# SAMBA

# Smartphone Apps Mapping and Benefits Assessment for the promotion of road safety

Final research report

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**EXCECUTIVE SUMMARY**

Driving is a complex task. Drivers have to appropriately manage the driving task while dealing with various distractions inside and outside the vehicle. Vast technological developments have emerged in recent years, enhancing our quality of life on the one hand, but largely increasing the potential for drivers to engage in distracting tasks while driving, on the other hand. Smartphone usage while driving, a prominent type of driver distraction, has become a major concern in the area of road safety. In Israel, the focus of this study, according to a global survey "'Our Mobile Planet" conducted by Google in partnership with Ipsos MediaCT, 2013 data show that the percentage of penetration and daily use of the smartphone is among the highest in the world.

While being a major cause of risk, smartphones apps may also serve as a means to monitor, control and reduce risky driving behavior. There are many safety-related apps in the market, but it is still vague and unclear what should characterize a safety app which have the greatest potential to reduce injury crashes.

Considering these aspects the SAMBA research has been delivered. The acronym stands for "Smartphone Application Mapping and Benefits Assessments for the promotion of road safety". SAMBA contribution is threefold: (1) To understand the current patterns and attitudes towards smartphone usage while driving in Israel and the differences in patterns and attitudes regarding types of usage and among the general population and professional drivers. (2) To perform a comprehensive mapping and description of hundreds of various types of apps, already in the market, and their possible safety benefits. (3) To evaluate and grade the various types of apps according to their potential for reducing injury crashes based on experts' opinion with respect to two key criteria: potential acceptance and potential contribution to safety.

Understanding the current patterns and attitudes towards smartphone usage while driving in Israel was based on an internet survey of 757 Israeli drivers who own smartphones and on a sample of 110 truck drivers, where the information was obtained based on roadside interviews performed at gas stations. In both samples, phone calls and texting were found to be the most common usages while driving, hence, both were chosen to be further analyzed. Responses were analyzed in order to first, gain insights regarding patterns of smartphone usage while driving and its motivation, and second to probe drivers' views on the perceived risk and the need to use smartphones while driving, as well as their willingness to use blocking apps that limit such usages.

73% (N=551) of the passenger car drivers sample  makes phone calls while driving and almost half of them may be considered frequent callers as they admit to do it intensively while driving. As for texting, 35% of the respondents (N=256) text while driving and a quarter of them do so frequently. 100% (N=110) of the truck drivers sample make phone calls and more than half of them may be considered as frequent phone call users as they admit doing it intensively. The frequency of texting is noticeably low compared to performing calls yet considering the documented gravity of the texting effect on driving safety, having  33% of the respondents (N=33) reported to do so is a reason for concern. These findings indicate more extensive usage compared to previous evidence from Israel (Tomer-Fishman, 2010) and may reflect an increasingly worrisome trend in drivers' behavior.

Among the passenger car drivers sample, while only 43% of the occasional phone calls users and 27% of the frequent phone calls users believe that phone calling compromises safety, most texting users (87% of occasional users and 74% of frequent users) are aware that texting compromises safety. Accordingly, texting users place limitations on themselves: more than 70% report avoiding texting when they think that they need to devote more attention to driving. This finding is strengthened by the results obtained among truck drivers: 39% of the texting users text although they acknowledge its effect on safety.  Adding the 56% of the texting users who acknowledge that texting can somewhat compromise safety, indicates that even within texting users - 95% acknowledge at least some effect of texting on safety. The paradox according to which high belief that texting compromises safety is not associated with low texting rates in practice is worrisome.

Logistic regression models regarding the factors affecting frequency of usage suggest that the main factor for both texting and phone calling, in both samples, is their perceived need, while perceived safety has an ambiguous effect.  This implies that perceived need determines the frequency of use more than perceived safety. The fact that respondents reported texting only when they really need to and that most of them avoid it to adjust to traffic conditions suggests that most respondents apply some “self-filtering” process with regard to texting.

Approximately half of the passenger cars drivers expressed willingness to use a blocking app with an extensive limiting configuration (complete blockage of phone calls and texting). The willingness to use such technology was found to be related primarily to perceived need. This may pave the way for technology based distraction prevention to serve as key countermeasures.

Blocking apps are one type of safety-related apps which are already in the market. A total of approximately 250 apps with indication regarding their potential benefits for safety were mapped and categorized according to their features. The mapped apps can be categorized according to the following three types: blocking apps, apps that change the interface with the user and driving-feedback apps. We would like to note that this 'three types' distinction is safety-oriented and takes into account drivers' modality (visual, auditory) and responses (manual, vocal). One can also create classifications based on the expected acceptability, social support, motivations for use and more. Navigation apps, the most prominent and popular type ,was not analyzed in this study. Its prominence over other types of apps might had biased the evaluation. From acceptance point of view it is clear that navigation apps gain high scores. However, their ambiguous effects on safety should be further and deeply investigated in a dedicated study.

Based on the mapping, nine leading types of apps were further investigated: (1) Texting prevention: No typing – complete prevention of typing capabilities (keyboard disappears). (2) Texting prevention - No reading of non-driving related texts or visuals (e.g. mail, SMS) – only driving aid information (e.g. navigation, parking assistance) may appear. (3) Call limitation – except for emergency and pre-defined phone numbers, both in-coming and out-going phone calls are blocked. (4) Voice control – enables the operation of a wide variety of smartphones features and apps using voice and dictation: Voice commands – by speaking (rather than typing) users can compose text messages and emails, or activate apps and features, and (5) Text-to-speech – only driving related text is being read by the app to the driver. (6) Gesture control – enables hands-free interface by using built-in proximity sensors and cameras which detect physical movements. (7) Heads up display – a transparent display on the front windshield which enables drivers not to take their eyes off the road ahead (8) Collision warnings – use the smartphone camera to detect risky events such as short head time and provide warnings for the driver and finally, (9) Green Box (IVDR) – provides indication about aggressive behavior (e.g. hard braking) to the driver and to the person in charge or related to the driver (e.g., parent, employer, insurer).

These nine apps have been evaluated in an experts study. Thirty seven experts from academia, industry and government, who cover various areas of expertise, namely: safety (13 experts), government (7 experts), technology (8 experts) and human factors (9 experts), participated in the study. The experts were asked to individually evaluate and grade the apps safety potential considering key criteria. While improving safe driving behavior was a key criterion, acceptance was found in the literature to be a leading criterion as well. Hence, the two main criteria included in SAMBA were: (1) Risky driving behavior - the potential of the app to reduce risky driver behavior and increase safer driving, and: (2) General acceptance - the potential of the app to be adapted, supported and widely used by the general public.

The general acceptance criterion was further sub-divided into three components: (a) Individual willingness - the potential of the app to be adopted and used by an individual (at zero cost), (b) Public support - the potential of the app's concept to be supported and accepted by the public (including policy makers, media, employers, etc.), and: (c) Potential functionality – belief in the potential of the app to work properly as it should in the near future (regardless of its functionality nowadays). In order to promote the ultimate goal of reducing injury crashes, risky driving behavior should be minimized and general acceptance (as well as its sub-components) should be maximized.

**The evaluation process was carried out via TransparentChoise AHP software http://www.transparentchoice.com/, a decision making software for AHP models. The general framework of the AHP model which served as the outline for the experts' evaluations is illustrated in**
Figure 1. The blocking apps are highlighted in light yellow, apps which provide of less distracting interfaces are highlighted in light blue, and coaching apps are highlighted in grid gray.

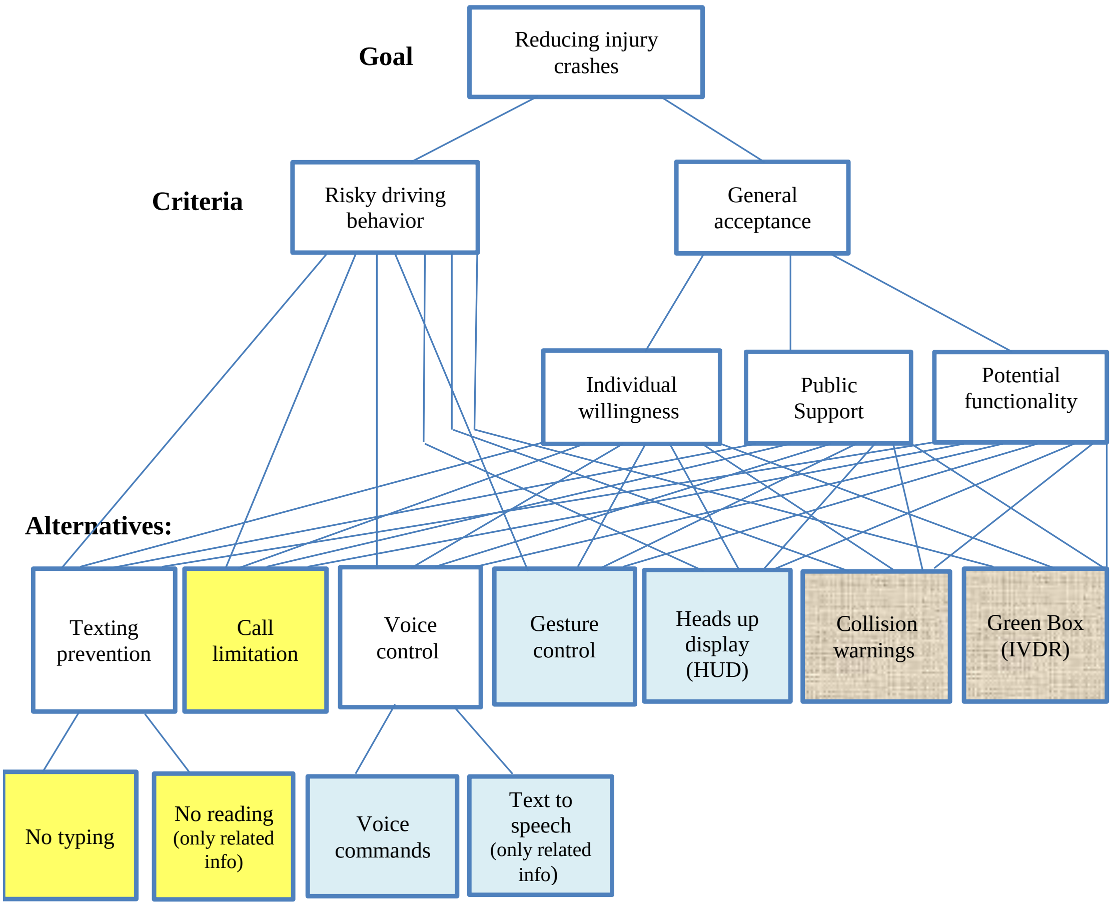


**Figure 1** General framework of the AHP model

The results have been analyzed based on two approaches. The first considered the original framework of the AHP model and the second was a "data driven" approach. A sensitivity analysis has been also been performed.

The two approaches used for analyzing the results produced similar results which clearly define the desired type of safety apps according to the following decreasing order: collision warning, texting prevention– no typing, texting prevention– no reading, voice control – text-to-speech, voice control – commands, and IVDR. However, while collision warning and voice control were considered to be publically accepted, it was found that texting prevention and IVDR were not likely to be widely accepted and used. These results are partially supported by a recent study (TRL et al., 2015). When weighing safety considerations versus acceptance concerns, they were found to be almost equally important. This result highlights the tradeoffs between safety and acceptance and emphasizes the need to consider both with caution when developing and implementing countermeasures.

Grouping the experts according to their discipline and organization, reveals an interesting finding according to which technology and government officials are more inclined towards the “acceptance” branch, whereas safety and human-factor experts place more importance to safety. Considering that experts with various perceptions and from different disciplines, cultures, states, can apply different weights to safety potential versus social support potential, the tool we provided for sensitivity analysis may be valuable.

Cluster analysis according to app types provided somewhat intriguing results; as expected in accordance to the literature, call limitation and texting prevention (both reading and typing) were grouped together into a blocking cluster; HUDs and gesture control were grouped together into an interface cluster. However, voice controls (both commands and text-to-speech) were grouped together with driver feedback apps (green box and collision warning). This may indicate a potential for an ADAS cluster.

Clearly, smartphones will continue to pose a key concern for road safety.  SAMBA paves the way to establish a blueprint for a "safety suit" for smartphone apps by highlighting the types of apps and the importance of key criteria that may have the greatest potential to improve safety in this challenging technology-oriented era.

## 1. INTRODUCTION AND MOTIVATION

Smartphone usage, is a major concern in the road safety literature, and is likely to remain a key issue as smartphone usage continues its global rise. By the end of 2011 there were 5.9 billion mobile phones subscribers worldwide (ITU, 2011), and 432.1 million smartphones were sold just in the second quarter of 2013 (IDC, 2013). In the United States, an annual survey (State Farm, 2013) found a progressive rise in the percentage of drivers reporting to access the internet while driving, from 13% in 2009 to 24% in 2013. Introduction of new features to smartphones encourages usages other than calling and texting. Hence, in 2014, 18% of drivers reported on responding to emails and 20% on reading social media networks while driving (State Farm, 2014).

The penetration rate of smartphones in Israel, where this study was conducted, is among the highest in the world. According to a global survey "'Our Mobile Planet" conducted by Google in partnership with Ipsos MediaCT (Ipsos MediaCT, 2014), the 2013 data shows that in Israel the penetration rate and daily use of the smartphone is among the highest in the world. According to the same survey, 93% of smartphone holders also use their device "on the road". In Israel, texting while driving is illegal, and so is hand-held performance of phone calls. In a phone usage survey (N=700) conducted in Israel (Tomer-Fishman, 2010) it was found that 81% reported not sending a text message in the past seven days, 48% avoided reading an incoming message, 13% read messages immediately, and 39% waited to attend to reading while the vehicle was stopped (for example, at a traffic light). In terms of phone calls, it was found that 44% of the sample reported making them while driving and 19% reported on doing it frequently. Furthermore, 28% of phone calling users reported that they initiated calls and not just responded to incoming calls. When asked about the reasons for talking on the phone, 41% of the callers mentioned work-related reasons, 21% did it to make up for lost time and 20% answered the phone in order to meet certain needs such as emergencies and daily arrangements.

Many recent studies indicated that actions involving usage of smartphones and smartphone applications (apps) while driving increase the risk of a crash (Asbridge et al., 2013; Caird et al., 2014). Texting, surfing the web, getting notifications from social networks, and even making phone conversations, all may lead to a distraction from the primary task of driving. The distraction may be multifaceted: visual, manual, audio, cognitive, and often, a combination of those distraction types. Consequently, the driver's ability to detect and attend to roadway stimuli and events is reduced (Caird et al., 2008, Fitch et al., 2013, Handel et al., 2014, Klauer et al., 2014, Strayer et al., 2013 ). Recent studies investigated driving distractions and confirmed the harmful effects of phone-related activities on driver performance.

Of the many types of mobile device use, texting was found to be the most risky behavior (Dingus, 2014, Hedlund, 2011, Klauer et al., 2014, Victor et al., 2014). Fitch et al. (2013) reported that texting brings diverting eyes off the road much more than other activities (for example: about 23 seconds compared to 8 seconds for dialing). Yager (2013) reported that response time of drivers who send text message double, even in the presence of voice interface. A recent meta-analysis study combined estimates from 28 (mostly simulator) studies about the effect of texting (reading, typing or both) on various performance measures such as: reaction times, lane discipline (the authors used the term “lateral control”), gaze based indices and collisions occurrences. The aggregation of the results indicated that across a majority of behaviors there was increased risk with varying levels of effects (Caird et al., 2014).

As for the "original" phone usage - phone calls - several studies found limited evidence of their impact on driving safety. A naturalistic driving study (Klauer et al., 2006) reported that while the odds ratio (OR) for a dialing task to predict involvement in crashes and near crashes was 2.79 (95% confidence interval (CI): 1.6-4.87), the OR for talking/listening to a hand-held phone was not significantly different from 1 (1.29, CI: 0.93-1.8). In a later naturalistic study (Klauer et al., 2014) the contribution of several secondary tasks to the occurrence of crashes was evaluated in two samples:  young drivers and experienced drivers. For both samples it was found that dialing increased crash risk (young drivers, OR: 8.32, CI: 2.83-24.42, experienced drivers, OR: 2.49; CI, 1.38- 4.54), while talking on the phone had insignificant impact. For other tasks such as eating, looking at roadside objects and reaching for an object other than the cellphone, a significantly higher than one OR values were estimated for the young drivers sample but not for the experienced drivers. These results indicate that experience on how (or when) to do these tasks can mitigate risk. Pertaining to phone calls, the literature yielded mixed results. Some studies indicated that during phone conversations, compared to in-car passenger conversations, driving performance is affected in terms of approach speeds, reaction times, and avoidance of road and traffic hazards (Charlton, 2009). Other studies indicated that conversing on the phone while driving does deteriorate performance such as attention and peripheral detection, but not significantly more than conversing with a passenger (Amado and Ulupınar , 2005;  Ferlazzo et al., 2008).

Absurdly, the public perceives smartphone usage while driving, and especially texting, as significantly compromising safety, but these views are not associated with actual driving behavior (Hamilton et al., 2013, Marcoux et al., 2012, Musicant et al., 2015). Various countermeasures from diverse disciplines have been suggested and implemented to try to mitigate the negative effects of smartphones usage while driving. Among them: legislation which forbids the use of hand-held cellphones, bans on texting, enforcement, generating "texting zones" along freeways, education, massive campaigns, and even recommendations to carmakers to limit the communication with electronic devices built into their vehicles (such as: surfing, entertainment and texting). However, there is an on-going discussion on the feasibility of implementing such measures, their effectiveness and their acceptability. Hence, the unsafe use of smartphones while driving continues to pose a serious risk to safety (Abouk & Adams, 2013, Goodwin et al., 2013, Kircher et al., 2012).

While being a major cause of risk, smartphones apps may also serve as a means to monitor, control and reduce risky driving behavior. Clearly, technologies are evolving rapidly and the greatest advantage of smartphone apps as countermeasures is their low cost and wide availability. This can be tailored to specific purposes and used to influence patterns of smartphone usage while driving. However, the usage of apps is voluntarily and most importantly: it is still vague and unclear which types of apps should be favored and what features and functions compose a "safety suit" app. Furthermore, its prospects for drivers' acceptance and adoption should be also considered.

Considering these aspects the SAMBA research has been delivered. The acronym stands for "Smartphone Application Mapping and Benefits Assessments for the promotion of road safety". SAMBA contribution is threefold: (A) To understand the current patterns and attitudes towards smartphone usage while driving in Israel and the differences in patterns and attitudes regarding types of usage and among the general population and professional drivers. (B) To perform a comprehensive mapping and description of hundreds of various types of apps, already in the market, and their possible safety benefits (C) To evaluate and grade the various types of apps for reduce injury crashes based on experts' opinion with respect to key criteria: potential acceptance and potential safety. Highlighting the types of apps that have the greatest potential to reduce injury crashes may pave the way to establish a blueprint for a "safety suit" for smartphone apps.

Consequently, this report includes three focal sections. Section 2 describes frequency and patterns of smartphone usage while driving in Israel, based on surveys. This section includes a refereed paper which the authors published in *Accident Analysis and Prevention* in 2015. Section 3 presents mapping of safety – related smartphone apps, based on literature and market review. Section 4 deals with evaluation of safety –related apps, based on experts opinions. This section incorporated a paper currently in press in *Transport Policy*. Finally, in Section 5 we present conclusions, discussion and recommendations.

## 2. FREQUENCY AND PATTERNS OF SMARTPHONE USAGE WHILE DRIVING

### 2.1 Overview

The main objective of this section is to understand the current patterns and attitudes towards smartphone usage while driving in Israel and the differences in patterns and attitudes regarding types of usage.
In light of the miscellaneous results about the safety implications of phone calls it is noteworthy that a public deliberation has emerged recently in Israel on what kind of smartphone usage governmental policies and actions (e.g., education, enforcement) should be focused. In this debate, the Israeli Road Safety Authority has adopted a view which concentrates on texting (Sheinin, 2013) and accordingly, promoted a public campaign to discourage drivers from texting while driving with the slogan "Words Can Kill". The campaign also recommends drivers to install texting blocking apps, indicating the potential of smartphones' technologies themselves to reduce driver distraction and consequently to improve road safety, as well as to encourage drivers to impose self-restrictions on usage.

In order to tap into key drivers segments, two separate sub-studies were conducted:
1) An internet survey of 757 smartphone-owner drivers, at least 18 years old who drive a car at least twice a week
2) A face-to-face interview of 272 professional drivers – respondents for which driving is their job, or whose job requires many daily hours on the road (truck, bus, or taxi drivers, salespersons and repair technicians, etc.), and own a smartphone.

Section 2.2 presents the first study and includes the paper which has been published: Musicant, O., Lotan, T., and Albert, G. (2015), Do We Really Need to Use Our Smartphones while Driving? *Accident Analysis and Prevention,* 85, pp. 13-21. Section 2.3 presents the second study. More details about these two studies can be found in Appendix A. Section 2.4 summarizes and concludes.

### 2.2 Do we really need to use our smartphones while driving?

Link to the pdf version of the published paper:
http://www.sciencedirect.com/science/article/pii/S0001457515300555

## 2.3 Frequency and patterns of smartphone usage while driving among professional drivers

### *2.3.1 Background and method*

Professional drivers, i.e. drivers of trucks, taxi, bus, or commercial vehicles, make up a very significant part of traffic, and their involvement in serious crashes makes them an important research target. In addition, a relatively high proportion of this segment is Arab-Israelis and the involvement of Arab drivers in serious accidents is also higher than their proportion in the population. The general feeling of the research team was that an effort should be made to measure this segment, even if in a limited study. This decision was not trivial. This is a relatively small segment within the general population, and some sub-segments are difficult (as well as budget- and time- consuming) to reach by phone or on-line methods. In addition, they generally do not belong to Hebrew-speaking on-line panels.

272 professional drivers who own smartphones participated in a road side interviews about smartphone usage while driving. The interviews took place in nine gas stations. Smartphone was defined as a cell phone with advanced capabilities, with no specific reference to internet connection. Note that we cannot estimate the extent to which our sample is representative since figures about age and gender distribution among truck drivers are not available in the Israeli Bureau of Statistics.

The sample comprised of:

- Taxi or bus drivers (N=84)
- Commercial drivers (N=78) – drivers of vans, pickup, etc., and for which driving is at the heart of the job. Examples for commercial drivers are: salesperson, repair and service, etc.
- Truck drivers (N=110). A variety of trucks was sampled – food, light, semi, building materials, etc.
- Jewish (N=144)
- Arab (N=128)

The survey included various questions concerning patterns and attitudes regarding texting and phone calls usage while driving. First, respondents were asked to rate the frequency of usage while driving using a five-point scale with the following markers: continuously, frequently, occasionally, rarely and never. Then, several questions referred for those indicating usage of a feature (at lease rarely usage). These users were asked about the reasons for usage and usage avoidance while driving.

In addition, to capture the perceived need for the feature, all the respondents who are also perform texting and phone calls were asked: "how would you feel if the feature was absent while driving?”. This question used a four-item scale: (1) I wouldn’t feel its absence at all, it wouldn’t bother me, (2) I wouldn’t feel its absence very much, I would get along without it, (3) I would somewhat feel its absence, it would somewhat inconvenience me, and: (4) I would feel its absence to a great extent, it would bother me.

Then, questions regarding drivers’ views about the safety of texting and phone calls usage while driving were presented to all the respondents (not only those using the feature). Respondents were asked “what is the effect of the certain feature on driving safety?" with the following response options: (1) compromise safety, (2) can somewhat compromise safety, (3) has no effect on safety and (4) increases safety. Finally, respondents were asked about their willingness to try an app which limits the phone usage while driving.

### *2.3.2 Results*

The results presented here are based on the analysis done for the largest group of professional drivers in the sample **-** truck drivers (N=110). The general results for the other types of professional drivers are presented in Appendix A.

#### *2.3.2.1 Usage frequency*

Respondents were asked first how often they use cell phone and texting while driving.

Table 1 reports on the joined phone calls and texting usage frequencies. All the respondents (N=110) use phone calls (legal in Israel) and 33% text (illegal) to some extent while driving. Only 2% “rarely” use phone calls and the rest (98%) do it at least occasionally. 55% (N=60) use phone calls at least frequently. Pertaining to texting, 33% of all the respondents admit text while driving; approximately half of them do it at least occasionally.

Obviously the rows in the Table for "never" and "rarely" use of phone calls are redundant and can be completely removed or merge with the “occasional users” without loss of information. Only 2 observations (respondents) are located above the diagonal (which is marked in gray background), indicating that the texting usage frequency is generally less than phone calls usage frequency. Overall 36 respondents indicate to use texting while driving to some frequency. There are only 6 respondents that frequently or continually use texting while driving.

**Table 1.** Frequency of calls and texting usage among respondents

| Calls\Texting | Never | Rarely | Occasionally | Frequently | Continuously | Total |
|---|---|---|---|---|---|---|
| Never | 0 | 0 | 0 | 0 | 0 | 0 |
| Rarely | 0 | 2 | 0 | 0 | 0 | 2 |
| Occasionally | 36 | 5 | 6 | 0 | 1 | 48 |
| Frequently | 26 | 2 | 4 | 1 | 1 | 34 |
| Continuously | 12 | 7 | 4 | 3 | 0 | 26 |
| Total | 74 | 16 | 14 | 4 | 2 | 110 |

Based on the information in Table 1 we decided for further analysis to reduce the number of levels of usage frequency: Two usage levels for texting: Users (N=36) and Non-Users (N=74) and three usage levels for phone calls: Continuously (N=26), frequently (N=34) and less than frequently (N=50).

*<u>The age impact</u>*:

Out of the 110 respondents seven are between 21 and 30 years old, 57 are between 31 and 40 years old, 29 are between 41 and 50 years old and 8 are older than 50. Nine respondents chose not to disclose their age. Thus the information pertaining to age impact is based on 101 participants.

Figure 2 presents the percentage of phone call usage frequency per age group. The data in Figure **3** suggests that the proportion of less than frequent usage increases with age. A test for trend in the frequencies did not detect it ($\chi2_{df=1}$=1.78, p. value=0.62). In addition an ordinal regression model for phone calls usage frequencies (three levels) with age as continuance (not grouped) explanatory variable suggested that the age coefficient (estimate: -0.029, standard deviation=0.025) was not significant (p. value=0.49).

Pertaining to texting users, the data in Figure **3** suggest that the proportion of non-users is larger for the age group of '>50'. Yet, again, the formal statistical test was not able to detect statistical significance ($\chi^2_{df=3}$=1.70, p. value=0.64). Also a logistic regression model for texting (with two levels) with age as a continuance explanatory variable suggested that the age coefficient although negative (estimate: -0.034, standard deviation=0.031) was not significant (p. value=0.27).

To conclude, while for both phone call and texting the visual analysis suggests that the higher ages demonstrates lower usage frequency, the formal statistical test was not able to detect it. This is perhaps due to small sample size in this group. We cannot claim that age does not play a role in reported usage frequency, yet in our sample, the importance of integrating age as an explanatory variable in a statistical model for usage frequency is of less importance.

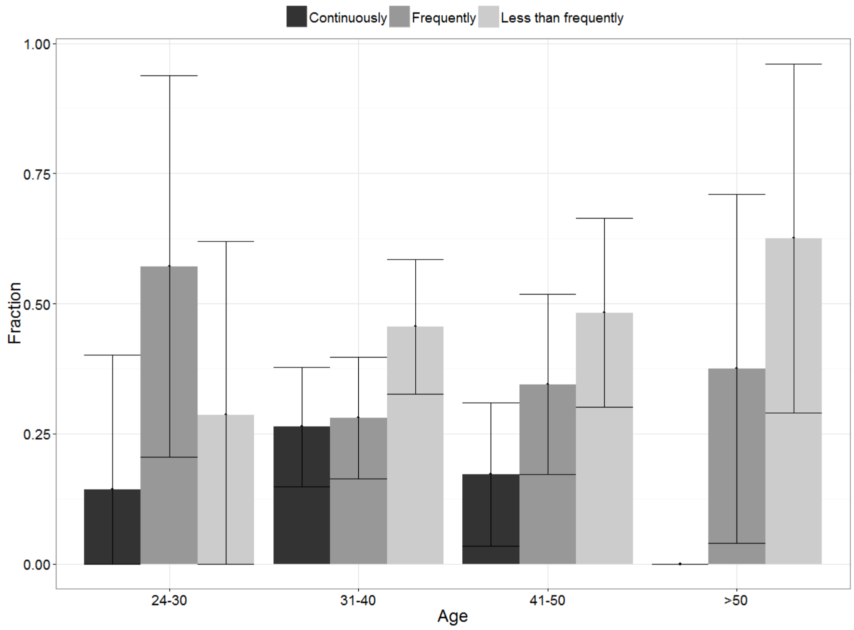


**Figure 2.** Proportion of phone calls users by usage level and age

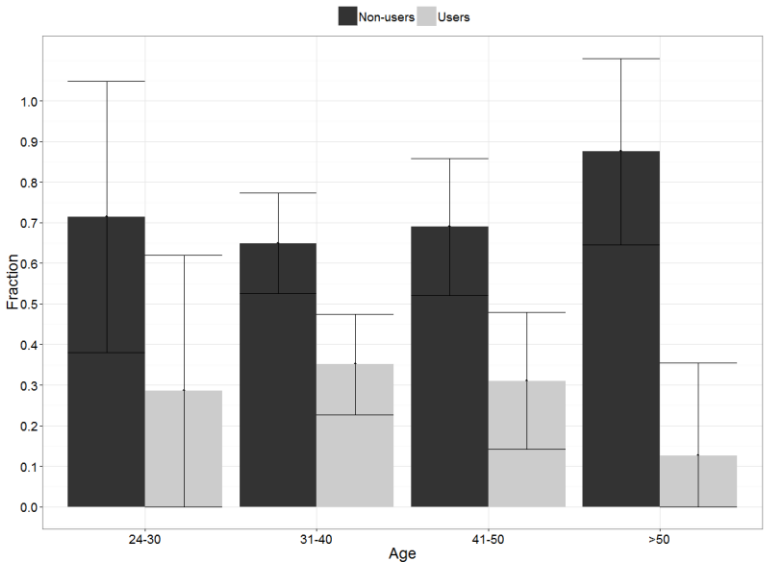


**Figure** 3. Proportion of texting users (at least rarely by age group)

*2.3.2.2 Circumstance of smartphone usage and usage avoidance*

The results regarding the circumstances of usage and usage avoidance among the phone call users (N=110) and texting users (N=36) are presented in Figure 3.

As can be seen, 39% of the phone call users report to use phone calls when they really need to and 40% use it any time, that is, with no particular reason.  17% mainly respond to incoming call.

Phone call users avoid using phone calls mainly when traffic conditions required heightened attention (35%). 16% avoid phone call usage in the presence of a police officer, and 7% avoid phone calls "While driving at high speed". To remind, using hands free phone calls while driving is legal in Israel.

Pertaining to texting, as shown in Figure 3, only 3% of texting user chose the "any time" option for usage circumstances. The most common circumstances for texting were "only when I really need to" (36%) and "when someone else texts me" (42%). The main reasons for avoidance texting are the presence of the police (43%) and when traffic conditions require heightened attention (31%). To remind, texting is illegal in Israel.

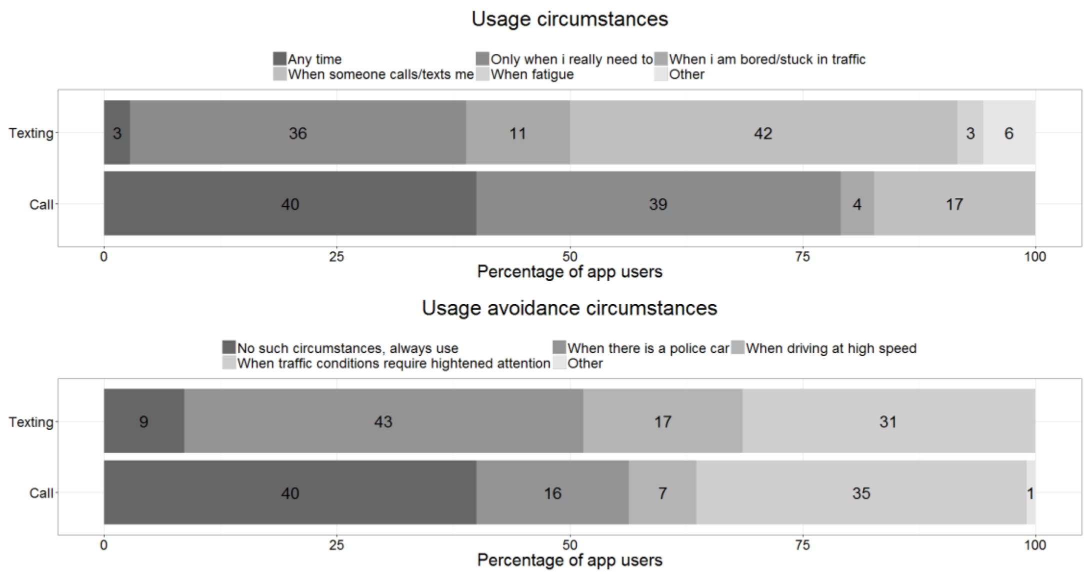


**Figure 4**. Usage and usage avoidance circumstances of phone calls and texting

*2.3.2.3 Perceived safety and need for smartphone usage while driving*

All respondents were asked about their perceived safety of phone calls and of texting. The results are summarized in Figure 4 and in Figure 5 by level of usage. The numbers on the bars represent the portion of respondents.

The information in Figure 4 indicates that as phone calls' usage frequency increases, the proportion of respondents believing that this usage compromises safety decreases ($\chi^2_{d.f=1}$=10.53, p.value<0.001). For example, 38% of the less than frequent phone-calls users believe that the use of phone calls compromises safety. This percentage in down by 10th to 3.8% (1 driver) for users that continuously use phone calls.

Figure 5 indicates that 91% of the non-users (N=74) indicated that texting compromises safety. While 39% of the texting users –text although they acknowledge its effect of safety. Adding the 56% of the texting users acknowledge that texting can somewhat compromise safety indicates that even within texting users 95% acknowledge at least some effect of texting on safety.

It should be noted that only very few (five drivers) believe that phone calls increases safety and only one driver believe that texting increases safety. The intention behind this response is unclear. It is possible that some of the respondents use smartphones to avoid fatigue (Tomer-Fishman, 2010, SARTRE, 2012).

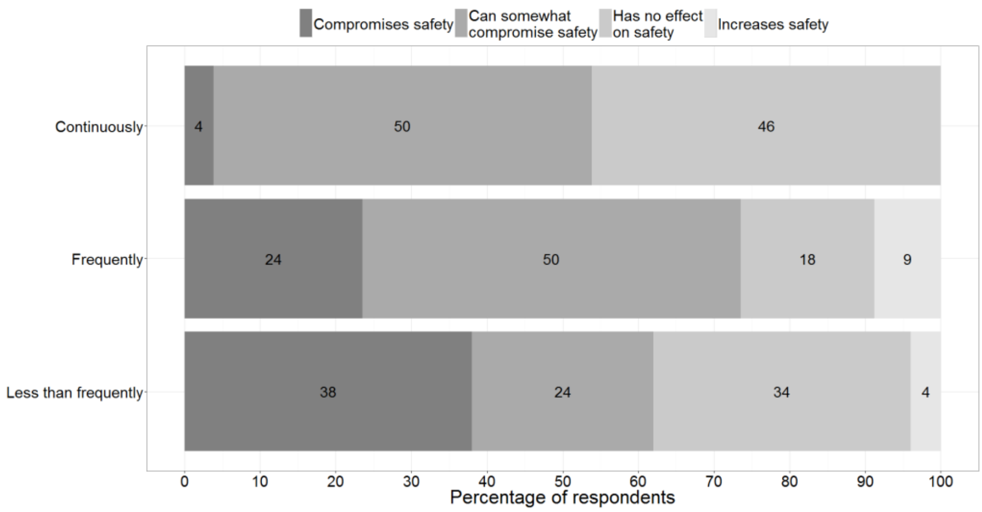


**Figure 5**. Perceived safety of phone calls by usage level

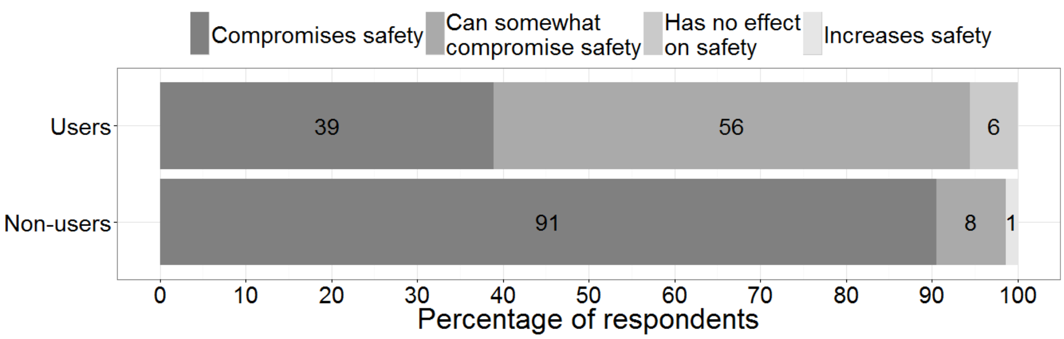


**Figure 6.** Perceived safety of texting by usage level

Users of phone calls and texting while driving were also asked about their perceived need to do these usages. The results for the 110 phone call users appear in Figure 6, and suggest, as may be expected, that as the usage frequency increases, more respondents would feel its absence to a large extent ($\chi^2_{d.f=1}$=33.7, p. value<0.001). 50 respondents are less than frequent phone calls users. 14% of them would feel its absence to a great extent and 52% would "somewhat" feel its absence. The remaining 34% would not feel its absence. When considering the 26 respondents that use the phone calls continuously, all of them will feel its absence to some extent and 22 (85%) would feel its absence to a large extent. Out of the 34 frequent phone call users 31 would feel its absence to a large extent. This indicate that excluding the usage of phone calls would not be accepted by most of truck drivers that use phone calls frequently and continuously.

Pertaining to the 36 texting users, 27 users "would not feel its absence at all" or "would not feel its absence very much". This indicate that the majority (75%) of the texting users may accept excluding the usage of texting. These results also indicate large differences with regard to the perceived need of texting and of the perceived need of phone calls.

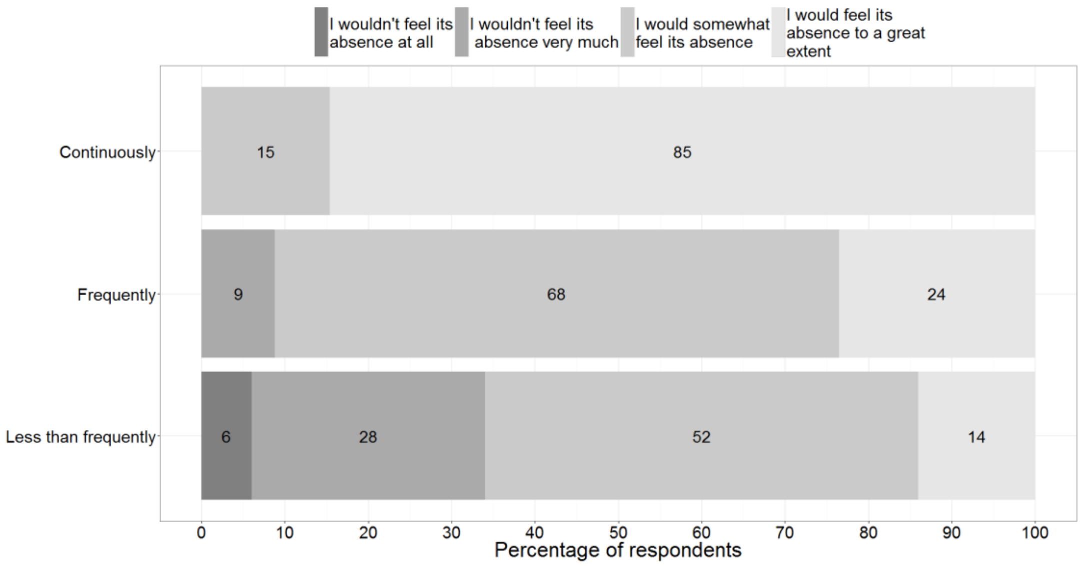


**Figure 7.** Perceived need of phone calls by levels of usage frequency

### *2.3.2.4 Modeling texting and phone calls usage frequency*

To analyze the role of perceived safety and perceived need in predicting the frequency of smartphone usage while driving, an ordinal regression was used.

Pertaining to phone calls usage - The dependent variable was phone calls usage frequency with three levels. The explanatory variables were: (1) perceived need, introduced as a continuous variable according to its scale (ranked from 0="I wouldn't feel its absence at all" to 3 ="I wouldn't feel its absence to a great extent"). (2) Perceived safety according to its scale (ranked from 0="compromises safety" to 3 = "increases safety"). (3) We also considered that phone calls usage frequency may be linked to texting usage frequency (two levels: non-user and user), thus, texting usage frequency was added as an explanatory variable.

The details for the fitted model are provided in Table **2**. Perceived need plays a significant role in predicting phone calls usage frequency. According to this model perceived safety has insignificant effect on usage. This result does not entirely fit the exploratory analysis presented in Figure 5 that suggested that as the percentage of drivers reporting that as phone calls' usage frequency increases, the proportion of respondents believing that this usage compromises safety decreases. Therefore, instead of defining the perceived safety as a continuance variable, it was redefined as a binary variable that indicates whether the respondent reported that phone calls compromises safety (coded as 1) or not (coded as zero). The results are provided in Table **3**. The smaller residual deviance indicates that this model has a better fit for the data. The overall conclusion indicates that both perceived need and the acknowledgment that phone usage compromises safety has a statistically significant effect on phone calls usage frequency.

The statistical model of phone calls usage frequency also includes texting usage frequency as an additional explanatory variable and the model of texting usage also includes phone calls usage as an additional explanatory variable. Statistical model may indicate a link between these two variables but they cannot indicate the direction of the effect. Examining the results of the phone calls model suggests that being a frequent user of texting is related to frequent use of phone calls while driving as well. This result is not mirrored in the model of texting frequency.

**Table** 2. Ordinal model for frequent use of phone calls (model 1)

| | Parameter,(SE) | Sig |
|---|---|---|
| Intercept (Less than frequently \| Frequently) | 8.61(1.65) | *** |
| Intercept (Frequently \| Continuously) | 10.51(1.77) | *** |
| Perceived safety (Between 0 and 3) | 0.3(0.26) | |
| Perceived need (Between 0 and 3) | 1.97(0.36) | *** |
| Usage frequency of texting | | |
| =Non-user (Reference) | 0 | |
| =User | 0.31(0.46) | |
| Model fit indices: | | |
| Residual Deviance | 187.3045 | |

*** p.value<0.001

**Table** 3. Ordinal model for frequent use of phone calls (model 2)

| | Parameter,(SE) | Sig |
|---|---|---|
| Intercept (Less than frequently \| Frequently) | 7.5(1.52) | *** |
| Intercept (Frequently \| Continuously) | 9.47(1.64) | *** |
| Perceived safety (Phone calls compromises safety) | -1.2(0.53) | * |
| Perceived need (Between 0 and 3) | 1.93(0.36) | *** |
| Usage frequency of texting | | |
| =Non-user (Reference) | 0 | |
| =User | 0.32(0.43) | |
| <u>Model fit indices:</u> | | |
| Residual Deviance | 183.2473 | |

* p.value<0.05**,** *** p.value<0.001

Modeling texting usage frequency followed the same general principles. The dependent variable was texting usage frequency with two levels (user/non-user) and a logistic regression was used. The explanatory variables were: (1) Perceived safety as a binary variable (compromises safety coded as 1 and other coded as 0). (2) phone calls usage frequency (three levels). Perceived need could not be used for this model as only the users were asked about their perceived need.

The fitted parameters for the logistic model are specified in Table **4**. The results indicate that perceived safety is a significant predictor for usage of texting. The probability that a respondent is a texting user is reduced by a factor of 0.069 (or by 93.1%) if the respondent believes that texting compromises safety is comparison to respondent that does not believe so.

**Table** 4. Logistic model for frequent use of texting

| | Parameter,(SE) | Sig |
|---|---|---|
| Intercept | 1.04(0.54) | |
| Perceived safety (Texting compromises safety) | -2.67(0.54) | *** |
| Usage frequency of phone calls | | |
| =Less than frequent (Reference) | 0 | |
| = frequent | -0.47(0.61) | |
| =continually | 0.78(0.60) | |
| <u>Model fit indices:</u> | | |
| Residual Deviance | 130.04 | |

*2.3.2.5 Willingness to limit smartphone usage while driving*

Respondents were introduced with an app which limits the usage of the smartphone while driving. The app works as follows: all features of text messaging as well as phone calls are blocked. Navigation is permitted without limitations. All respondents were asked about their willingness to try using this app on a four levels scale. Only 2 respondents (2%) indicated they "would definitely try it" 28 (25%) respondents indicated they would probably try it, 54 (59%) respondents indicated they would probably not try it and 26 (24%) indicated they would definitely not try it.
The probabilities are presented in figure 7 by texting users (all of them are also phone call users) and by those that only use phone calls and not texting. As indicated in the figure those using both texting and phone calls are less likely to try a blocking app.

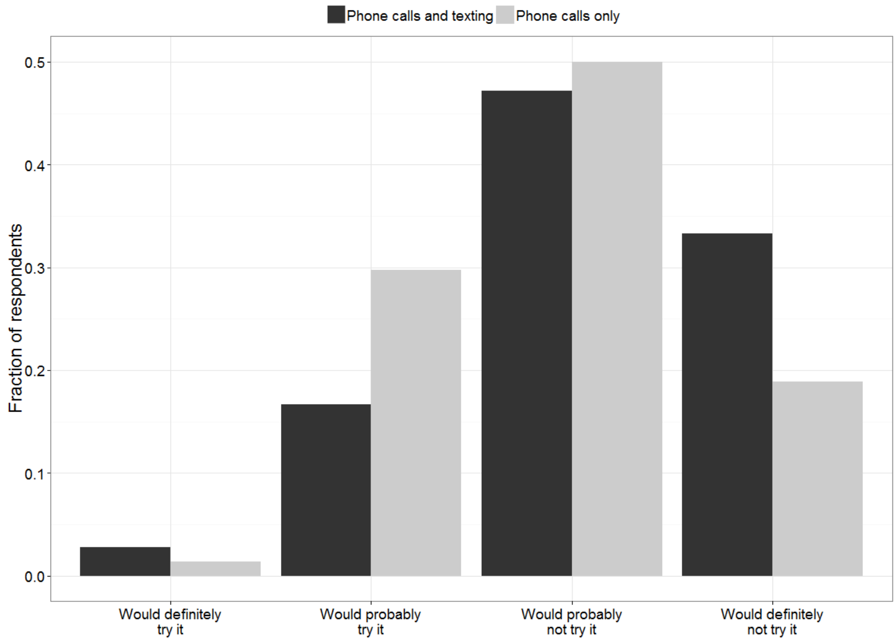


**Figure 8.** Would you try an app that limits the usage while driving?

In order to further investigate the reasons associated with the willingness to try a blocking app, we analyzed a logistic model. A two level response variable was defined: "positive intent" - if the respondent will probably or definitely try the app and otherwise "negative intent". The explanatory variables were based on the following:

1) Frequency of phone call usage with three levels: less than frequent, frequent and continuance usage.
2) Frequency of texting with two levels (user, non-user).
3) Perceived need of phone calls, introduced as a continuous variable according to its scale (ranked from 0="I wouldn't feel its absence at all" to 3 ="I wouldn't feel its absence to a great extent").Perceived need of texting with similar two levels.

4) Perceived safety of phone calls with two levels ('No' and 'Yes') expressing whether or not the respondent acknowledges that this compromise safety.
5) Perceived safety of texting with two similar levels.

In addition to these explanatory variables, age was added to control for its possible first order effect.

The fitted parameters are presented in Table **5**. Age group has marginal significance (p. value<0.1). The result indicates the older (senior) truck drives express higher levels of willingness to try a blocking app. Respondents that exhibit high need for phone calls are much less likely to try this technology. For example, according to this model, the odds ratio is reduced by nearly 72% a ($e^{-1.28}$=0.28) as the level of need for the phone increases. Phone calls frequency of usage had marginal significant, surprisingly phone calls users with higher level of usage are more likely to try this app. It is interesting to note also the insignificant variables – these are related to perceived safety (for both texting and phone calls) of texting. These may indicate that variables related to perceived safety may not have significant effect on willingness to try a blocking app.

**Table** 5. A Logistic model for willingness to try a blocking app

| | Estimate (standard error) |
|---|---|
| (Intercept) | -3(1.52) |
| Age | 0.8(2.12)+ |
| Phone calls variables | |
| Phone Calls Frequency | |
| Phone Calls Less than frequent usage (reference) | 0 |
| Phone Calls Frequent usage | 1.11(0.6)+ |
| Phone Calls Continuously usage | 1.34(0.88) |
| Phone Calls compromises safety | |
| FALSE (reference) | 0 |
| TRUE | -0.1(0.63) |
| Phone Calls Need | |
| FALSE (reference) | 0 |
| TRUE | -1.28(0.43)** |
| Texting variables | |
| Texting usage frequency | |
| Texting User =No (reference) | 0 |
| Texting User =Yes | 0.61(0.8) |
| Texting Compromises safety | |
| FALSE (reference) | 0 |
| TRUE | 0.61(0.8) |
| AIC | 115.36 |

+ p.value<0.1, ** p.value<0.01

**2.4 Summary**

This section investigates the timely and significant safety issue of smartphone usage while driving. It is based on a sample of 757 active passenger car drivers who participated in an internet survey and on a sample of 110 truck drivers, where the information was obtained based on roadside interviews taken at gas stations. In both samples, the focus was on two prominent smartphone usages: phone calls and text messaging.

Alarmingly, while driving, 77% (N=551) of the passenger car drivers sample make phone calls and almost half of them may be considered as frequent texting drivers as they admit doing it intensively. The frequency of texting is low compared to performing calls: 35% of the respondents (N=256) text while driving and a quarter of them do it at least frequently, however, the fact that more than one third admit doing the most risky usage of texting is worrisome.  These finding indicate more extensive usage compared to previous evidence from Israel and may reflect an increasingly worrisome trend in drivers' behavior. 100% (N=110) of the truck drivers sample make phone calls and more than half of them may be considered as frequent phone call users as they admit doing it intensively. The frequency of texting is low compared to performing calls yet considering the documented gravity of the texting effect on driving safety  having  33% (N=33) of professional drivers reported to do so is a solid reason for concern.

Among the passenger car drivers sample, while only 43% of the occasional phone calls users and 27% of the frequent phone calls users believe that phone calling compromises safety, most texting users (87% of occasional users and 74% of frequent users) are aware that texting compromises safety. Accordingly, texting users place limitations on themselves: more than 70% report avoiding texting when they think that they need to devote more attention to driving. Still, the paradox according to which high belief that texting compromises safety is not associated with low texting rates in practice is worrisome. This finding is strengthen by the results obtained among truck drivers: while 39% of the texting users –text although they acknowledge its effect of safety.  Adding the 56% of the texting users acknowledge that texting can somewhat compromise safety indicates that even within texting users 95% acknowledge at least some negative effect of texting on safety.

The success of introducing exclusion interventions to control smartphone usage while driving may largely depend on understanding the motivation for these behaviors and the countermeasures' potential for public acceptance. Our analysis regarding factors affecting frequency of usage suggests that the main factor both for texting and phone calling, in both samples, is their perceived need, while perceived safety has an ambiguous effect.  This implies that perceived need determines frequency of use more than perceived safety. The fact that respondents reported texting only when they really need to and that most of them avoid it to adjust to traffic conditions suggest that most respondents apply some "self-filtering" process with regard to texting.

When investigating the factors leading to a decision to try a limiting smartphone app, a tool readily available with various configurations, we found in both samples that these factors are mainly related to phone calls' perceived need. Approximately half of the passenger cars drivers expressed willingness to use a blocking app where only the most limiting configuration (complete blockage of phone calls and texting) was presented in the survey. This paves the road for technology based distraction prevention features to serve as key countermeasures.

## 3. MAPPING OF SAFETY–RELATED SMARTPHONE APPS

### 3.1 Outline

The main objective of this section is to present a mapping of safety –related smartphone apps, based on literature and market review**.** This includes the main functionalities (how they work?) of the apps and indication about their possible benefits for safety. To provide indication about the safety potential of the use of these apps, the review considered traffic safety indices: potential impact on crash risk and on driver performance, functional problems and limitations that these technologies may have in the context of driving. In parallel a scan of apps stores was conducted to learn about apps that are already used. An extensive mapping of smartphone apps with indication regarding their potential benefits for safety as mentioned in the apps descriptions was conducted. A total of approximately 250 apps, already in the market, were mapped and categorized according to their features. The mapped apps can be categorized according to the following three types: blocking apps, apps that change the interface with the user and driving-feedback apps. We would like to note that this three types distinction is safety-oriented and takes into account drivers' modality (visual, auditory) and responses (manual, vocal). However, one can also create other classifications.

In the last few years an increasing amount of innovations and technologies were introduced into the market.  In general, these apps are automatically activated once detecting driving and are deactivated once the trip ends. The movement detection is based on Smartphones' build-in sensors such as: GPS, 3G networks, gyroscope and accelerometer. However, generally, these apps cannot distinguish between a driver and a passenger, unless this is done manually or via dedicated technology. Various smartphone apps were developed to provide drivers a way to interact with the smartphone and to improve safety and can be calorized into three main groups:

The first group is the "Blockers" – apps that prevent or limit the driver of using common services while driving such as calling, texting (typing or reading), and the blocking of various notifications . The idea is to eliminate the distraction by prohibiting or preventing cell phone use or convincing drivers not to use cell phones. The second group includes apps that change the interface with the user and support "Eyes on the road Hands on the wheel", e.g., voice controls, heads up displays (HUDs) or hand gestures. The main purpose is to reduce the driver's attention needed for a distracting task by requiring or convincing drivers to physically interact with their cell phones. The third group is the coaching apps – similar to Advanced Driver Assistance Systems (ADAS) which are installed in the car such as and In-Vehicle-Data-Recorder (IVDR) and headway alert systems such as Mobile Eye (ME) – these apps aim to provide drivers with simple and cheap tools to cope with an impending risky situation (e.g. a lane departure warning in the vehicle or a rumble strip in the roadway).

Navigation apps, the most prominent and popular type ,was not analyzed in this study. Its prominence over other types of apps might had biased the evaluation. From acceptance point of view it is clear that navigation apps gain high scores. However, their ambiguous effects on safety should be further and deeply investigated in a dedicated study.

The following three sections 3.2, 3.3., and 3.4 present the three categories of safety-related apps in general and provide several examples. Section 3.5 presents a short summary.

### 3.2 "Blocker" apps and safety effects

The first type relates to apps that prevent or limit the driver from using common features of the smartphone such as: calling, texting (typing or reading), surfing the internet and the prevention of various notifications. Therefore, drivers are not aware of the communication attempt, and do not feel the pressure to attend to it. Users are usually alerted with incoming notifications and shown received messages once they stopped driving.

Most apps in this category prevent receiving notifications on incoming calls or text messages without literally blocking any usage. Some, more advanced, apps also limit the operation of some mobile components (as the phone interface), thus partially shutting off some features of the device. some apps that block incoming calls can be defined by users to make exceptions for certain phone numbers and allow calls from these numbers to come through, thus enabling operation in situations of emergency or of personal importance.

An important component of mobile communication prevention apps is the promptly automatic reply to incoming text messages or calls, which can be used for business purposes or by users who wish to refrain from being disturbed while notifying those who attempt to engage in conversation with them that they are unavailable. In some apps, incoming calls are either routed to voicemail or to a recorded message explaining that the user is unavailable to answer due to driving (in most apps the automatic message can be edited by users).

To the best of our knowledge, only little research was done to investigate the effectiveness of such "blocking" apps on safety. Funkhouser & Sayer (2013) investigated drivers' behavior while implementing cell phone blocking applications. In this study, two custom applications were used and 44 participants who use to drive as part of their job. Data was collected during 3 weeks prior the test and 3 weeks afterwards (the test itself took 3 weeks). The results show that fewer incoming calls at non-zero speeds during the blocking period were answered, participants placed outgoing calls at lower speeds and more calls at zero speed during the blocking period, Participants overall were neutral regarding the safety benefits from the cell phone blocking applications. Table 6 presents examples of main features of several "Blocker" apps.

**Table 6**. Examples of main features of "Blocker" apps

| App | Detecting driving | passenger overriding | Incoming SMS | Outgoing SMS | Incoming Notifications | Incoming calls | Outgoing calls | Interfa ce |
|---|---|---|---|---|---|---|---|---|
| **ProtextMe** | yes | yes | silenced, auto-reply | enabled | silenced | enabled | enabled | open |
| **Safe Driver** | yes | no | silenced, auto-reply | enabled | silenced | silenced, auto-reply | enabled | open |
| **Eyes on the road** | manually | no | silenced, auto-reply | enabled | silenced | silenced, auto-reply | enabled | open |
| **Verify** | yes | yes | silenced | blocked | disabled | disabled (except for VIP optional) | disabled (except for VIP optional) | locked |

Strengths

- Usage prevention apps can completely prevent smartphone-related driving distraction.
- The feature that enables automatic replies helps users to disengage from their devices while driving without feeling the pressure to initiate a reply.
- The automatically sent message for callers or texters may facilitate new norms among smartphone users and help decrease unnecessary communication during driving in general.
- None of the apps we reviewed completely locks out communication in emergency which may reduce anxiety among users and encourage adoption.

Weaknesses

- Apps that are able to automatically detect driving through the device's sensors often consume a substantial battery power.
- Drivers can easily override the disabling of manual operation (such as in Waze) by indicating that they are passengers and not drivers. Other solutions offer giving a task that only a passenger can successfully complete. Such tasks may have negative ramifications, such as causing distraction when challenge-seeking drivers attempt to complete the task.
- These apps may not be widely used and accepted by the general public.

### 3.3 "Changing interface" apps and safety effects

The second type includes apps which aim to introduce less distracting interface and enables "Eyes on the road hands on the wheel ". This is accomplished through: *voice controls* (includes either voice-to-text (V2T) or text-to-speech (T2S) interface), hand *gesture control* and *heads up displays (HUDs*).

*Voice control* technologies enable the operation of a wide variety of smartphones features and apps using voice and dictation. Most advanced smartphones have a built-in speech recognition functions. In addition, the technology is often included in virtual personal assistant apps, such as Siri (for iPhone) and Google Now (for Android phones) that use natural language and perform various online and offline tasks and services (such as schedule management and knowledge navigating). By speaking (rather than typing) to the built in microphone, users can compose text messages and emails, or activate apps and features (navigation systems, social networks, etc.), thus potentially enable hands-free and eyes-free usage while driving.

The effect of "voice-control" interface on driver behavior was investigated in numerous studies (Eriksson et al., 2014, He et al., 2013, Mehler et al., 2015, Reimer et al., 2013, 2015, Strayer et al., 2015, Yager, 2013). It may be concluded that voice interfaces are not necessarily free of visual-manual demands on attentional resources and might create high levels of cognitive workload.

He et al. (2013) examined the effects of speech-based versus handheld texting on simulated driving performance. The duration of the secondary task was held constant. They found that speech-based texting still resulted in significant impairment to driving compared to drive-only condition, but was less detrimental than handheld texting. The scholars concluded that conducting texting tasks result in a significant level of cognitive distraction that hinders performance, even in the absence of visual and manual distraction. Moreover, compensatory strategies commonly found among drivers while performing secondary tasks, such as increasing headway distance and reducing speed, were not observed among drivers who texted with speech recognition technology.

The potential safety of V2T mobile apps in sending and receiving text messages while performing real driving was assessed by Yager (2013), who tested situational awareness to periodically illuminating light while texting manually compared with using V2T applications (Siri and Vlingo). Results indicate that although drivers' perceived safety was higher when using handheld voice-to-text applications, they are no less impairing than manual-entry texting, and driver response times are equally high compared to no texting in both techniques. Moreover, texting times were almost doubled when those apps compared with manual texting. The researcher concluded that speech-to-text does not help to overcome the cognitive distraction and lead to driving impairment. However, the full potential of such apps was not examined in the study, since it focused on the regular, handheld use of voice input, while more advanced capabilities are reduce visual distraction considerably in the eyes and hands-free mode designed particularly for driving was not examined.

A perceived advantage of voice inputs compared with manual inputs is that they eliminate or reduce the competition for visual and manual resources between a secondary activity and the primary task of driving (Mehler et al., 2015). Reimer et al., (2015) found that voice interfaces, either in embedded system or on portable devices, place fewer visual demands on the driver than manual interfaces. They also emphasized that different system designs can significantly affect not only the demands placed on drivers but also the successful completion of tasks. However, recent research indicates that voice-based interactions may introduce noticeable visual or cognitive demand (e.g., Strayer et al., 2015).

Morris et al., (2014) claimed that speech-based systems were designed to overcome the inherent risks associated with visual displays so as to more safely convey information to the drivers by presenting information and allow communication through speech. But it was found that speech-based interfaces produce cognitive distraction. Thus, as mentioned above, when two tasks taps into the same resources required for driving, drivers are distracted and as a consequence tend to concentrate their fixations to the center of the road, which improves their lane keeping performance, but degrades their situation awareness and ability to detect targets across the entire driving scene, and prevent their proper response (e.g., braking in time to avoid crashes). Table 7 presents features of several speech recognition apps.

Table 7 Examples of main features of speech recognition apps

| App | Automatic activation | Voice commands | Text-to-Speech | Hebrew support |
|---|---|---|---|---|
| **BAZZ** | yes | yes | yes | yes |
| **Siri** | no | yes, intelligent | yes | partial |
| **Google Now** | yes (voice) | yes, literal | yes (limited) | yes (dictation) |
| **Vlingo** | no | yes, literal | yes | no |
| **Text'nDrive** | no | no | yes | no |
| **Dragon Mobile Assistant** | yes (motion) | yes, literal | yes | no |

*Gesture* (or motion) *control* refers to a new and evolving technology for hands-free interface in mobile phones. Gesture control enables a natural interface for drivers, to interact with devices by hand movements, without direct physical contact. Using built-in proximity sensors and cameras the technology detects physical movement. These movements are translated to commands that the smartphone and other apps “understands”. In currently developed gesture control apps, user interaction with the mobile device is accomplished via hand movements in which discreet or demonstrative hand gestures (e.g., palm swipe and finger movement) is captured to activate features and perform actions, without touching the phone display, and sometimes without requiring visual attention. In the app market, this technology is often referred to as "air gestures".

Gesture apps have the potential to reduce visual distraction, but such research is still scare. It was found preferable to touch interface in a simulator study by May et al., (2014) who investigated the effects of gesture designs as well as secondary task performance and workload on driving performance (e.g., lateral and longitudinal deviation). They found that selective mapped menu systems, as implemented with current technology, provided a feasible alternative to direct touch. Importantly, using the air gesture with sound interface allowed participants to distribute secondary task dwell time more safely than direct touch. The advantages of *Gesture control* was also demonstrated in during real driving (Loehmann et al., 2013) and in both (Parada-Loira et al., 2014). Gesture interaction is a promising modality, implementing "eyes on the road - hands on the wheel" principle, reducing drivers' distractions and increasing driving safety.

HUDs are transparent displays which superimpose information directly on the driving scene. Several studies presented combined interfaces of speech input and HUD visual output (Wang et al., 2014), or hand gestures as input with HUD visual output (Farooq et al., 2014, Lauber et al., 2014). Jakus et al., (2015) concluded that visual and audio-visual HUD interface is faster and more efficient than audio-only display. Although no significant difference between the visual only and audio-visual displays in terms of efficiency and safety was found, most participants preferred the multi-modal interface while driving.

<u>Strengths</u>

- Interactive nature, hand-free usage.
- Eyes-only mode has the potential to reduce distractions while driving to the minimum

<u>Weaknesses</u>

- Might legitimize and increase hands-free talking and therefore increase mobile-based cognitive distraction while driving.
- People often feel compelled to check the accuracy of the system
- Not entirely hands-free systems: Most apps require blended manual-hands-free usage
- Apps do not improve response times among drivers and lead to a false sense of security
- Speech recognition of natural language is still far from being actually implemented.

### 3.4 "Coaching" apps and safety effects

The third type includes "coaching apps" which aim to provide simple and cheap tools to cope with an impending risky situation. The current most widespread apps offer the basic features Mobile Eye (ME) and In-Vehicle-Data-Recorder (IVDR) technologies.

Mobile-based Advanced Warning Apps (AWS) offer camera-based warnings such as forward collision warning and lane departure warning. The apps' algorithms use data gathered from the smartphone's camera, as well as from GPS and other built-in sensors, in order to calculate a time-to-collision from the vehicle ahead, the minimum distance required to brake safely, and other measures, such as crossing over lane-marks. These indices are used to provide rear-end collision warning, lane departure warnings, alerting drivers when the vehicle has begun to cross the identified lane marker, speeding alerts, and other features that have originally been developed for and applied in AWS. In order for AWA to identify traffic conditions, the Smartphone must be fixed to the windshield and have a clear visibility of the road.

There are a variety of interfaces used: some include HUD in addition to a simply visual warning (e.g., red light) or auditory warning (e.g., beeping sound or voice). The two main AWA we obtained and reviewed in this document (iOnRoad and Augmented Driving, see the table below) visualize the safety-related information and warnings on their HUD interface through a computer graphic technology, which allow drivers to see virtual objects superimposed on the real road picture in the Smartphone display. In these AWA, the display models layers of virtual object points on the road surface captures from the camera. This often includes colorful dynamic overlays on the video display, marking the driving lane and its borders and the vehicles that are tracked by the software.

Driving feedback apps monitor risky driving behavior such as rapid acceleration or deceleration and dangerous cornering or lane change, in aim to facilitate safe driving habits. Studying the safety impact of a driving feedback app - RefuelMe (Lotan et al., 2014) did not find an improvement in safety-related scores calculated by the app during a trial period with teen drivers. However, self-reported measures indicated that drivers paid more attention to their behavior while using the app, and that most of them agree that it has improved their driving. The effectiveness of driving feedback apps on driving is yet to be examined using objective measures.

Performance feedback apps can be operated with minimal effort and cost, compared with conventional in-vehicle devices, which require a complex installation and are often expensive. Similar to other domains, the vitality potential of performance feedback apps can also increase through peer influence among young people.

Finally, to encourage usage, two particular elements common in this type of apps are gaming and incentive programs. These apps often create a game-like and enjoyable experience for drivers. Games are known to motivate people to engage in educational and training activities. Table 8 presents examples of the main features of such apps.

**Table 8**. Examples of main features of reviewed driver performance feedback apps

| App | Detecting driving | Augmented display | Visual feedback | Audio feedback | Distraction prevention |
|---|---|---|---|---|---|
| **iOnRoad** | yes | yes | yes | yes | partial (text-to-speech for incoming messages) |
| **Augmented Driving** | no | yes | yes | yes | no |
| **Refuel Me** | no | no | yes | yes | no |

Strengths

- Can make drivers more aware of imminent danger, and thus have the potential to prevent accidents and reduce injuries.
- Cheaper and more accessible compared to conventional in-vehicle devices. This may contribute to a widespread adoption.
- Provide easily comprehendible and constructive information for drivers, which may facilitate a learning process leading to behavioral changes.

Weaknesses

- May cause drivers to shift their gaze from the road. This may constitute visual distraction, particularly when real-time auxiliary warnings are issued.
- It remains to be tested whether apps are an appropriate and reliable alternative to installed devices.
- In order to be effective they require continuance and ongoing usage.

### 3.5 Summary

While being a major cause of risk, smartphones apps may also serve as a means to monitor, control and reduce risky driving behavior. Clearly, technologies are evolving rapidly and the greatest advantage of smartphone apps as countermeasures is their low cost and wide availability. Furthermore, the advantage of such apps relies on its accessibility and portability, assisting any in-vehicle system regardless of its communication requirements, and complementing any existing active safety features. This can be tailored to specific purposes and used to influence patterns of smartphone usage while driving.

We classified the apps according to three types: blocking apps, apps that change the interface with the user and driving-coaching apps. Among these types, usage prevention apps can, even completely, prevent smartphone-related driving distraction. However, these apps may not be widely used and accepted by the general public. Coaching apps proposed a smartphone-based alternative for ADAS. The advantage of such device relies on its accessibility and portability, assisting any in-vehicle system regardless of its communication requirements, and complementing any existing active safety features.

Pertaining to Voice-based interaction may be the most natural, but, it needs acoustically clean environments to work accurately, therefore, provoking some degree of stress for the user. Gesture-based devices are midway between touching and speaking to the system, so it inherited some of the pros and cons of both worlds. On one side, drivers are familiar with using their hands to access car parts, like the shift-stick or the controls of the front panel, so, gesturing is just an evolution of those actions but with the advantage of not taking the eyes of the road. On the other side, gestures, like speech, are not always executed exactly equal and are influenced by acquisition conditions, so they are prone to errors due to ambiguity on the realization and “noise” effects of imaging. HUDs are transparent displays which superimpose information directly on the driving scene. Among other disadvantages are that they provide limited field of view and their restricted boundaries within the windshield. Then again, through the information displayed on HUD, risk is reduced by keeping eyes on the road.

A recent study (TRL et al., 2015) aimed to investigate which ‘best practice’ approaches should be used to reduce road injuries caused by distracted driving. Plethora of technological developments that have the potential to impact driving distractions were reviewed. Based on the experts' judgement / opinion the most promising technologies were selected; those were voice recognition and head up displays, amongst others. In terms of costs and benefits by multi-criteria analysis, the final conclusion was that the most promising approaches to dealing with distraction are collision warning systems.

It should be noted that the usage of apps is voluntarily and most importantly: it is still vague and unclear which types of apps should be favored and what features and functions compose a valuable safe driving app. Furthermore, its prospects for wide market penetration, drivers' acceptance and adoption should be considered.

## 4. EXPERTS' EVALUATION OF SMARTPHONE APPS BASED ON AN AHP MODEL

### 4.1 Background

Section 4 deals with evaluation of the mapped safety-related apps, based on experts' opinions retrieved from an AHP model. As mentioned in the previous section, apps evaluation process should corporate various aspects in order to evaluate its safety potential. That is, while adapting the AHP process with the ultimate goal of reducing injury crashes by apps, the apps serve as alternative, but a caution consideration should be put on the criteria.

Among the various criteria, Acceptance seems to be a leading one. Drivers' acceptance of new in-vehicle technologies depends on various factors; trust, social desirability (Nemme and White, 2010), driver characteristics - age, gender, culture (Son et al., 2015, Wang et al., 2016) and technological limitations, such as the ability to identify the journey beginning, the ability to distinguish the driver from the passengers (Lindqvist & Hong, 2011). There are quite few ways to define acceptance (see Adell et al., 2014). In this report acceptance refers to the motivational aspects to use the app and is consist of (a) Individual willingness - the potential of the app to be adopted and used by an individual (at zero cost), (b) Public support - the potential of the app's concept to be supported and accepted by the public (including policy makers, media, employers, etc.), and: (c) Potential functionality – belief in the potential of the app to work properly as it should in the near future (regardless of its functionality nowadays).

Thirty seven experts from academia, industry and government, who cover various areas of expertise (safety (13 experts), government (7 experts), technology (8 experts) and human factors (9 experts) participated in a one-day workshop. In a plenary session the experts were presented with the general framework of the AHP model with focus on the research goal, the criteria and the nine types of apps. The presentation which was untaken to the experts can be found in Appendix B. Then, the experts were asked to individually evaluate and grade the criteria and apps. The

The next section presents an in press paper which describes evaluation process, the experts study, and the results and analysis in details: Albert, G., Musicant, O., Oppenheom, I. and Lotan, T. Which Smartphone's Apps May Contribute to Road Safety? An AHP Model to Evaluate Experts' Opinions. *Transport Policy*, in press.

### 4.2 Which smartphone's apps may contribute to road safety? An AHP model to evaluate experts' opinions

Link to the pdf version of the published paper:

http://www.sciencedirect.com/science/article/pii/S0967070X16303195

### 4.3 Summary

This section deals with experts' evaluation of the safety potential of smartphone apps. The overall evaluation provided by 37 experts who participated in an expert study suggests that the desired types of apps for reducing injury crashes are (in that order): collision warning, texting prevention - no typing, texting prevention - no reading, voice control - text-to-speech, IVDR, and voice control - commands. The three apps that received lower scores (in that order) were: gesture control, HUD and call limitation. The experts aggregated opinions provided equal weights for risky driving behavior and general acceptances criteria, which is consist of three sub-criteria: individual willingness, public support and potential functionality. This result indicates the equally importance of both - increased acceptance and mitigating of risky driving behavior - for promoting safety.

However, it is possible that a different group of experts (e.g. from another country and safety culture) may assign the relative importance scores differently. We therefore performed a sensitivity analysis for the relative importance of general acceptance vs risky driving behavior, which is presented in Figure **9**. The X-axis represents the relative importance where 1/9 (on the left side of the X-axis) corresponds to impact on risky driving behavior being 9 times more important than social support, and 9 (on the right side of the X-axis) corresponds to general acceptance being 9 times more important than safety potential. Although the possible range of values on the Y-axis was 1 to 7, we present the scale between 4 and 7 since experts rarely used the lower range of the scale.

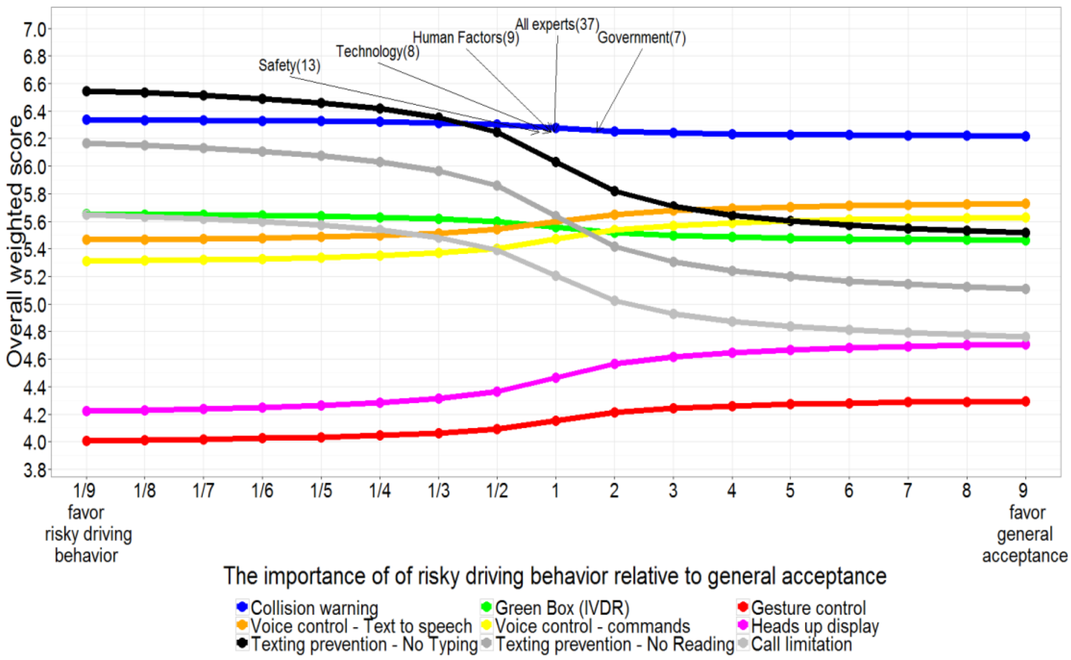


**Figure** 9. Alternative overall score by the importance of general acceptance relative to risky driving behavior

As can be seen in the Figure, If risky driving behavior, for example, is completely the favored criterion (on the left side of the X-axis), then texting prevention - no typing would be the most favorable app and gesture control the least favorable, while if social support is completely favored (on the right side of the X-axis), then collision warning is the most desirable app and gesture control is the least. The overall average for all 37 experts is presented by the arrow appearing at the top of the Figure indicating that acceptance is almost equally important to risky driving behavior (the value 1 on the X-axis). Considering the views of all experts, the five leading alternatives: collision warning (with an overall weighted score of: 6.28), texting prevention - no typing (6.04), Texting prevention - No Reading (5.64), voice control – Text-to-speech  (5.66) and Green Box (5.55).

Grouping the experts according to their discipline and organization, reveals an interesting finding according to which technology and government officials are more inclined towards the "acceptance" branch, whereas safety and human-factor experts place more importance to safety. Considering that experts with various perceptions and from different disciplines, cultures, states, can apply different weights to safety potential versus social support potential, the tool we provided for sensitivity analysis may be valuable.

## 5. DISCUSSION AND CONCLUSIONS

### 5.1 Insights concerning smartphone usage

In recent years, the prevalence of drivers operating smartphones while driving has become no less than a social epidemic which has raised heavy concerns among road safety experts and policymakers. Recent studies show that: (1)Texting, browsing and dialing resulted in the longest duration of drivers taking their eyes off the road. (2) Texting increased the risk of a crash or near-crash by two times and resulted in drivers taking their eyes off the road for an average of 23 seconds total. (3) Activities performed when completing a phone call (reaching for a phone, looking up a contact and dialing the number) increased crash risk by three times. (4) There is no direct increased crash risk from the specific act of talking on a cell phone. However, visual-manual tasks (locating the phone, looking at the phone and touching the phone) are always involved when using a hand-held cell phone. This makes the overall use of cell phone riskier when driving. (5) Even portable hands-free and vehicle-integrated hands-free cell phone use involved visual-manual tasks at least half of the time, which is associated with a greater crash risk (Chase, 2014, Hedlund, 2011, NHTSA, 2015).

To a large extent, we have focused on two specific smartphone usages, phone calls and text messaging, which were found to be rather commonly used while driving. Alarmingly, while driving in Israel, as indicated in this study, 77% (N=551) of the respondents driving in a passenger car make phone calls and almost half of them may be considered as frequent texting drivers as they admit doing it intensively. The frequency of texting is that 35% of the respondents (N=256) text while driving and a quarter of them do it at least frequently. These findings indicate more extensive usage compared to previous evidence from Israel (Tomer-Fishman, 2010; SARTRE, 2010) and may reflect an increasingly worrisome trend in drivers' behavior. Among professional drives, 100% (N=110) of the truck drivers sample make phone calls and more than half of them may be considered as frequent phone call users as they admit doing it intensively. The frequency of texting is yet considering the documented gravity of the texting effect on driving safety having 33% of the respondents (N=33) reported to do so is a reason for concern.

The paradox indicating high belief that smartphone usage while driving compromises safety is not associated with low self-reported rates of use is worrisome. Among the passenger car drivers sample, while only 43% of the occasional phone calls users and 27% of the frequent phone calls users believe that phone calling compromises safety, most texting users (87% of occasional users and 74% of frequent users) are aware that texting compromises safety. This finding is strengthened by the results obtained among truck drivers: 39% of the texting users –text although they acknowledge its effect of safety. Adding the 56% of the texting users that acknowledge that texting can somewhat compromise safety, indicates that even within texting users - 95% acknowledge at least some effect of texting on safety.

The success of introducing exclusion interventions to control smartphone usage while driving may largely depend on understanding the motivation for these behaviors and the potential of such countermeasures to gain public acceptance. Our analysis regarding factors affecting frequency of usage suggests that the main factor both for texting and phone calling, is their perceived need, while perceived safety had a non-significant effect for texting but had a significant effect on phone calling. This implies that perceived need determines frequency of use more than perceived safety.

### 5.2 Can smartphone apps contribute to safety?

While being a major cause of risk, smartphones apps may also serve as a means to control and reduce risky driving behavior. For example: blocking apps can mitigate distraction by limiting drivers' ability to manually operate the mobile phone while driving, apps may present less distracting interface by enabling voice control, by indicating unsafe and aggressive behaviors, or by alerting drivers regarding potential risks.

Our findings indicate that approximately half of the respondents expressed willingness to use a blocking app, a tool readily available with various configurations. Only the most limiting configuration (complete blockage of phone calls and texting) was suggested in the survey. It may well be the case that even higher acceptance rates could be manifested if less limiting apps are offered. This paves the road for technology-based distraction prevention to serve as key countermeasure.

This study also highlights the tradeoffs between safety and acceptance and emphasizes the need to consider both criteria which were found, based on the experts study, equally important. This should be considered with caution when developing and implementing countermeasures. Smartphone safety -based apps can be downloaded and used voluntarily, hence the issue of how to increase acceptance is prominent.

Our extensive mapping of smartphone safety-related apps revealed a total of approximately 250 apps, already in the market, which can be categorized according to their features into three types: blocking apps, apps that change the interface with the user and driving-coaching apps. The overall evaluation of apps provided by the

37 experts suggests that the desired apps for reducing injury crashes are (in that order): collision warning, texting prevention - no typing, texting prevention - no reading, voice control - text-to-speech, IVDR, and voice control - commands. The three apps that received lower scores (in that order) were: gesture control, HUD and call limitation. Collision warning appears to be a leading technology. It is interesting to note that the experts clearly distinguish between text reading and text typing and emphasized the importance of preventing both (but especially typing) to reducing risky driving behavior. In their views, voice control seems to be favored among the apps which change the interface, while, HUD raised curiosity as well as some doubts.

Cluster analysis according to app types provided somewhat intriguing results; as expected in accordance to the literature, call limitation and texting prevention (both reading and typing) were grouped together into a blocking cluster; HUDs and gesture control were grouped together into an interface cluster. However, voice controls (both commands and text-to-speech) were grouped together with driver feedback apps (green box and collision warning). This may indicate a potential for an ADAS cluster.

It should be noted that the analysis provided in this study treated each app type as a well-defined and uniformly understood concept. This was emphasized and discussed during the expert meetings. However, in real life, there may be variations in the implementation and usage scenarios of each app type. This should be further detailed, specified and researched.

### 5.3 Practical implications: What's next?

This study focuses on smartphone apps that may have the greatest potential to reduce injury crashes. Furthermore, it provides guidelines for prioritizing important features that smartphone apps should have. For example, it may suggest that navigation, although not included in the study, should have voice control activation, text prevention (either through voice activation or text blocking option while the car is in motion) and possibly heads-up-display. Some of these features are already implemented in leading navigation apps.

Therefore, this study may pave the way to establish a blueprint for a "safety suit" for smartphone app: what should be favored and what features and functions compose such a "safety suit". This "safety suit" may be applicable not only for smartphone apps but also to other vehicle interfaces.

In the safety-related apps world, which is changing rapidly mainly due to technology improvements, our results can provide a tool for apps evaluations. Each app can be evaluated by a "weight score". For example, the score may be relatively high if the evaluated app has to some extent capabilities of reducing typing of text messages. However, if the interface of incoming messages is using heads-up display, the score will be lower than if the interface used is text-to-speech. This "safety suit" may be applicable not only for smartphone apps but also to other vehicle interfaces.

The importance of acceptance, which has been found almost as equally important as safety consideration has been dealt in depth throughout this study. In our challenging technology-oriented era it may be that the key issue to acceptance is that technology and smartphone apps while driving have to be "context dependent", that is sensitive and adjusted to the drivers' condition and to the driving circumstances. For example: drivers would probably be very negative about blocking their phones from receiving text messages at all times, however, if they can pre-specify specific senders that would not be blocked while driving – they might be more receptive to blocking. Furthermore, if in-coming notifications and even calls will be blocked depending on traffic and environmental conditions (i.e. heavy rain, complicated right turn) while the complexity of driving task is obvious, then acceptance can be higher. This issue deserves further investigation and study.

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**APPENDIXES**

**Appendix A**: Self-reports about the frequency and patterns of smartphone usage while driving. Report Final.pdf

**Appendix B**: Experts study presentation
SAMBA-FINAL- מצגת למליאה - סקר מומחים.pdf

**Links to published papers:**

**Do we really need to use our smartphones while driving?**
Oren Musicant, Tsippy Lotan, Gila Albert
http://www.sciencedirect.com/science/article/pii/S0001457515300555

**Which smartphone's apps may contribute to road safety? An AHP model to evaluate experts' opinions**
Gila Albert, Oren Musicant, Ilit Oppenheim, Tsippy Lotan
http://www.sciencedirect.com/science/article/pii/S0967070X16303195