Chapter 49
Function-Specific Uncertainty Communication in Automated Driving

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ABSTRACT

Conveying the overall uncertainties of automated driving systems was shown to improve trust calibration and situation awareness, resulting in safer takeovers. However, the impact of presenting the uncertainties of multiple system functions has yet to be investigated. Further, existing research lacks recommendations for visualizing uncertainties in a driving context. The first study outlined in this publication investigated the implications of conveying function-specific uncertainties. The results of the driving simulator study indicate that the effects on takeover performance depends on driving experience, with less experienced drivers benefitting most. Interview responses revealed that workload increments are a major inhibitor of these benefits. Based on these findings, the second study explored the suitability of 11 visual variables for an augmented reality-based uncertainty display. The results show that particularly hue and animation-based variables are appropriate for conveying uncertainty changes. The findings inform the design of all displays that show content varying in urgency.

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INTRODUCTION

Considering that the vast majority of roadway crashes are attributed to human error (NHTSA, 2008), automating the driving task seems to be the logical countermeasure. Without sufficiently robust and capable automation systems, however, human operators will continue to assume an essential role in driving (Woods, 2016). As such, vehicles equipped with automated driving systems below SAE level 4 (SAE International, 2018) rely on the human operator to take over control if the automation fails – resulting in a series of human factors challenges, foremostly the out-of-the-loop (OOTL) performance problem (Endsley, 2017): Following an extended period of faultless automation performance, human operators are slow to detect and understand system problems when they occur and are likely not capable of performing the previously automated task if prompted to do so (Endsley & Kiris, 1995). The OOTL performance problem is primarily ascribed to a lack in situation awareness (SA), complacency and inappropriate trust in automation capabilities (Endsley, 2017; Kunze, Marshall, Summerskill, & Filtness, 2017).

The communication of system uncertainties was proposed as a means for overcoming the OOTL performance problem (Beller, Heesen, & Vollrath, 2013). Making operators aware of system fallibility by revealing the automation's current uncertainty was shown to lead to more calibrated trust and improved SA, resulting in safer takeovers (Kunze, Summerskill, Marshall, & Filtness, 2019).

Existing approaches to uncertainty communication have focused on conveying the overall uncertainty of a system (Beller et al., 2013; Helldin, Falkman, Riveiro, & Davidsson, 2013; Kunze et al., 2019; Louw et al., 2017). It remains to be addressed how an increase in information detail affects operators.

Addressing this shortcoming, the first study of this publication aims to investigate the implications of conveying function-specific uncertainties in contrast to the communication of overall uncertainties.

To date the existing body of research has also lacked an evaluation of visualization methods for uncertainties in a driving context. While previous work has highlighted the benefits of conveying uncertainties in a series of different scenarios (Beller et al., 2013; Helldin et al., 2013; Kunze et al., 2019; Louw et al., 2017), different visualization methods were not varied and explored. Rather, previous publications relied on information presented in the instrument cluster, requiring users to regularly shift their gaze between several areas of interest, namely road, instrument cluster, and non-driving related tasks (Kunze et al., 2019). Addressing this shortcoming, the second study presents an evaluation of visual variables for an augmented reality (AR) based uncertainty display.

Combined, the studies outlined in this publication highlight the implications of presenting function-specific uncertainties in a driving context and provide recommendations for implementing an uncertainty display.

BACKGROUND

Sufficient levels of SA are needed for the successful execution of takeovers. SA may be described as a non-linear, three-step process consisting of (1) the perception of elements in the environment, (2) an understanding of their implications for the ego vehicle, and (3) a projection of their future states (Endsley, 1995). In a driving context, SA can primarily be gained by glancing towards the field relevant for driving (FRD), essentially the driving scene. Thus, automation interfaces can aid the build-up of SA by managing the gaze behavior of human operators. Considering that operators' trust in automation and