GDV
Unfallforschung
der Versicherer

ACCIDENT RESEARCH IN SHORT – NO. 20

Perception of electric vehicles with AVAS

The number of electric vehicles is increasing. They are quieter than vehicles with internal combustion engines and may be harder for other road users to perceive. Since 2021, all newly registered electric vehicles in the EU have to be equipped with an Acoustic Vehicle Alerting System (AVAS) which emits an acoustic warning.

Background

To decide whether or not it is safe to cross a street, pedestrians need to accurately estimate when approaching vehicles will reach their own position. As an input to this decision, they use characteristic auditory information emitted by vehicles. Electric vehicles provide less auditory information. Consequently, they are harder to perceive and may pose a specific risk for pedestrians. This is why the German Insurers' Accident Research (UDV) commissioned a research study to assess how well electric vehicles with or without an AVAS are perceived by pedestrians compared to conventional vehicles with an internal combustion engine.

AVAS regulation

EU Regulation 540/2014 and its amendment 1576/2017[1] require (among other things) the AVAS:

- to emit an artificial sound to the outside world up to a speed of 20 kilometres per hour and while reversing (at higher speeds, it is assumed that the tire noises exceed those of the engine),
- to be acoustically similar to an internal combustion engine of the same vehicle category and
- to indicate the form of vehicle behaviour, e.g. through variations in sound levels or characteristics that are synchronized with the vehicle speed.

With regard to sound characteristics and test requirements, the EU regulation references UN ECE Regulation No. 138[2]. This sets a minimum and maximum sound level. To indicate a change in speed, at least one emitted tone in a specified frequency range must change proportionally to the speed (on average, 0.8 % per km/h). However, the sound itself is not specified and is left to the manufacturer's discretion. In the test protocol, only tests at constant speeds are required.

Research study

The research study included three experiments, each comparing electric vehicles with and without AVAS and a similar vehicle with an internal combustion engine:

- **1st experiment:** In a street crossing scenario, the participants estimated the time until the vehicles would reach their own position (contact time).
- **2nd experiment:** In a street crossing scenario, the participants decided whether or not they would cross the street before the arrival of the approaching vehicle (crossing decisions).
- **3rd experiment:** The participants were asked to indicate whether the vehicle was accelerating or traveling at a constant speed (acceleration detection).

To this end, audio tracks of various vehicles were recorded (vehicles: Kia Rio, Kia e-Niro with AVAS switched on and off). The recordings were made with the vehicles driving at constant speeds (10, 20, 30, 40 km/h) on a test track and with high and low acceleration (0.6 vs. 2.0 m/s²). These recordings were then transferred to a novel interactive audiovisual virtual reality system. The participants heard the vehicle sounds via 16 spatially arranged loudspeakers and saw a road traffic situation in which the vehicles were approaching via virtual reality goggles (Fig. 1). 69 participants with normal eyesight and hearing took part in the study.

Results

When the vehicles were driving at **constant speeds,** there were hardly any differences in any of the three experiments between electric vehicles with and without

1 Commission Delegated Regulation (EU) 2017/1576 of 26 June 2017 amending Regulation (EU) No 540/2014 of the European Parliament and of the Council as regards the Acoustic Vehicle Alerting System requirements for vehicle EU-type approval.

2 UN Regulation No. 138. Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility [2017/71]. Economic Commission for Europe.

Left: Setup of the 16 speakers in the lab and visual presentation of the street scene with vehicle.
Right: Test subject with VR goggles.

AVAS and the vehicle with an internal combustion engine. This indicates that vehicle sounds do not have an additional effect over and above that of visual information in terms of pedestrians' perception of constant speeds.

However, when the vehicles were **accelerating,** contact time estimates (Exp. 1) and crossing decisions (Exp. 2) differed between the vehicles:

The contact time of the electric vehicles was estimated to be longer than it actually was, especially at high accelerations. Such estimates could lead to riskier road crossings in the presence of approaching electric vehicles. The estimates were better for the vehicle with AVAS but still did not reach the level of the internal combustion engine vehicle, whose contact time was estimated best. The results also showed that AVAS improved the estimates above the speed of 20 kilometres per hour (the AVAS in the study was active up to the speed of 28 km/h). Apparently, even above 20 kilometers per hour, the tire noise is not the determining factor.

With regard to crossing decisions in the acceleration condition, higher collision probabilities were found for the electric vehicles (with and without AVAS) than for the vehicle with an internal combustion engine, especially at high accelerations. AVAS again mitigated this effect slightly, but decisions were still riskier than for the internal combustion engine vehicle.

This can be partly explained by the fact that acceleration was not well detected (Exp. 3), especially in the case of electric vehicles without AVAS. With AVAS, acceleration was detected significantly better, but not as well as for the internal combustion engine vehicle.

Conclusions

Accelerating electric vehicles do not give pedestrians sufficient auditory information to permit an accurate estimation of vehicle travel. An AVAS that complies with the current regulations improves the perception of electric vehicles without, however, reaching the level of a vehicle with an internal combustion engine. It is therefore necessary to further develop AVAS solutions as well as the regulation itself.

- The AVAS regulation should include acceleration as an indicator in addition to frequency shifts as indicators of speed changes. It appears that such frequency shifts provide inadequate information about actual acceleration. Pedestrians use this information for their decision-making and are at risk if they fail to do so correctly.

- Even above speeds of 20 kilometres per hour, the travel behaviour of electric vehicles with and without AVAS is estimated worse than that of an internal combustion engine. Therefore, the speed range in the AVAS legislation should be extended.

- The design of AVAS solutions should be optimized for acceleration estimations, especially in road-crossing situations and not only for acceleration detection.

- The AVAS test protocols should be further developed to include acceleration.

Further information can be found on our website:
www.udv.de/udv-en/perception_of_electric_vehicles

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