Final report: **Making sense of sound emitted by electric vehicles**

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Introduction

The rapid adoption of electric vehicles (EVs) has introduced a significant safety challenge: because they lack a combustion engine, they operate much more quietly than traditional vehicles, making them difficult for pedestrians to detect. Regulations now mandate synthetic exterior sounds for EVs at low speeds, but these must be carefully designed to balance *noticeability* for safety with *low annoyance* to prevent urban noise pollution. This project aimed to explore optimal synthetic sound signals through a combination of community-building events and rigorous virtual reality (VR) research.

Activities

1. **Workshop on sound design in engineering:** Held on 11 December 2024 at TU/e, this event brought together 18 participants and speakers from across the 4TU.Federation. Highlights included keynotes from Prof Berry Eggen and Dr Soyeon Kim, as well as a round-table discussion on industry challenges in sound design.
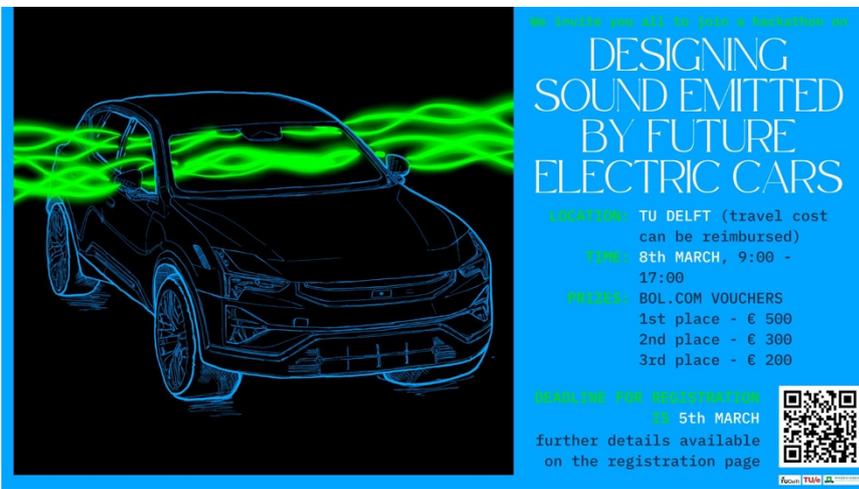
2. **[Hackathon](#) on designing sounds of future EVs:** Hosted at TU Delft on 8 March 2024, this competition challenged BSc, MSc, and PhD students to design synthetic sounds that provide maximum information to pedestrians while minimising noise. Participants from TU Delft, TU/e and WUR in five groups presented demonstrators for a chance to win prizes.

3. **Virtual reality experiments:** A major research component involved 20 participants experiencing 15 audiovisual scenarios in a VR environment. Using a Meta Quest 3 HMD and Sennheiser HD 560S headphones, participants rated various sounds for noticeability, informativeness, and annoyance while their crossing behaviour was tracked via trigger-press data.

Achieved results and impact

The findings of this project have been disseminated through two peer-reviewed articles:

1. **[Pedestrian crossing behaviour](#) (Inter-noise 2025):** This study revealed that diesel engine sounds remain the most effective baseline due to their familiarity, which provides high noticeability with relatively low annoyance. It also found that while intermittent tones (e.g., at 2000 Hz) are highly noticeable, they are often perceived as more annoying, highlighting a critical design trade-off.
2. **[Psychoacoustic assessment of sounds](#) (Forum Acusticum Euronoise 2025):** This research demonstrated that psychoacoustic sound quality metrics predict user annoyance much more accurately than conventional sound pressure level metrics.

Impact and open science

The project has strengthened the collaboration between TU/e, TU Delft and WUR, and contributed to the development of human-centred EV sound standards. To support the broader research community, the VR environment, sound stimuli, analysis code, and anonymised data have been made publicly available via [4TU.ResearchData](#) and [GitHub](#).