Designing Auditory Takeover Requests Under Different Automated Vehicle Operational Environments

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Abstract
As vehicle automation technologies mature, the role of human driver is shifting from being an active operator (e.g., handling dynamic driving tasks) to a passive one (e.g., monitoring the system or act as a backup). However, until full and reliable vehicle automation is developed, automated vehicles (AVs) cannot completely furlough human drivers and will require them to be either actively or passively engaged in driving. Under SAE Level 3 (or conditional) vehicle automation, drivers can engage in non-driving related tasks (NDRT) (e.g., watching a movie) without the need to constantly monitor the automation system. But the vehicle still requires a driver as a fallback option that will be prompted via takeover warnings (or takeover requests) to resume manual control of the vehicle in case it ventures out of its operational boundaries (e.g., uncertain road environment or traffic situations) or experiences system failure. A comprehensive understanding of the factors that may affect the driver’s takeover performance in such situations is necessary to enhance road safety, design fallback procedures (e.g., design takeover requests), and foster public trust in automation technologies.

Existing literature on takeover warnings suggests that multimodal alerts that combine different modalities (i.e., visual, auditory, and haptic) elicit faster response times from drivers compared to unimodal alerts. The results comparing takeover performance measures under different unimodal alerts are mixed. However, several existing in-vehicle critical warning systems (e.g., collision warning) use auditory alerts in either unimodal or multimodal setting as they are harder to miss (e.g., if driver is distracted) or misinterpret (e.g., with road vibrations) while driving. This study designs driving simulator experiments to analyze the impacts of different unimodal auditory alert designs on takeover performance under different traffic densities and takeover situations. Four auditory alerts are designed: two beeps (with different frequencies) and two speech (with different pitch). Before the experiment, we will ask participants for their preferred auditory alert to further analyze if individual preferences affect takeover performance. Data will be collected for each participant from four experiment sessions on different days with different auditory alerts (counterbalanced) on each day and four experiment drives during each session with randomized traffic densities (2) and takeover situations (2) scenarios. The key reason for collecting data from multiple sessions (on different days) is to mitigate psychological biases related to stimulus discrimination (which can lead to different response) and assimilation/contrast effects (i.e., response affected by previous stimulus). This work is currently ongoing, and we will start data collection soon. The analysis results should provide insights on designing takeover warnings for different traffic densities and takeover situations by comparing takeover performance under different auditory alerts and evaluate if individual preferences (for auditory alert) have significant impact on takeover performance.