"Assistance-On-Demand": a Speech-Based Assistance System for Urban Intersections

Nadja Schömig
Wuerzburg Institute for Traffic Sciences
Veitshöchheim, Germany
schoemig@wivw.de

Christian Maag
Wuerzburg Institute for Traffic Sciences
Veitshöchheim, Germany
maag@wivw.de

Martin Heckmann
Honda Research Institute Europe GmbH
Offenbach/Main, Germany
martin.heckmann@honda-ri.de

Alexandra Neukum
Wuerzburg Institute for Traffic Sciences
Veitshöchheim, Germany
neukum@wivw.de

Heiko Wersing
Honda Research Institute Europe GmbH
Offenbach/Main, Germany
heiko.wersing@honda-ri.de

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.
Copyright is held by the owner/author(s).

Automotive'UI 16 Adjunct, October 24-26, 2016, Ann Arbor, MI, USA
ACM 978-1-4503-4654-2/16/10.
http://dx.doi.org/10.1145/3004323.3004328

Abstract

We evaluated a system to support the driver in urban intersections (called "Assistance on Demand" AoD system). The system is controlled via speech and supports the driver in monitoring and decision making by providing recommendations for suitable time gaps to enter the intersection. This speech-based control of the system allows the implementation of an „on-demand"-concept where the driver can activate the assistance only if he desires support. 24 drivers took part in the study, performing three drives each. A comparison with a manual condition without system support showed that the AoD system was highly accepted, decreased workload and facilitated monitoring of traffic. In addition, subjective acceptance highly correlated with objective acceptance measured by the actual usage of the system. This clearly justifies the "on-demand"-concept.

Author Keywords

Assistance system, speech-based system, on-demand, glance behaviour, gap choice, acceptance.

ACM Classification Keywords

H.5.2. User interfaces: User-centered design; input devices and strategies; Voice I/O; interaction styles.

Introduction

Driving in dense urban traffic is highly demanding. In particular turning left at an unsignalized intersection from a subordinate road into a superordinate road with high traffic density is one of the most challenging tasks for drivers (e.g. [4], [7]). Currently available assistance systems for urban intersections mainly provide collision avoidance functionality which prevents safety-critical situations. Yet in many cases the driver might also benefit from support in the monitoring and decision making process before entering an intersection. In [3] information on safe gaps was presented via a HUD in a driving simulator. However the system rather led to a focus of the driver's attention to the centre instead of to the left and right and to more risky driving.

From observing drivers' natural behaviour we derive an alternative approach for assistance. When driving with a front seat passenger, they often use the opportunity to ask him for support while managing a difficult intersection. In particular when turning right they transfer the task of monitoring the right side traffic to the passenger and request feedback on suitable time gaps to enter the intersection. These considerations led to the development of the system as an assistance system for urban intersections which acts like a co-pilot with which the driver can interact via speech communication [5]. The system helps to find suitable time gaps to cross the intersection comfortably and safely. The system is not always active but the driver activates the system in situations where he/she wants to have support. Hence it is based on an "Assistance on demand" (AoD) concept. With this on-demand concept we aim to increase driver acceptance by increasing perceived usefulness, as perceived usefulness is one of the key influencing factors for a high user acceptance and therefore for the actual use of the system [2]. Assistance is perceived as especially useful in demanding or unpredictable situations and perceived as less useful in situations that can be easily solved by the drivers themselves [6]. Therefore, it can be expected that drivers would like to have support at intersections with high complexity, e.g. due to high traffic density and don't want to have it when there is no other traffic present. In [1] a very similar approach for the use case "turning left at a rural intersection with oncoming traffic" was applied with positive results for the system. In contrast to his approach the presented system variant more strongly pronounces the collaborative sharing of tasks between the driver and the system in a more demanding use case. The system is thought as a comfort system which should support the driver while waiting at an intersection and monitoring the traffic. Thereby the system takes over only the monitoring of one direction, namely the traffic from the right. Furthermore, it assists in manoeuver decision by recommending a suitable time gap for turning or crossing the intersection. The driver is still responsible for final decision and manoeuvre execution. We have chosen speech as the modality of interaction between the driver and the system as speech is thought to be the most flexible, natural, and interactive way of communication between the two agents. Following an explicit assistance request from the driver to the system via speech (e.g. "please check right"), the system will react by specific speech outputs.

Method

Participants

N=24 drivers took part in the study, half of them were female. They all had participated at least in a 2.5 h training session in the simulator before. Their mean age

Figure 1. Example of an urban intersection scenario in the WIVW static driving simulator.

was 49.1 years (SD = 19.3 years) with the youngest driver of 25 years and the oldest of 77 years. Their mean mileage driven in the last 12 months was 15408 km (SD= 9851 km).

Study environment

The study took place in the static driving simulator of the Wuerzburg Institute for Traffic Sciences (WIVW; see Fig. 1). The mock-up is an Opel Insignia for which outside rear-view mirrors are replaced with LCD displays. The scenery is projected on five screens. The steering wheel has an integrated steering force simulator. The mock-up interior includes two integrated LCD-displays, one replacing the speedometer, the other in the centre console to display e.g. non-driving related information.

System specification

The functionality of the AoD system realized for this study was restricted to the monitoring of traffic coming from the right. Therefore all system outputs only refer to traffic from the right. Traffic from the left still has to be monitored by the drivers themselves. In approaching the intersection the driver's request (e.g. „Please watch right") activates the system. In the simulator study this was triggered by a button pressed by the test leader (this was the only manual action of the experimenter). The system confirms the successful activation by answering "okay - I will watch". When the driver reaches the intersection the system starts giving recommendations:

If the time distance of the closest vehicle from right to the centre of the intersection is above 10 s, the system will interpret this as no vehicle being present and triggers the output "no vehicle from the right". It was deliberately decided not to announce "right is free" as this could be interpreted as a permission to drive without further monitoring the actual traffic which can create potentially hazardous situations. If a vehicle is approaching from right and reaches a critical time distance of 6 s to the intersection and simultaneously another vehicle is following with a time gap of 6 s the system interprets this as a sequence of vehicles which does not allow entering the intersection for turning. The linked speech output is "vehicle from the right".

If a vehicle is approaching from the right and reaches a time distance of 3 s to the intersection and simultaneously the time gap to the next oncoming vehicle is larger than 6 s, the system interprets this as a suitable time gap for entering the intersection. The system output is therefore already given before the previous vehicle has passed the intersection, in order to create a certain preparation time so that the driver can optimally make use of the recommended gap. Hence the speech output is "gap after approaching vehicle". If the time gap has elapsed and the next vehicle is approaching with the same conditions, the output is repeated with: "gap after next vehicle". The time gap of 6 s which the system recommends as suitable was derived from a commonly cited literature reference [8].

Driving course

Each experimental drive consisted of a set of several scenarios all containing an urban intersection. As basic layout for this scenario an X intersection was chosen with the host vehicle approaching from the subordinate road (see figure 1). Give way signs are placed at the roadside. A stop line should assure that all drivers stop at a comparable distance away from the intersection entrance. The surrounding at the intersection is created in a way that the drivers cannot see the arriving vehicles on the superordinate road when they approach the intersection. When having stopped at the intersection the sight distance is about 8 s to the right and 10 s to the left (taking 50 km/h as a basis). The instruction asks the driver to turn left at the intersection.

In each scenario there was continuously approaching traffic at the intersection from left and/or right. The vehicles were driving with a constant speed of 50 km/h and defined time gaps between each other. Traffic density for both directions was varied on five levels (no=0, continuously increasing=1, light=2, variable=3, high=4). The high traffic density was reached by time gaps of 2 s between the vehicles, the light one by 7s between vehicles. Variable traffic was created by varying the time gaps between 5 s and 7 s. The first time gap recommended by the system is the 6.5 s gap, as 6 s is set as threshold. By varying and combining traffic density from left and right a set of ten basic scenarios was created.

These scenarios were put together to one driving course meaning that the driver drove from one intersection to the next by always turning left. The scenarios were randomly assembled and the order of the scenarios was permuted in the different drives to avoid sequence effects.

Experimental plan

All 24 drivers performed several subsequent drives (each with a different experimental condition – within-factor design). The first drive was always a manual drive (MAN) where the drivers had to complete the scenarios without any assistance. In a subsequent drive drivers drove with the AoD system. In order to assure that all drivers have a comparable basis for system evaluation during this first AoD drive the drivers were instructed to use the system in all scenarios (even though the system's basic idea is to be activated „on demand"). This drive was called the AoD forced drive. In the final drive the drivers should again drive with the AoD system but could now use it according to their own preference only in those situations where they want to have support (AoD free drive). One driver did not finish this drive due to motion sickness and had to be excluded from respective analyses. In another drive an alternative system variant was experienced (presenting information on time gaps by the visual modality) which is not in the focus of this paper and therefore not further reported here.

Test procedure

Drivers first had the opportunity to get familiar with the simulator and the course. Following this they performed the manual, AoD forced and AoD free drive. After each drive they had to fill out a questionnaires related to the drive.

Measures

After each of the three drives, drivers rated the required attention, difficulty, perceived demand, riskiness, feeling of safety, and perceived performance quality. The used rating scale was a 16-point scale with verbal categories from "not at all" (0), "very low" (1-3), "low" (4-6), "medium" (7-9), "high" (10-12), to "very high" (13-15) helpfulness. After deciding for one verbal category, drivers are requested to further define their rating by numbers from 0 to 15 in total. During the AoD forced drive, the drivers rated the usefulness of the system online after each scenario. They should

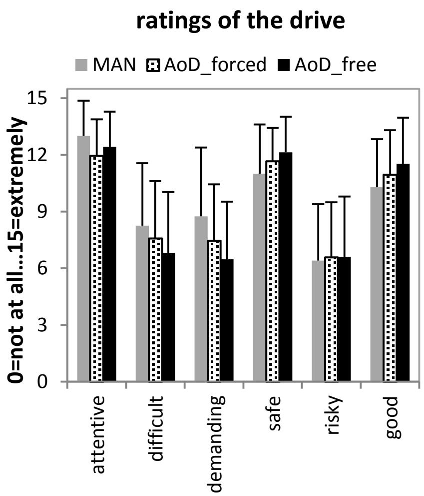

Figure 2. Subjective ratings of the three drives on the dimensions invested attention, difficulty, perceived demand, riskiness, feeling of safety and perceived performance quality.

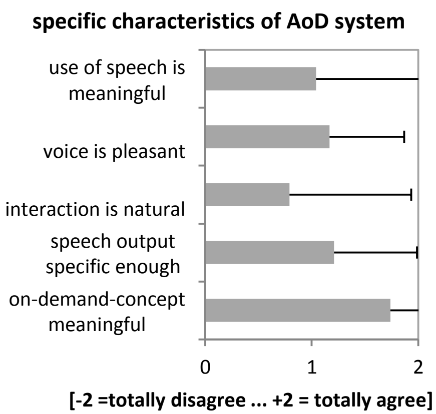

Figure 3. Rating of specific system characteristics- agreement to certain statements on a 5-point-Likert-scale.

answer the question „how helpful had the system been in the previous scenario?". Again, the 16-point-rating scale was used.

For behavioral measures the interaction with the AOD system was assessed in the AoD free drive by investigating in which situations drivers activated the system and requested its assistance. This can be interpreted as an objective measure for system acceptance.

Results

Subjective evaluation of the drive

The statistical approach for all analyses concerning the subjective evaluation of the drive was a within-subjects ANOVA with follow-up contrast tests.During all three drives drivers sustained a high level of attention (ratings around 12 on the scale up to 15, compare Fig. 2) with slightly higher values for the MAN and the AoD free drive. An ANOVA results in a significant main effect for condition ($F[2;44]=5.965$; $p=.005$). Post-hoc tests revealed a significant difference between MAN and AoD forced ($t(23)= 2.655$; $p=.014$) and between AoD forced and AoD free drive ($t(22)=-2.554$; $p=.018$.

The difficulty of the drives received a medium rating. No significant differences between conditions can be found $F[2;42]=2.456$; $p=.098$). The perceived demands of the drives show significant differences between the conditions ($F[2;44]=5.568$;$p=.007$) with fewer demands for the two AoD drives. Post-hoc tests revealed a significant difference between MAN and AoD forced ($t(22)= 2.099$; $p=.047$) and between MAN and AoD free drive ($t(22)=2.831$; $p=.010$.

There is also a significant main effect for condition regarding the perceived safety of the drive ($F[2;44]=4.945$; $p=.012$) with a significant difference between the AoD free drive and MAN ($t(22)=2.712$; $p=.013$) as well as between AoD free and AoD forced drive ($t(22)=2.12$; $p=.045$). Therefore, safety was perceived highest in the AoD free drive. Risk tolerance was comparable across all three conditions ($F[2;44]=.582$; $p=.563$, indicating that driving assisted does not lead to riskier behavior. The driving performance was perceived as different between the three conditions ($F[2;44]=7.698$; $p=.001$) with a significantly better driving performance rated for the AoD free drive compared to MAN ($t(22)=4.085$; $p<.001$) and compared to AoD forced ($t(22)=2.522$; $p=.019$).

Acceptance of specific system characteristics

In some statements on the specific characteristics of the system, the AoD system is rated consistently positive (see Fig. 3).The use of speech is rated as meaningful and the on-demand concept is highly appreciated.

Perceived usefulness in different traffic scenarios

The usefulness ratings per scenario in Fig. 4 show that the system is rated more useful in scenarios with higher traffic but with a high variability within the driver sample.

Correlation of usefulness rating and actual system usage

In the AoD free drive, drivers used the system according to their own preferences. Here it gets obvious that actual system usage reflects the subjective usefulness rating given in the AoD forced drive.

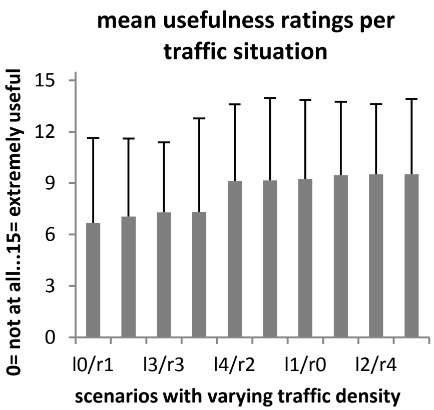

Figure 4. Mean usefulness ratings for AoD forced drive per traffic situation with abbreviations l=left, r=right combined with the traffic density from 0 - 4.

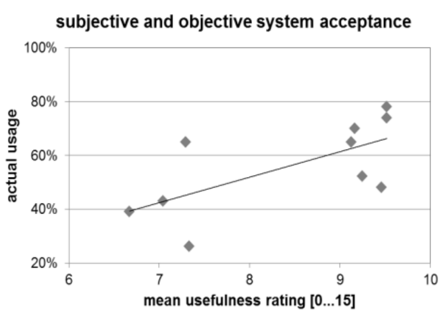

Figure 5. Correlation between mean usefulness rating in the AoD_forced drive and actual system usage in AoD_free drive.

The percentage of drivers activating the system varies from 26% in scenarios without any traffic (l0/r0) up to 78% in the scenario with dense traffic from both directions (l4/r4). Figure 5 shows the correlation between the subjective usefulness ratings and the actual system usage. Bivariate Pearson-correlation-index is r=.66, indicating a high correlation.

Conclusion

The results indicate a rather high acceptance of the AoD system. Driving with the system reduces subjectively reported workload and increases perceived safety and driving quality, especially in the drive where drivers chose themselves when to use the system. However, driving assisted was not perceived as increasing risk tolerance.

When asked about the appropriateness of specific system characteristics, i.e. using speech for communication and the "on-demand" concept drivers show very positive attitudes. Drivers perceived the use of speech as meaningful and as sufficiently specific. The on-demand concept is justified by the fact that drivers rated the usefulness of the system different dependent on the complexity of the situation with higher usefulness ratings in situations with increased traffic density. This is then also reflected in the actual system usage which was assessed in the AoD free drive. Subjective and objective acceptance measures proved to be highly correlated indicating that the on-demand concept would lead to be better acceptance of such a kind of assistance system.

Future work will include the evaluation of objective driving data and the comparison to an assistance system implemented via a HUD.

REFERENCES

1. Biester, L. (2009). Cooperative Automation in Automobiles. Dissertation. Humboldt-University: Berlin.
2. Davis, F.D. (1986). A technology acceptance model for empirically testing new end-user information systems: Theory and results. Dissertation, Massachusetts Institute of Technology.
3. Dotzauer, M., Caljouw, S.R., de Waard, D. & Brouwer, W. H. (2013). Intersection assistance: A safe solution for older drivers? *Accident Analysis and Prevention, 59*, 522-528.
4. Hancock, P.A., Wulf, G., Thom, D. & Fassnacht, P. (1990). Driver workload during differing driving maneuvers. *Accident Analysis and Prevention, 22* (3), 281-290.
5. Heckmann, M. & Wersing H. (2015). *Method for controlling a driver assistance system*. Europ. Patent Application EP 2 949 536 A1, 2 Dec. 2015.
6. Naujoks, F. & Neukum, A. (2014). Timing of in-vehicle advisory warnings based on cooperative perception. In D. de Waard, K., Brookhuis, R. Wiczorek, F. die Nocera, R. Brouwer, P. Barham, C. Weikert, A. Kluge, W. Gerbino & A. Toffeti (Eds.). Proc. Human Factors and Ergonomics Soc. Europe Chapter 2013 Annual Conference. ISSN 2333-4959
7. Stinchcombe, A. & Gagnon, S. (2009). Estimating workload demands of turning left at intersections of varying complexity, *Proc 5th Int. Driving Symp. Human factors in Driver Assessment, Training and Vehicle Design*, 440-446.
8. Weinert, A. (2001). Grenz- und Folgezeitlücken an Knotenpunkten ohne Lichtsignalanlagen. Dissertation, Ruhr-Universität Bochum, Bochum.