Exploring mobile phone usage and its context with naturalistic driving observations

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Abstract

Although the distractive effects of using a mobile phone while driving are well-known, a vast number of drivers keep using their mobile phone behind the wheel. Advances in mobile technologies even amplify the usage options. On the other hand, assistance functions are available in many vehicles and may lead to strategies for an integrated use of in-vehicle technologies. With the aim of exploring the context of phone usage while driving and its integration with the use of the Cruise Control and Speed Limiter, a naturalistic driving study was conducted. Participants drove an instrumented vehicle in their usual environment during four to six weeks and completed a diary on their phone usage in the car (about one week). Additionally, a semi-structured interview was conducted on habits and strategies related to the use of the mobile phone and assistance functions. The analysis of the number, type, duration, and context of interactions with the mobile phone revealed that the choice of specific driving situations differed between call types and that phone interactions occurred frequently in urban areas (possibly related to their motive). No conclusive results could be obtained on the activation of a speed regulation system in order to mitigate the distractive effects of the phone use, owing to the divergence between subjective and objective results.

Introduction

The growing relevance of distraction by mobile phone use has been illustrated in a recent report of the World Health Organisation (WHO, 2011), pointing out the visual, cognitive and physical distraction it may cause while driving. The primary concern attributed to this source of driver distraction results from the exponential increase of mobile phone usage in society and the corresponding growth of mobile phone usage while driving. A survey conducted for the French Road Observatory in 2006 revealed that 44% of French drivers who own a mobile phone also use it behind the wheel (IFSTTAR/Inserm, 2011). The introduction of smart phones, which are spreading fast, leads to an amplification of usage opportunities of the phone and correspondingly increases the opportunities of distracted driving. For instance, Basacik et al. (2011) found that drivers report frequent use of smart phones and that reaction times when interacting with the smartphone are dramatically increased compared to baseline driving.

In D. de Waard, K. Brookhuis, F. Dehais, C. Weikert, S. Röttger, D. Manzey, S. Biede, F. Reuzeau, and P. Terrier (Eds.) (2012). Human Factors: a view from an integrative perspective. Proceedings HFES Europe Chapter Conference Toulouse. ISBN 978-0-945289-44-9. Available from http://hfes-europe.org

By the same token, assistance functions are frequently available to drivers. As shown in studies by Stanton et al. (1997), being assisted by a speed regulation system can reduce workload, which in turn may induce the driver to engage more in secondary activities. Correspondingly, Bianchi Piccinini reported that the activation of ACC may promote the occurrence of secondary activities, such as calling or surfing on the internet (Bianchi Piccinini et al., in press).

Previous studies have concluded that the engagement in secondary tasks depends on the characteristics of the driving situation (Huemer & Vollrath, 2011). Regarding mobile phone use in particular, different usage patterns and strategies have been identified by Rauch et al. (2008). These include stopping the car in order to talk on the phone, taking the opportunity to make calls at a red traffic light or compensating by driving more slowly and performing fewer manoeuvres, such as lane changes.

In simulator experiments or real driving observations on pre-defined test routes, the experimenters decide about the phone and driving tasks and the drivers are not free to choose how and when to combine the mobile phone usage with driving (McCartt et al., 2006). Naturalistic driving studies (NDS), however, allow exploring actual habits and applied strategies of drivers without interference by experimenters. Using this methodology, the present study aims at exploring the actual context of phone usage while driving. The analyses presented in this paper focus on the choice of driving situations for mobile phone interactions and on its integration with the usage of in-vehicle systems that assist the driver with the speed regulation.

Method

Data collection for this study was conducted in two parts: a small-scale NDS and a detailed NDS with a more specific focus on phone usage. The majority of the participants took part in both studies consecutively.

Procedure and participants - small-scale NDS

N=16 participants borrowed an instrumented car for a mimimum duration of four weeks. They were asked to drive this car as they normally would, concerning the journeys they undertake as well as their driving style. Likewise, they were instructed to use the in-vehicle technologies and their mobile phone according to their habits. The participants were informed about the sensors and cameras that were present in the vehicle and about the confidential treatment of the driving and video data. They were financially compensated for their participation.

The recruitment of the participants was carried out through an announcement distributed by email, or by direct contact. The participants had to hold a valid driving licence for more than ten years and normally drive a minimum of 2000km per month, while using different road types. Only drivers who indicated a usage of a speed regulation system in at least half of the trips were recruited and they needed to report using the mobile phone while driving (without any specification on frequency). The sample was composed of ten men and six women, ranging from 33 to 50 years of age.

Procedure and participants - detailed NDS

In order to obtain more detailed information on the phone usage during driving, twelve drivers borrowed an instrumented car for about one week and were asked to register their calls, text messages and other types of interactions with their mobile phone in a diary. At the end of the study, a semi-structured interview was conducted, which explored the habits and strategies of the participants regarding their phone usage while driving.

Of the sample, eleven were participants from the previously conducted small-scale NDS and one participant was a secondary driver who had used the equipped car of a participant several times during the first study. The participants received a small remuneration once they had completed the detailed study. The sample was composed of seven men and five women, ranging from 33 to 50 years of age.

Data collection

Five instrumented vehicled were used for the study: a Peugeot 308, two Peugeot 207 SWs and two Renault Clio Estates. They were equipped with an built-in conventional Cruise Control (CC) and Speed Limiter (SL), a nomadic navigation device and a Bluetooth hands-free car kit. A data acquisition system (DAS) was installed along with three cameras capturing the driver view, the outside view and the dashboard (Fig.1).

Figure 1: View of the three cameras and speed recording by the DAS

Parameters, data processing and analysis

All valid files were extracted from the gathered driving and video data, excluding the files that could not be opened in the coding tool and those files that contained an external driver or no driver (car parked). Three previously trained data coders then identified the episodes of mobile phone interactions and the actuations of the SL/CC controls. In addition to the variables of the DAS and the coded parameters, the data from the detailed study were combined with the variables obtained through the call diaries. Thus, the files used for the data analysis contained all calls and handlings with their characteristics and context variables. The qualitative data from the interviews were treated separately. Table 1 shows the parameters that were included in the analysis.

Table 1: Parameters for the analysis (data only available for the detailed NDS are marked with (1), interview data with (2)).

Parameter	**Description**
Mobile phone interactions	
Type of interaction	hand-held vs. hands-free call
	incoming vs. outgoing call(1)
	handling (includes: take phone in hand, take phone in hand and manipulate it, manipulate phone without taking it in hand and visual handlings, i.e. clearly identifiable glances at the phone)
Duration of interaction	*short* [≤1 min]; *medium* [1 - 5 min]; *long* [> 5 min]
Motives of phone use in car	driver comments(2)
Context	
Type of road	road type during >90% of call [urban, rural, highway], calls taking place on more than one road type are excluded
Car movement	*Stopped* [≤1 km/h]; *moving slowly* [≤10 km/h]; *moving* [>10 km/h]
	(mean speed during interaction; speed at start of interaction)
Systems	
Cruise Control	activation status at start of interaction [on/off]
Speed Limiter	activation status t start of interaction [on/off]
Usage strategies	driver comments(2)

Statistical testing was performed in order to compare hand-held vs. hands-free calls (small-scale NDS) and incoming vs. outgoing calls (detailed NDS). Wilcoxon Signed Rank Tests were used, accounting for the within-subjects structure and possible skewness of the data. The comparison of categories for the handling data was made by means of Friedman tests (post-hoc comparisons: Wilcoxon signed rank tests). Corresponding to the non-parametric tests, figures with median values are reported along with the test statistics.

Exposure data

Small-scale NDS

A total of 698 driving hours was analysed, stemming from the n=16 participants of the small-scale NDS. On average, this corresponds to M=43.62h per participant (SD=14.08h). The participants spent 50% of their driving time on urban roads, 31% on rural roads and 19% on the highway. A total of 43h was spent on the phone, representing a mean of 6.34% of the driving time per participant (SD=0.05%). Seven of the participants were identified as exclusive CC users and eight drivers used both speed regulation systems. One participant did not use the CC or the SL.

Detailed NDS

From the detailed NDS, only ten out of the twelve datasets could be used. One participant made only one call and for another participant data recording problems led to the loss of data during more than 80% of the trips. A total of 179 valid driving hours was obtained (M=19.90h; SD=8.79h). Again, the highest time share was spent on urban roads (44%), with 27% of the time driven on rural roads and 29% on the highway. A total of 11h talking on the phone corresponded to 7.45% of the driving time per participant (SD=3.98%). Again, one part of the drivers was identified as exclusive CC users (n=6) and the others were mixed CC/SL users (n=4).

Results

Small-scale NDS

In the small-scale study, a total of 927 calls were identified. These were 629 hands-free calls (68%), and 298 hand-held calls (32%). The median number of hands-free calls per participant was Mdn_{hf}=31.5 and of hand-held calls Mdn_{hh}=12. Figure 2 shows the overall rates of calls in the three length categories, with a high proportion of short hand-held calls and still 13% of long hand-held calls. The statistical comparison of hands-free and hand-held calls regarding the rates of short, medium and long calls per participant reveals that there were more short hand-held calls than short hands-free calls (*Z*=-3.07, *p*=.002, Fig.3). By contrast, hands-free calls had a higher rate of medium duration (*Z*=2.33, *p*=.020, Fig.3) and of long duration (*Z*=3.18, *p*=.001, Fig.3) than hand-held calls.

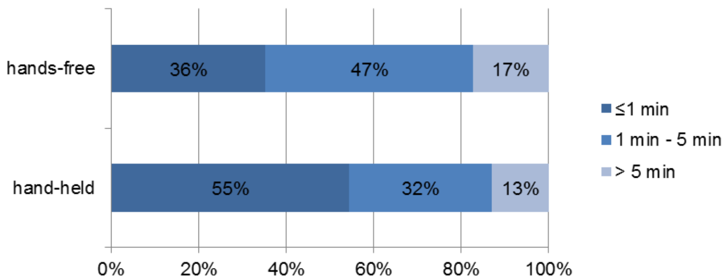

Figure 2: Overall distribution of hands-free and hand-held calls depending on call length.

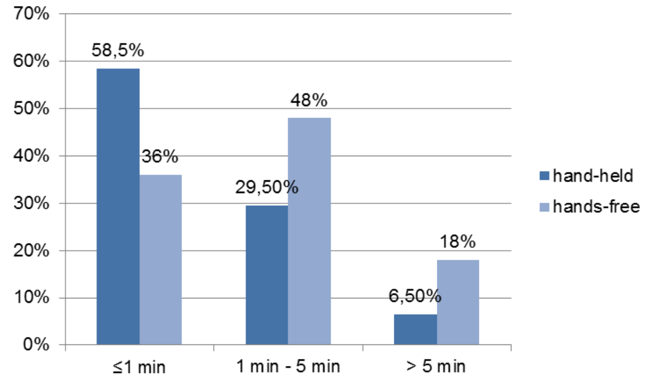

Figure 3: Median values over participants' distribution of hands-free and hand-held calls depending on call length.

Regarding the road type on which the call took place, no differences are visible in the overall distribution of the calls between hand-held and hands-free calls (Fig.4), nor were there any significant differences in the distributions per participant (Fig.5). However, the share of urban calls was strikingly high as compared to the exposure rate on urban roads (50% of driving time).

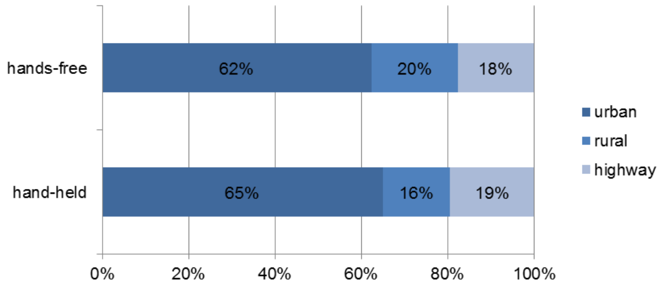

Figure 4: Overall distribution of hands-free and hand-held calls depending on road types.

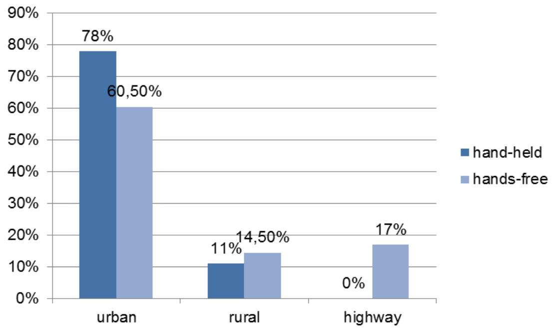

Figure 5: Median values over participants' distribution of hands-free and hand-held calls depending on road types.

In the overall distribution of calls depending on the car movement, hand-held calls when the car was stopped and hands-free calls when the car was moving stand out (Fig.6). Statistical testing of the shares of calls per participant confirms this: Compared to hands-free calls, hand-held calls occurred at a significantly higher rate when the car was stopped (Z=-3.29 p=.001, Fig.7), while hands-free calls occurred more frequently than hand-held calls when the car was moving (Z=3.41 p=.001, Fig.7). No systematic differences between the percentages of hand-held and hands-free calls were found when the car was moving slowly.

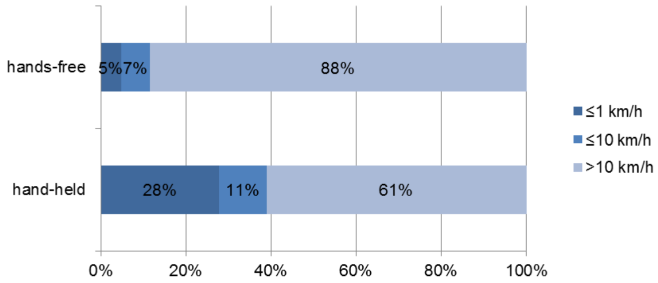

Figure 6: Overall distribution of hands-free and hand-held calls depending on car movement (mean speed during call).

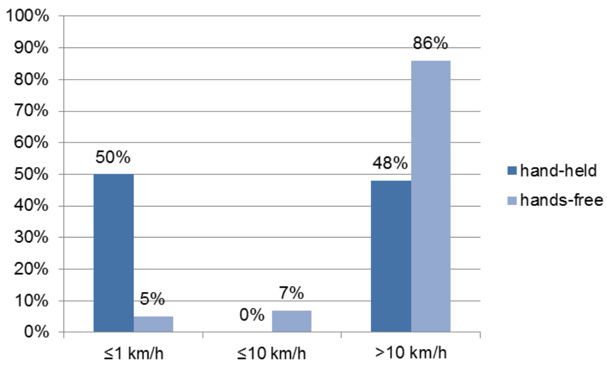

Figure 7: Median values over participants' distribution of hands-free and hand-held calls depending on car movement (mean speed during call).

Compared to the distribution of mean speed during calls, the shares of speed below 10km/h (car moving slowly or stopped) appears to be greater in the distribution of hand-free calls depending on the car movement when the call starts, i.e. when the driver starts speaking on the phone (Fig.8). However, there does not seem to be such a change regarding hand-held calls.

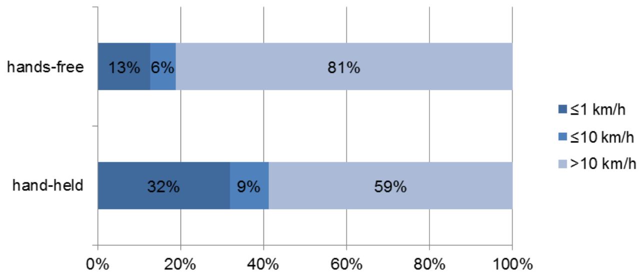

Figure 8: Overall distribution of hands-free and hand-held calls depending on car movement (speed when call starts).

Actually, the share of hands-free calls initiated in a moving car was significantly lower than the share of hands-free calls where the car was moving during the call (*Z*=-3.04 *p*=.002, Fig.9). The drivers may have taken the opportunity to start a call when the car was stopped or moving slowly, but they were still on the phone when they went on driving. This effect was not detectable for hand-held calls (Fig.9).

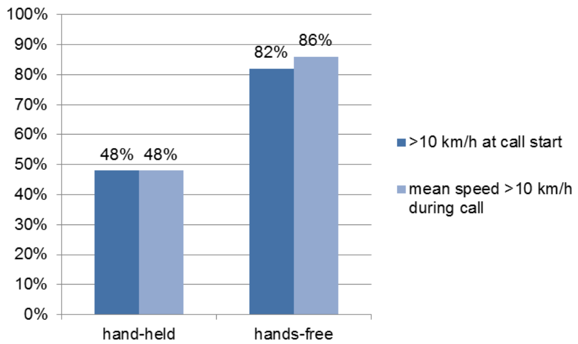

Figure 9: Median values over participants' share of calls when the car is moving (mean speed during call) and share of calls initated when the car was moving for hands-free and hand-held calls.

Previous analyses have shown that 87% of the CC use took place on the highway, and that 98% of the highway use occurred in free flowing traffic conditions (Lancelle et al., 2012). This corresponds with the situation the speed regulation system is primarily designed for. Therefore, the analysis of the integrated use of speed regulation assistance and the mobile phone only considers those calls that took place on the highway under free flowing traffic conditions. In 29 (36%) of the 81 identified calls, the driver's CC was switched on when the call started and additional nine calls (11%) started when the SL was activated. Thus almost half of the calls could be identified as integrated with speed assistance. However, it has to be considered that CC was active during 51% of the time on the highway under free flowing conditions (Lancelle et al., 2012). By comparison, the percentage of calls with active CC does not indicate a systematically integrated use of the speed regulation and the mobile phone.

Detailed NDS

A total of 255 calls were identified in the detailed NDS, with 228 (88%) hands-free calls and 27 (12%) hand-held calls. Figure 10 shows the types of calls that have been specified through the phone diaries. For the following analyses only incoming and outgoing calls were used. The considerable share of outgoing calls (n=126; 66%) confirms drivers' intentions to use the mobile phone in the car, compared to the 66 incoming calls (34%) that are not initiated by the driver.

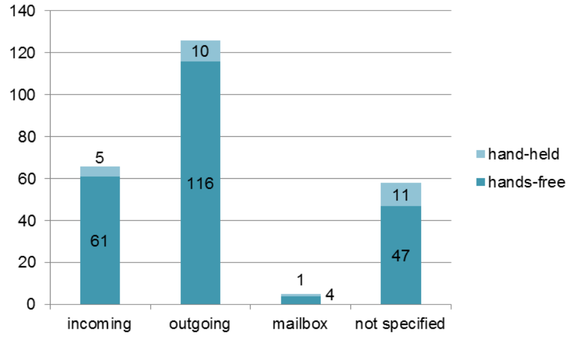

Figure 10: Overall distribution of hands-free and hand-held calls depending on call type.

The overall distribution of call lengths points towards an increased share of short outgoing calls (Fig. 11). Statistical analyses confirm the higher percentage of short outgoing calls than short incoming calls (Z=2.40, p=.017, Fig. 12). However, no systematic differences were detected for medium or long calls (Fig.12).

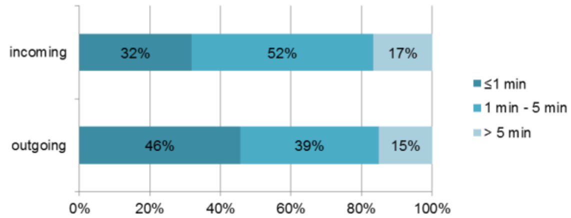

Figure 11: Overall distribution of incoming and outgoing calls depending on call length.

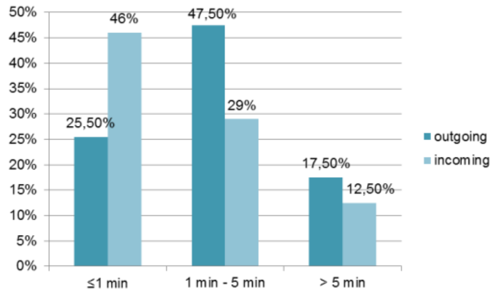

Figure 12: Median values over participants' distribution of incoming and outgoing calls depending on call length.

The fact that outgoing calls were short to a greater extent than incoming calls could be due to a stronger influence of the drivers on the call length when they initiate the call themselves, i.e. a better possibility to avoid long calls. On the other hand, the motive of the calls may explain this effect, if the drivers used the phone primarily for motives that could characterize such short calls. The following driver comments from the interview reinforce this assumption:

- *I use the phone for urgent calls.*
- *I make calls related to the trip.*
- *I inform about my arrival.*
- *It's useful if you need information regarding the trip.*
- *I use the phone to plan, organize and make appointments.*
- *You have access to information, also related to the trip.*

The higher percentage of outgoing calls on urban roads in the overall data (Fig.13) could not be confirmed statistically on participant level (Fig. 14). This could possibly be due to the existence of different user types or to the limitations of the small data sample.

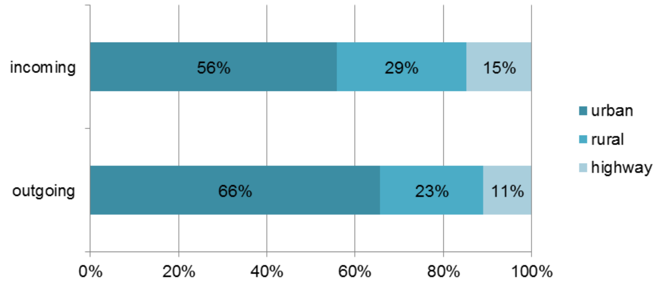

Figure 13: Overall distribution of incoming and outgoing calls depending on road types.

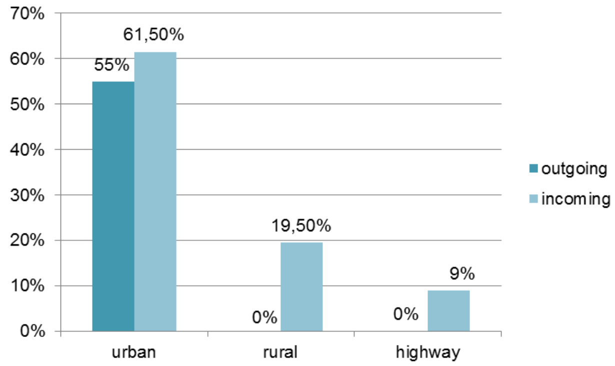

Figure 14: Median values over participants' distribution of incoming and outgoing calls depending on road types.

In accordance with the results on hands-free calls in the small-scale study, the calls in the detailed study mostly took place when car was moving (overall distribution: Fig. 15; participant level: $Mdn_{in,>10km/h}$=100%, $Mdn_{out,>10km/h}$ =92.5%). The data on the car movement at the beginning of the call (overall distribution: Fig. 16; participant level: $Mdn_{in,>10km/h}$=94%, $Mdn_{out,>10km/h}$ =86%) hints at a similar trend as in the small-scale study. Given that the numbers behind some percentages are very low here, no statistical testing was performed to verify this effect.

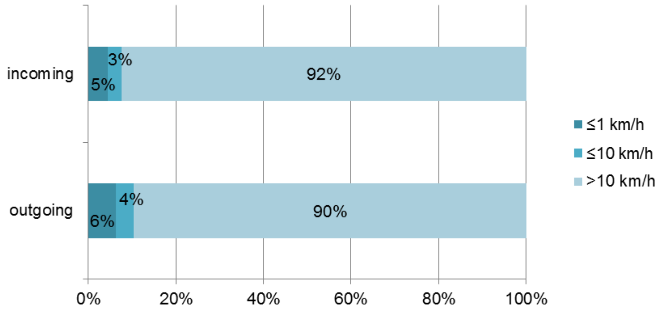

Figure 15: Overall distribution of incoming and outgoing calls depending on car movement (mean speed during call).

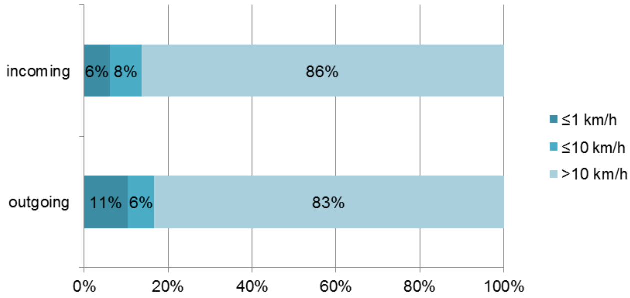

Figure 16: Overall distribution of incoming and outgoing calls depending on car movement (speed when call starts).

The 14 calls that have taken place on the highway under free flowing traffic conditions in the detailed study include eight outgoing calls, where the driver may have chosen an assisted driving situation to make the call. Although more than half of those calls were initiated when a speed assistance was active (n=3 with CC, n=2 with SL), the low number of cases does not allow any conclusion on the integrated use of speed regulation and the mobile phone. Still, the interview data points towards strategies that are related to the CC:

- *It happens that I put CC on for a call.*
- *I activate CC or SL when I prepare an outgoing call.*
- *Generally I try to stop the car or call back later. But if I am on the highway and the traffic is flowing, I keep talking on the phone with CC on.*
- *I take advantage of the CC on the highway in order to compensate the decrease of attention to the road.*

Due to a data processing problem, one handling data set could not be used. In the remaining nine handling data sets, 864 handling episodes were identified in the detailed study. Of those, 159 were directly related to a call (i.e. had an overlap with a call episode). Most of the handlings were less than one minute long (n=748). Figure 17 shows the histogram of handling durations up to one minute.

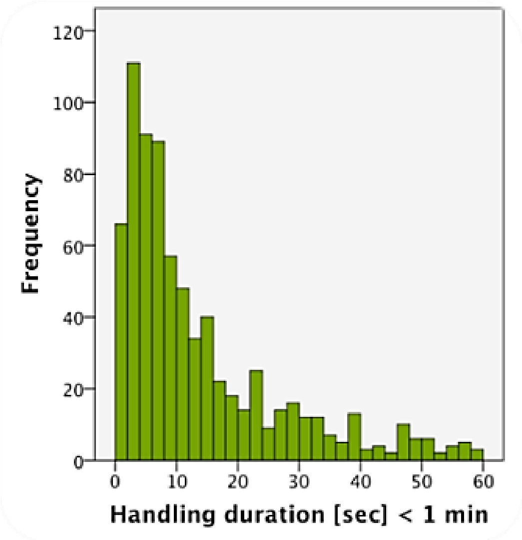

Figure 17: Histogram of handling durations <1 min.

Overall, the handlings occurred mostly in urban areas (64%; Fig.18). Statistical tests comparing the rates of handlings on the different road types per person confirmed that the rates were significantly higher on urban roads than on rural roads or highways ($\chi^2(2)=9.56$, $p=.008$, post-hoc comparisons: urban/rural: $Z=-2.31$, $p=.021$; rural/highway: *n.s.*; urban/highway: $Z=-2.67$, $p=.008$; Fig.19). This result reflects the fact that handlings include taking the phone in hand at the beginning and end of a trip, but it may also be related to the motives of the handling (preparation of call, need for information).

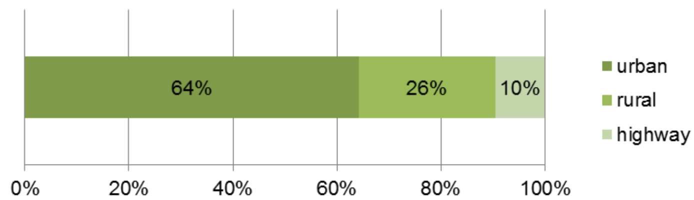

Figure 18: Overall distribution of handlings depending on road types.

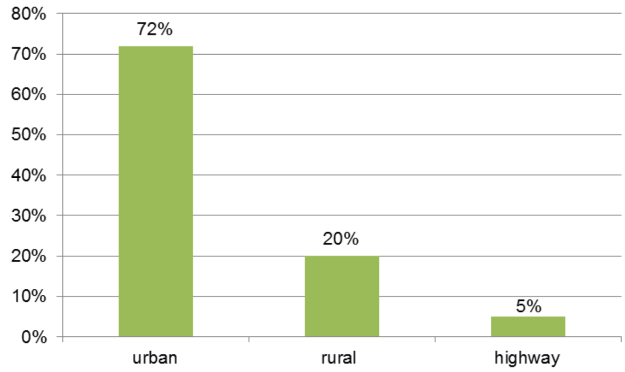

Figure 14: Median values over participants' distribution of handlings depending on road types.

As shown in Figure 18, significant shares of handlings took place when the car was stopped (40%) or moving above 10km/h (51%). On participant level, these two categories differ significantly from the category "moving slowly", but not between each other ($\chi^2(2)=14.00$, $p=.001$, post-hoc comparisons: stopped/moving slowly: $Z=-2.67$, $p=.008$; moving slowly/moving: $Z=2.67$, $p=.008$; stopped/moving: *n.s.*; Fig.19).

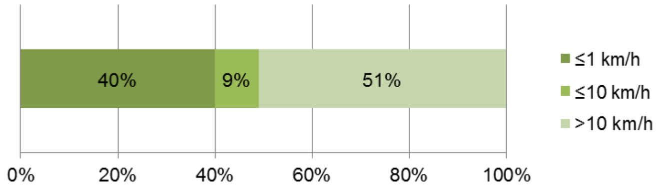

Figure 18: Overall distribution of handlings depending on car movement (mean speed during handling).

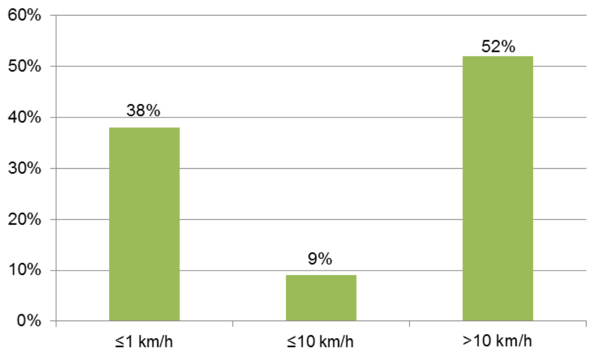

Figure 19: Median values over participants' distribution of handlings depending on car movement (mean speed during handling).

Discussion

By using naturalistic driving observations, the present study allowed exploring mobile phone use in a largely noninvasive way and gaining insights into the context of mobile phone use in everyday driving. The high percentage of hand-held calls found in the small-scale study is remarkable, given that this behaviour is prohibited by law in France and all participants had a hands-free kit at their disposal. On the one hand, the data coders did not have the support of the phone diaries in the small-scale study and may have failed to identify all hands-free calls, resulting in an underestimation of hand-held calls (and overestimation of hand-held call rate). On the other hand, the lower percentage in the detailed study may be due to differences in the participant sample or to more compliant behaviour of the participants, since the phone diary might have served as a constant reminder of being observed. In any case, exploring the reason of hand-held calls in future research could help finding measures to prevent this behaviour.

Still, the presence of safety-conscious behaviour was suggested by the characteristics of hand-held calls, i.e. high rates of short call durations and of calls when the car was stopped or moving slowly. The hands-free calls were typically longer and occurred to a great majority when the car was moving. Interestingly, they were initiated to a significant extent when the car was stopped or moving slowly. This behaviour could be an indicator of the drivers' awareness of the manual and visual distraction that the beginning of a call implies. A more thorough analysis of the situations when the car is stopped will be necessary so as to reach more specific conclusions. The shorter duration of outgoing calls may well be a sign of the drivers' intention to avoid long calls while driving, although the driver comments hint at an alternative explanation, since the main motives of mobile phone use during driving may imply predominantly short conversations. These motives could also explain the relatively high share of urban calls, although no differences were found between different call types regarding road preferences. There is a need to investigate interactions with the mobile phone in urban settings in more detail.

An integrated use of the mobile phone with speed regulation assistance could not systematically be detected in the ojective data, but indications for related usage strategies were found in the drivers' self-report data. As an important limitation, the present study did not consider whether the assistance system was activated once the call had started. Moreover, the level of automatisation or the nature of the support function provided by the system may be decisive regarding the integrated use of the mobile phone and should be investigated in future studies.

Finally, the study revealed that handlings of the phone (manipulations and glances) were frequent and to a large extent not directly related to a call. The fact that handlings took place regardless whether the car was moving or stopped and that a high share of handlings occurred in urban areas gives reason for concern, since handlings imply visual or manual distraction in addition to cognitive distraction. By consequence, a more thorough analysis of different types of handlings and their context needs to be carried out in the future.

The differences found between hand-held and hands-free calls indicate that the context choice of mobile phone usage may depend on the demands related to the phone usage. However, demands related to the driving task could not be confirmed as having an influence in the present study. More evidence is needed in order to conclude on an integrated use of the mobile phone with speed regulation assistance, for example. Most importantly, the study points towards a high relevance of the nature of the call. Not only are there differences between incoming and outgoing calls, but the call motive seems to be an important variable that could have a stronger influence on the choice to use the phone than situational factors. Further factors of potential relevance are person-related variables, but these were not analysed in this study.

Although this naturalistic study is of explorative character and limited to a relatively small participant sample, it allows obtaining important insights that go beyond the possibilities of self-report or observational studies. The high external validity achieved is worth facing the challenge of analysing and interpreting naturalistic driving data sets as it has been done in this study, despite the lack of automated triggers for the analysis of mobile phone interactions. Nonetheless, the influence of third variables that remained unconsidered given that the study context is not controlled cannot be ruled out. The main achievement of the present study is having met the challenge to find meaningful variables and suitable categories to describe mobile phone interactions within their natural context, and having identified specific situations of interest that will guide new analyses after more detailed coding.

Acknowledgements

The research leading to these results has received funding from the European Community's 7th Framework Programme (FP7/2007-2013) under grant agreement 238833 and 218560. The authors thank Philippe Deleurence, Fabien Moreau and Bruno Piechnik for their technical support during the conduction of the studies.

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