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"Please watch right" – Evaluation of a speech-based on-demand assistance system for urban intersections

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A B S T R A C T

In a driving simulator study we evaluated a speech-based driver assistance system for urban intersections (called Assistance on Demand AoD system) which supports the driver in monitoring and decision making. The system provides recommendations for suitable time gaps to enter the intersection based on the observation of crossing traffic. Following an "on-demand"-concept, the driver activates the assistance only if support is desired.

In one drive, drivers used the AoD system in every situation they experienced to guarantee that every driver had the same exposure to the system when evaluating it. During another drive, drivers were free to decide if they want to use the system or not. The experimental study compared the AoD system with driving manually and with driving supported by a more conventional visual-based system which was always active at intersections (system showing colored arrows in a simulated head-up display (HUD) to visualize the crossing traffic). This resulted in four drives the drivers had to perform. Every drive consisted of several intersections with varying traffic conditions. The drivers had to turn left at every intersection.

A total of 24 drivers took part in the study; one group with 14 middle-aged drivers and another group with ten high-aged drivers. Several questionnaires and online ratings were used to assess drivers' acceptance, perceived usefulness, benefits and specific characteristics of both system variants. In addition, driving behaviour with regard to gap choice and drivers' monitoring behaviour (using head tracking data) were analyzed.

The results show that the AoD system reaches high acceptance ratings and is preferred compared to the visual, always active system. Using the speech modality for communication and the on-demand concept were both highly appreciated by the drivers. With regard to driving behaviour, the AoD system is comparably safe as manual driving while at the same time making driving easier by facilitating the monitoring of vehicles while waiting at an intersection.

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1. Introduction

1.1. State of the art on intersection assistance

Turning left at an unsignalized urban intersection with high traffic density arriving from the subordinate road is one of the most challenging tasks for drivers (according to subjective reports and objective workload measures, e.g. Hancock, Wulf, Thom, & Fassnacht, 1990; Stinchcombe & Gagnon, 2009; Verwey, 2000). They have to monitor traffic from several directions, estimate suitable time gaps between vehicles, decide when to enter the intersection safely and finally execute the demanding left-turn manoeuvre. As a consequence, both cognitive and visual load are especially high in these situations. Additionally, they account for 26% of all crashes among lightweight vehicles in the United States (Najm, Sen, Smith, & Campbell, 2003). Therefore, there seems to be a need to support the driver in such situations.

Currently available assistance systems for urban intersections are mainly designed as collision avoidance systems dedicated to preventing the driver from safety-critical situations. These systems monitor crossing traffic and prompt the drivers to start an emergency braking by activating visual and acoustic warnings and/or automatically engaging the brakes (e.g. systems by Toyota or Mercedes Benz). I.e. these systems aim at correcting wrong decisions or driving manoeuvers already taken either by the drivers themselves or by other road users to avoid a collision. Research on intersection assistance aims to develop systems that are able to provide earlier warnings e.g. by means of Car-to-X technologies (Naujoks & Neukum, 2014) or even prevent the driver from entering the intersection (e.g. Klanner, Thoma, & Winner, 2008).

What could be a meaningful add-on to these systems is an assistance which supports the driver already in the monitoring and decision-making process before entering an intersection.

Donath, Shankwitz, Ward, and Creaser (2007) developed an intersection decision support system that identifies safe gaps in traffic on a high-speed rural expressway and communicates this information to drivers waiting to enter the intersection from a minor intersecting road. However, this system is designed as a Driver-Infrastructure system displaying information at an intersection outside the host vehicle on respective digital signs. An in-vehicle assistance system providing this kind of information was investigated by Dotzauer, Caljouw, de Waard, and Brouwer (2013) in a driving simulator study with 18 older drivers. They presented information about safe gaps in form of a bar in front of the driver by means of a head-up display (HUD). Their system is a three-stage system that dynamically changes from green to amber to red and vice versa as the traffic situation changes. A gap between cars greater than 5 s indicated safe crossing (green flag). Gaps between 2.5 and 5 s were classified as marginal indicated by an amber flag, and gap sizes smaller than 2.5 s were considered unsafe as conveyed by the red flag. Their results show that equipped with this system, drivers allocated more attention to the road center rather than the left and right, crossed intersections in shorter time, engaged in higher speeds and crossed more often with a critical time-to-collision value (TTC).

The present study presents an alternative approach for assistance derived from observing drivers' natural behaviour: When planning to turn left at an unsignalized intersection drivers often use the opportunity to ask a present front seat passenger for support, e.g. by transferring them the task of monitoring traffic from one direction, typically the traffic from the right and requesting feedback about suitable time gaps to enter the intersection. A typical dialogue sounds like this: "Can you please check the traffic from the right for me?" – "Sure, I can" – "vehicle from the right" – "still vehicle from the right" – "still vehicle from the right" – "now it's free" – "thank you". Also the passengers themselves could initiate this dialogue if they notice that the driver needs support.

In police emergency vehicle operations such a human-human cooperation proved to diminish risk, with notably more even and calm driver speed behaviour as well as significantly lower emotional workload (Neukum & Krüger, 2003).

The idea of the presented study was to develop and evaluate a system which transfers this human-human cooperation observable in natural behaviour into a human-system cooperation with the system acting as a co-passenger which is giving support when requested (i.e. only "on demand") and which is communicating with the driver via speech. Both, the question of how to design such a system as well as what benefits to expect, are topics of this paper.

1.2. Concept of cooperative control

We have chosen the concept of shared or cooperative control as theoretical concept for the design of the system. In this concept the driver and the system are considered as one combined system in which the two agents interact with each other, taking into account the intentions, potentials and weaknesses of their partner to reach the common goal (e.g. Bratman, 1992; Sheridan, 1992). Therefore, the task distribution between the two agents is relatively flexible, dynamic and adaptive to different influencing factors.

The term "cooperative control" is defined in a working definition by Biester (2009) by the following characteristics (p. 11):

- [...] a continuous exchange process between driver and automobile, with the exchange process creating a common knowledge base and goals [...]
- both participants are responsible for certain parts of the commonly defined whole task, which is the result of a continuous coordination process [...]