Combining roadside interviews and on-road observation for assessing prevalence of driver inattention

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Abstract

Inattention among car drivers on a motorway section with two lanes in each direction was investigated by a combination of two different methodological approaches. First, an observer in a driving car in the non-passing (right) lane observed 1337 passing drivers; i.e., all drivers passing during the observation period. At a service area about midway along the section, 273 drivers were interviewed during the same period. The observations showed that 14% of drivers were involved in some secondary activity, with handheld mobile telephone use (which is prohibited) being the most frequent activity (5%). Involvement in secondary activities were far more frequent among drivers without passengers, with 15%, compared to 9% for drivers with passengers. For the latter, interaction with passengers was observed for 6%. The interviews made a useful supplement to roadside observations, providing prevalence estimates also for non-observable activities and states like daydreaming and listening to radio or music. Concerning passenger interaction, duration data were uncertain because many drivers tended to report total driving time with passengers rather than time interacting with them. Consequently, prevalence estimates for passenger interaction as reported in interviews were uncertain, and we therefore estimated this prevalence from observation data only. Total prevalence of secondary activities and internal states presumably implying inattention was estimated at about 24% of total driving time when based on both methods combined.

1 Introduction

It has been long acknowledged that driver inattention is an important contributing factor in road crashes. For example, in the comprehensive “tri-level” study performed in the 1970’s it was shown that “improper lookout”, “inattention”, and “internal distraction” were among the most frequent contributing factors in road crashes (Treat, 1980). Furthermore, Gordon (2009) reviewed previous epidemiological studies and estimated the contribution of distraction at a minimum of 12% of crashes. More recently, Beanland, Fitzharris, Young, and Lenné (2013) analysed data from an Australian in-depth study of serious crashes and found evidence for inattention in about 15% of crashes. Although prevalence estimates vary across studies, several other studies have found similar or higher estimates regarding the contribution of distraction or other inattention to crashes (Stevens and Minton, 2001; Stutts, Reinfurt, Staplin and Rodgman, 2001, Glaze and Ellis, 2003; Bunn, Slavova, Struttmann, and Browning, 2005; Dingus, Klauer, Neale, and Petersen, 2006; Ascone, Lindsey, and Varghese, 2009; Curry, Hafetz, Kallan, Winston, and Durbin, 2011; Zhu and Srinivasan, 2011; Peng and Boyle, 2012; Stimpson, Wilson, and Muellman, 2013; Donmez and Liu, 2015; Zhang, Fu, and Cheng, 2015).

Definitions of inattention and distraction vary somewhat, which may partly explain some of the differences in prevalence estimates across studies. In the present study, we adopt the definitions of the "joint EU and US working group on driver distraction and HMI" (Engström, Hanowski, Horrey, Lee, et al., 2013). They define driver distraction as "the diversion of attention from activities critical for safe driving to a competing activity", and driver inattention is described as "mismatches between the driver's current resource allocation and that demanded by activities critical for safe driving". An implication of these definitions is that distraction is seen as one of several factors that may result in inattention. Apart from external distraction, factors contributing to driver inattention may be sleepiness, fatigue, or illness, as well as cognitive or internal distraction, like daydreaming or worrying about matters unrelated to the driving situation.

Although the studies referred to above show clearly that inattention contributes to a substantial number of crashes, prevalence of inattention in crashes does not necessarily imply anything about the magnitude of the associated crash risk. Knowledge about crash risk is paramount to implementing adequate countermeasures against a risk factor. And in order to estimate crash risk related to driver inattention, one needs information about its prevalence in general driving in addition to prevalence in crashes.

Obtaining valid information about prevalence of various kinds of inattention-related impairments in driving generally is, however, fraught with difficulties. This effort is methodologically challenging partly because inattention to a large extent is an internal mental state, and one must therefore rely heavily on using indirect indicators.

The most obvious indicators of inattention are involvement in secondary activities that require attention to stimuli unrelated to the road and traffic situation and looking away from the road for some other reason. Direct unobtrusive observation of drivers during normal driving is the method of choice for getting such data, and naturalistic studies where drivers have had their vehicles equipped with advances recording instruments have yielded much useful information about prevalence of secondary task involvement, e.g. from the SHRP2 study in the USA (e.g., Dingus, Guo, Lee, Antin, et al., 2016) and the UDRÌVE study in Europe (Carsten, Hibberd, Bärgman, Kovaceva, et al., 2017). Although providing lots of high quality data that are not otherwise available, even naturalistic studies have some limitations. Besides being very expensive, they cannot yet easily assess types of inattention that are not expressed in overt behaviour. There are indications that *cognitive distraction* is an important factor in driver inattention (e.g. Muhrer and Vollrath, 2011; Strayer, Watson, and Drews, 2011), and also inattention related to fatigue may be difficult to discover by naturalistic driving studies.

Therefore, the highly advanced method of naturalistic driving studies still needs to be supplemented by more traditional approaches, like interviews, questionnaires, external observation, and simulator studies, for estimating prevalence of driver inattention.

In the present study, we compare two different methods for estimating prevalence of driver inattention in normal driving. First, we observe secondary task involvement of drivers on the road from a moving car, and second, we carry out roadside interviews of drivers stopping at a motorway service area on the same road section.

Most previous observational studies of driver inattention have focused on mobile phone use only. A recent review of observational studies on secondary task engagement while driving (Huemer, Vollrath, Mennecke, and Schumacher, 2018) found a total of 51 studies during 2001-2016, out of which only ten studies looked at other types of secondary task. Thus, there seem to be rather few observational studies of inattention apart from mobile phone use and naturalistic driving research. One interesting example involving external observation of drivers is the study by Räsänen and Summala (1998) of driver looking behaviour in an intersection with a crossing bicycle path. This study was however focusing on just one aspect of behaviour; i.e., direction of looking. An example of external observation of secondary task involvement is the study by Johnson et al. (2004). They analysed 40 000 high-quality pictures of drivers taken randomly at different locations along a highspeed motorway (New Jersey Turnpike), combining each picture with spot speed measurements, and they estimated prevalence of secondary task involvement based on picture information. Use of mobile phones was the most frequent secondary task, observed for 1.5% of drivers. The authors point out that this share is lower than shown in other studies on lower speed roads.

Concerning specific secondary tasks, prevalence estimates from observational studies have been reported for eating and drinking, smoking, self-grooming, talking to passengers, adjusting in-vehicle equipment (radio, music player, navigation system, car controls), looking away from the road, or other potentially attention-demanding activities (Sullman, 2012; Sullman and Metzger, 2012; Gras, Planes, Font-Myolas, Sullman, et al., 2012; Prat, Planes, Gras, and Sullman, 2015; Sullman, Prat, and Tasci, 2015; Kidd, Tison, Chaudhary, McCartt, and Casanova-Powell, 2016; Vollrath, Huemer, Teller, Likhacheva, and Fricke, 2016).

Almost all observational studies so far used stationary observation. The only previous research we have seen where secondary task involvement was observed from a moving vehicle, was a recent study by the Danish police (Hels, 2017). Here, the purpose was to provide a representative national estimate of driver distraction prevalence. On two-lane roads, they observed drivers of oncoming vehicles, and on motorways they observed vehicles from the side when overtaking or being overtaken. About 26 000 drivers were observed, and 6.1% of passenger car drivers were involved in some secondary task; on motorways, the proportion was 6.7%. In the present study, we used a similar approach, and we limited the study to a motorway section. A possible advantage of observing from a moving vehicle rather than from a stationary position is that is enables easier observation of drivers on high-speed roads and also better opportunity to register all vehicles on a given road section.

A major limitation of all observation methods for assessing driver inattention is that they do not capture internal states of the driver. Therefore, self-reported inattention by interview or questionnaire may be a useful supplement to behaviour observation. There are, however, several methodological problems with self-reports of behaviour, such as distorted memory and tendencies to give socially desirable answers. We assume that problems related to memory are minimised when drivers are asked about their behaviour immediately after a trip, and consequently we followed the approached used in the study by Huemer and Vollrath (2011), who interviewed drivers at a motorway service area and limited the reporting period to the latest 30 minutes of the trip.

Some types of secondary activities are obtainable with both observation and interview methods; these include for example eating and drinking, smoking, using a handheld telephone, looking away from the road, adjusting equipment in the vehicle, grooming or clothing adjustments, body movements, and conversation with passengers. However, it may be difficult for the driver to estimate in retrospect the duration of the various activities. Duration information is important in order to estimate the proportion of total driving time for each activity. With the observation method, where each driver is observed just at one point in time, one can assume that the percentage of drivers observed while doing a certain task is equivalent to the share of total driving time for that task. For interview data on the other hand, the validity of duration data depends fully on driver recall.

The purposes of the present study are two-fold; first, to find prevalence estimates for involvement in secondary activities among drivers on a Norwegian motorway, and second, to compare results from on-road observations and roadside interviews, in order to discuss complementarity as well as relative strengths and weaknesses of the two methodological approaches. The study was part of a research project commissioned by the Norwegian Public Roads Administration in order to serve as a baseline study for the assessment of a campaign against inattentive driving.

2 Method

2.1 On-road observation

Observations were carried out from a moving vehicle on a motorway section on E18, about 70 km southwest from Oslo. The section had two lanes in each direction. It was 16.0 km long and had a 100 km/h speed limit. The observations took place on two weekdays (a Monday and a Tuesday) in May 2018, during three time intervals on each day: a) from 9 a.m. to 11 a.m., b) from 11.30 a.m. to 1.30 p.m., and c) from 2 p.m. to 4 p.m. The time intervals were chosen to avoid the early morning and late afternoon peak periods, while at the same time achieving a reasonable variation in traffic conditions, driving purposes, etc. It was not important to get estimates that were representative for all traffic; the main consideration was to do a study that could be repeated in the same way on a later occasion for assessing effects of a public awareness campaign against inattentive driving. During each 2-hour interval, effective observation time (with allowance for breaks) was about 1.5 hours. And with three intervals per day for two days, total observation time amounted to about nine hours.

The observation vehicle was a Toyota Prius model 2004, and the observer was seated in the front passenger seat. The car was driving in the right lane and with a speed so low (approximately 80 km/h) that almost all overtaking vehicles could be observed while passing in the left lane. During the observation we had no indications that this speed was so low as to attract particular attention from drivers of passing vehicles.

In order to obtain a cross-sectional data set for secondary tasks, the observation period for each vehicle was limited to maximum 5 seconds. The observer pushed the button of a timer when initiating the observation, and the timer gave a signal after 5 seconds. For most observed vehicles the relative speed compared to the observation vehicle was so high that the observation period was shorter than 5 seconds.

The following categories of secondary task involvement were noted during the observations: a) no secondary task, b) using a handheld telephone (all instances of holding a telephone, not distinguishing between talking and texting), c) texting or dialling on a dashboard-mounted telephone, c) driving with earbuds or headsets (which was considered to indicate possible use of a handsfree telephone), d) interaction with passengers, e) adjusting integrated equipment, f) eating or drinking, g) smoking, and h) other clearly visible secondary task (not listed above). In addition, there was one box for recording drivers being involved in more than one secondary task; type of task was written in text.

For each observed driver of a passenger car or van, the observer put a mark on a registration form with a box for each category of secondary task, to indicate whether the driver was involved in any of the tasks. Since we prioritised recording secondary task involvement for all passing vehicles, time did not allow registration of much additional information about each driver or vehicle. Thus, in addition to secondary task involvement, we recorded only presence of passenger(s), but we did not record driver age or gender, number of passengers, or type of vehicle.

2.2 Roadside interviews

The interviews took place at a service area located about midway along the road section where the on-road observations took place, and on the same days and during the same time intervals as the on-road observations. The service area was easily accessible for traffic in both directions on the motorway. The interviewers were university students, who had participated in a one-hour briefing session beforehand. They had also experience from similar work in other research projects. There were three interviewers on job during the whole data collection period, and each of them worked alone. Car or van drivers who had parked their vehicles were approached by an interviewer, who asked if the driver was willing to answer some questions about attention in traffic.

The drivers were informed that the interview would take about five minutes. Total interview time was about 27 hours (three interviewers, two days, three intervals per day, and about 1.5 hours per interval).

Those who consented to being interviewed were asked to consider the latest 30 minutes of their trip and try to recall whether they had been involved in any secondary task during that period. To assist driver recall, interviewers listed the following categories of secondary activities: a) eating or drinking, b) smoking, c) personal care, grooming, adjusting clothes, etc. c) adjusting driving-related integrated equipment, d) adjusting integrated radio or music player, e) using a telephone or any nomadic electronic equipment, f) interaction with passengers; including children in backseat, g) being disturbed by other things in the vehicle (animal, falling object, insect), or doing other things (e.g. reading a book or paper), h) reaching for, or putting away, objects in the vehicle or in a bag/pocket, and i) being distracted by objects, people or events outside the vehicle. In addition, the interviewers asked about cognitive and physiological states of the driver that may possibly result in impaired attention; i.e., whether they had been: a) daydreaming, talking to themselves, or thinking about problems or worries, b) deeply entrenched in listening to radio or music, i) being sleepy, or j) concerned about other urgent needs (hunger, thirst, need for a toilet, etc.). Regarding listening to talk or music, we used the term 'concentrated' in the interviews in order to identify instances of deep involvement rather than just having the audio equipment turned on without actually attending to it.

Concerning telephone use, drivers who had used their phone were asked about phone type (handheld or handsfree) and usage (talking, texting, playing music, using navigation, taking picture or video, or internet search).

For each reported secondary task or driver state, drivers were asked to estimate the duration of their involvement.

Drivers who reported some secondary task were asked whether they considered any of the tasks as a potential traffic hazard in general, and which task they believed to be most hazardous. Further, they reported whether their recent involvement in the mentioned secondary task had resulted in distraction or other inattention to them personally, and if they experienced the situation as dangerous.

We did not register the number of drivers that did not consent to being interviewed. Therefore, response rate for interviews cannot be computed. However, according to reports from the interviewers, a majority of the drivers consented. Type of vehicle (car or van) was also not registered, which means that we cannot present separate results for each of those driver groups.

Data from both interviews and on-road observations were anonymous. Since neither driver nor vehicle identification data were recorded, results could not be traced back to individual drivers. Therefore, this research was not eligible for being reported to the Norwegian Centre for Research Data, which is the national authority for privacy protection in research projects in Norway.

3 Data analysis

3.1 Behaviour observation

We observed 1337 vehicles/drivers in total; i.e., all passenger cars and vans that passed in the left lane during the observation period, and where the driver could be observed. For 83 additional vehicles it was not possible to observe the driver, due to tinted windows or sunshine reflection. These were not included in the analyses.

The number of vehicles was summed for each category of secondary tasks, and separate sums were computed for each combination of time of day, direction, and the presence of passengers. Based on these sums, we estimated the percentage of involved drivers for each secondary task category.

3.2 Interviews

Interview data were obtained from 273 drivers. For each category of secondary tasks, the percentage reporting an occurrence of the task was computed, as well as the percentage reporting any of the tasks. Because some drivers reported more than one task during the 30 minutes, the total percentage of drivers involved in some task is lower than the sum of percentages for each task. In addition to involved drivers, we estimated the mean share of driving time taking place with each of the tasks, as well as for secondary task involvement in total.

Estimation of total driving time with secondary task(s) was done in two steps. First, we estimated the typical duration for each type of task. An uncertainty in this estimation is that it is difficult for drivers to recall exactly how long they had been involved in a task, and consequently some drivers did not give a quantitative estimate, but rather answered 'just a few seconds', 'now and then', 'on and off', etc. For transforming such qualitative terms into quantitative time estimates, we decided on coding 'a couple of seconds" as 3 s and 'a few seconds' and similar terms as 5 s. Where a range was stated, e.g., 'ten to fifteen seconds', we chose the midpoint of the range. Based on the available estimates from drivers, the typical duration for each task was chosen as the mean of the individually reported estimates. For telephone conversations, eight drivers reported a "short talk"; these instances were coded as 30 seconds.

The second step was estimation of total driving time while involved in each type of secondary task, by multiplying the typical duration by the number of drivers involved in that task.

Finally, the proportion of total driving time during the last 30 minutes was then computed for each secondary task category.

4 Results

4.1 Behaviour observations

Table 1 shows the proportion of drivers who were involved in some secondary task during the moment of observation. A notable result is that secondary task involvement is much less frequent among drivers with passengers compared to those who were driving alone. The difference between 9.2% with passengers and 15.4% without passengers is statistically significant ($\chi^2 = 14.8$; df=1; $p<0.001$).

The most frequent secondary task was using a handheld mobile phone, which was observed for 5.0% of the drivers. There were also a very few drivers who were operating a dash-mounted telephone. In addition, some were using a handsfree mobile phone. Although handsfree telephoning could not be determined reliably from outside the vehicle, especially with integrated phone systems using the vehicle's microphone and speakers, wearing earbuds or a headset is a possible indication of handsfree telephoning, although listening to music is a possible alternative explanation. If we include all use of earbuds and headsets as indication of phone use, the total proportion is 7.3% of the drivers. This is probably a fairly correct estimate of telephone use, assuming that some of those using a headset were not talking on the phone, whereas some using an integrated system are missing.

Next to telephone use, the most frequent activities are eating or drinking, and interaction with passengers. For those driving with passengers, passenger interaction is the most frequent activity of all, since telephone use is much less frequent among those drivers.

Table 1. Drivers involved in secondary tasks while driving, by type of task and presence of passengers. Percent.

Secondary task	With passenger(s)	Without passenger(s)	Total
Eating or drinking	1.1	2.7	2.2
Smoking-related activity	0.3	0.4	0.4
Manipulation of equipment	0.8	0.9	0.9
Handheld mobile phone	0.3	6.8	5.0
Texting or dialling on dash-mounted mobile phone	0.2	0.0	0.1
Driving with earbuds or headset	0.0	3.0	2.2
Interaction with passenger	6.2	n/a	1.7
Other clearly visible secondary task	0.3	1.8	1.3
Sum	9.2	15.4	13.8
No. of observations	371	966	1337

Summing all secondary task involvements, we find that 13.8% of the drivers were involved in some observable task. No driver was observed being involved in more than one secondary task. Since the data are single point-time observations we can assume that the percentages shown in Table 1 reflect the total share of driving time with secondary task involvement at comparable times and under comparable driving conditions.

The category "other… task" consists of various activities that do not fit into any of the predefined categories. There were some ambiguous situations where it was not possible to see what the driver was doing, but it was clear that they were looking away from the road and traffic. There were also some cases of taking on or off glasses or sunglasses. Some rather peculiar cases were also observed, such as a driver with a dog on his lap, and one who was attending to a plant between the front seats.

4.2 Roadside interviews

Table 2 shows the number of drivers reporting involvement in each of the listed secondary activities, as well as the number of drivers reporting mean duration of the activities. Table 3 shows corresponding results for internal states. The percentage of drivers involved in a secondary activity who estimated duration of the activity differs between activities, because for many of the activities it was difficult to state how long their involvement lasted.

Accumulated driving time for each activity was computed by taking the product of mean duration and number of involved drivers. In the rightmost column of Tables 2 and 3, accumulated driving time is shown for each activity as a percentage of total driving time for all drivers during the latest 30 minutes.

Table 2. Self-reported involvement in secondary tasks while driving. Involved drivers (number and percent), average task duration (% of driving time, with 95% confidence interval), and share of total driving time (percent). Total number of drivers: 273.

Secondary task	Drivers reporting involvement: Number	Percent	Drivers reporting duration: Number	Percent	Mean share of driving time (%)	95% confidence interval	Share of total driving time (%)
Eating or drinking	89	32.6	47	17.2	9.7	6.0 – 13.5	3.32
Smoking	19	7.0	8	2.9	34.6	11.4 – 57.8	2.54
Grooming, clothes adjustment, etc.	22	8.1	7	2.6	1.2	0 – 3.3	0.09
Adjusting vehicle equipment	26	9.5	8	2.9	2.5	0 – 5.5	0.25
Adjusting radio or music player	92	33.7	38	13.9	0.6	0.1 – 1.1	0.21
Phone use, total	110	40.3	72	26.4	31.0	23.2 – 38.8	12.65
Talking	89	32.6	65	23.8	33.8	25.1 – 42.5	11.13
Messaging	10	3.7	3	1.1	1.3	0.1 – 2.5	0.05
Adjusting music app	28	10.3	2	0.7	0.5	0.2 – 0.8	0.05
Adjusting navigation app	9	3.3	4	1.5	3.1	0 – 8.3	0.11
Taking picture or video*	1	0.4	0	0	0.3	n/a	<0.01
Internet surfing	5	1.8	1	0.4	0.1	n/a	<0.01
Interaction with passenger(s)	81	29,7	2	0.7	58.3	22.5 – 94.2	17.60
Adjusting nomadic equipment	3	1.1	1	0.4	16.7	n/a	0.15
Searching for or putting away object	38	13.9	8	2.9	0.1	0 – 2.9	0.14
Other in-vehicle disturbance	8	2.9	2	0.7	1.3	0 – 6.4	0.03
Activities, persons or objects outside the vehicle	68	24.9	6	2.2	1.0	0 – 2.2	0.26

* The driver who had taken a picture did not report the duration; we roughly estimated it at 5 s.

An example may clarify interpretation of Tables 2 and 3. Out of all 273 drivers, 89 drivers (32.6%) reported that they had been eating or drinking. Forty-seven of them (17.2% of all) gave an estimate of the duration of eating/drinking, and the average of these estimates was 9.7% of average driving time for these 47 drivers. Assuming average duration was the same also for the remainder of the 89 drivers who had been eating or drinking, we estimate how much 9.7% of driving time for 89 drivers is in percent of total driving time for all 273 interviewed drivers and get 3.3% in the rightmost column.

Table 3. Self-reported cognitive distraction and internal states possibly implying attention impairment. Involved drivers (number and percent), average duration (% of driving time, with 95% confidence interval); share of total driving time (percent). Total number of drivers: 273.

Internal state	Drivers reporting involvement		Drivers reporting duration			95% confidence interval	Share of total driving time
	Number	Percent	Number	Percent	Mean share of driving time (%)		
Daydreaming	118	43.2	6	2.2	25.8	8.3 – 43.4	11.14
Concentrated on listening to radio, audiobook or music	33	12.1	4	1.5	44.6	0 – 100	5.43
Being sleepy	28	10.3	7	2.6	31.5	0 – 63.7	3.31
Other internal states	38	13.9	5	1.8	40.0	14.3 – 65.7	5.76

We see that all uses of a telephone combined amounts to 12.7% of total driving time, followed by daydreaming (11.1%), other internal states, like being hungry, stressed, worried, etc. (5.8%), concentrated on listening to something (5.5%), eating or drinking (3.3%) and being sleepy (3.3%). Twelve drivers (4.4%) did not report any secondary activity.

The very high prevalence estimate for passenger interaction is probably related to the fact that this is an activity that is difficult to estimate by self-report, since the passenger is present during the whole trip, and contact with the passenger occurs repeatedly and consists of several short episodes of varying duration, rather than a continuous activity. When asked about the duration of passenger interaction, several drivers gave answers like 'the whole trip', 'all the time', 'most of the time', 'on and off', and similar vague formulations that we consider difficult to translate into quantitative duration estimates. Our estimate is based on two drivers, who reported durations of 20 and 15 minutes, respectively, and thus the estimate is very uncertain.

To investigate whether involvement in secondary activities was related to any of the registered background factors, we performed logistic regression analyses with involvement as dependent variable and sex, age (years), driving experience (years holding a licence), and presence of passengers as independent variables. For total involvement (being involved in any of the listed activities), there were no significant relationships with the driver characteristics. Concerning specific secondary activities, there was a relationship with driver age for some activities. Fewer older drivers reported using a telephone (OR=0.963; 95% CI=0.943-0.984) and experiencing other disturbances (OR=0.970; 95% CI=0.942-0.999). On the other hand, more older drivers reported interacting with passengers (OR=1.028; 95% CI=1.004-1.054). For sex and driving experience, there were no significant associations with any of the listed activities.

Fewer drivers with passengers than without passengers reported involvement in phone use (OR=0.459; 95% CI=0.943-0.984), concentration on listening to radio etc. (OR=0.226; 95% CI=0.066-0.773), daydreaming (OR=0.223; 95% CI=0.118-0.424), and secondary activities totally (OR=0.376; 95% CI=0.158-0.893).

4.3 Subjective evaluation of risk and inattention

Out of the 261 drivers who reported involvement in some secondary activity or being in an inattentive mental state, 93 drivers (35.6%) reported that one or more of those activities or states could be dangerous in general. Table 4 shows the number of drivers reporting each of the activities and states as possibly dangerous, whether they personally experienced being inattentive, and whether they experienced a dangerous situation related to their inattention.

The question about getting inattentive was included because it is conceivable that a driver is engaged in highly automated secondary activity without being inattentive to the primary driving task. Operating vehicle controls like wipers, light switch etc. are examples of such activities. We were interested in recording drivers' subjective state of being inattentive in addition to the potential of an activity to cause inattention.

Table 4. Drivers' judging various secondary activities and mental states as 1) risky in general, 2) resulting in inattention to them personally, and 3) having resulted in a dangerous driving situation. Percent of drivers reporting involvement in respective activities (no. of drivers in parenthesis).

Activity or mental state	Risky in general	Driver got inattentive	Dangerous situation
Sleepiness (n=38)	44.7 (17)	15.8 (6)	2.6 (1)
Mobile phone use (n=110)	37.3 (41)	10.9 (12)	1.0 (1)
Outside distraction (n=68)	20.6 (14)	5.9 (4)	4.4 (3)
Searching for object (n=38)	7.9 (3)	2.6 (1)	0
Operating vehicle controls (n=26)	7.7 (2)	3.8 (1)	0
Daydreaming (n=118)	5.1 (6)	0.9 (1)	0
Self-grooming (n=22)	4.5 (1)	0	0
Passenger interaction (n=81)	3.7 (3)	1.2 (1)	0
Eating and drinking (n=89)	3.4 (3)	0	0
Operating radio or music player (n=92)	3.3 (3)	1.1 (1)	0
One or more reported condition (n=261)	35.6 (93)	9.6 (25)	1.9 (5)

About one-third (35.6%) of the drivers reporting one or more of the conditions possibly resulting in inattention judged the condition to be risky in general, 9.6% replied that they had become inattentive themselves, and 1.9% had experienced a dangerous situation resulting from of their inattention.

The condition judged to be most risky was sleepiness, which 44.7% of drivers considered risky. Sixteen percent of the drivers reporting to have been sleepy said they had been inattentive, and one driver reported a dangerous situation caused by sleepiness. Mobile phone use was judged to be risky by 37.3% of the drivers that had used their phone during the last 30 minutes, and outside distraction by 20.6%, whereas only 3.3% considered operating radio or music player as risky.

4.4 Share of total driving time: Comparing roadside interview and on-road observation

Five common secondary activities could be registered by both interviews and on-road observation; namely, eating and drinking, smoking, adjusting integrated or nomadic equipment, mobile phone use, and passenger interaction.

The two different methods resulted in rather similar estimates for eating and drinking, and for adjusting vehicle equipment (Table 5). For smoking, the estimated share of driving time is somewhat higher for the interview data than for the driver observations. Since smoking is an activity that is easy to observe, we assume that the on-road observations are highly reliable for this activity, and a likely explanation for the higher estimate based on interviews may be that drivers tend to overestimate the duration of smoking. The higher self-reported than observed prevalence for mobile phone use is at least partly explainable by handsfree telephoning that cannot be observed from outside the vehicle.

Table 5. Estimated prevalence of involvement in secondary activities, by type of activity. Percent of total driving time.

Activity	Data source: Roadside interviews (n=273)	Data source: On-road observation (n=1337)
Eating and drinking	3.3	2.2
Smoking	2.5	0.4
Adjusting equipment	[1]0.6	0.9
Mobile phone use	12.7	[2]7.3

[1] Combining categories 'vehicle equipment' (0.25%), 'radio or music player' (0.21%), and 'nomadic equipment' (0.15%) in Table 2. This figure may be an overestimation, since we have not adjusted for possible overlap between the combined categories.
[2] Combining categories 'handheld', 'texting or dialling', and 'earbuds or headset' in Table 1. There was no overlap between these categories.

In addition to the activities listed in Table 5, we compared estimates between the two methods also for passenger interaction, where we found a very large discrepancy, with 17.6% for interviews and 1.7% for observations. As mentioned in Section 4.2, the interview-based prevalence estimate for passenger interaction is very uncertain because of difficulties in estimating duration of such interaction. Another explanation of a higher estimate based on interviews is that they probably include talking with passengers irrespective of the driver looking away from the road or not, while the on-road observations included only interaction where the driver was looking at the passenger, which is the most interesting type of distraction. Thus, this is an example of a secondary activity where observation gives a much more valid estimate than interviews.

4.5 Total share of driving time with impaired attention

When estimating the total share of driving time with any of these activities we must take into consideration the possibility of overlap between activities. This means that the sum of shares for all tasks will be a correct estimate of the total share of driving time with secondary activities only if there is no overlap between activities. Otherwise, the share of driving time is overestimated. For the observation data, there was no overlap between activities, which means that the total time with secondary task involvement is equal to the sum of durations for each task. As we showed in Table 1 the total prevalence of involvement in any of the observed activities was estimated at 13.8% of total driving time.

For the interview data, which included several additional activities as well as certain internal states, a considerable overlap in time between two or more reported activities is likely. Drivers reported up to eight different activities during the 30-minute period (Figure 1), and we must assume that some of the activities occurred simultaneously.

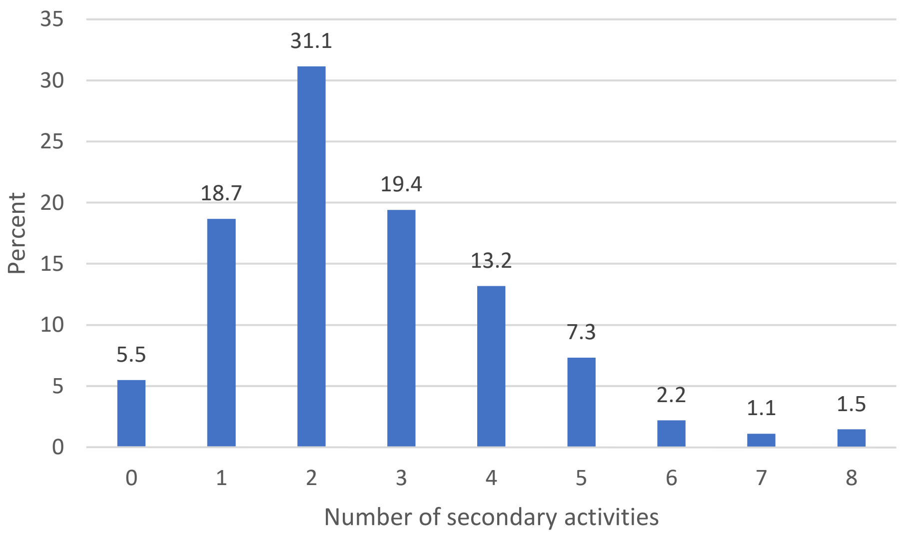

Figure 1. Drivers involved in secondary activities during latest 30 min of driving, by number of activities (n=273).

To avoid overestimation of total time with secondary activities, for each driver we took the longest reported duration of an activity as an indication of time involved in secondary activities, and we used this duration as a basis for estimating share of total driving time during the last 30 minutes. The fact that this is an underestimation of the actual duration of involvement in secondary activities should be taken into consideration when interpreting the results.

The minimum estimate for self-reported involvement in observable secondary activities when counting only the activity with the longest duration for each driver, is 16.9% of total driving time. Due to the mentioned problem of self-reported data on passenger interaction, we have not included this activity in the estimate. For the internal states, the prevalence as estimated by the same approach is 21.4% of total driving time. If we take all activities and internal states together and select the one activity or state with the longest duration for each driver, we get a prevalence estimate of 22.0% of total driving time. The relatively small difference between the estimates for activities and states separately and combined attests to the large overlap between reported activities and states.

If we include interaction with passengers and take the direct observation finding of 1.7% of total driving time as the best estimate, the share of total involvement in secondary activities or inattentive states increases to 23.7% of total driving time, assuming passenger interaction does not overlap with other secondary activities.

5 Discussion and conclusions

Both the behaviour observations and the interviews show that a considerable share of motorway driving takes place with a driver who is inattentive, either because of being involved in some secondary activity or being in a mental state of hypovigilance or low concentration, thus confirming previous research on driver distraction and inattention (e.g., Huemer and Vollrath, 2011; Sullman, 2012; Huising, Griffin, and McGwin, 2015; Farmer, Klauer, McClafferty, and Guo, 2015).

It is as expected that prevalence estimates differ somewhat between the two methods. The on-road observations, which we consider the most valid method for estimating prevalence of tasks that can be observed externally, indicate that 5% of driving takes place while the driver is using a handheld mobile phone, and that the total involvement in secondary activities amounts to 14% of driving. These must be considered minimum estimates of inattentive driving, primarily because the observation method does not capture cognitive distraction or other potentially attention-impairing mental states.

Our prevalence estimate of 14% of total driving time for involvement in observable secondary activities is very close to the prevalence found in an observational study among British drivers (Sullman (2012). Some other observational studies, however, show somewhat higher prevalence; for example, studies from Spain (Prat et al., 2015) and from the USA (Huisingh et al., 2015) reported prevalence of 20% and 33%, respectively, for involvement in observable secondary activities.

The estimate of 5% handheld mobile phone use is rather high, particularly since this is prohibited by law. It is also higher than some estimates from other countries. For example, the Danish study using the same method (Hels, 2017) found a prevalence of handheld mobile phone use of 1.9% among passenger car drivers on motorways. On the other hand, research from the USA shows prevalence of handheld mobile phone use in the same order of magnitude as our study; e.g., Dingus et al. (2016) analysed data from the SHRP2 naturalistic driving study and found a prevalence of

6.4% for use of handheld mobile phones. Our estimated prevalence of 12,7% for total use of mobile phones (including handsfree) based on interview data also agrees well with research from the USA, such as the naturalistic study by Farmer et al. (2015) showing prevalence of 7% for talking and 5% for other use, i.e., 12% for total use.

Another interesting result from the on-road observations is that involvement in secondary activities was much lower among drivers with passengers compared to those who were driving alone. Results from the interviews supported this result, and also indicated that the effect of passengers was most marked for cognitive distraction, in addition to telephone use. These findings raise the question of whether the presence of passengers has an inhibitory effect on the driver's motives for doing other things while driving. An additional explanation may be that passengers assist the driver, by for example using the mobile phone or adjusting the radio or navigation system. On the other hand, interaction with passengers is a commonly reported source of distraction, so an interesting question is to what extent the possibly inhibitory effect of passengers on other secondary activity involvement is counterbalancing the possibly distracting effect of interacting with the passenger.

The most important strength of the roadside interview compared to on-road observations is the possibility of assessing prevalence of internal states of the driver, and this explains why the estimates of total prevalence of inattentive driving are higher for the interview data.

In addition, interviews can be a useful supplement to observation regarding mobile phone use, since the use of an integrated handsfree phone system is difficult to detect by external observation.

The minimum estimate for total prevalence of secondary activities based on interview data is 22% of total driving time, when including both observable activities and internal states. However, the true prevalence is clearly higher than this, since our estimate is based only on one activity per driver, namely, the activity with the longest duration. It should also be noted that interaction with passengers is not included in this estimate. The prevalence estimates accord well with previous research results; for example, Huemer and Vollrath (2011) summarise previous observational studies (including naturalistic driving) by concluding that "... about 30% of driving time is spent with secondary tasks" (p. 1705).

A most noteworthy difference in prevalence estimates between observations and interviews is found for interaction with passengers, and we tend to conclude that the interview method is not very suitable for estimating duration of this source of inattention. Most instances of such interaction can be detected by observation, at least cases where the driver is looking at the passenger, which is probably the most interesting type of passenger interaction leading to inattention.

It is relevant to compare our results from the interview study with the results from the German study by Huemer and Vollrath (2011), which we used as a model for our research. It should, however, be mentioned that the German study included interviews both on motorway service areas and in urban parking lots, whereas we only included drivers on motorways, and consequently the studies are not quite comparable.

The distribution of number of activities across drivers (Figure 1) is rather similar to the corresponding distribution in the German study. They find that 80% of the drivers conducted one to three secondary activities, while we find 69%. The difference is probably explainable by a higher number of categories in our study.

Concerning percentage of drivers reporting the various activities, the findings are also rather similar. For distractions outside the vehicle, we find from the interviews that 25% reported attending to "activities, persons or objects outside the vehicle", compared to 23% for "outside distractions" in the German study. For passenger-related activity, the respective proportions are 30% and 38%, and for personal care they are 8% and 10%.

The results are most different for smoking, where we find a lower proportion (7% vs. 24%), and for eating or drinking, where we find a higher proportion (33% vs. 9%). The difference for smoking may be explained by a higher proportion of smokers in Germany. Concerning eating and drinking, these activities are probably more prevalent during motorway driving than in urban areas.

For drivers involved in secondary tasks, Huemer and Vollrath (2011) also estimated mean duration for each task, like we did, as the mean percentage of each driver's driving time (up to 30 min). For some activities, duration estimates from the two studies are rather similar, e.g. clothing and body care (1% in our study, vs. 3% in the Huemer and Vollrath study), smoking (35% in our study, vs 23%), and "self-initiated tasks" in the Huemer and Vollrath study, which is comparable to daydreaming in ours (26% in our study, vs. 37%). For other tasks, there are larger differences between the studies; for example, for eating and drinking (10% in our study, vs. 30%) and outside distractions (1% in our study, vs. 10%). It is interesting that our study shows a considerably shorter average duration for eating and drinking, whereas the percentage of drivers reporting this activity was less in our study compared to the Huemer and Vollrath study, as shown in the previous paragraph.

For the judgment of riskiness associated with the various secondary activities, results differ more between the two studies. In general, in our study a lower percentage of drivers considered the secondary activities as risky in general, and fewer reported that they had become distracted or inattentive themselves. Huemer and Vollrath (2011) found that about 11% of drivers reported "self-initiated tasks" as "currently distracting", compared to 5% for "daydreaming" in our study. For the other conditions, the differences were considerably larger.

Considering that there were differences both in types of vehicles that were observed, types of roads, and also in the definitions of some tasks, and also that there is sampling variability due to a limited number of observations in both studies, the results are similar enough to suggest that the roadside interview method is sufficiently valid to be useful for making comparisons of secondary task involvement between drivers in different contexts.

A possible limitation of the on-road observations is that we only observed drivers in the left lane. Some drivers may possible chose to stay in the right lane when engaging in secondary activities, particularly if the task is complex. Consequently, there may be differences in prevalence between traffic in the two lanes, implying that prevalence of some secondary activities may have been underestimated in our study. Our impression from the observations was that very few drivers kept on driving in the right lane when closing in on the observation vehicle, but rather changed lane in due distance before passing in the left lane. Furthermore, there were almost no vehicles driving so slowly that we had to change lanes to maintain our speed. However, we cannot exclude the possibility of lower prevalence of inattentive driving in the left lane. The existence of such a difference would further support the suggestion above that our results are minimum estimates of driver inattention.

It should also be noted that since we observed only motorway driving, our prevalence estimates cannot be generalised to driving in Norway generally. Our choice of time intervals for observations could also have influenced the prevalence estimates.

In conclusion, both roadside interviews and on-road observations are useful methods for estimating prevalence of driver inattention. The complementary strengths of the two methods imply that their combined use yields more precise estimates of total prevalence of inattention than either approach alone.

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