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THE USE OF NAVIGATION SYSTEMS IN NATURALISTIC DRIVING

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ABSTRACT

Objective: In this study we assessed the use of portable navigation systems in everyday driving by applying in-vehicle naturalistic driving.

Method: Experienced users of navigation systems, seven female and fourteen male, were provided with a specially equipped vehicle for approximately one month. Their trips were recorded using four cameras, GPS data and other sensor data. The drivers' navigation-system use data were coded from the video recordings, which showed how often and for how long the system was activated and how often and for how long a driver operated the system.

Results: The system was activated for 23% of trips, predominantly on longer and unique trips. Analyses of the percentage of time for which the speed limit was exceeded showed no evidence of differences between trips for which the navigation system was used or not used. On trips for which the navigation system was activated, participants spent about 5% of trip time interacting with the device. About 40% of interacting behaviour took place in the first 10% of the trip time, and about 35% took place while the car was standing still or moving at a very low speed, i.e. 0-10 km/h.

Conclusion: These results shed light on how and when drivers use navigation systems. They suggest that although drivers regulate their use of such systems to some extent, they often perform risky tasks while driving.

KEYWORDS

Naturalistic driving, distraction, road safety, navigation system

INTRODUCTION

Navigation systems have become common in the last decade. They are mainly classified as driver comfort systems (Brookhuis, De Waard, & Janssen, 2001), but their economic and ecological benefits (due to shorter routes) are unequivocal. Although we know a lot about how navigation systems affect driving, their effects on driver and road safety are largely unknown, as experimental studies do not tell us how drivers use navigation systems. Operating a navigation system, for example, might cause a driver to become distracted, which in turn could lead to unsafe behaviour in traffic. It is reported that visual-manual distraction in particular is typically associated with 5-25% (Hurts, Angell, & Perez, 2011), and some believe even up to 80%, of all crashes (Dingus et al., 2006), as well as significant increases in risk (Klauer, Guo, Sudweeks, & Dingus, 2010).

The current study focuses on the use of nomadic navigation systems: how and when they are used in naturalistic driving, and whether this can affect driving speed. First, we address the literature regarding two distinct tasks involved with navigation systems; namely, following route guidance instructions and operating the system.

Following Route Guidance Instructions

The primary task of a navigation system is to provide the driver with route instructions. Compared to traditional navigation methods, this is especially helpful when the driver is in unfamiliar surroundings, in terms of workload and driving errors, for instance (Antin, Stanley, & Cicora, 2009). One clear benefit of using a navigation system is that it can allow for decreased exposure to traffic by providing a shorter/faster route (Antin et al., 2009; Feenstra, Hogema, & Vonk, 2008). On the other hand, the fact that navigating has become so easy may also encourage some drivers to go to places that they would not otherwise have visited, thus increasing exposure (Emmerson, Guo, Blythe, Namdeo, & Edwards, 2013). Furthermore, having alternative routes may lead drivers off motorways onto access roads, which reduces safety (SWOV, 2010).

Between 35% and 55% of European drivers own a navigation system (Jamson, 2013) and roughly 25% of drivers, mostly high mileage drivers (Jamson, 2013), use such systems on a regular basis (Jamson, 2013; Lansdown, 2012).

Compared to driving with a paper map, driving with a navigation system reduces the driver’s mental workload (Feenstra et al., 2008). Other differences appear to be small (for example, a slightly higher mean speed) to non-existent (Feenstra et al., 2008). Olson et al. (2009) report that for commercial vehicle drivers, looking at paper maps is associated with a substantially increased likelihood of having a crash or near crash (odds ratio 7.02). In short, the literature seems to suggest that as long as route guidance instructions are kept simple (Dalton, Agarwal, Fraenkel, Baichoo, & Masry, 2013) and instructions are reliable (Ma & Kaber, 2007), drivers have sufficient support when using a navigation system for route guidance.

Operating the Navigation System

Several studies have investigated destination entry by the driver (e.g., Burnett, Summerskill, & Porter, 2004; Chiang, Brooks, & Weir, 2004). The respondents in a study by Lansdown (2012) rated the level of distraction caused by destination entry as ‘medium’ (3 on a 5-point scale). About 35% of respondents reported that they entered data while driving, while 12% did so on a daily or weekly basis. Jamson (2013) found that 10-30% of drivers say that they sometimes enter or change a destination while driving. In a field study by Metz et al. (2014), the drivers reduced their speed just before operating the navigation system and they maintained a longer headway distance. Furthermore, the nomadic device used in that study led to deterioration in lateral performance, whereas a built-in navigation system did not.

Operating a navigation system is a visual-manual task. Another visual-manual task, texting, increases the risk of being involved in a crash in naturalistic commercial vehicle driving (Olson, Hanowski, Hickman, & Bocanegra, 2009) and normal car driving (Fitch et al., 2013). It could be argued that practising visual-manual tasks could help drivers to avoid some of the consequences. Indeed, in a study by Nowakowski, Utsui, & Green (2000), practice shortened destination entry duration; however, lateral driving performance in particular still deteriorated.

Whereas voice-controlled destination entry may seem less distracting than manual programming, drivers still take their eyes off the road, because they seek confirmation that the input is correct. However, these glances are generally more rapid and the overall eyes-off-road time is shorter (Tijerina, Parmer, & Goodman, 1998).

In short, although following route guidance instructions may hardly affect driving, it is likely that operating a navigation system does. The net effect on safety is unclear, however, as we lack information about how drivers use their systems in practice and how this can affect their driving. Moreover, as navigation systems are changing rapidly and their use is increasing, past studies may not accurately represent current experiences.

Study Objectives

The present study assesses how experienced users of recent navigation systems are actually using such systems in everyday driving. The general research question addressed is: *How do drivers use their navigation systems in real driving?* More specifically, we investigated:

1. On what kinds of trips, how often, when and for how long do drivers use navigation systems?
2. What are the effects on speed behaviour of driving with a navigation system?

We analysed patterns of drivers’ use of navigation systems in order to identify behaviour that could potentially affect safety. Furthermore, as navigation systems often display information regarding speed (i.e., the current speed, the current speed limit and speed-check information), and speed is an important driving safety-related measure (Aarts & Van Schagen, 2006), we assessed whether we could infer the effects of using a system supplying such information on speed behaviour. For instance, as GPS speed shows a realistic speed (and the speedometer in many motor vehicles, including the ones used in our project, shows an optimistic speed), it could be the case that drivers drive slightly faster than they otherwise would when using a navigation system.

METHOD

Participants

Drivers were invited to participate by means of posters and digital newsletters distributed at the Delft University of Technology. Those who expressed an interest were sent a short questionnaire. Drivers who indicated that they use (1) a mobile phone and (2) a navigation system at least once a week, and (3) drove at least 200 km per week were selected. The eventual sample consisted of 21 drivers (fourteen male and seven female) with an average age of 37 (SD=9.7). They had had their driver's licences for fifteen years on average (SD=9.4) and reported that they drove an average of 23,226 km per year (SD = 6,974).

Procedure

Participants were briefed about the project, but not about the research goals. The project included driving in a vehicle for five to six weeks that had been equipped with a camera and other recording devices. The participants gave their consent and were asked to use the car as if it were their own. All participants received financial compensation after completing the study.

Vehicle

Participants were given either one of four Lancia Ypsilons or a Peugeot 207. All five cars were equipped with a data acquisition system containing several components, including a PC, four cameras (directed at the driver, the driver's face, the forward view and the navigation system, all recording at 12.5 Hz) and a 1 Hz GPS/GSM device. The system did not require participants to perform any tasks extraneous to their normal driving behaviour. Booting took about two minutes and the GPS device took another four minutes to receive a proper signal (depending on conditions), meaning that speed-related data were incomplete for some trips. This applied in particular to the beginning of trips, although GPS reception could sometimes also be distorted during trips.

Participants were provided with a Bluetooth hands-free device and a five-inch touch-screen TomTom Go Live 1005 navigation system that could be mounted in the car (see Figure A1). In the Lancia Ypsilons, the navigation system windscreen mount was installed to the left of the steering wheel, with a camera facing it. In the Peugeot 207, the system was mounted to the right of the steering wheel. The different vehicle dashboards layouts did not allow for an identical installation set-up. The navigation system was equipped with modern functions, including real-time traffic information, voice control, current speed and (mobile) speed camera information, and was fully operable during driving. One participant used his own navigation system (a different brand).

Data Analyses

Trips in the test vehicles made by drivers other than the registered participants were omitted from the analyses. Furthermore, each participant's first week of driving was excluded to ensure that they had become familiar with the vehicle. This was not communicated to the participants beforehand.

The video data were manually coded by four data reductionists using in-house designed software that allowed for connecting the numeric data (such as GPS speed) to the video data, and for enriching the data with observations inferred from the video recordings. For each task, the start time and end time were coded. The navigation system visual-manual tasks were defined as follows:

1. *Reaching, grabbing or mounting* (all interactions that were needed to make the navigation system ready for operation). This event would start as soon as the driver started looking for the device, and ended when the driver was either back in his normal driving position or started operating the device.
2. *Programming a destination*, including voice control. Operation would start with the driver's first glance at the device (before touching), or the first time the driver's hand started moving from its resting position (often the steering wheel). An event ended when the driver's hand was back to a normal position, or, when insecure, when the driver looked at the road again.
3. *Other operating* was coded when the driver was holding the device in his hands while operating it, as it was not possible to verify whether the operation concerned destination entry. This code also applied to other functions (volume, map zooming), so the coders were instructed to watch the navigation screen if available.

Coding always began at the start of a trip in order to record the mounting and destination-entering that was done before driving. Coding was paused when the car was parked during a trip (e.g., when waiting for passengers, not participating in traffic). Coding ended at the end of the trip, when the driver had parked. Hence, coding did not take place when drivers demounted the system at the very end of the trip, while parked. This avoided the data being contaminated with actions that did not involve any kind of actual driving.

Trips were randomly assigned to the coders, who watched each trip at a high video speed and slowed down or paused the video when an event (i.e. a task) occurred. They coded the start and the end of each event. In order to ensure high-quality data, the coders discussed potentially ambiguous behaviour on a weekly basis. Inter-coder reliability was assessed by having a total of 50 randomly-selected trips coded a second time, in addition to normal coding. The duration and presence of all events coded in those trips were compared and tested statistically using Krippendorff's α (Hayes & Krippendorff, 2007). The agreement level for code presence (nominal measurement level) was α = .89, and for duration (ratio) α = .83, which are both above the recommended level of agreement of α = .80.

RESULTS

Regarding the route guidance function, we included all trips during which the navigation system was activated, regardless of whether the destination was set or not. On a general note, the data did not reveal any crashes or major incidents.

Following Route Guidance Instructions

What kinds of trips? The navigation system was activated for about 23% of trips (300 of a total of 1306 trips). The 21 participants' general driving behaviour is summarised in Table A1.

It was determined whether trips were driven only once or repetitively over the observation period. Trips were considered repetitive if the start was within 1,000 m, the finish was within 500 m, and the difference in trip length was shorter than 3 km. A total of 740 (M 35.2, SD = 19.1) trips were recorded that matched other trips (that is, that were repetitive), and 566 that were unique (M = 27.0, SD 10.6), including a distinction between long (longer than 5 km) and short trips (shorter than 5 km). Not surprisingly, navigation systems were used the least for short, repetitive trips, while the average percentage of trips in which a navigation system was used was highest for unique long trips, which constituted almost half of the trips (see Table A2). A three-way loglinear analysis (navigation system use x repetitiveness x trip length) revealed a model that retained the three two-way interactions. The model's Likelihood Ratio was $\chi^2(1)= .019$, $p=.89$. The interaction navigation system use x repetitiveness interaction was significant, $\chi^2(1)= 75.2$, $p<.001$, indicating that participants used the navigation system less often on repetitive trips (odds = .13) than on unique trips (odds = .60), odds ratio = 4.53. The navigation system use x trip length interaction was significant, ($\chi^2(1)= 112.3$, $p<.001$. The odds ratio revealed that the odds of using the system were ten times more likely on long trips (.49) than on short trips (.049). Finally, the repetitiveness x trip length interaction was significant, ($\chi^2(1)= 38.0$, $p<.001$). This means that short trips had a higher likelihood of being repetitive (2.81) than long trips (.91), ratio 3.09.

Next, trips for which the navigation system was used were compared to trips with no use, as depicted in Table 1. Trips for which the navigation system was used were on average longer. Furthermore, the average speed was considerably higher, which is probably due to the higher percentage of motorway driving on longer trips. Table 2 shows the mean speed in several speed limit zones. In order to assess whether the participants on average drove faster with a navigation system than without, for different speed limits, a 2 (with or without navigation systems) * 5 (50, 70, 80, 100, 120 km/h speed limit sections) factorial repeated measures ANOVA was carried out. Mauchly's test indicated that sphericity could be assumed for the navigation system-use main effect. The navigation system-use main effect was not significant ($p=.097$, $r=.13$), meaning that the participants drove slightly but insignificantly faster during trips for which they were using the navigation system.

Table 3 shows the mean percentage of trips for which participants used a navigation system, across different temporal units. During the morning peak (excluding weekends), a relatively high percentage of use was observed compared to during the afternoon peak. Related to this observation, in the mornings and afternoons (including weekends) the percentage of trips for which the navigation system was used was relatively high compared to the evenings. Distinguishing between the first trip of the day, the last trip of the day and other trips (including trips on days when only one trip was made), it appears that participants used the navigation systems less often for the last trip of the day.

Navigation system use and speeding: We investigated whether navigation system use affects drivers' speed, as navigation systems provide information about current speed (based on GPS data), the current speed limit and speed cameras. Furthermore, drivers who know that GPS provides a realistic speed measure may drive closer to the limit or exceed the speed limit somewhat more often when using a navigation system. We compared the percentage of time the speed limit was exceeded for trips in which a navigation system was used and other trips. Table 4 shows the results for different speed limits and the extent of speeding. When we compared driving with or without a navigation system, no significant difference was found for exceeding the speed limit for either 50% or 20% of the time. The only substantial difference was found when the total percentage of time driving above the current speed limit (i.e. 50.1 km/h) was compared for trips with and without the navigation system.

Visual-Manual Tasks

When performed? The study distinguished between three visual-manual tasks (see data analyses section). The results regarding these coded events are presented in Table 5. The table shows that participants on average operated the device approximately 50 times in total, and that destination entry required the most time. For about 5% of the driving time, participants were engaged in operating/installing the device during trips that involved navigation system use, which adds up to about 1% of total driving time. Furthermore, participants showed more navigation system interactions during unique trips.

For each operating event, we determined for which part of the trip (as a percentage of trip time) the event started. Figure 1 shows that almost half of all the operating events occurred in the first 10% of the trip durations. The small increase in reaching/grabbing/mounting at the end of the trip (see the right side of Figure 1) reflects the fact that some drivers removed the navigation system from its mount near the end of the trip, while they were still driving. Likewise, about 40% of all interactions were performed at very low speed (up to 10 km/h; see Figure A2).

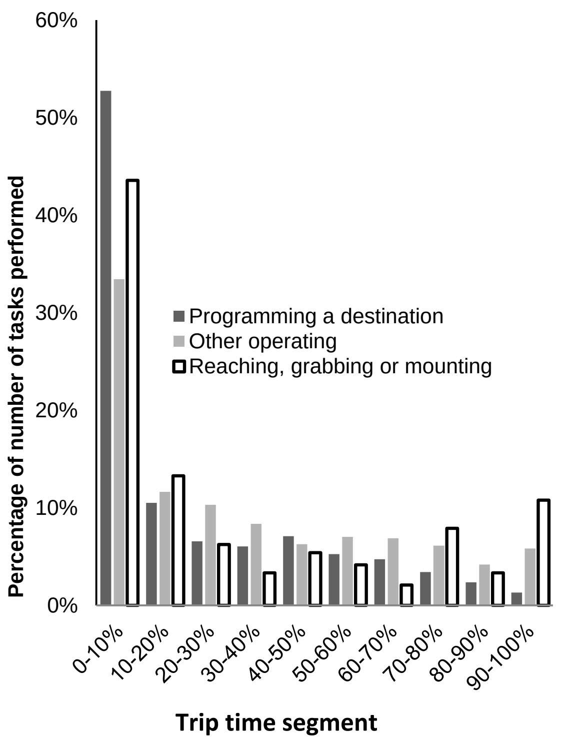

Figure 1: On which part of the trip did visual-manual tasks start? (See the data analyses section for a detailed description of these tasks.) To determine the trip time segment to which each operating event belonged, the following formula was used: $\frac{\text{event start time in s}}{\text{total trip time in s}} * 100\%$.

Effects of visual-manual tasks on speeding: The percentage of time (in seconds) that drivers drove at a speed above the speed limit was calculated for three timeframes: six seconds before operating the system, during the operation and for six seconds after the operation. Before operating, drivers drove above the speed limit for 10.3% of the timeframe; during operating, they were above the speed limit for 9.2% of the timeframe; and after, 13.8%. These differences are statistically significant ($F(2)=3.666$, $p<.05$, no sphericity violations). Comparison revealed no difference between the 'before' and 'during' conditions ($F(1)=.76$, $p>.05$), but in the six seconds after the operation, substantially more speeding was observed ($F(1)=5.51$, $p<.05$) than during the operation. Figure A3 presents these results as a boxplot.

DISCUSSION

The data reveal that the participants used the navigation system for about a quarter of all trips. Relatively frequent use was observed for trips that participants made only once during the observation period and for longer trips, both in terms of distance (over 5 km) and time (more than 40 minutes). Furthermore, morning peak hours showed higher use than afternoon peak hours, which may be attributed to the fact that trips home (in the evening, after work) tend to be to familiar destinations. The trips for which the navigation system was used showed higher percentages of time driving on motorways. This is probably related to the fact that these trips were longer and motorways are the fastest way to reach a destination. When controlling for speed limit, we found that drivers did not drive substantially faster with a navigation system than without.

Next, we compared GPS speed recordings to the posted speed limits, as we suspected that the drivers might know that the GPS speed shows a more realistic speed than many car speedometers (that are optimistic about speed, Wikipedia, 2015). During trips in which participants used a navigation system, we observed a slightly higher percentage of speeding, but only when including all speeding, including driving slightly above the speed limit (0.1 km/h or more). Several participants indicated that they knew that GPS data typically provide a lower speed than the car speedometer. Thus, drivers may drive slightly faster when using the speed information from the navigation system, which is reflected in the higher percentage of speeding. This effect might be tempered by the fact that drivers quickly learn how optimistic their vehicle speedometer is and adjust for it. A study by Feenstra, Hogema & Vonk (2008), also an on-road driving study, likewise found that somewhat higher speeds were driven while using a navigation system compared to driving with a conventional map. Note that this might be for another reason: as reading a map is so demanding, drivers may choose to drive more slowly.

During trips for which they used their navigation system, the participants operated their system mostly (about 50%) in the first 10% of the trip time. They spent about 5% of trip time mounting or operating the system, while practically standing still for about 40% of that time. This 5% is probably an underestimation, since the GPS often took a while to start up. Nevertheless, the results confirm Funkhouser & Sayer's (2012) finding that drivers regulate their behaviour to some extent by operating the system while (practically) standing still or driving at low speed, probably recognising the fact that this is the safest moment to do so. However, drivers still do a relatively large amount of operating during normal driving. Given the significant impact of operating navigation systems on driving performance, this may have a considerable effect on safety, certainly when we take into account the finding by Merat et al. (2005) that drivers have difficulties abandoning a secondary task, including when circumstances become more demanding. When they operated the navigation system the drivers slowed down somewhat, as compared to right before and right after operating. It is not uncommon for drivers to slow down when demands are high, for instance during texting (for an overview, see Caird, Johnston, Willness, Asbridge, & Steel, 2014; also see Metz et al., 2014). Although not entirely surprising, these are the first figures that accurately describe how and when drivers use navigation systems.

Limitations

Several limitations should be noted. Our sample was relatively small and consisted of voluntary participants, which could have caused self-selection bias. Furthermore, the fact that recruitment took place at Delft University could mean that the sample is somewhat biased. Our participants were both frequent drivers and experienced users of navigation systems, however, which may make them relatively safe users (Dingus, Hulse, & Mollenhauer, 1997). Furthermore, actual use for five weeks is a relatively long observation period, and this is the first study to report on real-life use in such detail.

Participants were not informed beforehand about the purpose of the study, but they may have suspected that the navigation system was the target of the investigation when they noticed the camera pointed at it. In addition, the fact that we provided a windscreen-mounted navigation system may have added to the ease of using the system, potentially increasing the use.

Another limitation is that the GPS system became active only after several minutes. This meant that a relatively small amount of valuable information was lost, because the speed, speed limit and environment could not be determined during the whole period. One important issue affecting the specific navigation system used in this study was the fact that the power button did not always function as expected: when pressed for too long, the system would shut down again. Participants were informed about this issue during the briefing. This did occasionally cause participants to perform actions that were related only to the specific device, however minor. Furthermore, although participants reported that they soon forgot that they were being observed, we received some signals that this may have occasionally influenced participants' behaviour.

Conclusion

In real-life driving, the participants used their navigation systems predominantly on relatively long, infrequent trips. During the trips for which they used their navigation systems, there was a mild increase (approximate 5%) in instances of speeding and they drove at slightly (but insignificantly) higher speeds. Our general conclusion is that while these effects are small, they have a negative impact on road safety, as driving at higher speeds increases the risk and severity of crashes (Aarts & Van Schagen, 2006).

In addition, of the time that participants spent operating the navigation system, about half of this time was spent at the beginning of the trip. During this time, the car was not moving for about 40% of the time, meaning that the major part of operation was performed while driving. Operating a navigation system is a visual-manual task. Conducting visual-manual tasks such as texting means taking one's eyes off the road, and thus increases the risk of crashing (Klauer et al., 2014).

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Table 1: Characteristics of trips for which participants did or did not use the navigation system

	Without navigation system		**With navigation system**		**T-test (df=20)**	
Trip characteristic:	**Mean**	**SD**	**Mean**	**SD**	**t**	**P**
Number per participant	47.9	20.3	14.3	9.5	-6.32	.00
Distance driven (km)	13.8	8.8	40.7	21.3	-5.79	.00
Duration (s)	1249.0	487.8	2661.4	938.2	-6.48	.00
Mean speed (km/h)	31.7	7.8	52.4	11.2	-7.00	.00
% of time on urban road	64.7	12.8	48.2	15.5	3.93	.00
% of time on rural road	13.0	10.8	16.7	7.6	2.16	.04
% of time on motorway	12.6	9.6	34.4	15.6	-6.34	.00
% of time road type unknown due to incomplete map	9.7	7.3	0.7	1.8	5.46	.00

Table 2: Mean speed for several speed limits, with and without use of navigation system

	Trips with navigation system		**Trips without navigation system**	
Speed limit	**Mean speed**	**SD**	**Mean speed**	**SD**
50	23.4	4.9	20.1	4.3
70	59.3	13.2	62.6	16.4
80	61.9	10.4	58.3	13.1
100	87.3	11.6	85.7	9.6
120	86.3	17.3	78.2	18.8

Table 3: Mean percentage of trips for which the navigation system was used in several time-related units

Temporal unit	Proportion of trips for which navigation system was used	
	Mean (%)	**SD (%)**
Week (Mo-Fr)	24.0	17.2
Weekend (Sa, Su)	25.6	19.3
Mondays	23.0	22.7
Tuesdays	25.0	19.7
Wednesdays	28.9	23.9
Thursdays	21.4	25.9
Fridays	19.3	22.2
Saturdays	24.6	25.4
Sundays	34.6	33.7
First trip of the day	26.9	17.6
Last trip of the day	19.0	18.1
Other trips	27.0	20.8
Morning peak (7.00-10.00)[a]	34.1	29.4
Afternoon peak (16.00-19.00) [a]	21.2	20.4
Off-peak/other hours [a]	25.4	19.6
Night (0.00-6.00)	n/a[b]	
Morning (6.00-12.00)	29.3	20.9
Afternoon (12.00-18.00)	25.3	18.9
Evening (18.00-24.00)	17.3	17.4

[a] Excludes weekends

[b] Only 9 trips fit this criterion

Table 4: Percentage of time that drivers exceeded the speed limit, driving with or without a navigation system

		Trips with navigation system		Trips without navigation system			
		Mean percentage	**SD**	**Mean percentage**	**SD**	**T-test (df=20)**	**Effect size (r)**
>50% over speed limit	Overall	.6	.5	.5	.4	NS	.13
>20% over speed limit	50	4.6	2.7	3.2	2.4	NS	.41
	70	10.9	11.9	14.7	20.3	NS	.17
	80	3.9	4.1	3.3	4.9	NS	.22
	100	5.9	8.0	5.0	7.2	NS	.17
	120	.2	.4	.1	.2	NS	.28
	Overall	4.1	2.8	3.2	2.6	NS	.40
All speeding (any speed above the speed limit)	50	12.2	5.4	9.7	4.1	NS	.40
	70	29.2	17.9	31.6	21.0	NS	.10
	80	22.2	13.4	19.2	14.0	NS	.21
	100	34.6	20.3	37.0	22.9	NS	.14
	120	15.2	18.4	15.5	19.7	NS	.03
	Overall	20.4	11.7	14.8	7.8	2.61, p=.017	.50

Note: Effect size r is calculated using $r = \sqrt{\frac{t^2}{t^2+df}}$

Table 5: Visual-manual task characteristics, as coded from the video data (see methods/data analysis section for definitions)

	Reach, grab, mount		**Destination entry**		**Other operating**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Total number of times the task was performed	11.5	10.3	18.1	14.3	31.9	28.0
- In repetitive trips	2.6	3.6	5.9	8.0	7.1	10.7
- In unique trips	8.9	8.2	12.2	9.2	24.8	22,8
Task completion time (s)	12.0	4.7	26.6	12.9	15.3	9.7
Number of actions performed in trips for which system was used	.7	.4	1.3	.4	2.2	1.2
% of driving time engaged in task (in trips for which system used)	.8	0.4	2.4	1.1	2.0	1.2
% of driving time engaged in task (for all trips)	.1	.1	.5	.5	.5	.5

APPENDIX

Table A1: General figures relating to participants' trips, including navigation system use

	Total number of trips	Number of trips with Navigation System activated	Total duration (h)	Total duration of trips with Navigation System (h)	Total distance driven (km)	Total distance driven with Navigation System (km)
Total	1306	300	572.3	229.6	26,327.6	12,895.9
Mean per participant (M)	62.2	14.3	27.2	10.9	1253.7	614.1
Standard Deviation (SD)	21.0	9.5	10.9	8.3	635.6	520.3
Min.	28	3	13.1	1.3	506.2	39.6
Max.	109	35	51.1	31.2	2450.1	2043.7

Table A2: Percentage of trips for which the navigation system was used, distinguishing between 'repetitive' and 'unique and long' (<5 km) and 'longer trips' (>=5 km)

	Trip repetitiveness	
Trip length:	**Repetitive**	**Unique**
<5 km	3.0%	9.2%
>= 5km	19.0%	45.2%

Figure A1: Vehicle cabin layout (Lancia Ypsilon), including a navigation system photo. The navigation system mount is installed to the left of the steering wheel, with a camera facing it. In the Peugeot 207 the system was mounted to the right of the steering wheel.

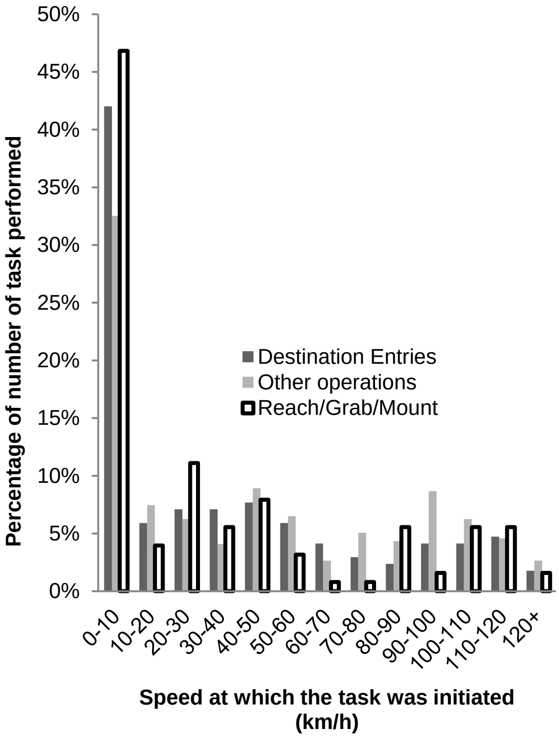

Figure A2: Percentage of visual-manual tasks that were performed at 10 km/h speed intervals.

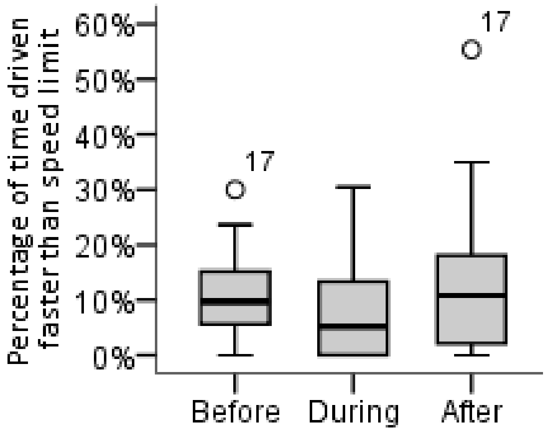

Figure A3: Percentage of time participants drove above the speed limit, 6 seconds before, during, and 6 seconds after they visually-manually operated the navigation system. The dots marked ‘17’ represent outliers (by one participant); the boxplots show minimum, first quartile, median, third quartile and maximum.