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Driver's exposure to distractions in their natural driving environment

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Abstract

Unobtrusive video camera units were installed in the vehicles of 70 volunteer drivers over 1-week time periods to study drivers' exposure to distractions. The video data were coded based on a detailed taxonomy of driver distractions along with important contextual variables and driving performance measures. Results show distractions to be a common component of everyday driving. In terms of overall event durations, the most common distractions were eating and drinking (including preparations to eat or drink), distractions inside the vehicle (reaching or looking for an object, manipulating vehicle controls, etc.), and distractions outside the vehicle (often unidentified). Distractions were frequently associated with decreased driving performance, as measured by higher levels of no hands on the steering wheel, eyes directed inside rather than outside the vehicle, and lane wanderings or encroachments. Naturalistic driving studies can provide a useful supplement to more controlled laboratory and field studies to further our understanding of the effects of all types of distractions on driving safety.

Keywords: Driving; Distraction; Exposure; Naturalistic; Cell phone

1. Introduction

This paper reports on the second phase of a research project examining driver distraction and its contribution to traffic crashes. The initial phase of the project involved analysis of 5 years of national Crashworthiness Data System (CDS) data to determine the role of driver distraction in U.S. traffic crashes and the specific sources of this distraction (Stutts et al., 2001). The second phase of the project has involved the collection of naturalistic driving data to document drivers' exposure to specific distracting events and the effects of these events on driving performance.

Driver distraction, and its implicit effects on hazard recognition and vehicle control, has been a prominent topic on highway safety agendas, as well as for the U.S. Congress, state legislatures, the media, and the public at large. Much of this attention stems from the enormous increase in cellular telephone use by drivers and the prospect of similar growth in other in-vehicle technologies such as vehicle navigation systems, wireless Internet capabilities, and wireless messaging. Although the proliferation of new in-vehicle technologies certainly merits concern, the analysis of national crash data documented in the first phase of this study revealed many things distracting drivers and contributing to crashes. The focus of the current paper is on the full range of events and activities that can draw a driver's attention away from the task at hand, delaying recognition of safety threats and impairing effective control of the vehicle.

The National Highway Traffic Safety Administration (NHTSA) has estimated that driver inattention is a contributing factor in 25–30% of crashes (Wang et al., 1996). A variable describing the attention status of the driver was added to the agency's CDS data in 1995. The variable included codes for attentive, sleepy or asleep, and "looked but did not see", along with 11 specific categories of driver distraction. Table 1, taken from the analysis of 1995–1999 CDS data carried out in the first phase of this project, identifies the primary sources of distraction for those drivers identified as distracted at the time of their crash. Heading the list is events,

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Table 1
Percentage distribution of specific driver distractions based on 1995–1999 National Crashworthiness Data System data (source: Stutts et al., 2001)

Source of distraction	% of drivers identified as distracted
Outside object, person, or event	29.4
Adjusting radio/cassette/CD	11.4
Other occupant	10.9
Moving object in vehicle	4.3
Using other device/object brought into vehicle	2.9
Adjusting vehicle/climate controls	2.8
Eating and/or drinking	1.7
Using/dialing cell phone	1.5
Smoking related	0.9
Other distraction	25.6
Unknown distraction	8.6
Total	100.0

objects or persons outside the vehicle, followed by adjusting the radio/cassette/CD and other occupants in the vehicle. All other sources of distraction, including cell phones, each accounted for less than 5% of the total.

A similar hierarchy of driving distractions has been found in analyses of state-level crash data from Pennsylvania (Pennsylvania Joint State Government Commission, 2001) and Virginia (Glaze and Ellis, 2003). Although cell phones were somewhat more prominent in these more recent data, they still comprised only 4–5% of the recorded distractions.

Many more studies have been carried out focusing on individual sources of driver distraction, and in particular cellular telephones, vehicle navigation systems, and other in-vehicle technologies (see, e.g., Redelmeier and Tibshirani, 1997; Laberge-Nadeau et al., 2003; Wilson et al., 2003). Most of these studies have been carried out in controlled settings in laboratories, on test tracks, or using driving simulators. As a group, they offer strong evidence that cellular telephones and other in-vehicle technologies can negatively affect some aspects of driving performance.

Largely absent from the literature are reports on drivers' exposure to various potentially distracting events while engaged in everyday driving. Without information on the frequencies with which drivers engage in such behaviors and the circumstances of this engagement, it is difficult to gauge their potential impact on driving safety. A recent attempt to gather such information relied on photographs of drivers traveling on the New Jersey Turnpike (Johnson et al., 2004). Over 40,000 high quality digital photographs were examined and coded with respect to the presence of cell phones or other distracting behaviors, with results showing cell phones to be the most frequent distraction. NHTSA has also begun incorporating observations of cell phone use into its annual occupant protection use surveys. For the 2004 survey, 5% of drivers were observed using hand-held cell phones, up from 3% 2 years prior (Glassbrenner, 2005).

The current study was intended to further address the need for real-world data on the occurrence and effects of driver distractions, using the specific distractions identified in Table 1 as a starting point. Driver distraction is defined in terms of an object or event that draws one's attention from the task of driving. It is this presence of a triggering event that distinguishes distraction from other forms of driver inattention, which might result from drowsiness or simply being preoccupied by other thoughts. The primary research questions we sought to address were: (1) How often do drivers engage in distracting behaviors? (2) Are there age and sex differences in the occurrences of driver distractions? (3) How do contextual variables such as vehicle movement affect driver distractions? and (4) What are some of the consequences of distractions on driving performance?

2. Methods

The study involved collecting unobtrusive video data from 70 volunteer participants, driving their own vehicles over a period of a week. The following sections describe the video logging methodology, data collection protocol, data coding and reduction, and data analysis procedures employed.

2.1. Video logging methodology

The system developed for continuous unobtrusive recording of in-vehicle driving behavior in drivers' own cars consisted of a camera unit, a recording unit, and trigger and connecting cables. The camera unit measured approximately 18 cm × 6 cm × 5 cm, and was designed to be mounted on the vehicle's front windshield, just under the rear view mirror, using suction cups. It contained a microphone and three miniature video cameras—one directed to capture a close-up view of the driver's face, another a broader view of the interior of the vehicle, and the third the roadway immediately ahead of the vehicle. The cameras were hidden from the driver's view by near-infrared filters covering both sides of the camera box. An infrared light source was mounted underneath the camera box to facilitate recording under low light conditions.

A trigger cable connected to the vehicle's accessory fuse was used to power the cameras whenever the vehicle ignition was turned on. A locked box stored in the vehicle's trunk contained a video recorder, quad processor, and battery pack. Cables connecting the camera unit, trigger, and recording units were discreetly routed along the edges of the windshield and door frame on the driver's side of the car, before passing through the back seat to the large box in the trunk of the car. More detailed information about the video logging methodology, including the User's Manual developed for installing and operating the equipment, is included in Stutts et al. (2003).

2.2. Data collection

The video logging equipment was installed in the vehicles of 70 volunteer drivers. Drivers were recruited primarily from ads placed in local newspapers. Half of the participants resided in the central Piedmont region of North Carolina (near

Chapel Hill and Durham), and half in the Philadelphia area and its suburbs. There were 35 male and 35 female participants, equally distributed among five age groups: 18–29, 30–39, 40–49, 50–59, and 60+.

Potential participants were screened via a brief telephone interview to ensure they had a valid driver's license, drove at least 6 h per week, and drove a vehicle that had rear seat access into the trunk. They also had to be willing to come to the research offices to have the equipment installed in their vehicle and return a week later to have it removed. The only other requirement for participation was that the person's age and gender quota had not already been met. All participants were compensated $100.

The consent form that participants were asked to read and sign when they came in to have the equipment installed identified the study only as an effort to learn "how traffic and roadway conditions affect driving behavior". Although participants were informed that their driving was being recorded, the true nature of the study was not revealed. If someone other than the recruited participant drove the vehicle during the time the equipment was installed, that person was also asked to provide written consent to use their recorded data; otherwise the data was not utilized in the study. Participants remained inside the research center offices while the equipment was being installed, during which time they completed brief pre- and post-study surveys. Installation of the equipment generally required 30 min or less, while removal required about 15 min.

Data collection activities were initiated in late November 2000 and extended into the following November, thus spanning a 1-year driving period.

2.3. Data coding and reduction

Data coding was based on a driver distraction taxonomy that evolved from the original CDS data analysis. The taxonomy incorporated all of the major driver distraction categories appearing in the CDS datafile, with some further refinements. In addition to driver distractions, the coding taxonomy incorporated a variety of contextual variables to describe the conditions under which drivers engage in various distracting activities, and three outcome or driver performance measures. The latter included (1) whether one hand, two hands, or neither hand was on the steering wheel, (2) whether the driver's eyes were directed outside the vehicle (i.e., on the driving task) or inside the vehicle, and (3) whether the vehicle was swerving or wandering within the travel lane, crossing into another travel lane, or stopping from sudden braking.

Data were coded by three staff members of the Highway Safety Research Center using special video reduction software. The software allowed individual "channels" of data to be coded simultaneously. Within each channel, coding options were required to be mutually exclusive and exhaustive. As an example, one channel was designated for recording cell phone use, with options for (1) phone not in use, (2) phone in use (talking or listening), (3) dialing phone, and (4) ringing phone. Since each distraction category was recorded in a separate channel, multiple distractions could be coded simultaneously, e.g., a person could be both talking on the cell phone and manipulating the radio controls or eating and drinking. Separate channels were also used to record the various contextual circumstances (lanes, traffic level, light conditions, etc.) and to track the three outcome measures (hand position, direction of eyes, and vehicle wanderings and encroachments).

Actual coding was carried out by simultaneously monitoring the three video screens on the monitor display and entering a 2-letter code associated with each behavior appearing on the tape. Generally at least two complete passes of the videotape were required—the first pass to record eye direction (outside or inside the vehicle) and hand position (both, one, or no hands on the steering wheel), and the second pass to record all other behaviors. For very active drivers, a third pass was sometimes necessary.

Due to the heavy time requirement for processing the data, and because there were varying amounts of available data across study participants, a decision was made to code only 3 h of total data per participant. For most of the 70 participants, the 3 h were evenly distributed across the total recorded time in one-half hour blocks, skipping the first one-half hour to allow drivers to adjust to having the equipment in their vehicle. Except in the unanticipated case where every trip made by the driver is exactly one-half hour in duration, this would accomplish our goal of randomly sampling driving behavior over a 1-week period, while guaranteeing that a total of 3 h data would be coded. For two participants there was less than 3 h of usable data, and all of this was coded. Altogether a total of 207.2 h of video data was coded.

2.4. Data analysis

As an initial step in the data analysis, basic descriptive results for each of the coded variables were generated for each participant. This allowed us to check for any inconsistencies in the data coding. If a questionable result was identified, it was checked and verified by reviewing the videotapes. The individual file summaries also allowed us to identify how many of the 70 participating drivers had displayed each of the various distracting behaviors; for example, how many used a cell phone, smoked, or transported young children. All subsequent analyses were based on the combined data for all participants, or a specially selected subset of participants (e.g., all drivers who used a cell phone).

After the coded data was cleaned and finalized, it was converted to a SAS datafile to allow for more in-depth analyses, including statistical testing. The longitudinal nature of the data violated an assumption of classical statistical analysis methods that observations be statistically independent draws from a binomial distribution. Consequently, confidence intervals for proportions and linear combinations of proportions (e.g., differences in the likelihood of eyes directed inward when dialing a cell phone versus not dialing a cell phone) were constructed using the bootstrap percentile method (Mooney and Duval, 1993). Bootstrapping is a computationally intensive nonparametric technique for constructing confidence intervals that employs large numbers of repetitive computations to estimate the shape of a statistic's sampling distribution, rather than strong distributional assumptions and analytic formulas. (See Appendix D in Stutts et al. (2003) for a description of how the procedure was applied to the current data.) In addition to the video data, the results of the pre- and post-surveys completed by the participants were entered into a separate Microsoft Excel database and analyzed descriptively using Version 8 of SAS (Statistical Analysis Software, Cary, NC).

3. Results

3.1. Characteristics of study participants

Study participants included seven male and seven female drivers in each of the following five age groups: 18–29, 30–39, 40–49, 50–59, and 60+. Thus, each age/sex combination contributed 10% of the total participants (and approximate driving time) to the study.

Results of the pre-driving survey showed that 81% of the participants drove to and from work on a regular basis. The average one-way commute distance was 17.8 miles, while the median distance was lower at 12.0 miles. Overall, participants reported driving an average of 244.6 miles a week, or 12,719 miles per year.

Responses to the post-driving survey revealed that 10 participants (14.5%) experienced some problem with the video recording equipment. Specific problems mentioned included loose suction cups, wires or tape; possible electrical or battery problems; and the camera obstructing their view out the front window. In addition, 15 respondents (21.7%) reported that having the equipment in their car changed their driving, with eight indicating that it made them more safety conscious or more aware of their driving. Interestingly, the comments of five of these participants suggested that they were aware of the audio, but not necessarily the video, recording (e.g., "I felt like I had to watch what I said").

Taken together, these results neither confirm the representativeness of the study population, nor do they raise "red flags" about possible unrepresentativeness or bias in the data collection process. Rather, they suggest that, as generally has been the case in studies of this type, participants engaged in generally normal driving activity and were not unduly influenced by the equipment installed in their vehicles.

3.2. Frequency and duration of potential driving distractions

Information on the percentage of drivers engaging in each of the identified activities, while their vehicle was in motion, is presented in Table 2 (column A). These data reflect any recorded incidence of a behavior, without considering the actual number or duration of these occurrences. Thus, a driver who tried one time to place a call while driving would be coded as using a cell phone, the same as a driver who placed calls and talked for most of the 3 h of recorded driving.

During their 3 h of coded driving time, all participants were observed dealing with internal distractions such as manipulating vehicle controls (e.g., air conditioning or window controls) or reaching for objects inside their vehicle while it was in motion (i.e., not just while it was stopped). Nearly as many were observed manipulating their vehicle's music or audio controls, or had their attention drawn to something outside the vehicle. Approximately three-fourths ate or drank something while driving or conversed with a passenger. Reading/writing and grooming activities were less common, but were still observed in almost half the participants. About a

Table 2
Percentage of drivers engaging in potentially distracting activities when their vehicle was moving, and percentage duration of these activities

Distraction	(A) % of subjects	(B) % of total time vehicle moving[a]	(C) Adjusted % of total time vehicle moving[b]
Using cell phone/pager (includes talking, dialing, answering)	34.3	1.30	3.8
Eating, drinking, spilling	71.4	1.45	2.0
Preparing to eat or drink	58.6	3.16	5.4
Manipulating music/audio controls	91.4	1.35	1.5
Smoking (includes lighting and extinguishing)	7.1	1.55	21.1
Reading or writing	40.0	0.67	1.8
Grooming	45.7	0.28	0.6
Baby distracting	8.6	0.38	4.4
Child distracting	12.9	0.29	2.2
Adult distracting	22.9	0.27	1.2
Conversing	77.1	15.32	19.9
Internal distraction	100.0	3.78	3.8
External distraction	5.7	1.62	1.9

[a] Based on total sample of 70 drivers.
[b] Adjusted to reflect the percentage of drivers engaging in that activity, i.e. (% total time)/(proportion of drivers engaged in distraction).

third of the participants used a cell phone or pager while driving, and nearly as many were distracted by passengers riding in their vehicle—either another adult, a child, or a baby.

Age differences in the likelihood of engaging in a particular distraction on at least one occasion were generally small, although numbers were too small for valid statistical testing. Compared to males, females were more likely to groom themselves ($\chi^2 = 8.467$, d.f. = 1, $p = .004$), and more likely to attend to things outside the vehicle ($\chi^2 = 4.456$, d.f. = 1, $p = .04$).

Altogether, excluding any time spent simply conversing with other passengers in the vehicle, drivers were engaged in some form of potentially distracting activity 14.5% of the total time that their vehicles were moving. Adding together the percentages shown in column B of Table 2 (minus time for conversing) results in a slightly higher number of 16.1%. This is because the individual time estimates in the table do not account for the fact that some of these activities could occur simultaneously (e.g., eating while reaching for something inside the vehicle, or talking on the cell phone while smoking a cigarette). With respect to the individual distractions, eating and drinking (including preparing to eat or drink and holding food in one's hands) headed the list, followed by internal distractions, external distractions, and smoking. Less total time was devoted to manipulating audio controls, using a cell phone, other occupant distractions, reading or writing, and grooming. For the cell phone and pager users, 1.10% of their total driving time was spent engaged in a cell phone conversation, 0.18% was spent dialing a cell phone, and only 0.02% was spent responding to a ringing phone or pager.

The percentages shown in column B of Table 2 reflect the overall observed level of exposure to the identified driving distractions; that is, the actual proportion of total driving time that the 70 participants in our study were observed engaged in each of the identified activities, while their vehicles were moving. However, one might also be interested in a driver's level of exposure, given that he or she engages in an activity at all. These are the adjusted percentages shown in column C of the table. Thus, among those 34.3% of drivers who used a cell phone or pager at all in their moving vehicle, the phone or pager was in use 3.8% of the time that they were driving. This latter percent also reflects the percent of total time exposed if *all drivers* use cell phones or pagers at the same level as did the 24 cell phone users in our study.

Following are descriptive highlights pertaining to some of the individual distractions. Due to the "naturalistic" nature of the data, these results necessarily include both time periods when drivers' vehicles were moving as well as when they were stopped.

3.2.1. Cell phone/pager

The 24 drivers in our sample of 70 who used a cell phone or pager placed 122 calls, received 15 calls and carried on 100 phone conversations. Based on 3 h of coded data per driver, this translates into 1.7 placed calls, 0.2 incoming calls or pages, and 1.4 conversations per hour *for those 24 drivers who used a cell phone or pager*. The average time required to place a call was 12.9 s, and to answer a call or page 7.9 s. The average conversation lasted 1.5 min, but ranged from only a second or two to over 20 min in length. All but one of the incoming cell phone calls were responded to within one or two rings, and none was ignored.

3.2.2. Music/audio

Participants adjusted their audio controls a total of 1539 times, or an average of 7.4 times each per hour of driving (1539/207.2 coded hours of driving). If the 9 h for the three individuals who did not record time with the radio on is subtracted from the total hours driving, the average number of audio control manipulations per hour of driving increases to 7.8. These manipulations averaged 5.5 s each.

3.2.3. Reading/writing

Reading or writing was observed on a total of 303 occasions. A review of the descriptive comments revealed about equal instances of each activity: sample comments included reading a map, reading a piece of paper, opening and reading mail, writing on an envelope, writing in a check book, reading the newspaper, writing in a notebook, etc.

3.2.4. Other occupant distractions

There were a total of 243 recorded instances of drivers being distracted by other occupants in the vehicle. This information is best interpreted in light of the percentage of time passengers in these age categories were being carried in the vehicles. The "hourly rate" of driver distractions for infants was 8.4, for children 4.5, and for other adults 1.1.

3.2.5. Internal distractions

The most frequently cited internal distraction (other than those coded individually) was reaching, leaning, looking for, picking up, etc. something inside the vehicle—purse, sunglasses, sun visor, glove compartment, tissue, garage door opener, change for toll booth, etc. This behavior was noted on 2246 occasions, or an average of 10.8 times per hour of driving. Almost as frequent was manipulating vehicle controls other than the radio or music controls. These might include heat and air conditioning controls, window controls, cruise control, etc. (but not turn signals, horn, or other controls integral to the operation of the vehicle). Manipulating vehicle controls was recorded a total of 2095 instances, or 10.0 times per driving hour. Reaching events lasted an average of 7.6 s, while manipulating vehicle control events lasted an average of 4.8 s.

3.2.6. External distractions

No attempt was made to identify a priori specific external distractions, since the potential list was so long and since, in many instances, the source or nature of the distraction might not be revealed by the outside-facing camera. Typical external distractions identified in the comment field included waving or talking to someone outside the vehicle, looking at houses or pretty scenery, toll booths, drive-through windows at banks or fast-food restaurants, work zone activity, simply looking out the side window at something, and bright sun glare. The overall count of 659 external distractions corresponds to an average of 3.2 external distractions per hour per driver, based on the full sample of 207.2 coded hours.

3.3. *Effect of vehicle movement*

Although a number of contextual variables were coded and analyzed, the variable most closely associated with distracting driving behaviors was whether the vehicle was stopped or moving at the time (see Table 3). Overall, vehicles were stopped 15.3% of the total recorded driving time. However, vehicles were more likely to be stopped when the driver was engaged in certain behaviors. These included reading or writing, manipulating vehicle controls, attending to events outside the vehicle (external distraction), reaching/leaning/etc., other internal distractions, grooming activities, and distractions associated with other adults in the vehicle. This suggests that, at least to some degree, drivers were choosing to engage in these potentially distracting activities at "safer" times while driving—either at the start or end of a trip, or when their vehicle was stopped in traffic. On the other hand, answering a cell phone or pager, eating and drinking, smoking, and distractions involving babies and children appear to have occurred independently of whether the vehicle was moving or stopped.

3.4. *Consequences of distractions on driving performance*

As described in the section on data coding, three measures of driving performance were identified and coded. These were (1) whether one hand, two hands, or neither hand was on the steering wheel; (2) whether the driver's eyes were directed outside or inside the vehicle; and (3) whether the vehicle was swerving or wandering within the travel lane, crossing into another travel lane, or stopping from sudden braking. Overall, when their vehicles were moving, drivers had both hands on the steering wheel only 34.8% of the time; one hand was on the steering wheel 63.8% of the time, and no hand on the steering wheel 1.4% of the time. With respect to eye direction, eyes were directed outside the vehicle 97.2% of the time and inside the vehicle 2.8% of the time. Thus, in these first two instances where the outcomes of interest were coded as event occurrences over time, our analysis was directed at determining whether drivers spent a greater proportion of their driving time with no hands on the steering wheel, or with their eyes directed inside rather than outside the vehicle, when engaged in a particular distracting behavior.

The last group of performance measures had no associated duration, but instead were coded as single point-in-time events. Overall, there were 900 instances of recorded lane wanderings (4.3 per hour of data collection), 444 instances of lane encroachments (2.1 per hour), and 22 instances of sudden brakings (0.11 per hour). Lane wandering was coded whenever a vehicle strayed from its normal path and *approached* (but did not cross) one of the lane lines, or what would be a lane line on an unmarked road; vehicle encroachment was coded whenever a vehicle strayed from its normal path and *crossed over* one of the lane lines, or what would be a lane line on an unmarked road; and sudden braking was coded whenever a driver braked hard enough that the vehicle stopped or slowed suddenly, possibly resulting in braking sounds, a bracing or rebounding of the body, etc. These three events were summed to create an overall "adverse vehicle event" outcome, and the analysis was designed to determine whether

Table 3
Percentage of time vehicle stopped or moving within levels of distraction variables

Distracting event	Movement status of vehicle	
	Stopped	Moving
Cell phone/pager		
Phone/pager not in use	15.1	84.9
Dialing phone	25.7	74.3
Answering phone/pager	15.9	84.1
Talking/listening	25.7	74.3
Eating or drinking		
Not eating or drinking	15.3	84.7
Preparing to eat/drink	18.0	82.0
Eating/drinking/spilling	13.7	86.3
Music/audio		
Music/audio not on	15.6	84.4
Music/audio on	15.2	84.8
Manipulating audio controls	15.1	84.9
Smoking		
Not smoking	15.3	84.7
Lighting or extinguishing	14.7	85.3
Smoking	13.8	86.2
Reading/writing		
Not reading/writing	14.9	85.1
Reading/writing	69.5	30.5
Grooming		
Not grooming	15.2	84.8
Grooming	34.1	65.9
Occupant distraction		
No occupant distraction	15.3	84.7
Distracted by baby	11.1	88.9
Distracted by child	10.7	89.3
Distracted by adult	22.2	77.8
Conversing		
Not conversing	15.1	84.9
Conversing	16.1	83.9
Internal distraction		
No internal distraction	14.1	85.9
Manipulating vehicle controls	43.3	56.7
Reach/lean/look for/pick up/etc.	36.6	63.4
Other internal distraction	34.8	65.2
External distraction		
No external distraction	14.7	85.3
External distraction	41.4	58.6
Overall	15.3	84.7

drivers experienced higher rates of adverse vehicle events when engaged in a particular distracting behavior.

Results of these analyses are summarized in Table 4. They represent 30 independent bootstrap analyses: one for each category of distraction examined with respect to each identified outcome measure. Within each distraction category, levels of that distraction (e.g., dialing or answering a cell phone, talking on a cell phone) are compared to the absence of the distraction (e.g., phone not in use). The table presents 95% confidence intervals for each estimated proportion or rate. In addition, each proportion was compared with the relevant baseline, and differences between proportions for the experimental and baseline distracting events that were statistically significant are identified at the .01 and .05 levels of confidence. No adjustment for multiple tests has been made since these are, in effect, independent tests of different hypotheses (see Bailar and Mosteller, 1992). However, the reader is cautioned that as with any situation involving multiple testing, on average one of every 20 will produce a p value smaller than .05 merely by chance.

In general, the models reveal fairly consistent trends of higher levels of no hands on the steering wheel and eyes

Table 4
Results of bootstrap analyses for three measures of driving performance as a function of each distraction event, when vehicle was moving[a]

Distracting event	% no hands on wheel		% eyes directed in		# vehicle events per hour	
	%	95% C.I.	%	95% C.I.	%	95% C.I.
Cell phone/pager						
Phone/pager not in use (Ref.)	1.35	0.95–1.87	2.63	1.77–3.73	7.77	5.88–9.82
Dialing/answering	8.21**	3.36–16.50	67.58**	48.93–81.79	14.24	3.40–31.61
Talking/listening	6.97*	2.01–17.75	1.35	0.55–3.51	6.24	1.90–13.78
Eating or drinking						
Not eating or drinking (Ref.)	1.25	0.85–1.74	2.61	1.77–3.68	7.40	5.63–9.38
Preparing to eat/drink	4.40**	2.13–7.83	5.52*	3.46–10.63	18.20*	7.77–30.19
Eating/drinking/spilling	5.32**	2.96–9.56	6.24*	2.89–10.14	9.02	5.24–14.23
Music/audio						
Music/audio not on (Ref.)	1.00	0.64–1.52	2.85	1.60–4.66	7.98	5.48–10.58
Music/audio on	1.58	1.07–2.26	2.40	1.63–3.42	7.65	5.45–10.19
Manipulating audio controls	2.06*	1.13–3.51	22.58**	13.58–34.31	10.08	5.14–14.81
Smoking						
Not smoking (Ref.)	1.43	0.99–2.00	2.76	1.87–3.90	7.83	5.90–9.99
Lighting or extinguishing	3.60	0.29–28.66	19.31*	2.98–69.14	30.16	0.00–145.5
Smoking	0.82	0.20–3.44	1.57	0.28–6.55	3.02*	1.23–5.38
Reading/writing						
Not reading/writing (Ref.)	1.39	0.97–1.93	2.51	1.71–3.51	7.73	5.83–9.87
Reading/writing	15.10**	4.24–34.39	91.50**	80.14–96.43	20.93	4.38–38.11
Grooming						
Not grooming (Ref.)	1.39	0.97–1.94	2.66	1.81–3.73	7.73	5.81–9.86
Grooming	12.44*	2.59–28.08	34.62**	16.79–58.70	20.18	6.32–32.14
Occupant distraction						
No occupant distraction (Ref.)	1.42	0.99–1.99	2.60	1.79–3.63	7.65	5.76–9.76
Distracted by baby	2.75	0.07–41.62	21.93	0.84–86.12	24.21	0.00–36.44
Distracted by child	0.27	0.00–7.72	14.64	1.75–89.83	11.59	0.00–12.46
Distracted by adult	2.82	0.11–22.84	19.00	0.81–68.97	22.88	0.00–33.23
Conversing						
Not conversing (Ref.)	1.41	0.97–1.98	2.53	1.72–3.60	7.54	5.73–9.60
Conversing	1.50	0.92–2.38	3.97	2.10–6.77	9.00	5.48–12.71
Internal distraction						
No internal distraction (Ref.)	1.24	0.85–1.75	2.22	1.48–3.17	7.52	5.64–9.63
Manipulating vehicle controls	9.79**	6.35–14.32	15.42**	10.59–21.57	11.30	6.52–16.82
Reach/lean/look for/etc.	3.80**	2.24–6.18	20.10**	13.51–29.33	18.37**	10.76–27.46
Other internal distraction	6.97**	3.66–14.63	12.17**	6.26–24.78	9.95	4.62–19.12
External distraction						
No external distraction (Ref.)	1.41	0.98–1.97	2.76	1.88–3.88	7.64	5.72–9.72
External distraction	2.30	0.99–5.16	2.40	1.07–5.36	15.45	5.78–31.57

[a] Each variable level compared to reference (Ref.) level, e.g., talking/listening on cell phone compared to phone not in use, dialing/answering cell phone compared to phone not in use, etc.

* Significant at $p < .05$.

** Significant at $p < .01$.

directed inside the vehicle, along with higher rates of adverse vehicle events, associated with each of the identified driving distractions. Although in the anticipated direction, however, the results frequently do not attain statistical significance. This may be due to a number of factors, including small sample sizes for some of the distraction categories, lack of precision in coding either the distraction or outcome measures, and the relative rarity of the outcomes as well as some of the measured behaviors. Nevertheless, the results do show significantly higher proportions of no hands on the steering wheel while dialing/answering or talking on a cell phone, eating and drinking or preparing to eat or drink, manipulating audio controls, reading or writing, grooming, and the various internal distractions including manipulating vehicle controls and reaching/leaning/etc. Eyes were significantly more likely to be directed inward when dialing or answering a cell phone, eating and drinking or preparing to eat or drink, manipulating audio controls, lighting or extinguishing a cigarette, reading or writing, grooming, and when manipulating vehicle controls or reaching for something inside the vehicle. And lastly, higher incidence rates of adverse vehicle events were associated with preparing to eat or drink and reaching for something inside the vehicle.

There were also some notable exceptions to the trend of higher levels of potentially dangerous driving behaviors for a few of the identified distractions. In particular, smoking (but not lighting or extinguishing a cigarette) was found to be associated with a *lower* incidence of adverse vehicle events, and talking on a cell phone was associated with a *lower* proportion of time with the eyes directed inward. The latter result, however, was not significant statistically.

4. Discussion

This study provides some of the first naturalistic data on drivers' exposure to potential distracting events that have been related to crash involvement. Results showed distractions to be a common component of everyday driving. Altogether, excluding any time spent simply conversing with other passengers in the vehicle, drivers were engaged in one or more potentially distracting activities 14.5% of the total time that their vehicles were moving. Eating and drinking (including preparing to eat or drink and holding food in one's hands) headed the list, followed by internal distractions, external distractions, and smoking. Less total time was devoted to manipulating audio controls, using a cell phone or pager, other occupant distractions, reading or writing, and grooming.

The occurrence of driver distractions was also shown to vary according to a number of contextual variables, with the most influential of these being whether the vehicle was stopped or moving at the time. This suggests that, at least to some degree and for some activities, drivers are choosing to engage in them at "safer" times on the roadway. Finally, the data provided some evidence that distractions can negatively affect driving performance, as measured by higher levels of drivers having no hands on the steering wheel, their eyes directed inside rather than outside the vehicle, and their vehicles wandering in the travel lane or crossing into another travel lane.

There were a number of important limitations to these field data collection efforts. Foremost were problems in objectively defining all categories of driver distraction, as well as context and outcome variables. We were also not able to distinguish between different levels of intensity of a distraction. Along with event frequency and event duration, information on event intensity is needed to draw conclusions about the riskiness of that particular behavior for safe motor vehicle operation. Another important limitation of the study is that the measures of driving performance we were able to code and analyze – hands on steering wheel, direction of eye focus, and vehicle wanderings or encroachments across travel lanes – have not been directly linked to crash risk. Most importantly, we were unable to capture any measure of cognitive distraction, which *has* been linked in the literature to poorer driving performance and increased likelihood of crashing (e.g., see Strayer et al., 2003).

As a result of these constraints, our study is not able to provide a definitive answer as to which activities, or which driver distractions, carry the greatest risks of crash involvement. What the study does provide is very detailed data, from a reasonably large sample of drivers, about the activities that people engage in while driving that affect some aspects of driving performance and that also might increase their risk or crashing.

Ultimately, a better understanding of the role of driver distraction in traffic crashes is most likely to emerge from a combination of research approaches including naturalistic data studies like the current one, but also analyses of crash data and a variety of more controlled research studies in laboratory, simulation, or test track environments.

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