Audiovisual time-to-collision estimation for accelerating vehicles: The acoustic signature of electric vehicles impairs pedestrians' judgments

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Abstract

To avoid collision, pedestrians intending to cross a road need to accurately estimate the time-to-collision (TTC) of an approaching vehicle. For TTC estimation, auditory information can be considered particularly relevant when the approaching vehicle accelerates. The sound of vehicles with internal combustion engine (ICEVs) provides characteristic auditory information about the acceleration state (increasing engine load and speed). However, for electric vehicles (EVs), the acoustic signature during acceleration is less salient. Although the auditory detection of EVs has been studied extensively, there is no research on potential effects of the altered acoustic signature of EVs on TTC estimation. To close this gap, we compared TTC estimates for ICEVs and for EVs with and without active acoustic vehicle alerting system (AVAS). We implemented a novel interactive audiovisual virtual-reality system for studying the human perception of approaching vehicles. Using acoustic recordings of real vehicles as source signals, the dynamic spatial sound field corresponding to a vehicle approaching in an urban setting is generated based on physical modeling of the sound propagation between the vehicle and pedestrian (listener) and presented via sound field synthesis (higher-order Ambisonics). In addition to the auditory simulations, the scene was presented visually on a head-mounted display with head tracking. Participants estimated the TTC of vehicles either approaching at a constant speed or accelerating positively. In conditions with constant speed, TTC estimates for EVs with and without AVAS were similar to those for ICEVs. In contrast, for accelerating vehicles, there was a substantial effect of the vehicle type on the TTC estimates. For the EVs, the mean TTC estimates showed a significant overestimation. Thus, subjects on average perceived the time of arrival of the electric vehicle at their position as longer than it actually was. The extent of overestimation increased with the acceleration and with the presented TTC. This pattern is similar to a first-order TTC estimation representing a failure to consider the acceleration, which is also consistently reported in the literature for visual-only presentations of accelerating objects. In comparison, the overestimation of TTC was largely reduced for the accelerating ICEVs. The AVAS somewhat improved the TTC estimates for the accelerating EVs, but without reaching the same level of accuracy as for the ICEVs. In real traffic scenarios, overestimations of the TTC of approaching vehicles might lead to risky road crossing decisions. Therefore, our finding that pedestrians are significantly less able to use the acoustic information emitted by accelerating EVs for their TTC judgments, compared to accelerating ICEVs, has important implications for road traffic safety and for the design of AVAS technologies.

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sciencesconf.org:ish2022:383541