online survey (above) regarding how restrictive DND is when activated (e.g., a high percentage reported they do not use DND because they want to listen to music). Following the training, a second survey was administered (Mid-Point Part B survey, Appendix B) and DND was activated on their smartphones. Importantly, DND was set to automatically turn on when driving was detected, and participants were told to keep this setting for the remainder of the study.

After 10 weeks (5 weeks after the training session), NDS participants returned to VTTI and the DAS was removed from their vehicle, the CMT App was uninstalled from their phone, and one final survey was completed (Post-Trial survey, Appendix B).

NDS participants who completed the full 10 weeks were paid $300; those who did not finish received a prorated payment. Participants who had any maintenance appointments to address technical issues were paid an additional $25 for the inconvenience of making a participant return to VTTI.

Data Sampling and Annotation

Driver behavior and phone use were recorded over time using the DAS and CMT App. The DAS collected video and kinematic data. Video data included over-the-shoulder, driver face, and external views, while kinematic data included vehicle dynamics (e.g., speed). CMT App data collected phone interactions (e.g., tapping on phone screen) and other driver behaviors (e.g., speeding) using the accelerometer and gyroscope in the participant's smartphone. Due to the differences in collection method for each dataset, different procedures were used to analyze the data.

The DAS recorded every trip taken by an NDS participant in their personal vehicle during the study. To identify DAS trips with smartphone use, the CMT App tapping data was matched to the recorded DAS trips by time and date with a minimum speed of 1 mph. Using the tapping start as the origin, 20-second segments (i.e., 5 seconds before to 15 seconds after tapping start; hereafter called DAS events) from a DAS trip were annotated for secondary tasks and other contextual factors (e.g., road type). Up to 18 DAS events were annotated by VTTI data reductionists per participant. DAS events were considered invalid if the participant was not driving the vehicle or if a passenger was using the participant's phone while the participant was driving. In addition to these DAS/CMT App events, eight 20-second baseline epochs or segments were randomly selected and annotated from the DAS trips to understand the prevalence of smartphone use. This sampling procedure produced three objective datasets: CMT App, DAS, and Baseline, in addition to the survey data collected at various time points throughout the study. The first 5 weeks before the DND-training session and activation are referred to hereafter as Pre-DND and the final 5 weeks as Post-DND. For each objective dataset, sampling was split Pre-DND/Post-DND activation. An overview of events in each objective dataset is provided in Table 6.

Table 6. Dataset Event Distribution

	Total Events	Pre-DND	Post-DND	Events Sampled per Participant
CMT App	13,458	6,741	6,398	-
DAS	369	185	184	Up to 18*
Baseline	216	108	108	8

**10 participants did not have enough DAS events with a matched CMT App tapping event to reach 18 DAS events.*

Each dataset had unique variables of interest related to it. Table 7 and Table 8 list several key variables and their operational definitions.

Table 7. Independent Variables

Name	Level	Definition
Driving phase	Pre-DND Post-DND	Split between the first and second 5 weeks of participation before and after the intervention for this study was implemented (i.e., DND training and activation)
Gender	Male Female	Self-reported gender
Phone use	Frequent Infrequent	Frequency of phone use split by the overall median of CMT tapping events (i.e., high > 370; Low ≤ 370).

Table 8. Dependent Variables of Interest for Each Objective Dataset

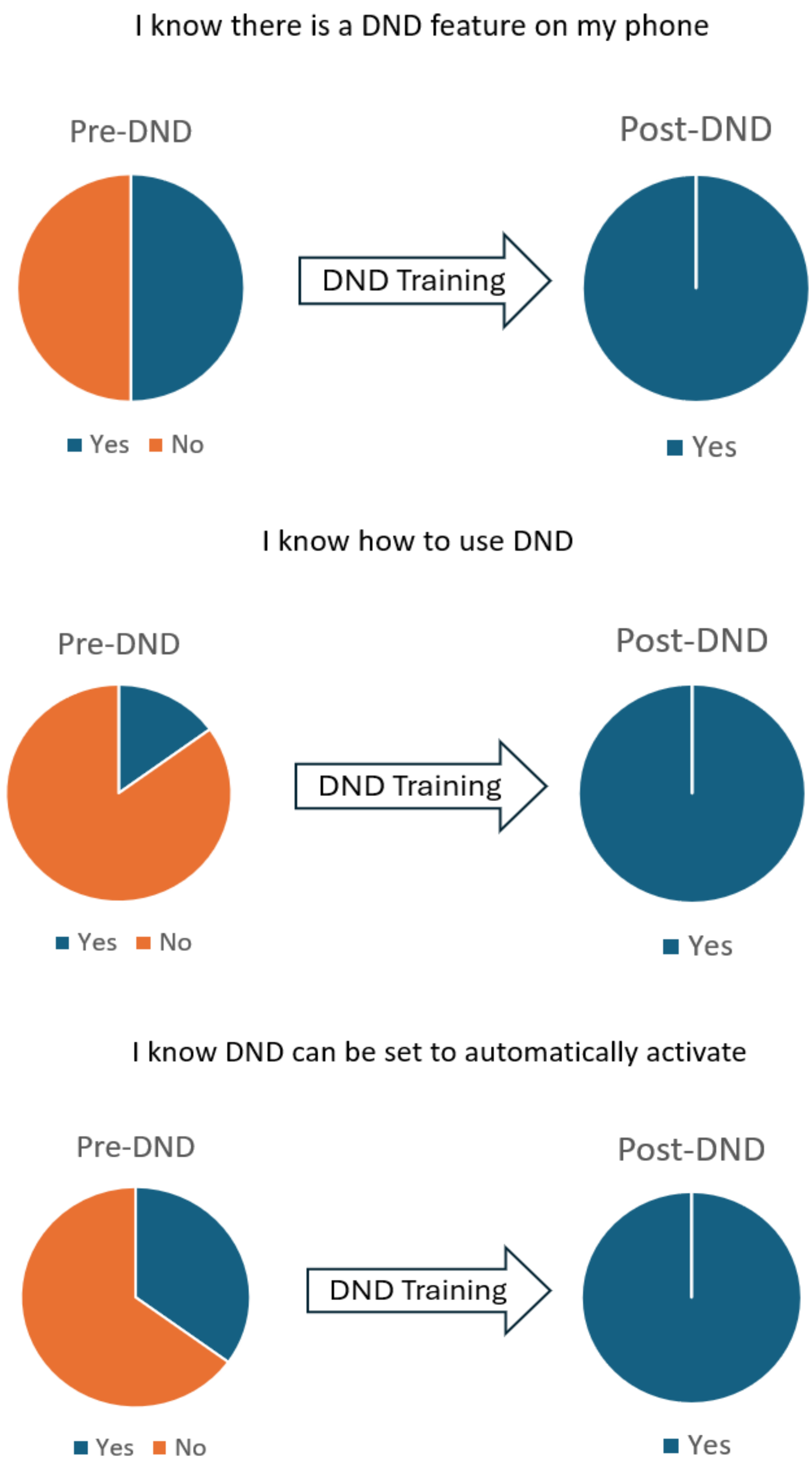
Name	Dataset	Definition	Metric
Opinion of DND	Survey	Participants' perception of DND as measured by the System Usability Scale	Score
Smartphone task prevalence	Baseline	Randomly selected 20-second epochs used to identify whether a smartphone task was present	Yes/No
Visual–manual smartphone task duration	DAS	Length of a visual–manual smartphone task as determined by VTTI data reductionists	Seconds
Visual–manual smartphone task occurrence	DAS	Occurrence of a visual–manual smartphone task	Yes/No
Tapping duration	CMT	Duration of an episode involving participant tapping their phone	Seconds
Tapping occurrence	CMT	Presence of participant tapping their phone (based on CMT algorithm)	Yes/No
Phone pick-up	CMT	Occurrence of a smartphone pick-up (based on CMT algorithm)	Yes/No

Results

Driver Knowledge and Opinion of DND

The results showed that NDS participant knowledge of DND changed by driving phase. Prior to DND training, 50% of participants did not know their phone had a DND feature, 85% reported not knowing how to use DND, and 65% did not know DND could be set to automatically turn on when driving was detected. Following DND training, 100% of participants knew their phone had DND, knew how to use it, and knew it could be set to automatically turn on when driving was detected (see Figure 15).

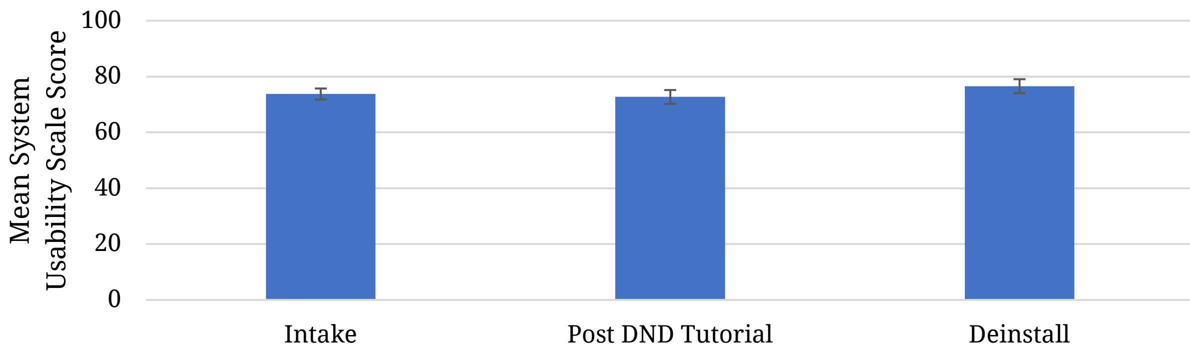
Figure 15. Pre- and Post-DND Training Measure of Participant DND Knowledge



Paired-sample *t*-tests were used to compare participant opinion of DND during the Pre-Trial (intake), Mid-Point (following training), and Post-Trial (deinstall) surveys. Results indicated no significant difference on participant opinion from Pre-Trial to Mid-

Point ($t(25) = 0.34$, $p = 0.74$), from Mid-Point to Post-Trial ($t(25) = -1.47$, $p = 0.16$), or from Pre-Trial to Post-Trial ($t(25) = -0.90$, $p = 0.38$), see Figure 16. For the specific item, "I think I would use DND frequently," there were no significant differences from Pre-Trial to Mid-Point ($t(25) = -1.87$, $p = 0.07$) or from Pre-Trial to Post-Trial ($t(25) = 0.82$, $p = 0.42$). However, there was a significant increase Mid-Point to Post-Trial ($t(25) = 2.57$, $p < 0.05$).

Figure 16. Mean Scores on System Usability Scale Score across Phases of Study (Standard Error Bars are Shown)



A mixed-effect analysis of variance was used to investigate the effect of gender (between subjects) and driving phase (within-subjects) on participant opinion of DND. The main effect of gender ($F(1, 24) = 0.36$, $p = 0.56$) and the two-way interaction were not significant ($F(2, 48) = 0.39$, $p = 0.68$). A similar model was used for the effect of phone use (between subjects) and driving phase (within-subjects) on opinion. Neither the main effect of phone use ($F(1, 24) = 0.06$, $p = 0.80$), nor the interaction were significant ($F(2, 48) = 0.53$, $p = 0.59$).

NDS participant responses regarding barriers and facilitators for DND use are broken out by gender and phone type as shown in Table 9, Table 10, and Table 11. The reasons for non-use of DND were generally similar across gender. With respect to phone type, there was some variability (e.g., "forget to turn on" was much higher ranked for Android than for iPhone; see Table 9). There was little variability across gender and phone type for the top ranked situations where automatic engagement of DND would be preferred (Table 10). With respect to factors that could increase DND use (Table 11), again there were similar responses across gender. For phone type, Android users were agreeable to all response options (rating 100% for each), whereas iPhone users believed that improvements to passenger or public transit recognition and insurance discounts were more important.

Table 9. Reasons for Non-Use of DND across Gender and Phone Type

	Gender		Phone Type	
	Male (N = 9)	**Female (N = 17)**	**iPhone (N = 21)**	**Android (N = 4)**
1	Use navigation (89%)	Use music (82%)	Use music (86%)	Forget to turn on (50%)
2	Use music (67%)	Use navigation (71%)	Use navigation (81%)	Connected with friends (50%)
3	Connected with friends (56%)	Connected with family (59%)	Connected with family (62%)	Connected with family (50%)
4	Connected with family (56%)	Connected with friends (47%)	Connected with friends (52%)	Use navigation (50%)
5	FOMO (44%)	Connected with work (42%)	Connected with work (43%)	Connected with work (25%)
6	Connected with work (33%)	Drive safely and message (35%)	FOMO (43%)	Use music (25%)
7	Drive safely and message (22%)	FOMO (35%)	Drive safely and message (33%)	FOMO (25%)
8	Drive safe with phone (22%)	See notifications (29%)	See notifications (29%)	Hard to turn on (0%)
9	Forget to turn on (11%)	Drive safe with phone (18%)	Drive safe with phone (24%)	Drive safely and message (0%)
10	See notifications (11%)	Forget to turn on (12%)	Notifications from social media (14%)	Hard to turn off (0%)
11	Notifications from social media (11%)	Notifications from social media (12%)	Forget to turn on (5%)	See notifications (0%)
12	Hard to turn on (0%)	Hard to turn off (12%)	Hard to turn off (5%)	Didn't know about it (0%)
13	Hard to turn off (0%)	Didn't know about it (6%)	Didn't know about it (5%)	Drive safe with phone (0%)
14	Didn't know about it (0%)	Hard to turn on (0%)	Hard to turn on (0%)	Notifications from social media (0%)

Table 10. Preferred Scenarios for DND Automatic Activation by Gender and Phone Type

	Gender		Phone Type	
	Male (N = 9)	**Female (N = 17)**	**iPhone (N = 21)**	**Android (N = 4)**
1	Heavy snow/rain (100%)	Heavy snow/rain (100%)	Heavy snow/rain (100%)	Heavy snow/rain (100%)
2	Heavy traffic (100%)	Heavy traffic (82%)	Heavy traffic (86%)	Heavy traffic (100%)
3	Night (78%)	Night (71%)	Night (71%)	City driving (100%)
4	City driving (78%)	City driving (71%)	City driving (67%)	Night (75%)
5	Changing lanes (67%)	Highway driving (53%)	Highway driving (48%)	Changing lanes (75%)
6	After social event (44%)	Changing lanes (47%)	Changing lanes (48%)	Home during week (50%)
7	Near traffic light (44%)	Near traffic light (35%)	Near traffic light (38%)	Trips to work/school (25%)
8	Home during week (33%)	Home during week (24%)	Traveling to social meet-ups (24%)	Traveling to social meet-ups (25%)
9	Traveling to social meet-ups (33%)	Traveling to social meet-ups (24%)	After social event (24%)	After social event (25%)
10	Highway driving (33%)	Trips to work/school (17%)	Trips to work/school (19%)	Highway driving (25%)
11	Trips to work/school (22%)	After social event (17%)	Home during week (19%)	Near traffic light (25%)

Table 11. Factors Likely Increase DND Use by Gender and Phone Type

	Gender		Phone Type	
	Male (N = 9)	**Female (N = 17)**	**iPhone (N = 21)**	**Android (N = 4)**
1	Improved passenger recognition (100%)	Improved passenger recognition (94%)	Improved passenger recognition (100%)	Automatic deactivation when driving (100%)
2	Insurance discount (100%)	Improved public transit recognition (82%)	Improved public transit recognition (86%)	Deactivate when parked (100%)
3	Improved public transit recognition (89%)	Insurance discount (82%)	Insurance discount (86%)	Improved passenger recognition (100%)
4	Deactivate when parked (67%)	Deactivate when parked (76%)	Deactivate when parked (67%)	Improved public transit recognition (100%)
5	Automatic activation when driving (56%)	Automatic activation when driving (65%)	Automatic activation when driving (52%)	Control of restriction (100%)
6	Control of restriction (56%)	Control of restriction (53%)	Control of restriction (43%)	Insurance discount (100%)

For comparison, data for Part II survey participants aged 18–24 were extracted from the online survey and shown side-by-side with the NDS participants in Tables 12, 13, and 14. Results for the NDS participants were taken from the Post-Trial survey (see Appendix B). In general, responses from the two cohorts were similar with a few exceptions: a smaller proportion of NDS participants reported forgetting to turn it on as a reason for non-use (Table 12); NDS participants were also less likely to indicate control over app restrictions as a reason that could increase DND use (Table 14).

Table 12. Reasons for Non-Use of DND, Comparison between Online Survey (Part II) and NDS Participants

	Ages 18–24 from Part II (N = 112)	NDS (N = 26)
1	Use music (70%)	Use music (73%)
2	Use navigation (60%)	Use navigation (73%)
3	Forgot to turn on (42%)	Connected with friends (58%)
4	Drive safely and message (39%)	Connected with family (50%)
5	See notifications (33%)	Connected with work (38%)
6	Stay connected with family (24%)	FOMO (38%)
7	FOMO (19%)	Drive safely and message (27%)
8	Stay connected with friends (15%)	See notifications (23%)
9	Didn’t know about it (13%)	Drive safe with phone (19%)
10	Stay connected with work (10%)	Notifications from social media (12%)
11	Drive safe with phone (10%)	Forget to turn on (12%)
12	Notifications from social media (5%)	Didn’t know about it (4%)
13	Hard to turn on (4%)	Hard to turn off (4%)
14	Hard to turn off (4%)	Hard to turn on (0%)

Table 13. Preferred Scenarios for DND Automatic Activation, Comparison between Online Survey (Part II) and NDS Participants

	Age 18–24 from Part II (N = 112)	NDS (N = 26)
1	Heavy snow/rain (74%)	Heavy snow/rain (100%)
2	Heavy traffic (60%)	Heavy traffic (88%)
3	Night (52%)	City driving (72%)
4	Highway driving (43%)	Night (72%)
5	City driving (42%)	Changing lanes (52%)
6	Home during week (24%)	Highway driving (44%)
7	Changing lanes (31%)	Near traffic light (36%)
8	Trips to work/school (24%)	Home during week (24%)
9	Near traffic light (22%)	Traveling to social meet-ups (24%)
10	After social event (14%)	After social event (24%)
11	Traveling to social meet-ups (9%)	Trips to work/school (20%)

Table 14. Factors Likely to Increase DND Use, Comparison between Online Survey (Part II) and NDS Participants

	Age 18–24 from Part II (N = 112)	NDS (N = 26)
1	Control of restriction (64%)	Improved passenger recognition (96%)
2	Improved passenger recognition (62%)	Improved public transit recognition (85%)
3	Insurance discount (57%)	Insurance discount (85%)
4	Improved public transit recognition (45%)	Deactivate when parked (69%)
5	Automatic activation when driving (41%)	Automatic activation when driving (58%)
6	Deactivate when parked (31%)	Control of restriction (14%)

Effects of DND on Driver Behavior

Smartphone use was investigated using the Baseline, NDS, and CMT App datasets. Generalized linear mixed models (GLMM) and analysis of variance were used to investigate smartphone use while driving. For the variables listed in Table 7 and Table 8, the independent variables were included as fixed effects, dependent variables as the outcome, and subject ID as a random effect.

The CMT App data were used to assess tapping duration and phone pickups. The CMT App collected events ranging from phone interactions to driving behavior. The driving behavior events were deemed out-of-scope for this project and were excluded from analyses. There were many instances where CMT-flagged events did not have an associated DAS trip event. This could be due to errors in the classification algorithm or due to other factors. For this reason, CMT events that did not have a connected DAS trip were excluded from analyses. See Table 15 for the final CMT event breakdown.

Table 15. Distribution of CMT Events

		Total	Had DAS Event	Used for Analyses	Final Total
Driving behavior	Harsh acceleration	1,042	629	-	-
	Harsh braking	2,250	1,500	-	
	Harsh cornering	1,974	1,205	-	
	Speeding	6,576	3,916	-	
Phone use	Phone call	1,540	886	886	13,458
	Phone motion	8,441	4,938	4,938	
	Tapping	13,035	7,634	7,634	

Engagement in Smartphone Tasks. In the baseline dataset, smartphone tasks were present in 21% of all events, 26% of events Pre-DND, and 16% Post-DND. A GLMM with a binominal distribution and logit link function was used to test prevalence of smartphone tasks by driving phase. As shown in Table 16, the odds of a smartphone task decreased by 41% Post-DND compared to Pre-DND (*OR* = 0.59; 95% *CI*: 0.38, 0.92).

Similarly, the occurrence of visual–manual smartphone tasks was compared by using a binominal GLMM. There were 197 visual–manual tasks Pre-DND and 179 Post-DND; however, the odds of this task occurring did not reach conventional levels of significance (*OR* = 0.81; 95% *CI*: 0.65, 1.02); see Table 16.

Tapping occurrence was also investigated using a binomial GLMM. There were 3,767 tapping events Pre-DND and 3,684 Post-DND. Interestingly, the odds of a tapping event increased by 5% Post-DND compared to Pre-DND (*OR* = 1.05; 95% *CI*: 1.01, 1.11). Phone pickups were investigated using a binominal GLMM. There were 2,514 phone pickups Pre-DND and 2,292 Post-DND. The odds of a phone pickup decreased by 6% Post-DND compared to Pre-DND (*OR* = 1.05; 95% *CI*: 1.01, 1.11); see Table 16 for statistical results.

Table 16. Model Results for Smartphone and Visual–Manual Tasks, Tapping, and Phone Pick Ups

Outcome	Term	Estimate*	95% CI Lower	95% CI Upper	*P*
Smartphone task	Intercept	0.18	1.000	1.000	<0.001
	Driving phase (Post-DND)	0.59	0.38	0.92	0.02
	Gender	1.69	1.09	2.62	0.44
	Phone use	1.34	0.68	2.63	0.38
	Driving phase*gender	1.20	0.77	1.86	0.43
	Driving phase*phone use	0.75	0.51	1.11	0.15
	Gender*phone use	0.83	0.43	1.63	0.58
Visual–manual smartphone task occurrence	Intercept	2.64	1.79	3.89	<0.001
	Driving phase	0.81	0.65	1.02	0.07
	Gender	1.13	0.77	1.66	0.53
	Phone use	0.87	0.59	1.28	0.45
	Driving phase*gender	1.08	0.86	1.36	0.51
	Driving phase*phone use	0.89	0.72	1.11	0.31
	Gender*phone use	1.34	0.91	1.97	0.13
Tapping occurrence	Intercept	1.44	1.29	1.60	<0.001
	Driving phase (Post-DND)	1.05	1.01	1.11	0.04
	Gender	0.96	0.86	1.07	0.40
	Phone use	0.90	0.80	1.00	0.05
	Driving phase*gender	1.01	0.96	1.06	0.83
	Driving phase*phone use	0.98	0.93	1.03	0.35
	Gender*phone use	0.96	0.86	1.07	0.44
Phone pick-up	Intercept	0.53	0.47	0.59	<0.001
	Driving phase (Post-DND)	0.94	0.89	0.99	0.01
	Gender	1.06	0.94	1.20	0.30
	Phone use	1.08	0.96	1.22	0.18
	Driving phase*gender	0.98	0.95	1.03	0.45
	Driving phase*phone use	1.04	0.99	1.09	0.09
	Gender*phone use	0.99	0.95	1.03	0.09

**Log-odds ratios and confidence intervals have been exponentiated to convert to odds ratios.*

Duration of Smartphone Engagements. In the NDS dataset, visual–manual smartphone task duration was investigated using a repeated measures analysis of variance. A breakout of the events categorized as visual–manual is shown in Table 17.

Table 17. Visual–Manual Smartphone Task Categorization

Task Type	Count
Cell phone, unknown task type, visual + manual	164
Cell phone, browsing, hand-held	43
Cell phone, holding and glancing, hand-held	26
Cell phone, texting	47
Cell phone, dialing hand-held	3
Cell phone, navigation, visual + manual	15
Cell phone, locating/reaching/answering	78

As shown in Table 18, the average duration of visual–manual tasks was 12.46 seconds Pre-DND (*SE* = 0.61) compared to 11.19 (*SE* = 0.66) Post-DND; however, this difference was not significant ($F(1, 368.9) = 2.19$, $p = 0.14$). None of the other main effects or interactions were significant.

Table 18. Analysis of Variance for Duration of Visual-Manual Tasks (DAS Dataset).

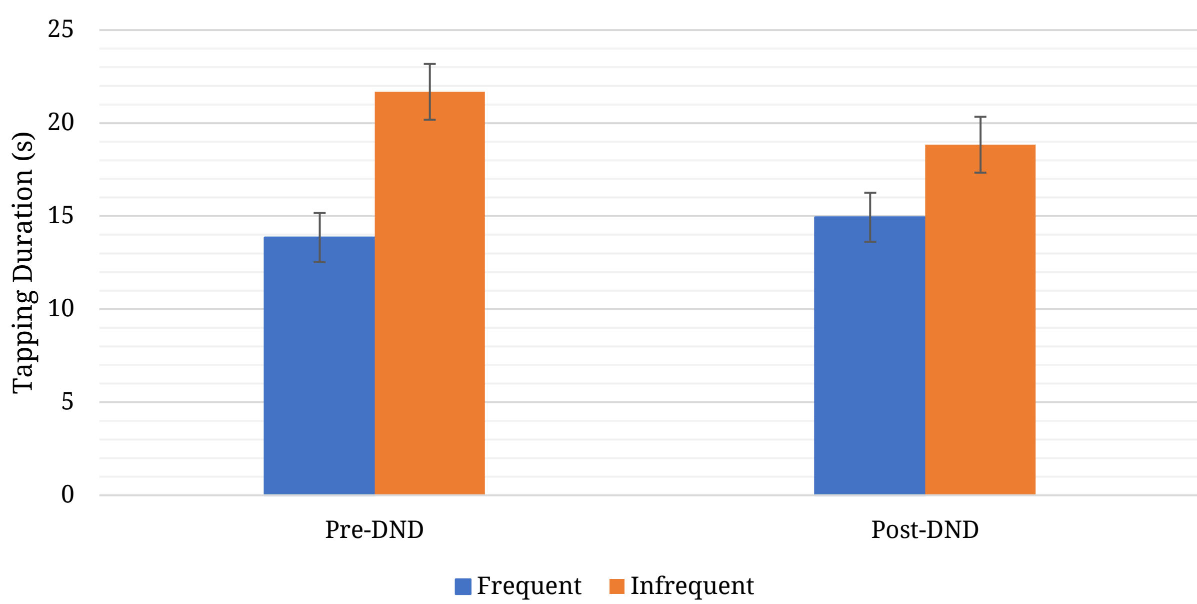
Outcome	Effect	*F*(df1,df2)	*P*	Level	*M*	*SE*
Visual–Manual Duration	Driving phase (A)	2.19(1, 368.9)	0.14	Pre-DND	12.46	0.61
				Post-DND	11.19	0.66
	Gender (B)	0.10(1, 15.23)	0.76	Male	11.68	0.80
				Female	11.97	0.50
	Phone use (C)	3.31(1, 15.09)	0.09	Infreq	12.68	0.72
				Freq	10.97	0.60
	A*B	1.61(1, 367.6)	0.20	-	-	-
	A*C	0.32(1, 361.7)	0.57	-	-	-
	B*C	1.56(1, 15.05)	0.23	-	-	-

As shown in Table 19, tapping duration was investigated using a repeated measures analysis of variance. Drivers' average tapping duration was 17.76 seconds Pre-DND (*SE* = 1.00) compared to 16.89 (*SE* = 1.03) Post-DND; this difference was not significant ($F(1, 7174) = 1.95$, $p = 0.16$). Interestingly, infrequent phone users had longer tapping durations (*M* = 20.26; *SE* = 1.43) compared to frequent phone users (*M* = 14.40; *SE* = 1.29; $F(1, 21.41) = 9.27$, $p < 0.01$). The interaction between phone use and driving phase was also significant ($F(1, 7180) = 10.28$, $p < 0.01$). Tukey pairwise comparison revealed that infrequent users had longer tapping durations (*M* = 21.68; *SE* = 1.50) than frequent users Pre-DND (M = 13.85; SE = 1.32; difference M = 7.83; SE = 2.00, $p < 0.05$) but not Post-DND (difference M = 3.90; SE = 2.04, $p = n$; see Figure 17).

Table 19. Analysis of Variance for Duration of Tapping Episodes (CMT App Dataset)

Outcome	Effect	*F*(df1,df2)	*P*	Level	*M*	*SE*
Tapping duration	Driving phase (A)	*1.95*(1, 7174)	0.16	Pre-DND	17.76	1.00
				Post-DND	16.89	1.03
	Gender (B)	*0.47*(1, 21.50)	0.50	Male	17.99	1.55
				Female	16.67	1.14
	Phone use (C)	*9.27*(1, 21.41)	<0.01	Infreq	20.26	1.43
				Freq	14.40	1.29
	A*B	*0.28*(1, 7284)	0.60	-	-	-
	A*C	*10.28*(1, 7180)	<0.01	Pre-DND, Freq	13.85	1.32
				Pre-DND, Infreq	21.68	1.50
				Post-DND, Freq	14.94	1.32
				Post-DND, Infreq	18.84	1.56
	B*C	*4.41*(1, 21.50)	0.05	-	-	-

Figure 17. Mean Tapping Duration by Driving Phase and Phone Use; Standard Error Bars are Shown



Discussion

The purpose of this phase of the study was to examine whether training or educational material could improve drivers' awareness and understanding of DND as well as their phone-use behaviors. Twenty-six participants who were 18 to 24-years old participated in an NDS study for 10 weeks. The participants' personal vehicles were instrumented with a DAS, and they downloaded the CMT App to monitor phone use. Participants drove normally for 5 weeks, then received training on and activated DND, and drove for another 5 weeks. Subjective survey responses were collected at multiple time points.

Driver Knowledge and Opinions of DND

Results suggest that participants' knowledge of DND improved after receiving DND training. The training was designed to address misconceptions about DND functionality that were evident in the online survey from Part II (e.g., desire to listen to music). Pre-training knowledge of the DND feature ranged from 50% to 85% accuracy. However, post-training, all participants reported they knew how to use DND, that the feature was readily available on their phones, and that it could be set to automatically activate. However, participant opinions of DND did not change after receiving DND training, possibly due to other factors. For example, improved context recognition was one of the top reasons that participants said would increase DND use (i.e., accurate detection of driver versus passenger or on public transit). So, while the training increased participants' awareness and knowledge of the automatic activation feature, more development and refinement to the detection algorithms are needed to address this concern.

It is important to note that "control of restriction" was the top reason to likely increase DND use mentioned in Part II and the lowest in the NDS study. This suggests that participants' concerns about DND restrictions were alleviated through the training.

DND and Phone Use

Participants were engaged in a smartphone task 21% of the time while driving. While higher than previous studies that report prevalence of 6.4% (Dingus et al., 2016), it could be due to the focus of the current study on 18 to 24-year-olds who are more likely to engage with their phones while driving (Guo et al., 2017; National Center for Statistics and Analysis, 2022).

Results revealed a 41% decrease in the odds of a smartphone task after DND was activated, suggesting that DND was effective in lowering the number of smartphone interactions while driving. The results also showed that phone tapping duration decreased for infrequent phone users after receiving training (though not for frequent phone users). Although tapping duration decreased Post-DND for some participants, they were 5% more likely to have a tapping event Post-DND. This could be due to the additional steps (and phone taps) needed to disengage DND to unlock their phone (i.e., iPhone users must clear a prompt, Android does not require this extra step[2]). Finally, participants were 6% less likely to pick up their phone Post-DND compared to Pre-DND, which supports the idea that DND decreases phone pickups and lowers the potential for smartphone interactions while driving.

General Discussion

The current study investigated barriers for using smartphone-based countermeasures (i.e., *Do Not Disturb while Driving*; *Driving Focus*) using a mixed-method approach. Part II involved an online survey of drivers to understand their opinions and knowledge of DND. Part III involved instrumenting the vehicles of drivers who were likely to use their cell phone while driving for 10 weeks. A DND training module was given to those drivers at the 5-week mark, and they were told to activate DND for the remaining 5 weeks of participation. Part III investigated driver smartphone use while driving and their knowledge and opinions of DND before and after that training.

Barriers to Smartphone Countermeasures

In Part II, participants cited wanting to use music and navigation apps while driving as the most frequent reasons for not using DND. In addition, most previous DND participants forgot to turn DND on, while a third of those who had never used DND did not know the feature existed. These reasons are all contrary to DND functionality and suggest a lack of understanding of DND, its features, and what happens when it is activated. To address this, a training module was used that addressed those specific items. In Part III, participants were told that music/navigation apps could still be used and DND was set to automatically turn on when driving was detected. However, those in Part III still cited wanting to use music and navigation apps as their top reasons for not using DND post training. Given that they were trained on DND and knew this was still possible, participants may not want to deal with the type of forced interaction required when DND is active; that is, participants with iPhones were forced to use music and navigation apps through voice-control when *Driving Focus* was active. Research suggests some drivers prefer manual interaction with their phone as opposed to voice control when driving (Schreiner, 2006) and interaction modality preference can change

[2] The effect of driving phase was still significant when excluding Android phones from the model (*OR* = 1.06; 95% *CI*: 1.01, 1.13).

depending on a task that is being performed on an in-vehicle infotainment system (Huang et al., 2024).

Further, it is important to note trends in reasons for non-use of DND between each study phase. For example, notifications from social media were infrequently selected as a barrier to use DND in Parts II and III. This may have been assumed to be a high priority for users age 18–24, as this age group is especially likely to report social media use (Auxier & Anderson, 2021). Participants in Part III reported staying connected with friends, family, and work as their next reasons for non-use following music and navigation. This is represented by 85% of participants in Part III allowing family contacts to come through when DND was activated and 81% letting both friends and family come through. This differs from participants in Part II, who cited forgetting to turn on DND as their next reason for non-use. Participants in Part III had DND set to automatically activate when driving was detected, which could explain this difference in ranking. FOMO was ranked similarly across objectives and this, combined with the emphasis on staying connected, suggests participants were more concerned about missing text messages or calls as opposed to social media notifications. Finally, those with Android phones in Part III stated forgetting to turn DND on and staying connected with friends and family as their top reasons for not using DND. This differs from iPhone users who state music and navigation (in line with the overall sample) as their top reasons for non-use. This difference is likely due to the design approach to DND by each operating system as Android users can still access applications when DND is active as opposed to iPhone users who must clear a prompt deactivating DND.

Although participants' opinions of DND did not change after training or use in Part III, participants from both Part II and III approved of DND automatic activation in various driving scenarios. Heavy snow/rain and heavy traffic were the top choices for automatic activation, while a mix of other scenarios were rated depending on study phase (see Table 13). This suggests participants recognize the attentional demand of these driving environments and that they would benefit from decreased phone distraction while in them. However, this would require accurate scenario recognition to avoid any false positives that could decrease DND use out of annoyance (Naujoks et al., 2016; Camden et al., 2022). As mentioned above, improved passenger/transit recognition were the top reasons that would increase DND use, suggesting that errors in driver classification encourage DND deactivation and non-use.

Overall, results from both Part II and Part III suggest that participants prioritize music, navigation, and incoming communication while driving. Training did not affect participant opinion of DND in Part III; however, both phases suggest drivers are open to DND automatic activation in demanding driving environments. This suggests that drivers may be open to DND use if it were not an "all-or-nothing" approach; that is, DND would only turn on in demanding driving environments. Although this approach does not address all phone use while driving, it could address use in dangerous driving scenarios that are more likely to produce a crash (Eisenberg & Warner, 2005; Xu et al., 2015).

DND and Phone Use While Driving

Results suggest that DND is effective at decreasing phone pickups and the prevalence of smartphone tasks. This implies that DND lowered incentives (e.g., notifications) for phone pickups (and subsequent phone use) that were prevalent pre-activation. Previous research shows that drivers are more likely to respond to incoming messages than initiate conversations (Waddell & Wiener, 2014), supporting the silencing of notifications. However, in Part III, communication with friends, family, and work was frequently cited as a reason for non-use of DND and is an implied incentive for phone use. Indeed, previous research suggests communication with members of important relationships can influence phone use while driving (Foreman et al., 2016). Training emphasizing the auto-reply function that is available with DND may alleviate concerns about maintaining contact with important relationships while driving.

Participants still interacted with their phones while driving, regardless of DND activation, and their opinion of DND did not change over the study. This suggests that restrictive countermeasures to phone use may not promote a high rate of user acceptance and prolonged use. This is evident with other countermeasures that have been developed to address phone use while driving. For example, state laws that prohibit handheld phone use while driving have shown some effectiveness (Nikolaev et al., 2010; Rudisill & Zhu, 2017); regardless, phone use while driving persists, even in states with cell phone bans (Rudisill et al., 2019). As mentioned above, drivers want to use their phones while driving, especially for music and navigation (Oviedo-Trespalacios, Williamson, & King, 2019). Other countermeasures have been developed (e.g., Apple CarPlay and Android Auto) that allow phone use while driving but attempt to make interactions with a phone while driving less complex (e.g., project interface onto larger in-vehicle screen; larger interface buttons). Although a large portion of new vehicles support these interfaces (Straits Research, 2023), not all vehicles on the road do. In those cases, applications that alter the phone user interface in a manner similar to that of CarPlay and Android Auto could support phone interactions while driving (e.g., DriveMode app).

Limitations and Future Research

Participants in Part II responded to an online survey. Online surveys provide subjective responses that are useful for gaining insight into user opinions but also have limitations (e.g., selection bias; Nayak & Narayan, 2019). This was controlled in part by the use of the Prolific crowdsourcing platform that has been shown to provide responses from quality respondents (Peer et al., 2021; Palan & Schitter, 2018). In Part III, participants set DND to automatically activate when driving was detected and were told to use DND for the second 5-week block of participation. Although self-reported DND use increased from 4% to 81% of trips over the study, DND activation status was not recorded during Part III. This level of phone use detail could not be obtained through the CMT App. The current study assumed DND was active at the start of each trip; however, the participant could have disengaged the feature while driving. Future research should employ a more objective measure of DND activation that can confirm the frequency of trips for which DND is activated. This could investigate further context for DND use and non-use by confirming when it is deactivated while driving. Further, although an effort was made to control for CMT App measurement error, the CMT events that were included for analyses (see Table 15) were only confirmed as happening in the participant's vehicle but not that the participant was driving. As mentioned in the Data Sampling and Annotation section above, DAS events were considered invalid if a participant was not driving the vehicle or if a passenger was using the participant's phone when the participant was driving. This level of detail could not be controlled for in the CMT data as manually reviewing the DAS video trips for all events was not in-scope for this project. As such, it is assumed participant driver recognition error is possible in the included CMT events. Future research should control this variation to confirm that all events included meet those requirements.

Conclusion

Drivers tend to overestimate the smartphone use restrictions that DND imposes when activated. Training designed to educate users on DND functionality and what it does and does not restrict did increase their knowledge of DND but did not change their opinion of it. DND did decrease the prevalence of smartphone tasks and the odds of a phone pickup, supporting the efficacy of this technology in lowering phone use while driving. Developers of DND apps should investigate better context recognition as false positives for DND activation were frequently listed as reasons for not using DND. With better context recognition, developers could have DND automatically activate in risky driving scenarios (e.g., heavy snow or rain), a method that was favored by participants in the current study.

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Appendix A: Online Survey (Part II)

Demographic Information

1. What is your age? __________ (criteria: all age ranges, 18-25 primary interest)
2. What is your gender?
   a. Male
   b. Female
   c. Other
3. What is the highest level of education you have completed?
   a. Elementary school
   b. High school or equivalent
   c. Vocational/technical school (2 year)
   d. Some college
   e. Bachelor's degree
   f. Master's degree
   g. Doctoral (Ph.D.) or professional (M.D., J.D., Psy.D.) degree
4. How long have you been a licensed driver? (criteria: $\geq 18\ months$)
5. Have you previously been in a crash? That is, has your car hit another vehicle or object within the past 5 years? (criteria: yes)
6. Have you previously had any traffic violations within the past 5 years? Check all that apply.
   a. Speeding
   b. Running red light
   c. Not stopping at stop sign
   d. Other
7. How often do you drive?
   a. Never
   b. Rarely; I drive once every few months
   c. Sometimes; I drive once every month
   d. Often; I drive once a week
   e. Very often; I drive more than once a week
   f. All the time; I drive every day
8. Do you own a smartphone?
   a. Yes
   b. No (end survey, partial payment)
9. Which type of smartphone do you own?
   a. iPhone
   b. Android
   c. Other (end survey, partial payment)

10. Do you use the "*Driving Focus*" feature? *(if iPhone)*
    a. Yes
    b. No
    c. No, but I have in the past
11. Do you use the "*Do not Disturb while Driving*" feature? (*if Android*)
    a. Yes
    b. No
    c. No, but I have in the past

Problematic Phone Use Questionnaire

1. How long have you owned a smartphone?
    a. Less than 1 year
    b. 1 to 5 years
    c. 6 – 10 years
    d. Over 10 years
2. How many calls do you make with your smartphone per day?
    a. 0 – 2
    b. 3 – 5
    c. More than 5
3. How much time do you spend on your smartphone per day?
    a. 0 – 10 minutes
    b. 10 – 30 minutes
    c. More than 30 minutes
4. How many SMS (text messages) do you send per day?
    a. 0 – 3
    b. 4 – 10
    c. More than 10
5. Do you consider yourself addicted to your smartphone?
    a. Yes
    b. No
6. I use my smartphone while driving.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
7. I try to avoid using my smartphone when driving on the highway.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
8. I use my smartphone in situations that would qualify as dangerous.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
9. While driving, I find myself in dangerous situations because of my smartphone use.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree

10. I use my smartphone while driving, even in situations that require a lot of concentration.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
11. I don’t use my smartphone when it is completely forbidden to use it.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
12. I don’t use my smartphone in a library.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
13. I use my smartphone where it is forbidden to do so.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
14. When using my smartphone on public transport, I try not to talk too loud.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
15. I try to avoid using my smartphone where people need silence.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
16. Please select “agree” to demonstrate you are paying attention.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
17. It is easy for me to spend all day not using my smartphone.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree

18. It is hard for me <u>not</u> to use my smartphone when I feel like it.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
19. I can easily live without my smartphone.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
20. I get irritated when I am forced to turn my smartphone off.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
21. I feel lost without my smartphone.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
22. I don’t attach a lot of importance to my smartphone.
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree
23. It is hard for me to turn my smartphone off.*
    a. Strongly Agree
    b. Agree
    c. Disagree
    d. Strongly Disagree

Susceptibility to Distracted Driving Questionnaire

Susceptibility to Involuntary Distraction

While driving you find it distracting when:						
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Never Happens
Your phone is ringing						
You receive an alert from your phone (e.g., incoming text message)						
You are listening to music						
You are listening to talk radio						
There are roadside advertisements						
There are roadside accident scenes						
A passenger speaks to you						
You are daydreaming						

Distraction Engagement

When driving you:					
	Never	Rarely	Sometimes	Often	Very Often
Hold phone conversations					
Manually interact with a phone (e.g., sending text messages, browsing the internet)					
Adjust the settings of in-vehicle technology (e.g., radio channel or song selection)					
Read roadside advertisements					
Continually check roadside accident scenes if there are any					
Chat with passengers if you have them					
Daydream					

Attitude about Voluntary Distraction

You think it is all right for you to drive and:					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Hold phone conversations					
Manually interact with a phone (e.g., sending text messages, browsing the internet)					
Adjust the settings of in-vehicle technology (e.g., radio channel or song selection)					
Read roadside advertisements					
Continually check roadside accident scenes if there are any					
Chat with passengers if you have them					

Perceived vehicle control while driving distracted

You believe you can drive well even when you:					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Hold phone conversations					
Manually interact with a phone (e.g., sending text messages, browsing the internet)					
Adjust the settings of in-vehicle technology (e.g., radio channel or song selection)					
Read roadside advertisements					
Continually check roadside accident scenes if there are any					
Chat with passengers if you have them					

Perceived Social Norms about Distracted Driving (1)

Most drivers around me drive and:					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Hold phone conversations					
Manually interact with a phone (e.g., sending text messages, browsing the internet)					
Adjust the settings of in-vehicle technology (e.g., radio channel or song selection)					
Read roadside advertisements					
Continually check roadside accident scenes if there are any					
Chat with passengers if you have them					

Perceived Social Norms about Distracted Driving (2)

Most people who are important for me think it is all right for me to drive and:					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Hold phone conversations					
Manually interact with a phone (e.g., sending text messages, browsing the internet)					
Adjust the settings of in-vehicle technology (e.g., radio channel or song selection)					
Read roadside advertisements					
Continually check roadside accident scenes if there are any					
Chat with passengers if you have them					

Understanding Phone Use While Driving

In the questions to follow, we are interested in learning about how you use your phone while driving and the car is moving. Please keep this context in mind when answering.

1. Looking at/reaching for my phone while I am driving....

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
... allows me to be entertained while I drive (1)	○	○	○	○	○	○	○
.... allows me to get to quickly and easily navigate to where I need to go (2)	○	○	○	○	○	○	○
... allows me to be productive while I drive (3)	○	○	○	○	○	○	○
... allows me to stay connected to my friends and family while I drive (4)	○	○	○	○	○	○	○
... reduces my visibility of my surroundings while I drive (5)	○	○	○	○	○	○	○
... reduces my control of my vehicle while I drive (6)	○	○	○	○	○	○	○
... increases my risk of a crash (7)	○	○	○	○	○	○	○
... reduces my ability to focus while I drive (8)	○	○	○	○	○	○	○

2. While driving, my ability to...

	Not at all important (1)	Low importance (2)	Slightly important (3)	Neutral (4)	Moderately important (5)	Very important (6)	Extremely important (7)
be entertained is... (1)	○	○	○	○	○	○	○
navigate quickly and easily to where I need to go is... (2)	○	○	○	○	○	○	○
be productive is... (3)	○	○	○	○	○	○	○
stay connected is... (4)	○	○	○	○	○	○	○
have visibility while I drive is... (5)	○	○	○	○	○	○	○
have control of my vehicle while I drive is... (6)	○	○	○	○	○	○	○
avoid a car crash is... (7)	○	○	○	○	○	○	○
focus while I drive is... (8)	○	○	○	○	○	○	○

Countermeasure Apps

1. Did you **know** that you have a “Do Not Disturb” feature on your phone?

○ Yes (1)

○ No (2) (if no, go to brief description, skip Q6)

---

2. Do you know **how to use** the “Do Not Disturb” feature on your phone?

○ Yes (1)

○ No (2) (if no, go to brief description, skip to Q6)

---

3. Did you know that you can set “Do Not Disturb” to **automatically turn on** when you start to drive?

○ Yes (1)

○ No (2)

---

4. What percentage of the trips when you are driving do you use "Do Not Disturb”?

	None of my trips	About half of my trips	Every trip
	0	50	100
% ()			

---

5. How easy is it to activate "Do Not Disturb" for your drives?

○ Extremely difficult (1)

○ Somewhat difficult (2)

○ Neither easy nor difficult (3)

○ Somewhat easy (4)

○ Extremely easy (5)

○ I do not use “Do Not Disturb” (6)

---

6. How often do you turn "Do Not Disturb" **off** after it's been activated while driving?

○ Never (1)

○ Sometimes (2)

○ About half the time (3)

○ Most of the time (4)

○ Always (5)

○ I do not use “Do Not Disturb” (6)

---

7. Please select “about half the time” to demonstrate you are paying attention.

- ◯ Never (1)
- ◯ Sometimes (2)
- ◯ About half the time (3)
- ◯ Most of the time (4)
- ◯ Always (5)
- ◯ I do not use “Do Not Disturb” (6)

8. How **easy** is it to turn "Do Not Disturb" off after it's been activated for your drives?

- ◯ Extremely difficult (1)
- ◯ Very difficult (2)
- ◯ Neither difficult nor easy (3)
- ◯ Very easy (4)
- ◯ Extremely easy (5)
- ◯ I do not use “Do Not Disturb” (6)

9. Please mark your response for the following statements:

	Extremely unlikely (1)	Very unlikely (2)	Slightly unlikely (3)	Neither improbable nor probable (4)	Somewhat likely (5)	Very likely (6)	Extremely unlikely (7)
My parents/caregivers/ guardians using "Do Not Disturb" while they drive is... (1)	○	○	○	○	○	○	○
My friends using "Do Not Disturb" while they drive is... (2)	○	○	○	○	○	○	○
Other people my age using "Do Not Disturb" while they drive is... (3)	○	○	○	○	○	○	○

10. Do any of the things below stop you from using "Do Not Disturb" when driving? Select all that apply.

- ☐ I forget to turn "Do Not Disturb" on (1)
- ☐ I want to stay connected with ***friends*** (2)
- ☐ I want to stay connected with ***family*** (3)
- ☐ I want to stay connected with ***work*** (4)
- ☐ "Do Not Disturb" is hard to turn on (5)
- ☐ I can drive safely when receiving messages (6)
- ☐ It's too hard to turn off if I have it on (7)
- ☐ I want to see notifications (8)
- ☐ I want to use my music apps (9)
- ☐ I want to use navigation apps (10)
- ☐ I did not know about this feature (11)
- ☐ I can drive safely while using my phone (12)
- ☐ I want to receive notifications from social media apps (13)
- ☐ I am afraid of missing out on important events and/or communication (14)
- ☐ Other (15) ____

11. If "Do Not Disturb" could come on automatically when driving is difficult, which of the below scenarios would you like "Do Not Disturb" to automatically enable? (Select all that apply)

- ☐ Trips to work/school (1)
- ☐ Trips home during the week (2)
- ☐ Trips to social meet ups (3)
- ☐ Trips home after social meet ups (4)
- ☐ Trips made at night (5)
- ☐ Trips made when there is heavy snow/rain (6)
- ☐ When there is heavy traffic (7)
- ☐ When driving through the city (8)
- ☐ When driving on the highway (9)
- ☐ When driving near a traffic light (10)
- ☐ When changing lanes (11)
- ☐ Other (12)

12. I would be more likely to use "Do Not Disturb" if (Select all that apply)

- It turned on automatically once I start driving (1)
- It turned off once I park my vehicle (2)
- It recognized when I am a passenger as opposed to driver (3)
- It recognized when I am a passenger on a train/bus as opposed to a driver (4)
- It would allow me to control what apps are restricted during use (5)
- I received a discount on my auto insurance (6)
- Other (7)

13. How often do you use "Do Not Disturb" in the following situations?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Very often (5)	All the time (6)
Sleep (1)	○	○	○	○	○	○
Personal Time (2)	○	○	○	○	○	○
Work (3)	○	○	○	○	○	○
Other (4)	○	○	○	○	○	○
Driving (5)	○	○	○	○	○	○

Appendix B. Surveys from Naturalistic Driving Study (Part III)

Pre-Trial Survey

1. What type of smartphone do you have?

   A. iPhone
   B. Android

In the questions to follow, we are interested in learning about how you use your phone while driving and the car is moving. Please keep this context in mind when answering.

2. Looking at/reaching for my phone while I am driving....

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
... allows me to be entertained while I drive (1)	○	○	○	○	○	○	○
.... allows me to get to quickly and easily navigate to where I need to go (2)	○	○	○	○	○	○	○
... allows me to be productive while I drive (3)	○	○	○	○	○	○	○
... allows me to stay connected to my friends and family while I drive (4)	○	○	○	○	○	○	○
... reduces my visibility of my surroundings while I drive (5)	○	○	○	○	○	○	○
... reduces my control of my vehicle while I drive (6)	○	○	○	○	○	○	○
... increases my risk of a crash (7)	○	○	○	○	○	○	○
... reduces my ability to focus while I drive (8)	○	○	○	○	○	○	○

3. While driving, my ability to...

	Not at all important (1)	Low importance (2)	Slightly important (3)	Neutral (4)	Moderately important (5)	Very important (6)	Extremely important (7)
be entertained is... (1)	○	○	○	○	○	○	○
navigate quickly and easily to where I need to go is... (2)	○	○	○	○	○	○	○
be productive is... (3)	○	○	○	○	○	○	○
stay connected is... (4)	○	○	○	○	○	○	○
have visibility while I drive is... (5)	○	○	○	○	○	○	○
have control of my vehicle while I drive is... (6)	○	○	○	○	○	○	○
avoid a car crash is... (7)	○	○	○	○	○	○	○
focus while I drive is... (8)	○	○	○	○	○	○	○

System Usability Scale

Response rated 1 – 5; Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree

1. I think that I would like to use Do Not Disturb frequently

2. I found Do Not Disturb unnecessarily complex

3. I thought Do Not Disturb was easy to use.

4. I think that I would need the support of a technical person to be able to use Do Not Disturb.

5. I found the various functions in Do not Disturb were well integrated.

6. I thought there was too much inconsistency in Do Not Disturb.

7. I would imagine that most people would learn to use Do Not Disturb very quickly.

8. I found Do Not Disturb very cumbersome to use.

9. I felt very confident using Do Not Disturb,

10. I needed to learn a lot of things before I could get going with Do Not Disturb.

<u>Mid-Point Survey</u> (5 weeks)

<u>Part A: Pre-DND Training</u>

1. Did you **know** that you have a ”Do Not Disturb” feature on your phone?

○ Yes (1)

○ No (2)

3. Do you know **how to use** the “Do Not Disturb” feature on your phone?

○ Yes (1)

○ No (2)

---

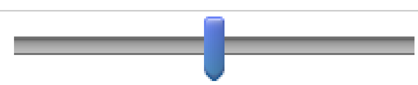
4. Did you know that you can set "Do Not Disturb" to **automatically turn on** when you start to drive?

○ Yes (1)

○ No (2)

---

5. What percentage of the trips when you are driving do you use "Do Not Disturb”?

	None of my trips	About half of my trips	Every trip
	0	50	100
% ()			

Part B: Post-DND Training

System Usability Scale

Response rated 1 – 5; Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree

1. I think that I would like to use Do Not Disturb frequently

2. I found Do Not Disturb unnecessarily complex

3. I thought Do Not Disturb was easy to use.

4. I think that I would need the support of a technical person to be able to use Do Not Disturb.

5. I found the various functions in Do not Disturb were well integrated.

6. I thought there was too much inconsistency in Do Not Disturb.

7. I would imagine that most people would learn to use Do Not Disturb very quickly.

8. I found Do Not Disturb very cumbersome to use.

9. I felt very confident using Do Not Disturb,

10. I needed to learn a lot of things before I could get going with Do Not Disturb.

<u>Post-Trial Survey</u> (10 weeks)

The Post-Trial survey was identical to the survey used in Appendix A. They also completed the System Usability Scale, shown above.

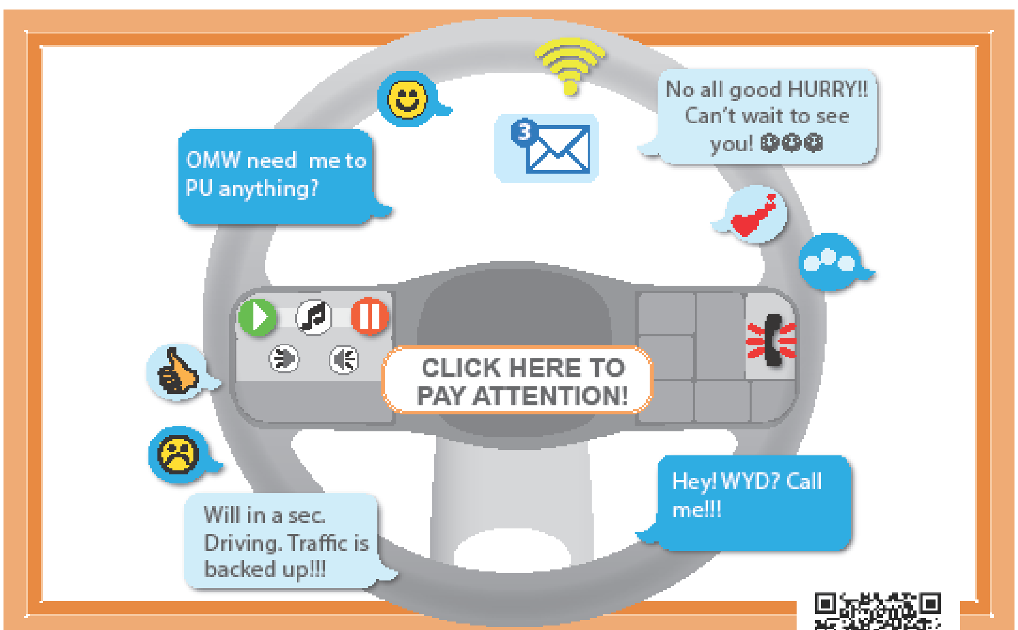
Appendix C. DND Training Handout Used at 5-Week Mid-Point

iPhone User Training

DRIVING FOCUS

What it Does Do
Blocks distracting notifications while you are driving
Turns on when you are driving and off when finished
Allows music or navigation use if activated before driving
Prevents manual phone use

What it Doesn't Do
Restrict all notifications • Callls from important contacts can be customized to notify even when active
Remain active indefinitely • Can be set to only activate during driving
Restrict all application use • Music and navigation applications continue to run in the background
Restrict all phone use • Siri voice-commands can be used



Do Not Disturb While Driving
How-to for iPhone, Android, Pixel

DO NOT DISTURB WHILE DRIVING

What it Does Do
Blocks distracting notifications while you are driving
Turns on when you are driving and off when finished
Still allows application use

What it Doesn't Do
Restrict all notifications • Notifications from specific apps, callers, and texts can be customized
Remain active indefinitely • Can be set to only activate during driving
Restrict all application use • Music, navigation and other applications can still be used

Do Not Disturb While Driving
How-to for iPhone, Android, Pixel