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The influence of roadway situation, other contextual factors, and driver characteristics on the prevalence of driver secondary behaviors

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ABSTRACT

Drivers may modulate their secondary behavior based on roadway or driving demand, but there is little research capturing secondary behaviors in a range of driving situations among a large sample of drivers on actual roadways. Weekday daytime and nighttime roadside observations were conducted of drivers traveling in free-flowing traffic on a straightaway, in a roundabout, and when moving or stopped at a signalized intersection on the same roadway in four Northern Virginia communities. The presence of 12 secondary behaviors were noted for each of the 16,556 drivers observed. Overall, 23% of drivers observed were engaged in some kind of secondary behavior. The most common secondary behaviors were holding (5.1%) or talking on (4.2%) a hand-held cellphone, eating or drinking (3.1%), and talking or singing with a passenger (2.7%). Based on logistic regression analysis, the prevalence of any kind of secondary behavior and of more manually demanding behaviors, like manipulating a hand-held cellphone and eating or drinking, was highest among drivers stopped at red lights and lowest among drivers in roundabouts. Other factors also influenced the prevalence of driver secondary behavior. Drivers were more likely to be eating or drinking and less likely to be talking on a handheld phone in the morning than at others time of the day. Drivers estimated to be 60 and older were least likely to be engaged in any secondary behavior, but drivers younger than 20 and drivers 20–59 years old were equally likely. Drivers with and without passengers were equally likely to be engaged in any secondary behavior, but drivers with passengers were most likely to be talking or singing with the passengers, whereas drivers without passengers were most likely to be eating or drinking or holding, talking on, or manipulating hand-held phones. The current findings in combination with past research suggest that drivers may engage in secondary behaviors when perceived driving demand is reduced, and that roadway demand and contextual variables are important factors to consider when studying driver secondary behavior.

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1. Introduction

Distraction is a common occurrence for drivers with potentially serious consequences. The National Highway Traffic Safety Administration (NHTSA) estimated that in 2013, 10% of fatal crashes, 18% of injury crashes, and 16% of all police-reported crashes involved drivers coded as distracted (NHTSA, 2015). Secondary behaviors are behaviors unrelated to the driving task that often can divert attention away from activities critical for safe driving (Engstrom et al., 2013). Cellphone use is the activity most commonly associated with driver distraction. Dialing, texting, reading and writing emails, and other manual interactions with phones may be especially concerning since they involve visual, manual, and cognitive resources needed to drive safely.

In the most recent national roadside observational survey of electronic device use (Pickrell, 2015), 4.6% of drivers stopped at controlled intersections during the daytime were observed talking on hand-held phones, and 1.7% were manipulating phones or other hand-held electronic devices. Concerns about drivers' use of wireless communication devices has led to laws limiting that use. Talking on hand-held cellphones is banned in 14 states and the District of Columbia, and 46 states and the District of Columbia bar drivers from texting (Insurance Institute for Highway Safety, 2015).

Many controlled experiments have documented the deleterious impact of using cellphones and other secondary behaviors on simulated or instrumented driving performance (e.g., Alosco et al., 2012; Caird, Willness, Steel, & Scialfa, 2008; Horrey & Wickens, 2006). Using data from naturalistic studies that monitor drivers over an extended period of everyday driving, research has linked manual interactions with cellphones with an increased risk of safety–critical events like crashes, near-crashes, and other traffic conflicts (e.g., Farmer, Klauer, McClafferty, & Guo, 2014; Klauer et al., 2014). However, several studies also found that drivers may seek to compensate for any degradations in driving performance by adjusting their driving when engaged in secondary behaviors. For example, drivers using cellphones slow down (Farmer et al., 2014), allow more headway (Drews, Pasupathi, & Strayer, 2008; Strayer & Drews, 2004), and make fewer lane changes (Beede & Kass, 2006).

Drivers also may engage in secondary behaviors when they believe the impact on the driving task may be less. For instance, drivers may delay beginning a secondary behavior when roadway demand is high (e.g., Liang, Horrey, & Hoffman, 2014; Schömig, Metz, & Krüger, 2011) or wait for less demanding situations like when they are stopped. Huisingh, Griffin, and McGwin (2015) observed drivers at controlled intersections and found that secondary behaviors were o more frequent among drivers in stopped vehicles than among drivers in moving vehicles. Similarly, three analyses of video recordings of daily driving found that drivers made phone calls and interacted with their cellphone more often when the vehicle was stopped compared with when it was moving, especially at higher speeds (Farmer et al., 2014; Funkhouser & Sayer, 2012; Metz, Landau, & Just, 2014).

Although previous research suggests that drivers may modulate their secondary behavior based on roadway or driving demand, there is little real-world data capturing driver secondary behaviors in a wide range of driving situations and for a large sample of drivers. Furthermore, most research on the prevalence of driver secondary behaviors has focused on cellphone use, with only a few studies examining the prevalence of other secondary behaviors like eating, drinking, and grooming (e.g., Huisingh et al., 2015; Klauer et al., 2014; Stutts et al., 2005; Sullman, Prat, & Tasci, 2014).

Other factors apart from the roadway situation may influence driver engagement in secondary behaviors. Metz et al. (2014) analyzed video recordings of daily driving and reported that drivers were less likely to engage in cellphone conversation when a passenger was present. A similar pattern was observed among novice drivers (Foss & Goodwin, 2014). Farmer et al. (2014) found that cellphone interactions were more common among drivers younger than 21 than among those 21 and older, and, in a recent roadside observational study, drivers estimated to be younger than 30 were more likely to be engaged in secondary behaviors than drivers ages 30–50 or older than 50 (Sullman et al., 2014). In contrast, naturalistic research by Klauer et al. (2014) found that the prevalence of various cellphone interactions was similar between novice teenage drivers and adult drivers. In the 2013 national roadside survey, nearly twice as many female drivers as male drivers were manipulating a hand-held device (Pickrell, 2015). However, biological sex differences in drivers' cellphone use were not found in other studies (e.g., Farmer et al., 2014; Hamilton, Arnold, & Tefft, 2013). Certain secondary behaviors also may vary by time of day (e.g., Sullman et al., 2014).

Roadside observational surveys can measure behaviors in a large population of drivers and have been used to estimate the prevalence of cellphone use statewide and nationally in the United States (e.g., Cooper, Ragland, Ewald, Wasserman, & Murphy, 2013; Pickrell, 2015; Wenners, Knodler, Kennedy, & Fitzpatrick, 2013) and to evaluate interventions aimed at changing driver behavior (e.g., Chaudhary, Casanova-Powell, Cosgrove, Reagan, & Willaims, 2012; Chaudhary, Connolly, Tison, Solomon, & Elliott, 2015; McCartt, Braver, & Geary, 2003; McCartt, Hellinga, & Geary, 2006).

A pilot study determined that 14 secondary behaviors could be reliably recorded with moderate to substantial agreement by roadside observers standing at straightaways, controlled intersections, and roundabouts (Kidd, Chaudhary, Cassanova-Powell, McCartt, & Tison, 2015). However, the design did not allow for determining whether the prevalence of secondary behaviors varied across different roadway situations independent of other factors that varied across the situations (e.g., speed limit, roadway features, driver population). In the current study, the prevalence of secondary behaviors was measured in different roadway situations located along the same roadway corridor to minimize the effect of important factors that could influence the prevalence. The prevalence of secondary behaviors was expected to be lower during inherently more demanding roadway situations and higher during less demanding roadway situations. The prevalence of secondary behaviors as a function of other contextual factors like passenger presence, time of day, and driver characteristics also was explored.

2. Method

2.1. Site selection and timing of observations

Roadside observations of motorists were conducted in July 2014 at several locations in Northern Virginia, an affluent, densely populated area. Observations were conducted on a straight roadway segment with free-flowing traffic (straightaway), at a roundabout, and at a signalized intersection along a single roadway corridor in four communities (Alexandria, Loudoun County, Mount Vernon, Purcellville) for a total of 12 observation sites. The distances from the first to the third site ranged from 0.6 to 6.5 miles, ensuring that the stream of traffic and the roadway features were reasonably similar. Only passenger vehicles (excluding police, fire, or ambulance vehicles) in the nearest lane were observed, and locations where the nearest lane of traffic was a dedicated turn lane were not considered.

Observations were conducted Monday–Thursday in clear weather for 45-min sessions in the morning (6:30–10 am), afternoon (11 am–1 pm), and evening (4:30–7 pm), and for 60 min sessions at night (9 pm–1 am). Each site was observed once during each time period, with the order counterbalanced across communities. Both directions of travel were observed simultaneously during the daytime and in contiguous hours at night, which controlled for potential differences related to the dominant flow of traffic (e.g., moving with versus against rush-hour traffic). Restricting observations to the nearest lane allowed observing secondary behaviors occurring below the steering wheel. Observers were stationed on the curb when possible for a better view into the vehicle and were stationed on the road shoulder at 5 sites without a curb.

Observers recorded estimated driver age category (<20, 20–59, 60+ years old) and perceived driver sex based on observed physiological characteristics; passenger presence (none, passenger(s) in front, passenger(s) in rear, passengers in front and rear); whether vehicle was stopped or moving; and whether the driver was engaged in specified secondary behaviors. Only moving traffic was observed at straightaways and roundabouts. Both moving and stopped traffic was observed at signalized intersections, as described below. For moving vehicles, the observers identified a reference point on the opposite side of the road (e.g., tree) to select vehicles for observation. Once data for a vehicle were recorded, the observer recorded data for the next vehicle passing the reference point. This procedure ensured that observed vehicles were randomly selected. Observers were instructed to record driver characteristics and any secondary behaviors during their initial glance into vehicles.

At signalized intersections, when the traffic light turned red, the observer waited for the first vehicle to stop at the intersection stop bar. Data were recorded for this vehicle and each subsequent stopped vehicle in the queue. When the light turned green, the observer observed moving traffic. When observing stopped and moving vehicles, observers were instructed to record driver characteristics and any secondary behaviors during their initial glance into vehicles. Hence, the duration of observation for each vehicle was similar across roadway situations.

All daytime and most nighttime observations were recorded by one observer using a paper-and-pencil form. At four locations with insufficient ambient light to permit one person to conduct nighttime observations, observations were conducted using a night-vision goggle/infrared spotlight combination, with another person recording the observer's verbalized observations.

The study protocol was determined to be exempt from human subjects review by the Chesapeake Institutional Review Board.

2.2. Data analysis

The presence of 12 secondary behaviors were recorded (Table 1). Information on whether the driver was talking or singing and on passenger presence was combined to create two variables: driver talking or singing with passenger present and driver talking or singing with passenger not present.

The prevalence of any secondary behavior and of each specific secondary behavior was examined by estimated driver age and perceived sex, roadway situation (straightaway, roundabout, stopped traffic at signalized intersection, moving traffic at signalized intersection), time of day, passenger presence, and community.

Binary logistic regression analyses examined whether the likelihood of observing a driver engaged in any secondary behavior and in each of the five most prevalent secondary behaviors was associated with roadway situation, driver age, driver sex, community, or time of day. Community was entered first in each model. Four observations with missing or unknown driver sex and five observations with missing driver age were excluded. Separate logistic regression analyses examined if the likelihood of observing any secondary behavior and the five most prevalent behaviors was associated with passenger presence after adjusting for community. Odds ratios and 95% confidence intervals were computed between the different levels of each independent variable, with odds ratio considered statistically significant if the 95% confidence interval did not include 1. All analyses were performed using the binary logistic regression option in SPSS version 19.

3. Results

Of the 16,556 vehicles observed, approximately one-third were observed at signalized intersections (32.5%, including 23.8% moving and 8.7% stopped vehicles), in roundabouts (35.0%), and in straightaways (32.5%). Morning and afternoon sessions each accounted for about one-quarter of observations (27.1% and 23.2%, respectively), evening sessions accounted for

Table 1
Operational definitions of observed driver secondary behaviors.

Secondary behavior	Operational definition
Talking on hand-held cellphone	Holding cellphone to ear or between head and shoulder, or talking while holding cellphone at or above steering wheel midline
Manipulating hand-held cellphone	Manually interacting with cellphone. Excludes looking at cellphone in mount or other storage location
Holding hand-held cellphone	Holding but not manually interacting with cellphone in hand. Excludes holding related to conversation or when device is resting on lap out of driver's hand
Wearing Bluetooth earpiece or headset with microphone	Wearing headset with microphone or visible earpiece
Wearing headphones or ear buds	Wearing headphones or ear buds. Note that ear buds or headphones may be used for hands-free use of cellphone or listening to music
Manipulating in-vehicle system	Touching radio, climate control, embedded touchscreen display, or other controls located in center console. Excludes operating stalks or buttons on steering wheel
Manipulating or holding mobile electronic device other than cellphone	Holding or manually interacting with non-cellphone electronic device, e.g., tablet computer, laptop, or mounted portable navigation system
Talking or singing	Driver's lips moving and appearing to form words
Eating or drinking	Holding or consuming food or beverage
Smoking	Lighting/extinguishing/holding/smoking cigarette, cigar, or other smoking implement
Grooming or applying makeup	Shaving, brushing, or flossing teeth; combing hair; applying makeup; nose picking. Excludes stroking face or hair twirling (i.e., casual/habitual behaviors)
Other	Reaching for object (arm or hand moving in discernible motion toward unknown object or object that is not in-vehicle system, cellphone, or other mobile electronic device), reading print material (looking at newspaper, map, book, etc.), adjusting sun visor, putting on sunglasses, holding other non-electronic objects in hand (e.g., spray bottle), and all other observable secondary behaviors

37.2%, and night sessions accounted for 12.5%. The distribution of observations across cities was as follows: Mount Vernon (36.2%), Alexandria (23.1%), Purcellville (22.4%), and Loudoun County (18.3%).

The majority of drivers were male (60.3% male), and 84.3% were judged to be ages 20–59, with 4.1% younger than age 20 and 11.6% older than age 60. Most drivers were alone (78.9%). Overall, 23.4% of drivers were engaged in at least one secondary behavior; 1.6% were involved in more than one. The most common behaviors were holding a cellphone (without manipulation or talking, 5.1%), talking on a hand-held cellphone (4.2%), eating or drinking (3.1%), talking or singing with a passenger present (2.7%), and manipulating a cellphone (2.3%) (Table 2).

3.1. Roadway situation

The rates of any secondary behavior ranged from 21.2% in roundabouts to 30% among drivers stopped at signalized intersections (Table 2). The majority of specific secondary behaviors were most prevalent among drivers stopped at signalized intersections. Based on the logistic regression models (Table 3), the likelihood of a driver engaging in any secondary behavior was significantly higher when stopped at a signalized intersection compared with driving in a straightaway (+41%), through a signalized intersection (+47%), or in a roundabout (+66%), after adjusting for driver age and sex, community, and time of day. Drivers stopped at intersections also were significantly more likely to be talking or singing with passenger(s) present, eating or drinking, or manipulating a phone compared with drivers in other driving situations. However, drivers stopped at signalized intersections were significantly less likely to be holding a cellphone compared with drivers in straightaways (−60%), moving through intersections (−63%), or in roundabouts (−42%). The likelihood of talking on a handheld phone did not vary significantly across the roadway situations.

The prevalence of any secondary behavior did not differ between drivers in straightaways and drivers moving through signalized intersections (Table 3). The prevalence of any secondary behavior among drivers in roundabouts was significantly lower than among drivers in straightaways (−15%) or moving (−11%) or stopped (−40%) at signalized intersections. Drivers in roundabouts also were significantly less likely to be manipulating a cellphone compared with drivers in the other roadway situations (−40% to −73%), significantly less likely to be holding a cellphone than drivers in straightaways (−30%) or moving through intersections (−36%), and significantly more likely to be holding a cellphone than drivers stopped at intersections (+73%).

3.2. Time of day

The percentages of drivers engaged in secondary behaviors by time of day are shown in Table 4. Based on the results of the logistic regression models, the probability of a driver being engaged in any secondary behavior was significantly higher in the afternoon compared with the morning (+35%), the evening (+12%), or at night (+27%), after adjusting for driver sex and age, community, and roadway situation (Table 3). The likelihood of any secondary behavior was significantly higher in the evening than at night (+13%) or in the morning (+20%).

Table 2
Percentage of drivers engaged in secondary behaviors in different roadway situations and overall.

Secondary behavior	Straightaway (n = 5379)	Roundabout (n = 5798)	Moving at intersection (n = 3943)	Stopped at intersection (n = 1436)	Overall (n = 16,556)
Any secondary behavior	24.1	21.2	23.3	30.0	23.4
Holding cellphone	6.0	4.2	6.3	2.2	5.1
Talking on hand-held cellphone	4.4	4.2	4.0	3.6	4.2
Eating or drinking	3.3	2.6	2.7	5.5	3.1
Talking or singing with passenger present	2.0	3.4	2.1	4.3	2.7
Manipulating cellphone	2.8	1.2	2.7	3.8	2.3
Talking or singing without passenger present	1.8	2.5	1.7	3.3	2.1
Smoking	1.4	1.6	1.7	2.6	1.6
Wearing headphones or earbuds	1.2	1.6	1.2	1.3	1.3
Other	1.3	0.7	1.2	3.8	1.3
Wearing Bluetooth device	0.5	0.6	0.5	0.8	0.6
Manipulating in-vehicle system	0.5	0.2	0.5	0.9	0.4
Grooming	0.5	0.1	0.2	1.3	0.4
Manipulating or holding device other than cellphone	<0.1	<0.1	<0.1	<0.1	<0.1

Note. Multiple secondary behaviors could be coded for each driver.

Table 3
Odds ratios [95% confidence intervals] from logistic regression modeling the log odds of observing a driver engaged in any secondary behavior and in each of the five most common behaviors associated with estimated driver age, perceived driver sex, time of day, and roadway situation.

	Secondary behaviors					
	Any secondary behavior	Holding cellphone	Talking on hand-held cellphone	Eating or drinking	Talking or singing with passenger present	Manipulating cellphone
Perceived sex						
Female vs. Male	1.12* [1.04, 1.20]	1.12 [0.97, 1.29]	1.15 [0.98, 1.34]	1.14 [0.95, 1.36]	1.37* [1.13, 1.66]	1.02 [0.82, 1.25]
Estimated age						
20–59 vs. <20	1.03 [0.85, 1.25]	0.81 [0.56, 1.18]	1.03 [0.72, 1.48]	1.47 [0.89, 2.43]	1.03 [0.62, 1.69]	0.68 [0.42, 1.10]
60+ vs. <20	0.37* [0.30, 0.47]	0.16* [0.09, 0.28]	0.42* [0.26, 0.67]	0.68 [0.37, 1.23]	0.53* [0.29, 0.96]	0.14* [0.06, 0.30]
Time of day						
Morning vs. night	0.94 [0.82, 1.07]	0.74* [0.59, 0.93]	0.48* [0.36, 0.63]	3.95* [2.63, 5.94]	0.42* [0.30, 0.59]	0.85 [0.59, 1.23]
Afternoon vs. night	1.27* [1.12, 1.44]	0.95 [0.76, 1.19]	0.96 [0.75, 1.23]	2.34* [1.52, 3.58]	1.35* [1.01, 1.81]	1.09 [0.76, 1.56]
Evening vs. night	1.13* [1.00, 1.27]	0.68* [0.55, 0.85]	0.97 [0.77, 1.21]	2.04* [1.35, 3.08]	0.73* [0.54,0.97]	1.23 [0.88, 1.70]
Roadway situation						
Intersection (moving) vs. straightaway	0.96 [0.87, 1.06]	1.09 [0.92, 1.30]	0.88 [0.72, 1.09]	0.82 [0.64, 1.05]	1.03 [0.77, 1.38]	0.97 [0.75. 1.25]
Intersection (stopped) vs. straightaway	1.41* [1.24, 1.61]	0.40* [0.28, 0.58]	0.77 [0.56, 1.04]	1.70* [1.29, 2.24]	2.34* [1.69, 3.23]	1.50* [1.09, 2.06]
Roundabout vs. straightaway	0.85* [0.78, 0.93]	0.70* [0.59, 0.83]	0.94 [0.78, 1.13]	0.81 [0.65, 1.01]	1.70* [1.34, 2.17]	0.40* [0.30, 0.54]

Note. N = 16,547. Models exclude 9 cases where perceived driver sex was unknown or missing or estimated driver age was missing. Community was included in each model as a covariate and is not shown.
* $p < 0.05$.

There were some clear patterns in the prevalence of specific secondary behaviors by time of day. For example, drivers were significantly more likely to be eating or drinking and less likely to be talking on a handheld phone in the morning than at other times, whereas drivers were most likely to be talking or singing with passengers in the afternoon (Table 3).

3.3. Perceived driver sex and estimated driver age

The rates of secondary behaviors by perceived driver sex and estimated driver age are shown in Table 5. The logistic regression analyses indicated that drivers judged to be female had a significantly higher probability of being engaged in any secondary behavior (+12%) and talking or singing with a passenger (+37%) compared with drivers judged to be male

Table 4
Percentage of drivers engaged in secondary behaviors at different times of day.

Secondary behavior	Morning (n = 4485)	Afternoon (n = 3844)	Evening (n = 6162)	Night (n = 2065)
Any secondary behavior	21.0	25.2	24.3	22.9
Holding cellphone	5.0	5.5	4.5	6.5
Talking on hand-held cellphone	2.4	4.7	4.8	5.2
Eating or drinking	4.8	2.9	2.6	1.3
Talking or singing with passenger present	1.4	4.2	2.5	3.3
Manipulating cellphone	1.9	2.2	2.7	2.4
Talking or singing without passenger present	1.2	2.1	3.1	1.4
Smoking	1.6	1.6	1.7	1.6
Wearing headphones or earbuds	1.6	1.2	1.5	0.6
Other	1.0	1.4	1.5	1.0
Wearing Bluetooth device	0.5	0.7	0.6	0.2
Manipulating in-vehicle system	0.6	0.4	0.5	0.3
Grooming	0.3	0.5	0.4	0.3
Manipulating or holding device other than cellphone	<0.1	<0.1	<0.1	<0.1

Note. Multiple secondary behaviors could be coded for each driver.

(Table 3). Drivers estimated to be younger than age 20 or ages 20–59 were significantly more likely to be engaged in a secondary behavior of any kind and in each specific secondary behavior compared with drivers judged to be 60 years and older. Secondary behaviors involving phone use were especially rare among the oldest drivers. For example, the likelihood that a driver was manipulating a cellphone was more than seven times as high among drivers younger than 20 and about five times as high among drivers 20–59 years old as among drivers age 60 and older. The prevalence of any secondary behavior did not differ significantly between drivers younger than age 20 years and drivers ages 20–59, and the prevalence of specific secondary behaviors generally did not vary between these age groups.

3.4. Passenger presence

The proportion of drivers engaging in any secondary behavior was similar for drivers transporting and not transporting passengers, but the prevalence of specific secondary behaviors varied by passenger presence (Table 6). By far the most common secondary behavior among drivers transporting passengers was talking or singing with the passenger(s) (12.7%). The prevalence of phone-related secondary behaviors was higher among drivers without passengers than among drivers with passengers.

Binary logistic regression examined the effect of passenger presence on the prevalence of any secondary behavior and on the five most common behaviors after adjusting for community. The likelihood that a driver engaged in any secondary behavior was not significantly influenced by passenger presence (OR = 1.06, 95% CI [0.97, 1.16]). However, drivers were significantly more likely to be holding (OR = 2.83, 95% CI [2.22, 3.61]), talking (OR = 2.36, 95% CI [1.84, 3.01]), or manipulating a cellphone (OR = 3.10, 95% CI [2.13, 4.50]), or eating or drinking (OR = 1.35, 95% CI [1.07, 1.70]) when traveling alone.

4. Discussion

The findings of the current study suggest that, to some degree, drivers may attempt to reduce driving performance impairments and increased risk by engaging in secondary behaviors more often in less demanding situations like when the vehicle is stopped and less often in more demanding roadway situations like a roundabout. The effect was most pronounced for secondary behaviors with greater visual and manual demands like manipulating a hand-held cellphone. Although the current study did not examine the same drivers' choices in different roadway situations, the observed changes in the prevalence of secondary behaviors are consistent with previous research tracking individual driver cellphone use when the vehicle is stopped and moving (e.g., Farmer et al., 2014; Funkhouser & Sayer, 2012), and suggest driver engagement in secondary behaviors other than cellphone use also may be affected by roadway or driving demand.

Consistent with past research (e.g., Farmer et al., 2014), manipulating a cellphone was significantly more common among drivers stopped at red lights compared with other roadway situations. There was no significant difference in the prevalence of drivers talking on a hand-held cellphone across roadway situations, and holding a cellphone was less prevalent among drivers stopped at red lights. Perhaps holding a cellphone was replaced by more manually and/or visually demanding secondary tasks when drivers were stopped, like manipulating a cellphone and eating or drinking.

Similar to previous roadside observational studies (Sullman, 2012; Sullman et al., 2014; Young, Rudin-Brown, & Lenné, 2010), temporal patterns were observed in the prevalence of some secondary behaviors. For example, eating or drinking was most frequent in the morning. Data from the 2008 National Household Traffic Survey (Santos, McGuckin, Nakamoto, Gray, & Liss, 2011) show that early morning trips are mostly work-related so it makes sense that some drivers may integrate eating or drinking into their morning commutes. Non-work-related travel mostly occurs during the middle of the day and afternoon (Santos et al., 2011). Accordingly, the increased prevalence of drivers' talking or singing with passengers in the afternoon may reflect increased social or recreational travel.

Table 5
Percentage of drivers engaged in each secondary behavior category by perceived driver sex and estimated driver age.

Secondary behavior	Perceived driver sex		Estimated driver age		
	Female (n = 6572)	Male (n = 9980)	<20 (n = 676)	20–59 (n = 13,954)	60+(n = 1921)
Any secondary behavior	24.5	22.7	24.3	25.1	11.0
Holding cellphone	5.3	4.9	5.0	5.7	1.0
Talking on hand-held cellphone	4.5	4.0	5.3	4.4	2.0
Eating or drinking	3.3	2.9	2.5	3.3	1.7
Talking or singing with passenger present	3.2	2.3	2.7	2.8	1.6
Manipulating cellphone	2.3	2.3	3.0	2.5	0.5
Talking or singing without passenger present	2.8	1.7	2.8	2.3	1.0
Smoking	1.2	1.9	1.6	1.7	1.3
Wearing headphones or earbuds	1.2	1.4	1.0	1.5	0.4
Other	1.2	1.3	1.8	1.3	0.9
Wearing Bluetooth device	0.3	0.7	0.2	0.6	0.5
Manipulating in-vehicle system	0.5	0.4	0.2	0.5	0.3
Grooming	0.5	0.3	1.0	0.3	0.4
Manipulating or holding device other than cellphone	<0.1	<0.1	<0.1	<0.1	<0.1

Note. Multiple secondary behaviors could be coded for each driver. Percentages for driver sex exclude 4 observations where sex was unknown or missing. Percentages for estimated driver age exclude 5 observations where age was missing.

Table 6
Percentage of drivers engaged in secondary behaviors with and without passenger(s) present.

Secondary behavior	No passenger (n = 13,056)	Passenger present (n = 3499)
Any secondary behavior	23.7	22.5
Holding cellphone	5.9	2.1
Talking on hand-held cellphone	4.8	2.1
Eating or drinking	3.2	2.5
Talking or singing with passenger present	–	12.7
Manipulating cellphone	2.7	0.9
Talking or singing without passenger present	2.7	–
Smoking	1.7	1.3
Other	1.3	1.0
Wearing headphone or earbuds	1.5	0.6
Wearing Bluetooth device	0.6	0.2
Manipulating in-vehicle system	0.5	0.2
Grooming	0.4	0.3
Manipulating or holding device other than cellphone	<0.1	<0.1

Note. Multiple secondary behaviors could be coded for each driver. Percentages do not include 1 observation where passenger presence was missing.

Passenger presence did not affect the overall prevalence of any secondary behavior. However, by far the most common secondary behavior among drivers with passengers was talking to the passenger or singing, and phone-related secondary behaviors were much less common among drivers with passengers. These findings are consistent with naturalistic studies of adult drivers (Farmer et al., 2014; Metz et al., 2014) and teenage intermediate license holders (Foss & Goodwin, 2014). In contrast to the current study, however, Metz et al. (2014) found that solo drivers were less often engaged in secondary behaviors overall than drivers with passengers (25% vs. 40% of driving time), and nearly all of the secondary behaviors of drivers with passengers were comprised of passenger interactions. Metz et al. were able to code behaviors in greater detail using video recordings. For example, they defined passenger interaction as a driver talking to, gesturing towards, or looking at a passenger, whereas in the current study passenger interaction was coded when the driver was talking or singing in the presence of passenger(s). Metz et al. analyzed video recordings of 49 volunteer German subjects who owned a specific vehicle make, whereas the current study involved roadside observations of a much larger sample of U.S. drivers in northern Virginia.

Some prior research findings found that drivers younger than 21 years are more likely to interact with cellphones while driving than older drivers (Farmer et al., 2014), but this pattern was not observed in the current study. However, the prevalence of any secondary behavior and of all specific secondary behaviors among drivers estimated to be younger than age 20 or ages 20–59 was greater than among drivers estimated to be age 60 and older. Older drivers are less likely than middle-age and younger drivers to use technologies like cellphones not just when driving but also in general (Olson, O'Brien, Rogers, & Charness, 2011). The percentage of drivers traveling with passengers was similar across age groups so differences in passenger prevalence does not seem to explain the age effect on secondary behaviors involving technology. In addition, an age effect was observed for behaviors that did not involve technology like talking or singing and eating or drinking. Hence, the current study suggests that there are age-related differences in the proclivity to engage in secondary behaviors more broadly.

In the current study female drivers were about 12% more likely than male drivers to be engaged in any secondary behavior. Female drivers also were more likely to have been talking or singing with passengers even though female drivers and male drivers were about equally likely to be transporting passengers (20% for of female drivers vs. 22% of male drivers). The prevalence of talking on a cellphone was higher among drivers judged to be female than male in a recent roadside observational study (Huisingh et al., 2015), but biological sex differences were not identified by other researchers (e.g., Farmer et al., 2014; Hamilton et al., 2013). Thus, the relationship between driver sex and engagement in secondary behaviors remains unclear.

In the current study, the category "manipulating a hand-held cellphone" can be compared with the category "visibly manipulating hand-held devices" used in NHTSA's periodic national surveys of driver electronic device use. The 2013 NHTSA survey indicated that about 1.7% of drivers stopped at controlled intersections during the daytime were visibly manipulating hand-held devices (Pickrell, 2015). In contrast, about 4% of drivers in vehicles stopped at red lights in the current study were manipulating a hand-held cellphone. Drivers manipulating devices other than cellphones were rarely observed in the current study. In the NHTSA surveys, it appears that the visible manipulation of a hand-held device also includes activities like looking at the device to view information (e.g., e-mails) (NHTSA, 2010). In the current study, a driver holding and viewing a cellphone without manipulating it or talking was coded as "holding a hand-held cellphone;" 7.4% of drivers were holding or manipulating a hand-held phone, which yields an even bigger discrepancy with the NHTSA estimates of manipulating a hand-held device.

In NHTSA's protocol, observers primarily observe stopped vehicles in the nearest lane, including dedicated turn lanes, at stop-sign and signalized controlled intersections (NHTSA, 2010). In the current study, only vehicles in the nearest lane at signalized intersections were observed, and dedicated turn lanes were excluded. Relative to drivers stopped at traffic lights in lanes that can either go straight or turn right, drivers stopped in dedicated right turn lanes at signalized intersections and especially drivers stopped at stop signs may limit engagement in secondary behaviors because they may be stopped for a shorter period of time and must more closely monitor the roadway situation while negotiating the intersection. Furthermore, more drivers stopped at intersections would be expected to be manipulating a phone than drivers in moving vehicles based on the current findings. Hence, estimates of electronic device use from NHTSA's ongoing national surveys would be more precise if a wider variety of roadway situations, especially those with moving vehicles, were included.

There were several limitations in the current study. The prevalence of secondary behaviors varied by roadway situations in the expected manner, and the selection of roadway situations sought to account for differences in driver populations. However, the study did not examine how individual drivers modify their behavior based on the demands of these situations. Although it is reasonable to assume that driving through a double-lane roundabout places more demands on drivers than driving on a straightaway or waiting at a red light, this assumption was not tested objectively.

Observer reliability is a concern with any roadside observational study. A pilot study indicated that most of the secondary behaviors observed in the current study, and all of the most common secondary behaviors, could be reliably recorded by a roadside observer in the roadway situations examined in the current study (Kidd et al., 2015). However, the reliability of nighttime observations was lower than for daytime observations. Some relatively infrequent secondary behaviors, like drivers wearing a Bluetooth earpiece or headset, had low inter-rater reliability. Other behaviors could have been miscoded; for example, some drivers coded as talking or singing may have been using hands-free electronic devices.

The observations all were conducted in a single geographic region, which is a densely populated, relatively affluent area. As such, the findings may not be representative of roadway situations and drivers in other areas or nationally. Furthermore, Virginia law prohibits drivers younger than 19 from using a cellphone while driving (VA Code § 46.2-334.01, 2007) and prohibits all drivers from using a hand-held cellphone to manually enter text for personal communication and reading personal communications except in the case of an emergency (VA Code § 46.2-1078.1, 2013). The findings may not be representative of jurisdictions with different laws on drivers' cellphone use.

5. Conclusion

In conclusion, the prevalence of driver secondary behavior of any kind and of specific behaviors was higher in roadway situations with inherently less driving demand than roadway situations that were more demanding. The prevalence of driver secondary behavior also varied significantly according to contextual variables like passenger presence, time of day, and driver characteristics. The current findings in combination with past research suggest that drivers may engage in secondary behaviors when perceived driving demand is reduced and that roadway demand and contextual variables are important factors to consider when studying driver secondary behavior.

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