International Co-operation on Theories and Concepts in Traffic Safety

# Evaluating the Need for Additional Noise in Autonomous Electric Vehicles: A Virtual Reality-Based Study

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## 1. Introduction

Autonomous Vehicles (AVs) aim to enhance road safety by reducing the involvement of human drivers and therefore driving errors, while also optimizing road usage and reducing congestion [1]. To improve the safety perception of these vehicles and facilitate their communication with other road users (e.g., cyclists), external Human-Machine Interfaces (eHMIs) have been utilized in AVs, enabling better interpretation of AV behaviour [2]. Recently these AVs are also being developed as Electric Vehicles (EVs). EVs are favoured for their lower emissions and noise, but their low noise levels cause unease among other road users due to low detectability [3]. Therefore, the EU has introduced regulations requiring electric vehicles to install Acoustic Vehicle Alerting Systems (AVAS), which enhance their detectability on the road by generating simulated car noises. Cyclists, as vulnerable road users, face risks from higher speeds and wind noise, thus requiring improved auditory signals [4].

Currently, AVs use eHMI for communication with other road users, while EVs are equipped with AVAS for detectability. Both AVAS and eHMI aim to attract attention and facilitate better judgment of the vehicle's actions, potentially leading to redundancy and increased processing times, which could pose safety risks. Combining AVAS and eHMI in AEVs raises questions about the necessity of both systems due to their overlapping functions. This research aims to assess if it's feasible to eliminate AVAS or just add simple noise to reduce costs without compromising the safety of cyclists while interacting with AEVs. The study will use distinct audio signals to determine if additional sounds are required to help cyclists recognize AEVs and make safer decisions with eHMI.

## 2. Research Methodology

Figure 1: Experiment Environment

Figure 1 showcases the virtual environment used in this study, built using Unreal Engine. It features a straight street, 700 meters long and 5.8 meters wide, with 10 parking areas on the right side. Each parking area is 30 meters long and arranged perpendicular to the street, with residential zones interspersed between them to enhance the scene's realism. In the experiment, participants begin cycling from the right side of the road to a designated endpointas(indicated by the arrow in Figure 1). Along the way, the cyclist encounters the vehicles parked perpendicular to the road, some of which interact with the cyclists by emitting visual and auditory signals when leaving the parking. The study focuses on the impact of these vehicle signals on cyclist behavior, including changes in riding direction, reaction times, and cycling speed.

This study investigates the effect of three independent variables, each divided into three categories, as shown in Table 1. Using a controlled variable method, these three variables with three levels each result in 27 different scenarios. These scenarios were categorized into three levels based on environmental noise, with each level containing nine different scenarios. Each participant, will experience all of the 27 scenarios in groups of 9, and will have a break for a few minutes in between. By manipulating one variable at a time while keeping the other variables constant in a controlled virtual environment, the experiment precisely assesses the impact of different variables on cyclists' behavior. This experiment setup ensures a focused analysis of how cyclists perceive and react to AEVs under different auditory conditions.

*Table 1: Experiment Variables*

| Environment Sound Level | Vehicle Type | Additional Signal Trigger distance |
|---|---|---|
| Quiet Residential area (54dB) | AVs | 15 m |
| Moderately busy Streets (60 dB) | AEVs | 20 m |
| Very busy Streets (68 dB) | AEVs with Additional noise | 25 m |

## 3. Results

The experiment will collect two types of data. Participants' movement trajectories (i.e., coordinates x, y, z), timestamps, and cycling speeds will be recorded at a frequency of 5Hz using Unreal. Additionally, after completing the virtual reality experiment, participants will fill out a survey questionnaire that explores their subjective attitudes towards whether additional noise should be added to AEVs. The survey will focus on participants' comfort and perceived reliability regarding the additional noise.

## 4. Conclusions

The objective of the experiment is to assess the necessity of adding additional noise to AEVs by collecting and analyzing participants' behavioral data and subjective perceptions. Currently, this project is in the setup phase of the experiment, and the data analysis and results will be ready by the time of the conference.

## REFERENCES

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