Evaluation of Navigation Systems from a Road Safety Perspective

Claus AICHINGER[1], Eva AIGNER-BREUSS[2], Michael ALEKSA[1], Susanne KAISER[2], Anna MÜLLER[2], Katharina RUSSWURM[2]

ABSTRACT

Navigation systems play an essential role in today's traffic system. The increasing availability of navigation-related data changes driving behaviour and reduces routing time. Yet this development also bears risks for users, in terms of distraction or inattention. Empirical findings regarding the distracting effects of navigation systems are heterogenous. The research project ORTUNG aimed at shedding light on these divergent findings by observing drivers under real traffic conditions. In particular, the visual distraction of the use of navigation systems in comparison to traditional map-based navigation was examined by means of eye-tracking and the monitoring of driving dynamics. Differences in routing were also explored. Data analysis indicates increasing road safety when a navigation system is used in unfamiliar areas. Fewer gazes exceeding 2 seconds were found for users of the navigation system whereas map navigation leads to higher eyes-off-the-road time.

1 INTRODUCTION

In the last decade, navigation systems have become a popular and widespread user device in vehicles. Their variability and complexity has increased manifold in the past years. Their benefits are set against their possible distracting effects, which raise the probability of having an accident. Studies show that distraction could be the cause of up to 10 % of all accidents [1].

The increasing amount of research that is being conducted in the field of driver distraction has led to a variety of definitions. Young & Regan [2, p.380] suggest that distraction occurs "when a driver's attention is, voluntary or involuntary, diverted away from the driving task by an event or object to the extent that they are no longer able to perform the driving task adequately or safely".

[1] Austrian Institute of Technology GmbH (AIT), Austria
[2] Austrian Road Safety Board (KFV), Austria

Previous research concerning distraction caused by navigation systems is somewhat heterogenous. The mode of use seems to play an important role: Manual data entry during driving takes up to 9 minutes and is more distracting than talking on a mobile phone or tuning a radio [3, 4]. Even selecting a predefined destination requires 10 to 12 looks at the screen and therefore often leads to inattention. Young [2] identified three aspects that reduce distraction: spoken instead of manual data entry, auditory instead of visual directions and step-by-step instead of overall instructions.

Research commissioned by one manufacturer [5] indicates a positive influence of navigation systems on road safety and the number of accidents, stress level, driver attention and performance. Knapper et al. [6] compared the use of navigation systems and paper-based maps and found no differences between the two test conditions. In contrast, other studies have revealed higher values for reaction time and mental workload [7] as well as lower driving performance [8] for the use of paper maps as opposed to electronic guidance systems.

The objectives of the ORTUNG study were to evaluate the distractive potential of navigation systems as well as to assess their benefits compared to map navigation in unfamiliar areas under natural driving conditions.

2 METHODOLOGY

In order to assess the potentially distracting effects of navigation devices, test drives with 57 participants were carried out in the period from May to August 2013 in and around Vienna, Austria. The test subjects were recruited based on gender, age and driving experience in order to represent the average driving population. Furthermore, unfamiliarity with the test route (38 km), which included all kinds of road types (urban/rural roads, motorways etc.) and information densities, was an important criterion in participant selection. A between-group design was chosen for the study. One group drove the test route using a navigation system (group 1), the other using a paper-based map (group 2). Allocation to one of these groups depended on the subject's own stated preference.

2.1 Test vehicle & sensor systems

Capturing both driver behaviour and visual distraction places a high demand on the measurement system. Accordingly, the following sensor systems were employed in the test vehicle: a faceLAB (Seeing Machines) dash-mounted eye-tracking system, a 3-axial accelerometer, an inertial motion unit, a high precision positioning system as well as the vehicle's own CAN Bus system. The data obtained from these different systems were synchronized to provide a detailed description of both the driver and the vehicle.

2.2 Procedure

Subjects were given the task of navigating a route with five required stopovers. To this end, group 1 was supplied with an ordinary Garmin Nüvi navigation system with a predefined route. Probands navigating using a paper map (group 2) were provided with a road atlas and additional Google Maps printouts showing the exact positions of the predefined stopovers. The subjects in group 2 had to devise an appropriate route for themselves. After the test drives, the probands were asked to complete a questionnaire regarding perceived distraction and difficulties during the drive as well as their experience with and attitudes towards navigation systems.

2.3 Data analysis

Visual distraction was assessed for group 1 (navigation system) by means of eye-tracking. The eye-tracking system provided information about frequency and duration of gazes towards the navigation system. Two seconds are considered the maximum accepted duration for a gaze when interacting with in-vehicle telematics such as navigation devices. Gazes that exceed this critical limit are associated with reduced road safety [e.g. 9, 10]. To examine visual distraction for group 2 (map users), a video tool for semi-automatic event annotation was developed during the project (Fig. 1).

Fig. 1: Eye-tracking and navigation systems in test vehicle (left), data visualisation tool (right). Source: AIT.

3 RESULTS

3.1 Routing

As expected, differences were identified between the two test groups with regard to total driving time and total distance driven. The test subjects who were equipped with navigation systems predominantly followed the proposed route. This resulted in a 17% reduction in route length as well as a 23% reduction in overall driving time compared to the map-using group. While average speed during driving did not differ significantly, the number of standstills was twice as high for group 2 (map users). On average, the driving time for group 1 (navigation system) participants was about 50 minutes for a covered distance of 38 km whereas the members of group 2 spent an average of 65 minutes on the road and covered a distance of 46 km.

Focusing on the difference in route length and driving duration, it is worth noting that from a safety perspective navigation systems help reduce the risk of accident since drivers' exposures tend to be smaller.

3.2 Gaze behaviour

3.2.1 General conclusions

Referring to the overall test run time (including standstills) the comparison of the frequency of gazes at the navigation aid shows that test subjects in group 1 (navigation system) looked more frequently at the device (M=198 glances, SD=110) than subjects in group 2 (map) (M=140 glances, SD=108). However, gaze durations were shorter for group 1 (M=0.46 seconds, SD=0.14) than for group 2 (M=4.1 seconds, SD=2.7). When excluding the standstills, both groups spent the same relative amount of time looking at the navigation aid while the vehicles were in motion.

As a next step, gazes exceeding 2 seconds – which can be considered critical in terms of road safety – were analysed. 31% of these gazes of group 1 occurred while the vehicle was in motion whereas this was the case for 14% of the gazes for group 2. However, the total duration of all gazes exceeding 2 seconds when excluding standstills was much higher for group 2 (group 1: 44 seconds, group 2: 1093 seconds).

Considering the overall test run time (including standstills) all participants of group 2 (map) were found to have had at least one longer gaze at the navigation aid whereas this was the case for only a quarter of the drivers in group 1 (navigation system).

3.2.2 Gazes in the context of speed

Fig. 2 combines driving speeds and gaze analysis: velocity values during long gazes (≥ 2 sec) are visualized using a violin- and boxplot. The larger range of values in terms of velocity in group 2 (map) is evident, suggesting that gazes at the map occur at even higher speeds, where possible accidents are usually more serious.

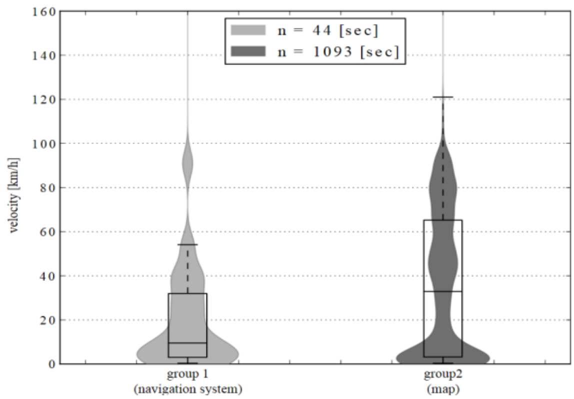

Fig. 2: Violin- and Boxplot of velocity values during gazes with duration ≥ 2 seconds.

3.2.3 Percent Road Centre analysis

In order to obtain a better understanding of possible differences in gaze patterns between the two groups the percent road centre (PRC) was calculated. The PRC is a performance indicator describing the fraction of gazes dedicated to the road centre. Following the methodology devised by Victor et al. [11] a density-based spatial clustering method was applied to the eye-tracking data to calibrate driver-specific ellipsoids defining central viewing areas (Fig. 3). By computing the fraction of gazing falling into these areas a PRC-like indicator was estimated.

The two populations were then compared with respect to certain driving situations such as points of decision along the route. Obviously, group 1 was automatically informed by the navigation system about exits and turns upon approaching a decision point whereas the other group had to solve the navigation task on their own by consulting road signs or the map. Therefore the hypothesis was formulated that the PRC of group 2 (maps) is lower at points of decision compared to group 1 (Fig. 3). This hypothesis was verified as a Welch-test comparing the groups' PRC-values resulted in a p-value of 0.008. It should however be mentioned that the small sample sizes as well as the possibility of non-normal distributed variables may limit the general validity of this finding. Nevertheless analysis suggests that drivers relying on a navigation system are in a better position to focus on the traffic situation in front of the car because of the simplified and 'outsourced' routing and decision making process.

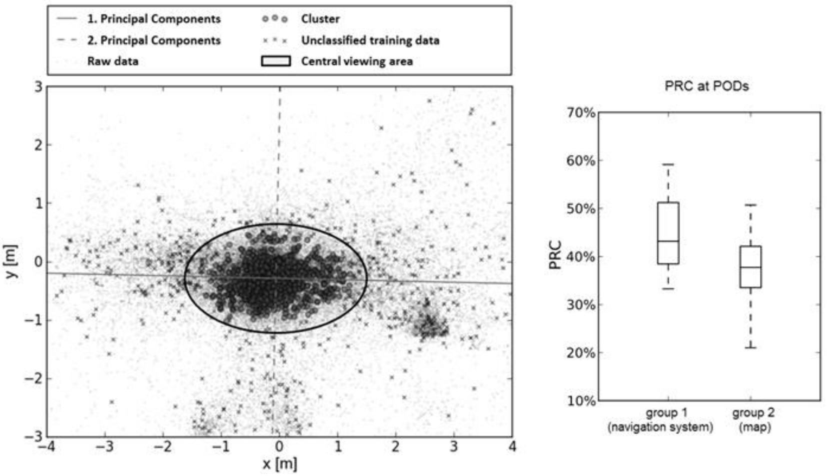

Fig. 3: Left: central viewing field. The dense region in the lower right part represents the navigation system. Right: Boxplot showing difference in PRC at points of decision

3.2.4 Gaze behaviour and driving dynamic data

In order to investigate changes in driving dynamics during gazes on the navigation aids, the cars' speeds, longitudinal and lateral accelerations and steering wheel, velocity pedal and braking pedal angles were compared visually before, during and after gazes ≥ 2 sec. No changes in driving dynamics could be identified.

4 DISCUSSION AND CONCLUSION

The project ORTUNG identified road safety related benefits and disadvantages of navigation systems when used on unfamiliar routes as opposed to navigating with paper maps.

The study confirmed expectations that navigation systems help decreasing travel times and distances.

Navigation systems are looked at more frequently than maps, but – as long as the vehicle is in motion – no differences in the relative amount of time looking at the navigation aid were recorded. However, the total duration of gazes exceeding 2 seconds – which can be considered critical in terms of road safety – is clearly higher for group 2. A comparison of the Percent Road Centre (PRC) indicator suggests that drivers supported by a navigation system are in a better position to focus on the road scene. No changes in driving dynamics during critical gazes were recorded.

The presented results indicate a lower visual distractive potential of navigation systems in the study setting (no data entry during the test drive was needed), when compared to paper map navigation. Less time is spent in traffic, fewer kilometres are driven and the total duration of critical gazes at the navigation system is shorter. However, these gazes do occur in both test conditions and bear risks in terms of road safety.

Acknowledgments

This research project was funded by the Austrian Safety Council (VSF) and is a cooperation project between Austrian Institute of Technology (AIT) and the Austrian Road Safety Board (KFV).

References

[1] Kubitzki, J.: ‚Ablenkung im Straßenverkehr – die unterschätzte Gefahr‘, (Allianz Deutschland AG, 2011, self-published)

[2] Young, K., and Regan, M.: ‘Driver distraction: A review of the literature’, in: Faulks, I.J., Regan, M., Stevenson, M., Brown, J., Porter, A., and Irwin, J.D. (Ed.): ‘Distracted driving’, (Australasian College of Road Safety, 2007), pp. 379-405

[3] Bayly, M., Young, K.L., and Regan, M.A.: ‘Sources of distraction inside the vehicle’, in Regan, M.A., Lee, J.D., and Young, K.L. (Ed.): ‘Driver distraction: Theory, effects and mitigation’ (CRC Press, 2009), pp. 191-213

[4] http://www.nuance.com/industries/automotive/whitepapers/DistractedDriving_Report_EN_Final.pdf, accessed May 2013

[5] https://www.tno.nl/downloads/Key%20Findings%20document%20June%202008%20FINAL.pdf, accessed May 2013

[6] Knapper, A., Hagenzieker, M., and Brookhuis, K.: ‘Phoning, texting, operating a navigation system and following route guidance while driving’. 5th Int. Conf. on Traffic and Transport Psychology, Groningen, Netherlands, August 2012, pp. 1-19

[7] Srinivasan, R., Jovanis, P.: ‘Effect of selected in-vehicle route guidance systems on driver reaction times’, Human Factors: The Journal of Human Society, 1997, 39, pp. 200-215

[8] Lee, W-C., Cheng, B-W.: ‘Effects of using a portable navigation system and paper map in real driving’, Accident Analysis & Prevention, 2008, 40, pp. 303-308

[9] Monk, C.: ‘Driver Distraction Research and Policy: An update from NHTSA’. Proc. 3rd Int. Conf. on Driver Distraction and Inattention, Gothenburg, Sweden, September 2013, pp. 4-6

[10] McGehee, D.V.: ‘New design guidelines aim to reduce driver distraction’, Human Factors and Ergonomics Society Bulletin, 2001, 44, (10), pp. 1-3

[11] Victor, T.W., Harbluk, J.L., Engström, J.A.: ‘Sensitivity of eye-movement measures to in-vehicle task difficulty’, Transportation Research Part F, 2005, 8, pp. 167-190