

Eye-Movement Characteristics of Fatigued Drivers During Nighttime Takeover Events

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Abstract

Driver fatigue is a major risk factor in road safety, as fatigued drivers often exhibit reduced vigilance and diminished attention to the driving environment. With the increasing deployment of conditionally automated driving systems, drivers are more likely to engage automation when feeling tired. However, when a takeover request (TOR) is issued, drivers must rapidly regain situational awareness and resume manual control. This transition is particularly critical during nighttime driving, where limited visibility further constrains perceptual processing. The present study aims to investigate how fatigue influences drivers' visual attention behavior during takeover scenarios under nighttime conditions. A driving simulator experiment was conducted in which participants encountered different road hazard events with varying TOR timing. Eye-movement data were collected to assess attentional allocation and visual search patterns in response to these experimental manipulations. The results revealed a significant interaction between driver state and event type on total fixation duration. In low-visibility fog scenarios, fatigued drivers exhibited significantly longer fixation durations than non-fatigued drivers, indicating greater visual processing demand and less efficient attention allocation. Additionally, significant interactions were found between event type and TOR timing on both fixation frequency and total fixation duration. Specifically, fog-related events elicited higher fixation frequency and longer fixation durations than lane-change and collision events, particularly under conditions with extended TOR lead times. These findings provide empirical evidence on how driver fatigue affects visual attention during automated vehicle takeovers at night. The outcomes contribute to a deeper understanding of human performance limitations in safety-critical takeover situations and offer valuable references for the design of future human-machine interfaces and takeover strategies in automated driving systems.

Keywords: Driver fatigue; Takeover request; Eye movements; Nighttime driving