Traffic Injury Prevention (2014) **15**, S21–S26

ISSN: 1538-9588 print / 1538-957X online
DOI: 10.1080/15389588.2014.934958

Comparing Handheld and Hands-free Cell Phone Usage Behaviors While Driving

SUSAN A. SOCCOLICH, GREGORY M. FITCH, MIGUEL A. PEREZ, and RICHARD J. HANOWSKI

Virginia Tech Transportation Institute, Blacksburg, Virginia

Received 18 March 2014, Accepted 11 June 2014

Objective: The goal of this study was to compare cell phone usage behaviors while driving across 3 types of cell phones: handheld (HH) cell phones, portable hands-free (PHF) cell phones, and integrated hands-free (IHF) cell phones. Naturalistic driving data were used to observe HH, PHF, and IHF usage behaviors in participants' own vehicles without any instructions or manipulations by researchers.

Methods: In addition to naturalistic driving data, drivers provided their personal cell phone call records. Calls during driving were sampled and observed in naturalistically collected video. Calls were reviewed to identify cell phone type used for, and duration of, cell phone subtasks, non–cell phone secondary tasks, and other use behaviors. Drivers in the study self-identified as HH, PHF, or IHF users if they reported using that cell phone type at least 50% of the time. However, each sampled call was classified as HH, PHF, or IHF if the talking/listening subtask was conducted using that cell phone type, without considering the driver's self-reported group.

Results: Drivers with PHF or IHF systems also used HH cell phones (IHF group used HH cell phone in 53.2% of the interactions, PHF group used HH cell phone for 55.5% of interactions). Talking/listening on a PHF phone or an IHF phone was significantly longer than talking/listening on an HH phone ($P < .05$). HH dialing was significantly longer in duration than PHF or IHF begin/answer tasks. End phone call task for HH phones was significantly longer in duration than the end phone call task for PHF and IHF phones. Of all the non–cell phone–related secondary tasks, eating or drinking was found to occur significantly more often during IHF subtasks (0.58%) than in HH subtasks (0.15%). Drivers observed to reach for their cell phone mostly kept their cell phone in the cup holder (36.3%) or in their seat or lap (29.0% of interactions); however, some observed locations may have required drivers to move out of position.

Conclusions: Hands-free cell phone technologies reduce the duration of cell phone visual–manual tasks compared to handheld cell phones. However, drivers with hands-free cell phone technologies available to them still choose to use handheld cell phones to converse or complete cell phone visual–manual tasks for a noteworthy portion of interactions.

Keywords: naturalistic driving, driver distraction, cell phone, integrated hands-free

Introduction

Cell phones have become an indispensable tool for adults in the United States. The pressure for people to stay connected and multitask is high. In a survey conducted in 2013, the Pew Research Center found that 91% of adults in the United States use a cell phone (Smith 2013). The number of cell phone subscriptions has surpassed the U.S. population (International Telecommunications Union 2011). A survey of young drivers found that over 58% of respondents would feel "lost" if they did not have their phone and over 60% would feel uncomfortable if they did not have their phone with them for a long period of time (Weller et al. 2013).

Associate Editor Matthew Maltese oversaw the review of this article
Address correspondence to Susan A. Soccolich, Virginia Tech Transportation Institute, 3500 Transportation Research Plaza (0536), Blacksburg, VA 24061. E-mail: ssoccolich@vtti.vt.edu

Driving is one activity where people have been observed to use their cell phone. In a 2005 survey, 81% of cell phone users reported using a cell phone when they drive (Wogalter and Mayhorn 2005). The National Occupant Protection Use Survey (NOPUS) observed drivers' electronic device use when stopped at randomly selected controlled intersections nationwide. NOPUS estimates that, in 2010, drivers used a handheld (HH) cell phone 5% of the time (NHTSA 2011). Furthermore, the percentage of drivers who were text messaging or visibly manipulating HH devices was 0.9%. NHTSA applied the hands-free to handheld cell phone ratio observed in NHTSA's 2007 Motor Vehicle Occupant Safety Survey to the NOPUS findings and estimated that 9% of drivers were using either an HH or hands-free (HF) cell phone while driving during a daylight moment in the United States in 2010 (NHTSA 2011). The Integrated Vehicle-Based Safety System Field Operational Test study used light vehicle naturalistic driving data to estimate HH and HF cell phone use during driving (Funkhouser and Sayer 2012). The study found that drivers conversed on an HH or HF cell phone 6.7% of the time and performed visual–manual (VM) HH cell phone subtasks 2.3% of the time.

Using an HH cell phone involves several different tasks beyond talking and listening, such as reaching for the phone or dialing. The risk of distraction by an HH cell phone during driving is well documented. Klauer et al. (2006) collected and analyzed naturalistic driving data for light vehicles. Dialing an HH device, a VM task, was associated with an increased risk of safety-critical events (SCEs). Talking or listening on an HH device was not associated with an increased risk (Klauer et al. 2006). Olson et al. (2009) analyzed naturalistic driving data for heavy vehicles and found similar results. Dialing a cell phone and reaching for an object were associated with a significant increase in risk of SCEs (Olson et al. 2009). Talking or listening on an HH phone was not found to increase the risk of SCEs and talking or listening on an HF phone showed a significant protective effect (Olson et al. 2009). In contrast, non-naturalistic driving study (non-NDS) research has found that driving performance degrades when conversing on a cell phone (Atchley and Dressel 2004; Drews et al. 2004; Horrey et al. 2008; Strayer et al. 2003).

Research has shown that VM tasks associated with cell phone use increase risk during driving. Technology has attempted to reduce the number and complexity of these VM tasks. One such development allows drivers to accept incoming calls and talk or listen without holding a cell phone via headsets and earpieces that wirelessly connect to the cell phone or speakerphone technology. However, these technologies may require drivers to physically interact with a device. Drivers have to use their hands to reach for the phone or headset/earpiece, dial, end the call, and put the device away after use. In the current study, these technologies form a category that has been termed *portable hands-free* (PHF) cell phone interfaces. Another technological development is systems that integrate the cell phone with the vehicle. These systems, including microphones, speakers, steering wheel push buttons, and voice recognition software installed in the vehicle by the manufacturer, enable all cell phone subtasks to be performed while the driver keeps his or her hands on the steering wheel. These systems may allow drivers to keep their eyes on the road longer, track their course more consistently, and have lower mental demand than when these devices are controlled manually (Owens et al. 2010). Having an IHF system available does not guarantee that a driver will use it for all cell phone tasks. In the current study, these systems are called *integrated hands-free* (IHF) cell phones.

Drivers' perceived risk of cell phone use while driving may affect their decision to use a particular cell phone interface or engage in cell phone–related VM tasks. A 2006 survey of drivers from 23 European countries found both handheld and hands-free cell phone use to be considered low risk (Vanlaar and Yannis 2006). White et al. (2004) surveyed drivers in the United Kingdom in 2 studies. The first study found that drivers judged initiating or answering a call on a handheld cell phone to be high risk, whereas the same tasks on a hands-free cell phone were less risky. A second study confirmed the previous findings: drivers consider cell phone use during driving to increase risk, but hands-free cell phone use is less risky than handheld cell phone use (White et al. 2004). Nelson et al. (2009) surveyed younger drivers with high ownership of cell phone use and found that they considered safety of the driving environment before deciding to initiate or answer a phone call.

In a 2013 study by Fitch et al. (2013), naturalistically collected video data were used to quantify cell phone use during driving, assess adaptive driving behaviors associated with cell phone use, and calculate risk of cell phone use during driving. The study evaluated the differences in cell phone use during driving across 3 cell phone interfaces: HH, PHF, and IHF. Fitch et al. (2013) found that drivers did not have significant differences in speed, headway, likelihood to travel in slowest lane, or inclination to change lanes when comparing driving while using each of the 3 cell phone interfaces. The mean unintentional lane departure rate was significantly lower when talking on a handheld cell phone compared to baseline. HH VM tasks such as locating, dialing, texting, browsing, and ending an HH call all increased the percentage of total eyes off roadway time compared to baseline. The risk of cell phone use while driving was calculated using both rate ratio and case-control analyses. The data set included 342 SCEs, with 4 crashes, 2 curb strikes, 72 near-crashes, and 264 crash-relevant conflicts. Talking on a cell phone, of any interface type, while driving was not found to be associated with an increased SCE risk. Visual–manual subtasks performed on an HH cell phone were associated with an increased SCE risk. PHF and IHF cell phone use, absent of any VM handheld cell phone subtasks, was not associated with an increased SCE risk (Fitch et al. 2013).

The current article presents findings from Fitch et al. (2013) quantifying cell phone use during driving. Sampled calls were used to compare the 3 cell phone interfaces for (1) cell phone types used within self-identified cell groups, (2) duration of subtasks, (3) occurrence of non–cell phone–related secondary tasks, and (4) overall placement of cell phone or headset in car when not in use. Determining how the 3 cell phone type interfaces are used during driving is key to fully understanding the implications of HF systems on driving safety.

Methods

Naturalistic driving data were collected from 204 drivers for 3 to 4 weeks. Drivers were recruited if they reported using a cell phone at least once per day while driving. Drivers were recruited from rural and urban/suburban locations in North Carolina and Virginia. State laws in North Carolina were similar to those in Virginia with regard to cell phone use by drivers. One difference, however, is that North Carolina has a primary law banning texting (but not handheld calls), whereas Virginia had a secondary law banning texting. Some drivers in Northern Virginia drove in Washington, DC, where there was a primary law banning texting and all other HH cell phone use. Some also drove in Maryland, where there is also a primary law banning texting.

Naturalistic driving data are defined as data collected from participants while they drive their regular routes. In this study, the drivers were not exposed to any experimental conditions. The naturalistic driving data consisted of video data and sensor data. The video data were collected from 4 in-vehicle cameras that continuously recorded video of the driver's face, steering wheel/center console, and the forward and rear roadway. The sensors installed in the vehicles included accelerometers, Global Positioning System, forward RADAR, lane tracker machine vision, and other sensors.

In addition to the naturalistic data collected, drivers provided their cell phone records, from their cell phone provider, for analysis. Cell phone call records were provided by 191 of the 204 drivers. The call records were overlaid on the driving data. One driver had records that did not overlap driving, 3 drivers had calls that were prior to or at the end of driving, and 187 drivers (92%) had calls placed/received while driving. Each video file was reviewed by a reductionist to verify that the participant was indeed operating the vehicle. Data recorded from nonparticipating drivers were excluded from any further reduction or analysis.

Calls during driving were sampled at a rate of 10% of calls per driver, with a minimum of 4 calls per driver, for further reduction. This sampling method resulted in a data set of 1,564 calls. Researchers reviewed the video and noted cell phone subtasks and which phone type was used to complete the task, as well as several usage and environmental factors during the cell phone subtasks. Each sampled call was classified as HH, PHF, or IHF if the talking/listening subtask was conducted using that cell phone type. The cell phone types are operationally defined in Table 1. The sampled calls were used to compare the 3 cell phone types for: (1) cell types used within self-identified cell groups, (2) duration of subtasks, (3) occurrence of non–cell phone–related secondary tasks, (4) holding the steering wheel with both hands, and (v) overall placement of cell phone or headset in car when not in use.

Because talking on a cell phone could be a lengthy subtask, only a random 6-s interval of the talking subtask was reduced. Care was taken to ensure that talking was the only cell phone subtask that took place in the sample. Furthermore, any holding of the cell phone or wearing of a PHF headset/earpiece that lasted longer than 5 s was treated as a separate subtask. Similar to talking on a cell phone, only a random 6-s interval was sampled because this subtask could also be quite long in duration. If the holding subtask lasted longer than 30 s, then reduction was stopped. A sampled phone call with multiple phone types used for the talking/listening subtask was considered "Mixed" and was not used in the analyses. The list of subtasks can be found in Table A1 (see online supplement).

Subtasks were classified as above 8 km/h if the driver maintained a speed equal to or greater than 8 km/h during the reduced subtask sample. Many of the following analyses were conducted for driving at speeds at or above 8 km/h. The analysis of where phone was kept prior to reaching included all reaching regardless of speed. For similar analyses for driving at speeds below 8 km/h, please see Fitch et al. (2013). The driving speed during a subtask was found by overlaying the speed data with the subtask beginning and end frames.

All study protocols were approved by the Virginia Tech and Westat Institutional Review Boards.

Results

Phone Interface Type Use

In the first analysis, drivers' self-reported phone use was compared to their actual phone use. At the start of the study, prior to any naturalistic driving data collection, drivers self-reported the cell phone type they used at least 50% of the time (HH, PHF, or IHF). For this particular analysis, drivers were grouped together based on the self-reported cell phone type. Using video data to verify, sampled calls were classified as HH, PHF, or IHF if the talking/listening subtask was conducted using that cell phone type. The percentage of sampled calls by cell phone type was calculated for each of the self-reported driver groups (Table 2). HH cell phones were used in interactions by participants in each self-reported cell phone type group. Drivers in the self-reported HH group used an HH phone for 93.6% of sampled calls, drivers in the self-reported IHF group used an HH cell phone in 29.7% of sampled calls, and drivers in the self-reported PHF group used an HH cell phone for 58.5% of sampled calls. When considering the other subtasks, self-reported PHF drivers used an HH phone for at least one cell phone subtask in 55.5% of sampled PHF phone interactions. Self-reported IHF drivers used an HH phone for at least one cell phone subtask in 53.2% of sampled IHF phone interactions.

Duration of Cell Phone Use by Phone Interface Type

For calls where the reduced talk/listen portion was greater or equal to 8 km/h, the average cell phone interaction for

Table 1. Definition of cell phone type for sampled calls

Cell phone type	Operational definition
Handheld (HH)	All cell phone subtasks including reaching, dialing, and talking are performed on a handheld phone. This included holding the cell phone while its built-in speakerphone feature was enabled. Note: Using the speakerphone feature while the cell phone was not held constituted PHF cell phone use.
Portable hands-free (PHF)	Refers to instances when some cell phone subtasks, including reaching, dialing, and talking, were performed with a PHF device. PHF devices included headsets (wired or wireless) or other aftermarket Bluetooth or hands-free devices that were not integrated into the vehicle by the manufacturer. PHF did include voice activation performed through the PHF device.
Integrated hands-free (IHF)	Refers to when some cell phone subtasks, including reaching, dialing, and talking, were done with a cell phone technology that was integrated into the vehicle. This included equipment installed by the vehicle manufacturer such as microphones and speakers for cell phone use, a speech-based user interface to dial the phone, and other phone controls built into the vehicle (e.g., center stack and/or steering wheel buttons). IHF included both vehicles that had a cell phone built into the vehicle itself and vehicles that detected and interacted with the user's portable device without requiring direct manipulation of the phone itself.

Table 2. Percentage of call interactions by cell phone type across self-reported cell phone type groups assigned during recruitment

Driver self-reported cell type group	Observed handheld interactions (%)	Observed integrated hands-free interactions (%)	Observed portable hands-free interactions (%)
HH	93.63	1.33	5.04
IHF	29.67	63.74	6.59
PHF	58.48	9.33	32.19

cell phone calls including VM subtasks and conversing for all cell phone types was 3.94 min long (SE = 0.17). The cell phone interaction counts, average durations, and standard errors are listed for each cell phone type in Table 3. A Kruskal-Wallis nonparametric test comparing phone interaction duration across cell phone types was significant ($\chi^2 = 35.9888$, df = 2, $P < .0001$) and follow-up tests were conducted. Two phone types were compared at a time using Kruskal-Wallis nonparametric tests. HH interactions were significantly shorter than PHF interactions ($\chi^2 = 35.6023$, df = 1, $P < .0001$) and IHF interactions ($\chi^2 = 4.0071$, df = 1, $P = .0453$). IHF interactions were significantly longer than PHF interactions ($\chi^2 = 14.4695$, df = 1, $P = .0001$).

Frequency and Duration of Cell Phone Subtasks

The following cell phone subtasks were analyzed for changes in duration across cell phone types: talking/listening, dialing or begin/answer, browse/read on a handheld phone while talking/listening, and end task. These subtasks were observed to occur in some form in each cell phone type. It was possible for drivers to use different cell phone types to complete these subtasks within the same cell phone interaction. For each subtask, the cell phone type used to complete the subtask was recorded and used for the analyses comparing cell phone types. The cell phone subtask duration distributions were right skewed and transformed using a log transformation before proceeding with analyses. The data were analyzed using analysis of variance (ANOVA) and Tukey's post hoc tests with 95% confidence intervals (CIs). Counts, average durations, and standard errors are listed in Table 4. The significant differences in subtask duration by cell phone type are indicated by the superscript letter next to each cell phone type in the table.

The cell phone subtask talking/listening was tested for significant differences in duration across the 3 cell phone types. The ANOVA was significant ($F = 16.2$, $P < .0001$). Talking/listening on an HH phone was significantly shorter than

Table 3. Phone interaction descriptive statistics for duration

Cell phone type	N	Mean duration (min)	SE	25th Percentile	75th Percentile
Handheld[a]	527	3.4	0.2	0.9	3.4
Portable hands-free[b]	158	5.5	0.5	1.5	7.4
Integrated hands-free[c]	237	4.0	0.4	1.1	4.5

Different letters in superscript following cell phone type indicate statistical significance in Kruskal-Wallis comparisons of two phone types at a time.

Table 4. Cell phone subtask frequency and duration with significance test results

Subtask category	Cell phone type	N	Mean duration (s)	SE
Talk/listen	HH: talk/listen[a]	525	178.7	12.1
	PHF: talk/listen[b]	156	297.7	27.0
	IHF: talk/listen[c]	237	226.8	21.6
	HH: dial[a]	309	12.4	0.5
Dialing or begin/answer	IHF: begin/answer[b]	13	2.9	1.0
	PHF: begin/answer[c]	120	4.6	0.6
Browse/read while talking/listening	HH: browse/read, HH: talk/listen[a]	133	4.4	0.8
	HH: browse/read, IHF: talk/listen[b]	31	6.8	1.0
	HH: browse/read, PHF: talk/listen[a]	35	4.1	0.8
End task	HH: end task[a]	461	4.0	0.1
	IHF: end task[b]	154	2.9	0.2
	PHF: end task[a,b]	33	3.0	0.5

The superscript letter for each cell phone type indicates significant differences within the subtask category found in the Kruskal-Wallis test for duration; if 2 entries have different superscript letters, they were found to be significantly different.

talking/listening on a PHF phone (log difference 95% CI = −0.8953 to −0.3622) or an IHF phone (log difference 95% CI = −0.4980 to −0.0405). Talking/listening on a PHF phone was significantly longer than talking/listening on an IHF phone (log difference 95% CI = 0.0581–0.6608).

The subtasks "dialing" and "begin/answer" were compared across cell phone types used for the subtask, regardless of the phone type used for talking/listening. The overall ANOVA was significant ($F = 119.5$, $P < .0001$). HH dialing was significantly longer in duration than were PHF (log difference 95% CI = 1.2413–2.2900) or IHF begin/answer tasks (log difference 95% CI = 0.9906–1.3890). This was because drivers would frequently pause during the dialing subtask to look back at the forward roadway. The mean subtask duration was also longer because some subtasks involved 10-digit dialing. IHF begin/answer tasks were significantly shorter than PHF begin/answer tasks (log difference 95% CI = 0.0351–1.1166).

The subtask "browse/read while talking/listening" was recorded when a driver viewed a HH cell phone display, with or without pressing buttons or manipulating the touch screen, during a talking/listening task. The talking/listening task could occur on an HH, IHF, or PHF system. The overall ANOVA for the duration of subtask browse/read while talking/listening was significant ($F = 8.54$, $P = .0003$) and follow-up tests were conducted. The subtask duration was significantly longer for IHF phone calls than for HH phone calls (log difference 95% CI = 0.0760–1.2949). The subtask was significantly longer for IHF phone calls than for PHF phone calls (log difference 95% CI = 0.0760–1.2949). The task was not significantly longer during HH phone calls compared to PHF phone calls (log difference 95% CI = −0.2924 to 0.6465).

The final subtask evaluated for difference in duration across cell phone types was "end task." Depending on the cell phone type, drivers could end the phone call by pressing a button on the phone, headset/earpiece or connecting wire, center

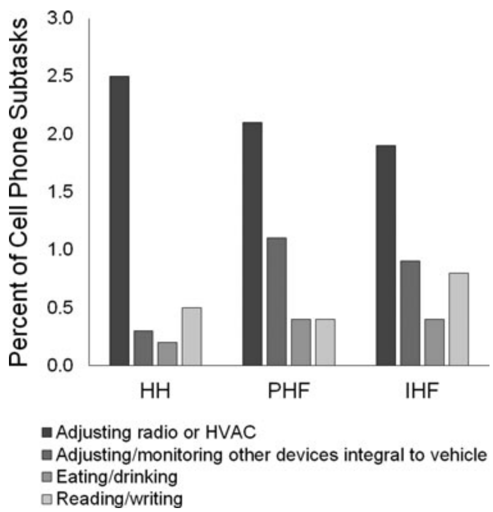

Fig. 1. Non–cell phone secondary task frequency during cell phone use.

stack, or wheel. Drivers with HH phones could also end a call by putting the phone down or flipping or sliding the phone closed. The overall ANOVA was significant ($F = 61.0$, $P < .0001$). The post hoc tests revealed that the end task duration was significantly longer for HH phone calls than for IHF phone calls (log difference 95% CI = 0.1459–0.5542). The end task duration was not significantly different for PHF phone calls compared to HH phone calls (log difference 95% CI = −0.1337 to 0.6569) or IHF phone calls (log difference 95% CI = −0.3323 to 0.5092).

Frequency of Non–Cell Phone Secondary Tasks

Drivers also engaged in non–cell phone–related secondary tasks during driving while using the phone. The list of all secondary tasks is presented in Table A2 (see online supplement). The frequencies of these secondary tasks during cell phone use were compared across cell phone types to see whethe drivers using HF devices were more inclined to engage in additional non-driving-related secondary tasks when not holding a phone. The differences in proportions of the following secondary tasks were tested with Fisher's tests across cell phone types: adjusting radio or heat, ventilation, and air-conditioning; adjusting/monitoring other devices integral to vehicle; eating or drinking; and reading or writing. The distribution of the percentage of cell phone subtasks with the above secondary tasks is displayed in Figure 1. For this analysis, no distinction was made for different speed levels. Eating or drinking did occur significantly more often in IHF subtasks (0.58%) than in HH subtasks (0.15%; $P = .0249$); however, the difference was less than 0.5%. The other secondary tasks were not found to occur significantly more often among any of the cell phone types.

Where Cell Phone Was Kept Prior to Reaching

Drivers who were observed to reach for their cell phone mostly kept their cell phone in their seat or lap (32.1% of interactions) or in the cup holder (30.0%). Other locations within arm's reach of the driver included center console storage (1.9%), in a cradle (1.4%), or on the dashboard (1.4%). Observed locations that may require drivers to move out of position included the passenger seat (15.3%), their purse (5.6%), in the driver door cubby (2.1%), and pants or shirt pocket (6.1%). Very few observations were made of drivers reaching into their rear seat, onto the floor, or retrieving the phone from their visor. A plot of all of the observed locations with percentage of observations is displayed in Table A3 (see online supplement).

Discussion

The goal of the current study was to better understand cell phone use during driving. The study investigated the difference in cell phone use behaviors during driving for users of 3 cell phone interface types: handheld, portable hands-free, and integrated hands-free.

Cell phone use behaviors were found to differ across the cell phone interface types. Calls where the talking/listening task was completed on a PHF interface were significantly longer ($M = 5.5$ min) than calls made on IHF cell phones ($M = 4.0$ min) and HH cell phones ($M = 3.4$ min). The talking/listening portion of the cell phone interaction followed a similar pattern. Talking/listening on a PHF interface ($M = 297.7$ s) was significantly longer than talking/listening on an IHF interface ($M = 226.8$ s) or HH interface ($M = 178.7$ s). The hands-free systems make it easier for drivers to converse—they may be able to continue conversations in driving environments that are more difficult to navigate with an HH system. Another possibility is that drivers with both HF and HH systems available to them may choose to use an HF system for phone calls that are expected to be long.

Dialing on an HH cell phone ($M = 12.4$ s) was significantly longer than beginning/answering a cell phone call on PHF ($M = 4.6$ s) or IHF interfaces ($M = 2.9$ s). Another VM subtask, ending the phone call, showed parallel results. Ending an HH cell phone call ($M = 4.0$ s) was significantly longer than ending an IHF call ($M = 2.9$ s). In Fitch et al. (2013), dialing on an HH cell phone was found to have a significantly longer average total eyes-off-road time than simpler VM subtasks such as begin/answer an IHF call or ending an HH call. Interestingly, Fitch et al. (2013) found that percentage total eyes-off-road time when ending a call on a PHF device was significantly less than when ending a call on an HH or IHF interface.

Hands-free systems allow drivers to keep their hands free from manipulating the device. It was hypothesized that drivers, with their hands now free, might engage in other tasks during HF cell phone use. This was not found to be the case in this study. No significant differences were found in the prevalence of non–cell phone–related secondary tasks, such as adjusting radio or heat, ventilation, and air-conditioning, adjusting/monitoring other devices integral to vehicle, and reading or writing across the cell phone types. Though eating or drinking did occur significantly more often in IHF subtasks

(0.58%) than in HH subtasks (0.15%), the difference was less than 0.5%.

In several previous studies, drivers have rated HF cell phone use to be less risky than HH cell phone use (Vanlaar and Yannis 2006; White et al. 2004). In Fitch et al. (2013), VM tasks using an HH cell phone were associated with an increased risk, but pure hands-free cell phone use, without VM handheld tasks, was not associated with an increased driving risk. In the current study, drivers with IHF or PHF systems continued to find HH cell phone use necessary to complete calls. Drivers who self-reported using IHF systems at least 50% of the time were observed using an HH cell phone to talk/listen in 29.7% of sampled calls and drivers in the self-reported PHF group were observed using an HH cell phone to talk/listen in 58.5% of sampled calls. Drivers in the self-reported PHF group used an HH phone for at least one subtask in 55.5% of sampled PHF phone interactions. Drivers in the self-reported IHF group used an HH phone for at least one subtask in 53.2% of sampled IHF phone interactions.

By using an HH device when HF interfaces are available to them, drivers are exposing themselves to an increase in SCE risk. Although true HF cell phone use could reduce the risk of completing a call during driving, the benefit of eliminating VM tasks through current HF cell phone technologies has not been attained. Drivers with HF technology available may continue to use a HH cell phone for the following reasons: HF technology may not reliably execute voice commands, HF technology may require more steps to complete certain tasks, and HF technology such as PHF systems still require some HH cell phone use to complete VM tasks. With the introduction of smart phone devices, HH cell phones with Internet access are growing in popularity. A survey of young drivers found that 16.8% of those with Internet service on their cell phone reported accessing websites while driving at least once (Weller et al. 2013). As cell phones become more advanced and are used for tasks besides making phone calls, HF technology may need to address new HH cell phone abilities in order to be a desirable and safer option for drivers.

Acknowledgment

The authors thank Lisandra Garay-Vega, for her technical direction, insight, and support throughout the entire project. The authors also acknowledge Westat for providing assistance with data collection. The opinions expressed in this document are those of the authors and do not necessarily reflect the official position of NHTSA, any other organization, or others who are not authors of this document.

Funding

This light vehicle naturalistic driving study was funded by NHTSA under DTNH22-11-D-00236, Task Order 0005 and DTNH22-05-D-1002, Task Order 0022.

Supplemental Materials

Supplemental data for this article can be accessed on the publisher's website. www.tandfonline.com/GCPI

References

Atchley P, Dressel J. Conversation limits the functional field of view. *Hum Factors.* 2004;46:664–673.

Drews FA, Pasupathi M, Strayer DL. Passenger and cell-phone conversations in simulated driving. In: *Proc Hum Fact Ergon Soc 48th Annu Meet.* 2004;48:2210–2212.

Fitch GA, Soccolich SA, Guo F, et al. *The Impact of Hand-held and Hands-free Cell Phone Use on Driving Performance and Safety-Critical Event Risk*. Washington, DC: NHTSA; 2013. Report No. DOT HS 811 757.

Funkhouser D, Sayer J. A naturalistic cell phone use census. In: *Proceedings of the 91st Annual Meeting of the Transportation Research Board*, Washington, DC; 2012.

Horrey WJ, Lesch MF, Garabet A. Assessing the awareness of performance decrements in distracted drivers. *Accid Anal Prev.* 2008;40:675–682.

International Telecommunication Union. *Measuring the Information Society*. Geneva, Switzerland: Author; 2011.

Klauer SG, Dingus TA, Neale VL, Sudweeks JD, Ramsey DJ. *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data*. Washington, DC: NHTSA; 2006. No. DOT-HS-810-594.

Nelson E, Atchley P, Litle TD. The effects of perception of risk and importance of answering and initiating a cellular phone call while driving. *Accid Anal Prev.* 2009;41:438–444.

NHTSA. *Driver Electronic Device Use in 2010. Traffic Safety Facts Research Notes*. Washington, DC: Author; 2011. No. DOT HS 811 517.

Olson RL, Hanowski RJ, Hickman JS, Bocanegra J. *Driver Distraction in Commercial Vehicle Operations: Final Report*. Washington, DC: Federal Motor Carrier Safety Administration; 2009. Contract DTMC75-07-D-00006, Task Order 3.

Owens JM, McLaughlin SB, Sudweeks J. On-road comparison of driving performance measures when using handheld and voice-control interfaces for mobile phones and portable music players. *SAE International Journal of Passenger Cars - Mechanical Systems*. 2010;3:734–743.

Smith A. *Smartphone Ownership—2013 Update*. Washington, DC: Pew Research Center; 2013.

Strayer DL, Drews FA, Johnston WA. Cell phone–induced failures of visual attention during simulated driving. *J Exp Psychol Appl.* 2003;9:23–32.

Vanlaar W, Yannis G. Perception of road accident causes. *Accid Anal Prev.* 2006;38:155–161.

Weller JA, Shackleford C, Dieckmann N, Slovic P. Possession attachment predicts cell phone use while driving. *Health Psychol.* 2013;32:379–387.

White MP, Eiser JR, Harris PR. Risk perceptions of mobile phone use while driving. *Risk Anal*. 2004;24:323–334.

Wogalter MS, Mayhorn CB. Perceptions of driver distraction by cellular phone users and nonusers. *Hum Factors.* 2005;47:455–467.