Under which driving contexts do drivers decide to engage in mobile phone related tasks? An analysis of European naturalistic driving data

Tina Morgenstern [1*], Frederik Naujoks[2], Josef F. Krems [1], Andreas Keinath [2]

[1] Cognitive & Engineering Psychology, Technische Universität Chemnitz, Chemnitz, Germany
[2] BMW Group, München, Germany
[*]tina.morgenstern@psychologie.tu-chemnitz.de

Abstract: Mobile phone related task engagement while driving has increased dramatically over the past years. However, research has shown that drivers attempt to compensate for the associated performance degradation in the primary driving task by using various self-regulatory strategies, such as deciding *when* to engage in a secondary task. Unfortunately, there are only a few existing studies that focus on contextual factors associated with secondary task initiation. Goal of the present study was to investigate which driving contexts encourage drivers to initiate a mobile phone related task using European naturalistic driving data. In total, 165 trip segments involving mobile phone engagement were analysed. The driving context at the moment of task initiation was compared to the context 30 seconds prior to task initiation. With the exception of conversation, the results show that drivers were much more likely to be stopped at task initiation than 30 seconds prior, indicating that most drivers stopped their vehicle before initiating the secondary task. Further, for texting or browsing tasks, making turns or driving in a stable traffic flow was significantly less likely at task initiation. The results suggest that drivers choose to engage in mobile phone tasks when the driving task demand is low.

1. Introduction

In recent years, the use of mobile phones while driving has increased tremendously [1, 2], particularly among younger drivers [3, 4]. However, mobile phone interaction while driving, especially texting, can adversely affect driving performance. Texting can cause slower reaction times [5, 6] and more lane deviations [7, 8]. Previous studies also show an alarmingly high crash risk of texting compared to other common secondary tasks (e.g., eating and drinking, talking with passengers) while driving [9, 10].

At the same time, there is evidence from simulator studies that drivers use self-regulatory strategies on an *operational* level to decrease the driving demand during secondary task engagement, such as limiting the number of lane changes [11], increasing the following distance to a lead vehicle [5, 12] or reducing speed [6, 8, 13]. The effect of speed reduction during secondary task engagement is a particularly common finding reported across different driving simulator studies. However, analyses of naturalistic driving data showed that these effects are rather small, if they are found at all. For instance, Schneidereit, Petzoldt, Keinath et al. [14] examined data from the SHRP 2 naturalistic driving study and found only a small indication regarding a speed adjustment for texting while driving. The engagement in other secondary tasks, such as smoking or eating, did not significantly alter speed. Tivesten and Dozza [15] found comparable results when analysing visual-manual phone task engagement in their Swedish naturalistic driving study, revealing little to no changes in speed prior to or after mobile phone task initiation.

Based on these results, it seems more likely that drivers self-regulate on a *strategic* level, such as deciding *when* to engage in a secondary task while driving. Some evidence exists that drivers engage in secondary tasks more frequently when the driving task demand is low, for example during slow speeds [16] or when stopped [4, 15, 17]. Huisingh, Griffin and McGwin Jr. [18] found in their roadside observational study that drivers were engaged in secondary tasks much more often when the car was stopped. However, when focusing on mobile phone calls, the prevalence of this secondary task did not differ significantly depending on the vehicle speed. For texting or dialing tasks it even turned out that more drivers actually dialed or texted at speeds greater than 50 mph than at lower speeds or while stopped [18]. These results are somewhat surprising as visual-manual mobile phone tasks, such as texting, are considered as one of the most distractive and dangerous secondary tasks to engage in while driving that force drivers to take their eyes off the road, which, in turn, lead to a high safety-critical risk [9].

Aside from some of the findings regarding speed, evidence also exists that drivers' secondary task engagement is associated with specific road types. Huisingh, Griffin and McGwin Jr. [18] noted that the overall secondary task engagement was more common on local than on arterial roads; however, texting and dialing tasks actually occurred more frequently on arterial roads (i.e., in urban centres). Further, there are indications that drivers tended to avoid secondary task engagement in dense traffic environments, while turning, or under adverse lighting or weather conditions [3, 15].

In fact, it appears that there are certain contextual factors where drivers are either more or less likely to engage in secondary tasks. However, findings on mobile phone related tasks are rather inconsistent regarding the actual extent of drivers' behaviour adaptation to different driving contexts. For instance, some studies have shown that drivers' mobile phone engagement was much higher when the vehicle was stopped (e.g., at a red light) [4, 19], whereas in other studies the exact opposite was found [18]. Furthermore, most of the previous findings are based on roadway observations or survey studies. Only a few studies on this topic currently exist that use naturalistic driving data [15, 19]. Naturalistic driving data create a clear image of drivers' mobile phone behaviour across different driving contexts. Moreover, it allows for the comparison of the driving context at the precise moment of task initiation with the driving context before the mobile phone task was initiated. Thus, contextual factors increasing the prevalence of mobile phone task initiation can be assessed. The aim of the present study was therefore to identify the contexts under which drivers decide to engage in mobile phone related tasks using European naturalistic driving data.

2. Method

The current study is based on European naturalistic driving data collected in the UDRIVE project [20]. Within UDRIVE 120 cars in five countries (France, Germany, Poland, United Kingdom, and Netherlands) were equipped with seven video cameras (three forward, one cabin, one cockpit, one face and one footage camera) and a data acquisition system that was developed for the project (e.g., to record GPS, speed behaviour, brake pressure or steering wheel angle). Drivers' natural behaviour was observed for up to two years. Overall, 192 drivers participated in the study [21].

2.1. Sampling and Annotation

The analyses presented in this paper rely on a dataset containing four randomly selected trips per driver. For our analyses we used all trip segments in which a mobile phone interaction took place. The trip segments were annotated using video data regarding the *main mobile phone related task* (i.e., conversation hand-held, conversation hands-free, texting/ browsing, reading hand-held, reading hands-free, holding, other; for a detailed description of the tasks see Table 7, Appendix A), the precise moment of *task initiation* and the precise moment of *task conclusion*. Task initiation and conclusion were defined as the first/ last glance or hand movement (whatever occurred first/ last) towards the mobile phone. At task initiation (further referred to as "I-0") we also annotated if *other passengers* were present (i.e., yes, no) as well as *weather* (i.e., clear, rain, snow, fog, other) and *lighting conditions* (i.e., daylight, dawn/ dusk, darkness). *Locality* (i.e., urban-residential, urban-motorway, rural, motorway/ highway, other), *traffic density* (i.e., free flow, free flow with restriction, stable flow, unstable flow, traffic jam/ stop-and-go, other), *stopping* (i.e., yes, no), *location when stopped* (i.e., traffic light, traffic sign, parking lot, traffic jam, other) and *turning* (i.e., yes, no) were annotated at I-0 and also 30 seconds prior to task initiation (further on referred to as "I-30").

Overall, 305 trip segments were annotated. 269 of these trip segments were relevant, i.e. contained a clear mobile phone related task (in some cases, for example, it was not obvious whether the driver engaged in a hands-free mobile phone conversation or talked with a passenger). The 269 trip segments stemmed from 129 different trips. For further analyses, we randomly selected one segment per trip in case multiple trip segments per task category stemmed from one trip. This was done to avoid an overrepresentation of single trips. Thus, 104 trip segments were excluded from the analyses (see Table 1).

Table 1 Frequencies across mobile phone tasks for the dataset including all trip segments and the dataset with one segment per trip

Task category	Dataset with all trip segments	Dataset with one segment per trip
Conversation hand-held	19	18
Conversation hands-free	7	6
Texting/ browsing	143	64
Reading hand-held	37	30
Reading hands-free	8	8
Holding	21	16
Other	34	23
All	**269**	**165**

2.2. Sample Description

The 165 trip segments analysed consisted of 57 different drivers (30 female, 27 male) with a mean age of 40 years (*SD* = 11.25). Most of the drivers in our sample came from Poland, whereas the fewest originated from Germany. Table 2 gives an overview of the sample characteristics.

Table 2 Sample description per secondary task category

Mobile phone task category	Number of trip segments	Number of drivers	Gender		Mean Age (*SD*)	Operational Site				
			Female	Male		DE	FR	NL	PL	UK
Conversation										
hand-held	18	15	7	8	40.75 (11.38)	2	2	0	9	2
hands-free	6	6	3	3	37.00 (9.03)	0	2	1	2	1
Texting/ browsing	64	34	17	17	37.59 (11.26)	1	10	3	12	8
Reading										
hand-held	30	22	14	8	36.35 (10.04)	2	5	1	6	8
hands-free	8	6	4	2	38.4 (7.02)	0	1	1	3	1
Holding	16	14	8	6	36.08 (8.65)	1	3	1	4	5
Other	23	19	10	9	38.07 (11.97)	1	6	0	7	5
All	**165**	**57**	**30**	**27**	**40.08 (11.40)**	**4**	**14**	**5**	**18**	**16**

Especially for texting or browsing, it must be noted that multiple trip segments stemmed from one driver. However, this was rarely the case for the other mobile phone related tasks (see Table 2).

2.3. *Analyses*

Prevalence ratios were used to assess the association between the frequency of different contextual factors and the initiation of mobile phone related tasks. Prevalence ratios are calculated exactly like risk ratios and indicate how common an event is in one group or data collection point relative to another group or data collection point [22]. More precisely, the proportion of specific contextual factors (e.g., a free flow traffic condition) at I-0 (i.e., at task initiation) was divided by the proportion of the same contextual factors at I-30 (i.e., 30 seconds prior to task initiation). A prevalence ratio less (greater) than 1 means that the prevalence for the respective contextual factor at I-0 is lower (higher) than at I-30. Prevalence ratios were calculated for locality, traffic density, stopping and turning. Frequencies are reported for the other categories.

3. Results

During most annotated trips, the drivers engaged in texting or browsing, followed by hand-held reading and other mobile phone related tasks (see Table 1). Only 18 observed trips included hand-held mobile phone conversations. In further analyses, “conversation hand-held” and “conversation hands-free”, “reading hand-held” and “reading hands-free”, as well as “holding” and “other” were combined due to their low number of observed events.

3.1. *Texting/ Browsing*

Texting or browsing tasks were the most observed mobile phone related tasks in our sample. The mean duration of texting or browsing was 46 seconds (*SD* = 50.78), ranging from 3 to 271 seconds. Other passengers were present in 16% of the trip segments. Most of the trip segments in which drivers engaged in texting or browsing took place in daylight (78%), under clear weather conditions (93%) and in an urban area (68%).

The prevalence ratios indicate an association between the initiation of texting or browsing and traffic density, stopping and turning (see Table 3). Specifically, the data show that a stable traffic flow was observed significantly less often at I-0 than at I-30. In contrast, the prevalence of the “other traffic density” category was two times higher at I-0 than at I-30. This category contains all events in which the vehicle was stopped (e.g., at a red light) and therefore traffic density could not be assessed. This is also reflected in the high prevalence ratio of stopping, indicating that the prevalence of a stopped vehicle at I-0 was 3.5 times higher than at I-30. Furthermore, we found a significant prevalence ratio regarding turning, such that turning occurred less often at I-0 in comparison to I-30.

Table 3 Prevalence ratios and 95th confidence intervals regarding locality, traffic density, stopping and turning for texting or browsing tasks

Contextual factor	Prevalence ratio	95th CI
Locality		
Urban residential	0.92	0.67-1.25
Urban motorway	0.92	0.34-2.45
Rural	1.60	0.50-5.21
Motorway	0.57	0.20-1.66
Other	2.45	0.68-8.79
Traffic density		
Free flow	0.55	0.26-1.17
Free flow with restriction	0.55	0.14-2.21
Stable flow	0.37*	0.17-0.78
Unstable flow	0.92	0.13-6.32
Traffic jam	1.38	0.52-3.64
Other	3.17*	1.69-12.71
Stopping	3.58*	1.95-5.93
Turning	0.20*	0.05-0.91

Note. *Significant prevalence ratios (i.e., 95th CI does not cross 1).

Regarding vehicles' stopping location at time I-0, it could be shown that in more than half of the events the vehicle stopped at a (red) traffic light, whereas waiting at a traffic sign (e.g., a stop sign) was not observed in our sample (see Fig.1).

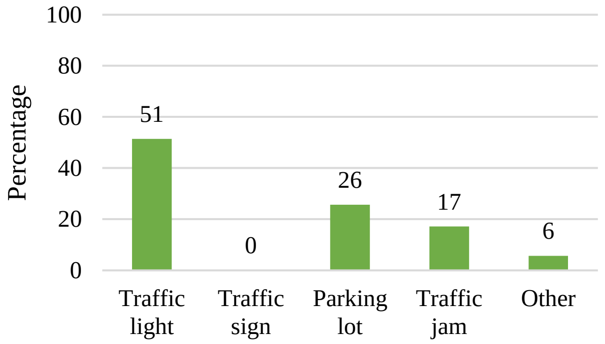

Fig. 1*. Percentage of annotated stopping locations when initiating texting or browsing tasks*

3.2. Conversation

Hand-held or hands-free mobile phone conversations lasted on average 250 seconds (*SD* = 407.34), ranging from 35 to 1464 seconds. Other passengers were only present in 8% of all events. Here again, most trips including a mobile phone conversation occurred in daylight (75%), under clear weather conditions (86%) and in an urban area (64%).

For mobile phone conversation, no significant associations existed between the initiation of a conversation and specific contextual factors (see Table 4). A stopped vehicle was more frequently observed at I-0 than at I-30; however, this effect was not statistically significant.

Table 4 Prevalence ratios and 95th confidence intervals regarding locality, traffic density, stopping and turning for conversation tasks

Contextual factor	Prevalence ratio	95th CI
Locality		
Urban residential	1.24	0.71-2.15
Urban motorway	0.48	0.05-4.90
Rural	0.64	0.12-3.45
Motorway	0.95	0.27-3.34
Other	0.95	0.15-6.19
Traffic density		
Free flow	0.64	0.27-1.50
Free flow with restriction	1.91	0.39-9.32
Stable flow	0.41	0.12-1.40
Unstable flow	–	–
Traffic jam	–	–
Other	2.55	0.79-8.17
Stopping	3.82	0.93-15.63
Turning	0.76	0.24-2.48

Note. "–"Prevalence ratios could not be calculated due to missing values in this category.

Due to the small sample size of mobile phone conversation events, vehicles' location when stopping at I-0 will not be reported.

3.3. Reading

Mobile phone tasks involving reading a message/ post (hand-held or hands-free) lasted on average 18 seconds (*SD* = 12.54), ranging from 1 to 61 seconds. Another passenger was present in 24% of all events. Further, reading was mostly observed in daylight (74%), under clear weather conditions (94%) and in an urban area (75%).

The prevalence ratios indicate a link between the initiation of reading a message/ post on the mobile phone and the category "other traffic density" as well as the category "stopping" (see Table 5). The prevalence of "other traffic density" was five and the prevalence of a stopped vehicle was two times higher at I-0 than at I-30.

Regarding vehicles' stopping location at time I-0, most events occurred when the vehicle was stopped at a (red) traffic light, followed by stopping in a traffic jam (see Figure 2).

Table 5 Prevalence ratios and 95th confidence intervals regarding locality, traffic density, stopping and turning for reading tasks

Contextual factor	Prevalence ratio	95th CI
Locality		
Urban residential	1	0.71-1.40
Urban motorway	0.92	0.20-4.24
Rural	0.92	0.20-4.24
Motorway	1.15	0.34-3.92
Other	0.92	0.06-14.10
Traffic density		
Free flow	0.58	0.25-1.34
Free flow with restriction	0.69	0.17-2.86
Stable flow	0.55	0.14-2.14
Unstable flow	0.37	0.08-1.77
Traffic jam	1.53	0.62-3.73
Other	5.04*	1.21-20.89
Stopping	2.29*	1.21-4.33
Turning	0.46	0.12-1.70

Note. *Significant prevalence ratios (i.e., 95th CI does not cross 1).

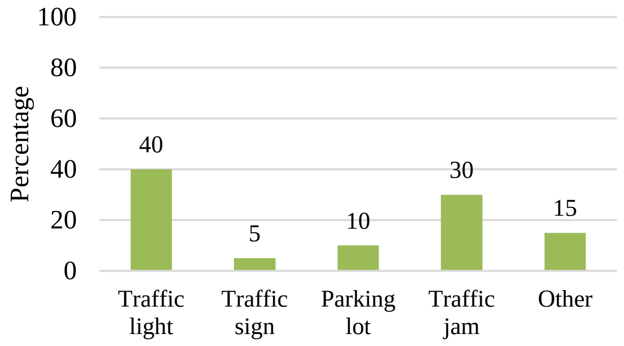

Fig. 2. *Percentage of annotated stopping locations when initiating reading tasks*

3.4. Other Mobile Phone Related Tasks

Other mobile phone related tasks include, for example, holding the phone or taking a picture. On average, these tasks lasted around 26 seconds (*SD* = 51.13), ranging from 1 to 292 seconds. Another passenger was present in 21% of these events. Other mobile phone related tasks mainly occurred in daylight (82%), under clear weather conditions (92%) and in an urban area (65%).

The prevalence ratios were statistically significant for the contextual factors “other traffic density” and “stopping” (see Table 6). The prevalence of “other traffic density” was nearly ten times higher at I-0 than at I-30. This is also reflected in the significant prevalence ratio for “stopping”, indicating that a stationary vehicle was much more common at I-0 than at I-30. A statistically significant association was not found for the other contextual factors.

Table 6 Prevalence ratios and 95th confidence intervals regarding locality, traffic density, stopping and turning for other mobile phone related tasks

Contextual factor	Prevalence ratio	95th CI
Locality		
Urban residential	1.05	0.67-1.64
Urban motorway	0.89	0.24-3.30
Rural	1.02	0.41-2.52
Motorway	0.89	0.19-4.14
Other	1.22	0.19-8.06
Traffic density		
Free flow	0.77	0.43-1.40
Free flow with restriction	0.25	0.06-1.15
Stable flow	1.02	0.41-2.52
Unstable flow	–	–
Traffic jam	2.68	0.29-24.53
Other	9.81*	1.34-71.49
Stopping	4.46*	1.44-13.82
Turning	0.89	0.24-3.30

Note. *Significant prevalence ratios (i.e., 95th CI does not cross 1); “–“Prevalence ratios could not be calculated due to missing values in this category.

As shown before, most stops occurred at a (red) traffic light, followed by traffic jam (see Figure 3).

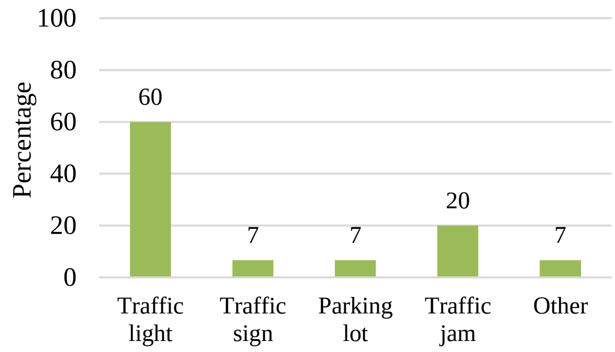

Fig. 3. *Percentage of annotated stopping locations when initiating other mobile phone related tasks*

4. Discussion and Conclusion

The aim of the present study was to investigate the contexts under which drivers engage in mobile phone related tasks using European naturalistic driving data. Prevalence ratios were calculated to assess the association between different contextual factors and the initiation of a specific mobile phone related task (i.e., texting or browsing, conversation, reading or another mobile phone related task). The results show a very clear pattern. The prevalence of a stopping vehicle was much higher at task initiation than 30 seconds prior to task initiation. This is in line with other study findings [4, 15]. Hence, drivers seem to selectively engage in mobile phone tasks when the driving task demand is low. Apart from mobile phone conversation, this effect existed for all other analysed mobile phone related tasks. One possible explanation why this effect was absent for mobile phone conversations is that these tasks include both incoming and outgoing calls. The drivers themselves initiate outgoing calls, whereas incoming calls are beyond the drivers' control. Although the driver has the choice to ignore the phone call, it can be suggested that in most cases drivers' curiosity (or need to know who calls) is too powerful.

Further, our analyses showed that drivers initiated texting or browsing tasks significantly less often when driving in a stable traffic flow or when turning. Such driving situations normally require much attention as traffic conditions can change rapidly, which might increase the driving task demand. Thus, drivers seem to avoid initiating texting or browsing in these complex situations. This corresponds to what was found by Tivesten and Dozza [15], showing that drivers initiate visual-manual mobile phone tasks more often *after* making sharp turns.

It must be pointed out that the results for stable traffic flow and turning were only significant for texting or browsing tasks. There was no association between task initiation and the presence (or absence) of these contextual factors for the other mobile phone related tasks. As texting requires visual, manual and cognitive resources, it is one of the most dangerous secondary tasks to conduct while driving. The meta-analysis by Caird, Johnston, Willness et al. [7] showed that texting while driving adversely impacts nearly all aspects of driving performance due to the repeated off-road glances necessary. Although reading text messages showed smaller effect sizes, driving performance was still negatively affected. Consequently, it can be assumed that with increasing secondary task difficulty, the more important contextual factors (e.g., traffic density, turning) become for secondary task initiation.

However, it is important to state that the sample sizes of the present study are rather small. Mobile phone conversations, for example, were only observed in 24 events, leading to a low level of statistical power. Analyses of larger sample sizes shall be performed to validate our findings. Moreover, in some cases multiple trip segments stemmed from one driver, which could lead to an overrepresentation of single drivers and thus might bias our results.

It has to be kept also in mind that in our analyses contextual factors *within* a single trip were compared. This was done to examine whether the traffic situation 30 seconds prior to drivers' engagement in a mobile phone related task differed from that at task initiation. This may have led the driver to consciously choose to (not) engage in the mobile phone related task at that precise moment. However, the influence of other contextual factors, such as passenger presence, cannot be investigated with this approach. For this, comparisons with baseline trips (i.e., trips without secondary task engagement) would be necessary. In general, although naturalistic driving data give insight into natural driving behaviour, it remains unclear why drivers act as they do. Personal motives and reasons are not directly apparent. Here, surveys and focus groups might provide additional information.

Nevertheless, our research gives an initial insight into drivers' self-regulatory behaviour adaptation on a strategic level when engaging in different mobile phone related tasks. The findings indicate that drivers strategically decide when to engage in a mobile phone related task by choosing low-demand driving situations. However, even though drivers across most of our analysed trip segments initiated the mobile phone task when stopped at a red light, there cannot be a presumption that this behaviour is “safe”. For this, the moment of task conclusion must be further examined. If drivers, for example, continued with secondary task engagement after the light turns green, this poses a real traffic safety danger. Therefore, future studies focusing on specific contextual factors, such as red light situations, are necessary to better understand how often, why and how drivers use such situations for secondary task engagement.

5. Acknowledgments

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7. Appendix A

Table 7 Description of mobile phone task categories

Mobile phone task category	Description
Conversation hand-held	Driver is talking on a hand-held mobile phone or has the phone up to ear as if listening to a phone conversation
Conversation hands-free	Driver is talking or listening on a mobile phone using a hands-free device, such as a headset, in-vehicle integrated system, or hands-free speaker phone
Texting/ browsing	Driver is pressing buttons or a touch screen on the mobile phone to create and/ or send a text message or to browse in the internet or phone applications
Reading hand-held	Driver is looking at the screen of the mobile phone and clearly reading something, without a physical interaction
Reading hands-free	Driver looks to the cell phone regularly, without holding it and without a physical interaction
Holding	Driver is holding a mobile phone, but not manipulating it and not reading something
Other	Driver is interacting with a mobile phone in some other manner (e.g., taking pictures)

Note. According to the UDRIVE annotation codebook, see Heinig et al. [23].